Q. Please provide a copy of the 2011 AMEC Consulting report on the condition assessment of the Holyrood Gas Turbine.

A. Please refer to NP-NLH-022 Attachment 1.

19 December 2011

Mr. Todd Collins, P. Eng.
Mechanical Design Engineer, Engineering Services
NALCOR Energy
Hydro Place, 500 Columbus Drive
PO Box 12400
St John's, NL, Canada
A1B 4K7

Dear Todd,

Holyrood Thermal Generating Station (Holyrood) Gas Turbine Condition Assessment & Options Study – Final Report

As per our Agreement, we have completed the Holyrood Thermal Generating Station Gas Turbine Condition Assessment. I trust that the report satisfies your needs.

Thank you for the opportunity to work on this very interesting project.

Yours truly,

Blair Seckington
Director, Power Technology
Direct Tel.: 905-403-5004
Direct Fax: 905-829-1707
E-mail: blair.seckington@amec.com

BRS/brs
c: C. Woodall
c. R. Livet
c: A. Duplessis

**Holyrood Thermal Generating Station**

**Gas Turbine Condition Assessment & Options Study**

**December 19, 2011**

# Holyrood Thermal Generating Station
# Gas Turbine Condition Assessment & Options Study

Blair Seckington
Prepared by: Date

Ian Leach
Checked by: Date

Bob Livet
Approved by: Date

| Rev. | Description | Prepared By: | Checked: | Approved | Date |
|---|---|---|---|---|---|
| A | Draft Report | Blair Seckington | | | |
| 0 | Final Report | Blair Seckington | Ian Leach | | 30 Aug 2011 |
| 1 | Final Report | Blair Seckington | | Bob Livet | 19 Dec 2011 |
| | | | | | |

## IMPORTANT NOTICE

This report was prepared exclusively for Newfoundland and Labrador Hydro, a subsidiary of NALCOR Energy, by AMEC Americas Limited. The quality of information, conclusions and estimates contained herein is consistent with the level of effort involved in AMEC Americas Limited services and is based on: i) information available at the time of preparation; ii) data supplied by outside sources; and iii) the assumptions, conditions, and qualifications set forth in this report. This report is intended to only be used by Newfoundland and Labrador Hydro, as support for planning and regulatory filings with its regulatory body, subject to the terms and conditions of its contract with AMEC Americas Limited. Any other use of, or reliance on, this report by any third party for purposes unrelated to Newfoundland and Labrador Hydro's planning and regulatory proceedings is at that party's sole risk.

# HOLYROOD THERMAL GENERATING STATION
# GAS TURBINE CONDITION ASSESSMENT & OPTIONS STUDY

## EXECUTIVE SUMMARY

The Holyrood gas turbine generator is a nominally 13.5 MW packaged generating unit system. It serves as a black start unit for the station and is occasionally used for system support. Due to the critical nature of the role that the Holyrood GT plays, it must operate with a high degree of operational reliability.

The gas turbine went in service at Holyrood in 1986. As of December 2010, the unit had a total of approximately 4717 operating hours, +386,000 idle hours, and 2548 starts. Due to the age of the gas turbine and balance of plant, the large number of idle hours, and its exposure to a marine environment, it was necessary to perform a comprehensive condition assessment and life extension study. In general, the unit and balance of plant equipment requires refurbishment or replacement work to continue operating with a high degree of reliability to its required end of life of 2020. The study will identify the measures that need to be taken to ensure reliable operation of the gas turbine (GT) and balance of plant. AMEC Americas Limited (AMEC) was contracted by NL Hydro to conduct a Condition Assessment and Refurbishment/Replacement Study for the Holyrood BlackStart Gas Turbine Generator and balance of plant equipment.

The scope of work consists of an engineering study that will assess the condition of the Holyrood Thermal Generating Station (HTGS) gas turbine and balance of plant and make recommendations for work including cost estimates that will be required to extend its useful life to 2020 with the same high degree of reliability as that experienced in the past. The engineering study will include a Level 2 study as per the guidelines of the Electrical Power Research Institute (EPRI). During the 1970's and 1980's, EPRI developed a three level methodology for performing condition assessment and life extension studies within the utilities industry in which the level of sophistication and detail increases progressively through Level I, Level II, and Level III studies. AMEC shall apply this process to the gas turbine generator and balance of plant equipment.

Part A of the study is primarily a detailed condition assessment and refurbishment study of the existing gas turbine plant located at HTGS with recommendations and cost estimates to extend the life of the gas turbine plant as a highly reliable operation to the year 2020.

Part B of the study examines the replacement of the existing gas turbine plant with a new or good used mobile generating plant considering either:

a) A GT plant consisting of two 5 MW mobile/transportable units.

b) A diesel generating plant consisting of five 2 MW diesel units.

As a result of the assessment, AMEC makes the following conclusions and recommendations:

### <u>ASSESSMENT BASIS</u>

1. A black-start installation of ten (10) megawatts (MW) is required at the Holyrood Thermal Generating Station site to ensure the capability of the Holyrood units to quickly return to service in the event of a major system failure.

2. The black-start capability must be maintained during any refurbishment or replacement period. This particularly impacts the existing GTG refurbishment option since refurbishment of the existing unit may take an outage of months during which another standby generation unit may be needed and its costs borne by the project. For the existing unit, the lease cost can vary from about $170,000 for the

lease of a reconditioned gas generator and power turbine to swap into the existing unit to about $4.7 million for the lease of a complete 10 MW portable/transportable installation including all associated balance of plant systems and installation.

3. Each of the options has a "terminal value" at the end of the 2020 period. The amount is a function of both the age and condition and market value of the units at that time, and/or of its internal value for redeployment for other uses within Hydro post 2020 (i.e. regional distribution line outage/maintenance support). Potential short term alternative uses prior to 2020 may also have value, but were not assessed.

**TERMINAL VALUES IN 2020**

| Option | Purchased Equipment Cost M$ | System Terminal Value in 2020 M$ | Comment |
|---|---|---|---|
| Option 0 - Refurbished Existing Unit | $3.0 | $0 | Terminal value covers cost for demolition |
| Option 1 - New 2 x 5 MW GT | $10.9 | $7.0 | Low use, essentially new condition. |
| Option 1A - Nearly New 2 x 5 MW GT | $9.2 | $4.0 | Lower percent recovery than new given prior use. |
| Option 2 - New 5 x 2 MW Diesel Genset | $8.6 | $5.0 | Lower market value – more available. |
| Option 2A - Nearly New 5 x 2 MW Diesel Genset | $7.5 | $3.0 | Lower percent recovery than new given prior use. |

4. The system failure cost" of each of the options during the period to the end of 2020. This is a function of the expected or predicted difference in reliability between the options and the cost per hour of electric system black-out/disruption. The situation assumed to occur would be similar to the 1986 island blackout which lasted about 30 hours

**ECONOMIC VALUES – FAILURE TO OPERATE ASSUMPTIONS**

| **Failure To Operate** | | % Probability once over 2013-2020 | Value of Hr Shutdown | # Hrs Per Shutdown | Probable $/Incident |
|---|---|---|---|---|---|
| | | % (A) | MM$/Hr (B) | Hrs (C) | MM$ (D) = AxBxC |
| Option 0 | Refurbished Unit | 10% | $5 | 20 | $10 |
| Option1 & 1A | New/Used 2 x 5 MW GT | 0% | $5 | 20 | $0 |
| Option 2 & 2A | New/Used 5x2 MW Diesel | 4% | $5 | 20 | $4 |

**Notes:**
Value/ Hr Shutdown = $5 MM (Impact to Newfoundland Economy)
Probability risk is relative to the new 2 x 5MW GT option
One occurrence assumed nominally in 2016
Probable $/incident increases proportional to (A), (B), or (C)

## CONCLUSIONS

### Existing Gas Turbine Generator Unit

1. The existing GT generator should not be operated (started, operated, shutdown) except in an emergency situation, and in such an emergency its operation should be observe remotely to ensure personnel safety.
   i) Fire from lube oil system gearbox seals remains a possible safety issue.
   ii) Catastrophic failure of the power turbine disk is a possibility due to corrosion and high stress that may be present at blade roots and attachments
2. The existing GT generator requires extensive overhaul and repair work:
   i) Power turbine disk may require replacement (9 month manufacturing lead time)
   ii) One or more power turbine blades may require replacement or significant repair
   iii) Gas generator blading requires cleaning and recoating
   iv) Inlet filter media requires replacement and inlet duct requires refurbishment (including cooling air duct to power turbine disk)
   v) Exhaust stack requires replacement or extensive repairs
   vi) Gearbox lube oil system requires modification and refurbishment
      a. Seals require replacement/modification
      b. Venting system modifications required to reduce lube oil pressure buildup
      c. Lube oil pump system requires upgrade for start-ups.
      d. Lube oil cooling fan is experiencing some leaks and snow and ice and water build-ups in its containment can cause start-issues
   vii) Gearbox bearings likely worn and need refurbishment or replacement and/or unit re-alignment
   viii) Unit generator requires significant testing and possibly rewind
   ix) Unit generator exciter needs refurbishment and likely replacement
3. GT electrical and controls system has elements that are not in compliance with current standards and/or are obsolete and hence necessitates replacement:
   i) Unit AVR
   ii) Unit MCC's
4. The GT and generator enclosure rooms require modification to their fire detection and suppression systems to provide better coverage, as evidenced by the failure of the system to initially detect or suppress the gearbox lube oil fire in 2010.
5. GT fuel oil receiving, forwarding, and delivery system are in operable condition, but climatic conditions (icing, snow-buildup, water build-ups from rain, rusting from salty ambient air) result in significant periods where starts may fail or be significantly delayed. The GT generator building is in generally good condition, except for:
   i) Major leaks in and around the GT exhaust stack which are impacting the gas turbine power turbine volute and back end blades;
   ii) Minor leaks at generator ventilation stack; and
   iii) Minor air leaks as a result of minor siding holes (corrosion) which require repair/ refurbishment
6. The electrical services room require expansion to allow for new electrical systems and current systems to be in compliance with current standards (i.e. space, separation distance for arc flash).

7. The earliest in-service dates for refurbishing the existing unit and returning it to service:
   a. Without back-up during the existing unit outage, but restricting the outage to lower risk, late spring to early fall periods is October 2013, with a roughly six month outage.
   b. With a nearly new 2 x 5 MW GT leased unit required during an existing unit outage is July 2013 with the existing unit on outage about five months.
   c. With shorter duration engineering and procurement times for BOP, fuel system and electrical systems, the in-service can theoretically be advance two to three months, but outage scheduling would likely mitigate this.

   Note: Using leased parts during outage, or procuring used parts and refurbishing them, has no significant positive impact.
8. The capital cost for refurbishing the existing unit is between $4.5 and $5 million, depending on the amount of additional work found during refurbishment. If leasing a replacement 2 x 5 MW unit is required to avoid any outage, then the total capital cost would be between $9.5 and $10.0 million, depending on the market price and availability of portable/mobile equipment. There is some opportunity to slightly reduce costs if used parts for the unit, and in particular the power turbine disk, are available.

**New and Nearly-New 2 x 5MW Portable/Transportable Gas Turbine Generator Units**

1. The two 5 MW transportable gas turbine units option is consistent with the requirements for black start power, the need to start a 3 MW power block (one boiler feed pump motor), and simplicity of managing the number of black start units in parallel.
2. The space requirements for the two 5 MW transportable gas turbine units (2 trailers each plus a common electrical building) cannot be accommodated in the existing GT area.
3. Space and civil requirements support the use of the existing well graded area behind the old security building as the best location.
4. Two new 5 MW transportable gas turbine units could be readily purchased, with a manufacturing time of about 12 months.
5. Two nearly new, used 5 MW transportable GT units may be possible to acquire to a shorter time. Their availability and cost are functions of the market place. The units may also have to be adapted to suit Holyrood conditions (motor and start voltages, applicable codes, design fuel combustors, NOx levels).
6. Emissions, particularly NOx emissions, will have to be addressed:
   i) NOx emissions are dependent on the nitrogen content of the diesel fuel oil used.
   ii) NOx emissions will be lower than those of the current GTG units, but being oil fuelled units will be challenged to meet Canadian Council of Ministers of the Environment (CCME gas turbine NOx emission guidelines
   iii) Newfoundland & Labrador environmental regulations require Best Available Control Technology (BACT), although the regulations have provisions relaxing BACT requirements for both economic impacts as well as flexibility of approval by the Minister considering roles.
      a. The current designs do not have special technology (i.e. Selective Catalytic Reduction (SCR)). Their costs, the impacts of the technology on black start readiness and reliability, and the costs and impacts of ammonia use and storage for SCR use, make their consideration unreasonable for the roles contemplated.

   b. A project going forth will have to seek approval for an exemption from the BACT requirement, and will likely have restrictions placed on the unit such as a limit on the number of operating hours per year.

7. Five MW units are likely the upper limit of useful unit size for redeployment in support of transmission and distribution line maintenance support either post 2020 or periods up to 2020.
8. The earliest in-service date for procuring and installing 2 x 5 MW new gas turbine generators is May 2013. The earliest in-service date for procuring and installing 2 x 5 MW nearly new/used gas turbine generators is March 2013.
9. The capital cost for procuring and installing 2 x 5 MW new gas turbine generators is $13.3 million. The capital cost for procuring and installing 2 x 5 MW nearly new/used gas turbine generators is $11.5 million.

**New and Nearly-New 5 x 2MW Portable/Transportable Diesel Engine Generator Units**

1. The five 2 MW transportable diesel engine generator units option is potentially consistent with the requirements for black start power, but:
   i) The units may have significant difficulty responding to a block load start of 3 MW power block (one boiler feed pump motor), and
   ii) Islanded synchronous operation during start-up of five units may be difficult to maintain and affect overall system capacity available and overall system start-up reliability. It will also likely require a more complex control system.
2. The space requirements for the five 2 MW transportable diesel engine generator units (5 trailers plus two electrical trailers plus a common electrical building) cannot be accommodated in the existing GT area.
   i) Space and civil requirements suggested that use of the existing well graded area behind the old security building was the best location.
   ii) Spacing requirements are increased by separation requirements between units
3. Five new 2 MW transportable diesel engine generator units could be readily purchased, with a manufacturing time of about 12 months.
4. Five nearly new, used 2 MW transportable diesel engine generator units may be possible to acquire to a shorter time. Their availability and cost are functions of the marketplace and the units may have to be adapted to suit Holyrood conditions (motor and start voltages, applicable codes, design fuel combustors, NOx levels).
5. Emissions, particularly NOx emissions, will have to be addressed:
   i) NOx emissions are dependent on the nitrogen content of the diesel fuel oil used.
   ii) NOx emissions, particularly for some used engines, may not be lower than those of the existing GT unit. They will have higher emission levels than the GT options.
   iii) Applicable diesel engine generator emission regulations in the US and Canada are in flux, with significantly more stringent requirements likely for units coming into service in the 2012 through 2015 period. Emergency power non-mobile (i.e. not on road or off-road units) will face significant but less stringent levels, but will have their operation limited to emergency use only (in effect similar to the restriction imposed on the existing GT).
   iv) Newfoundland & Labrador environmental regulations require BACT, although the regulations have provisions relaxing BACT requirements for both economic impacts as well as flexibility of approval by the Minister considering roles.
      a. The current designs do not have special technology (i.e. Selective Catalytic Reduction (SCR)). Their costs, the impacts of the technology on black start

readiness and reliability, and the costs and impacts of ammonia use and storage for SCR use, make their consideration unreasonable for the roles contemplated.

b. A project going forth will have to seek approval for an exemption from the BACT requirement, and will likely have restrictions placed on its role and likely a limit on the number of operating hours per year.

6. Two MW units are good candidates for redeployment in support of transmission and distribution line maintenance support either post 2020 or in possible periods up to 2020. They are typical of larger unit sizes deployed for that purpose now.

7. The earliest in-service date for procuring and installing 5 x 2 MW new diesel gensets is May 2013. The earliest in-service date for procuring and installing 5 x 2 MW nearly new/used diesel gensets is March 2013.

8. The capital cost for procuring and installing 5 x 2 MW new diesel gensets is $10.8 million. The capital cost for procuring and installing 5 x 2 MW nearly new/used diesel gensets is $9.6 million.

**Overall Economics**

Using the Assessment Basis,

1. The base capital cost comparison of the options is as follows:

**BASE CAPITAL COST COMPARISON OF OPTIONS**

**Capital Cost Comparison**
**Capital cost estimate $1,000 Can 2011**

| **Option Number** | **0** | **1** | **1A** | **2** | **2A** |
|---|---|---|---|---|---|
| **Option** | **Existing GT Refurb** | **New 2 x 5 MW GT** | **Used 2 x 5 MW GT** | **New 5 x 2 MW Diesel** | **Used 5 x 2 MW Diesel** |
| GT/Diesel Cost | $2,950 | $10,865 | $9,234 | $8,553 | $7,453 |
| Civil Works | $224 | $131 | $131 | $131 | $131 |
| Electrical Works | $541 | $759 | $759 | $801 | $801 |
| BOP Systems | $330 | $129 | $129 | $129 | $129 |
| Existing Unit Demolition & Removal | $0 | $7 | $7 | $7 | $7 |
| **Sub-Total - Directs and Indirects** | $4,046 | $11,891 | $10,260 | $9,620 | $8,520 |
| Project Engineering | $324 | $625 | $544 | $513 | $458 |
| Project Management | $283 | $832 | $718 | $673 | $596 |
| Total | $4,652 | $13,348 | $11,522 | $10,807 | $9,575 |

| | |
|---|---|
| + Standby = Total | $4,825 |
| | |
| + New Rental Stdby = Total | $9,421 |

- The life cycle cost comparison of the options in 1) un-escalated non-discounted (not present worthed), 2) un-escalated discounted (present worthed), 3) escalated non-discounted (not present worthed), and 4) escalated discounted (present worthed) costs is as follows.

The existing unit refurbishment option costs include the lower cost standby option assuming that a replacement gas generator and power turbine are leased and installed while the existing units are sent out for refurbishment. This adds only about $170,000 to the base cost. The existing unit refurbishment option costs assuming the standby option using a complete, installed 2 x 5 MW nearly new GT leased option would add an additional $4.7 M. The options include a cost for differences in the likelihood of a failure occurring once during the period – an additional $10 million (2011 Cdn $) in 2016 for the existing GT and $4 million in 2016 for the 5 x 2 MW diesel options.

| | | Refurbished Unit, Use of Spare Gas Generator & Power Turbine | | | | | |
|---|---|---|---|---|---|---|---|
| | | Capital Cost | OMA | Fuel | Sub-Total | Elect Value | Total |
| 1 | UNESCALATED | $14,825 | $1,885 | $1,408 | $18,118 | ($1,648) | $16,470 |
| 2 | UNESCALATED, DISCOUTED CASHFLOW | $11,454 | $1,291 | $959 | $13,704 | ($1,122) | $12,582 |
| 3 | ESCALATED CASHFLOW | $16,260 | $2,159 | $1,660 | $20,079 | ($1,943) | $18,136 |
| 4 | ESCALATED, DISCOUTED CASHFLOW | $11,521 | $1,302 | $992 | $13,815 | ($1,161) | $12,654 |

| | | Option 1 New 2x5 MW GT | | | | | |
|---|---|---|---|---|---|---|---|
| | | Capital Cost | OMA | Fuel | Sub-Total | Elect Value | Total |
| 1 | UNESCALATED | $6,348 | $1,714 | $1,237 | $9,300 | ($1,648) | $7,652 |
| 2 | UNESCALATED, DISCOUTED CASHFLOW | $8,766 | $1,175 | $842 | $10,783 | ($1,122) | $9,661 |
| 3 | ESCALATED CASHFLOW | $4,940 | $1,963 | $1,459 | $8,362 | ($1,943) | $6,419 |
| 4 | ESCALATED, DISCOUTED CASHFLOW | $8,731 | $1,185 | $871 | $10,787 | ($1,161) | $9,626 |

| | Option 1A Used 2x5 MW GT | | | | | |
|---|---|---|---|---|---|---|
| | Capital Cost | OMA | Fuel | Sub-Total | Elect Value | Total |
| 1 | $7,522 | $1,714 | $1,237 | $10,473 | ($1,648) | $8,826 |
| 2 | $8,632 | $1,175 | $842 | $10,649 | ($1,122) | $9,527 |
| 3 | $6,815 | $1,963 | $1,459 | $10,236 | ($1,943) | $8,294 |
| 4 | $8,618 | $1,185 | $871 | $10,674 | ($1,161) | $9,513 |

| | | Option 2 New 5x2MW Diesel | | | | | |
|---|---|---|---|---|---|---|---|
| | | Capital Cost | OMA | Fuel | Sub-Total | Elect Value | Total |
| 1 | UNESCALATED | $9,807 | $323 | $1,237 | $11,366 | ($1,648) | $9,719 |
| 2 | UNESCALATED, DISCOUTED CASHFLOW | $10,231 | $220 | $842 | $11,293 | ($1,122) | $10,171 |
| 3 | ESCALATED CASHFLOW | $9,358 | $370 | $1,459 | $11,187 | ($1,943) | $9,244 |
| 4 | ESCALATED, DISCOUTED CASHFLOW | $10,232 | $222 | $871 | $11,325 | ($1,161) | $10,164 |

| | Option 2A Used 5x2MW Diesel | | | | | |
|---|---|---|---|---|---|---|
| | Capital Cost | OMA | Fuel | Sub-Total | Elect Value | Total |
| 1 | $10,575 | $323 | $1,237 | $12,134 | ($1,648) | $10,487 |
| 2 | $10,128 | $220 | $842 | $11,190 | ($1,122) | $10,068 |
| 3 | $10,593 | $370 | $1,459 | $12,422 | ($1,943) | $10,479 |
| 4 | $10,143 | $222 | $871 | $11,236 | ($1,161) | $10,075 |

## RECOMMENDATIONS

1. The existing gas turbine generator should not be operated (started, operated, shut down), except in an emergency situation, and in such an emergency its operation should be observed remotely.
2. Using the Assessment Basis, the preferred option is Option 1, the 2 x 5 MW new GT installation.
3. Hydro should review the Assessment Basis and any impacts of changes in it as part of its internal decision-making process on the options.
4. Hydro should proceed with a preferred option as soon as practically possible, given that the likelihood of safely and successfully starting the existing GT unit in an emergency condition in its existing state is very poor and likely to decrease rapidly with time idle.
5. If Hydro internally chooses refurbishment of the existing GT generator as its preferred option, then the existing GT generator should undergo an extensive overhaul and repair program, including:

   i) Gas Turbine Unit

      a. Power turbine disk replacement (9 month manufacturing lead time);
      b. Power turbine damaged blades replacement (one or more) or significant repair;
      c. Gas generator blading cleaning and recoating;
      d. Inlet filter media replacement and inlet duct refurbishment (including cooling air duct to power turbine disk); and
      e. Exhaust stack replacement or extensive repairs

   ii) Gearbox lube oil system modification and refurbishment

      a. Seals replacement/modification;
      b. Venting system modifications to reduce lube oil pressure buildup;
      c. Lube oil pump system upgrade for start-ups; and

   d. Lube oil cooling fan replacement

iii) Gearbox bearings refurbishment or replacement and/or unit re-alignment

iv) GT Generator testing and refurbishment

   a. Unit generator electrical testing and possible rewind; and
   b. Unit generator exciter testing, and refurbishment/replacement as necessary

v) GT electrical and controls system update to compliance with current standards and/or obsolescence replacement

   a. Unit AVR
   b. Unit MCC's

vi) The GT and generator enclosure rooms' fire detection and suppression systems modifications to provide better coverage (as evidenced by the failure of the system to initially detect or suppress the gearbox lube oil fire in 2010).

vii) GT fuel oil receiving, forwarding, and delivery system replacement in an enclosed shed.

viii) GT generator building repairs:

   a. Major leaks in and around the gas turbine exhaust stack
   b. Minor leaks at generator ventilation stack
   c. Minor air leaks as a result of minor siding holes (corrosion)

ix) Expansion of the electrical services room to allow for new electrical systems and current systems to be in compliance with current standards (i.e. space, separation distance for arc flash)

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# GLOSSARY

| | |
|---|---|
| °F or oF | Degree Fahrenheit |
| °C or oC | Degree Celsius |
| ATS | Automatic Transfer Switch |
| BTU | British Thermal Unit |
| CO2 | Carbon dioxide |
| CW | Circulating or cooling water |
| DCS | Distributed Control System |
| DG | Diesel Generator |
| Gen | Generator (Only) |
| GTG | Gas Turbine Generator |
| HP | High Pressure |
| JB | Junction Box |
| kV | Kilovolt |
| kVAR | Kilovolt ampere reactive |
| kW | Kilowatt |
| kWh | Kilowatthour |
| LP | Low pressure |
| Max | Maximum |
| MCC | Motor control centre |
| MCR | Maximum continuous rating |
| mm | Millimetres |
| Mg | Megagrams |
| mg | Milligrams |
| MOT | Main output transformer |
| MTS | Manual Transfer Switch |
| MVA | Megavoltampere |
| MVAR | Megavolt ampere reactive |
| MW/MWg/MWn | Megawatt /megawatt gross/megawatt net |
| MWh/MWhg/MWhn | Megawatt hour/ megawatthour gross megawatthour net |
| Min | Minute |
| O2 or $O_2$ | Oxygen |
| psig or $psi_g$ | Pound per hour pounds per square inch gauge |
| psia or $psi_a$ | Pounds per square inch absolute |
| ppmvd or $ppm_{vd}$ | Parts per million (dry volume basis) |
| % | Percentage |
| PT | Power Turbine |
| Rpm | Revolutions per minute |
| Scfh | Standard cubic feet per hour |
| T9 | Transformer #9 |
| TGS | Thermal generating station |
| VAR | Vars |
| V | Volts |

# HOLYROOD THERMAL GENERATING STATION
# GAS TURBINE CONDITION ASSESSMENT & OPTIONS STUDY

## 1 INTRODUCTION

### 1.1 Holyrood Thermal Generating Station and Black Start Gas Turbine Generator

#### 1.1.1 Holyrood Thermal Generating Station (Holyrood)

Holyrood Thermal Generating Station is a three unit, nominally 500 MW, heavy oil fired, steam cycle fossil generating station. It is located on the south shore of Conception Bay in the province of Newfoundland and Labrador, between the towns of Holyrood and Conception Bay South. Holyrood was constructed in two stages - Units 1 and 2 in the late 1960's and Unit 3 in 1977.

When all three units are in operation at full MCR (maximum continuous rating), Holyrood is capable of supplying approximately 33% of the Newfoundland and Labrador electricity demand. Typically, the units operate during the late fall to spring peak period and supply a minimum load of between 80 MW and 150 MW. The Unit 3 generator is also capable of synchronous condenser operation for grid voltage control.

#### 1.1.2 Holyrood Black Start Gas Turbine Generator (GT)

The Holyrood gas turbine generator is a nominally 13.5 MW packaged generating unit system. It serves as a black start unit for the station and is occasionally used for system support. Due to the critical nature of the role that the Holyrood GT plays, it must operate with a high degree of operational reliability.

The gas turbine generator is comprised of a number of components: inlet plenum, AVON 1533-70L gas generator and power turbine, exhaust system, gearbox, generator, fuel oil system, governor/fuel control and lubricating oil system.

Ambient air enters the intake structure, passes through an intake air filter and enters the inlet air plenum. The air is compressed via a 17- stage axial flow compressor in the forward section of an AVON 1533-70L.gas generator. Fuel is supplied to an eight burner combustion section between the gas generator air compressor section and its turbine section. Combustion of the fuel results in a rapid increase in the temperature and velocity of the axial hot combustion gas flow. A three-stage turbine in the back end of the AVON 1533-70L uses a portion of the axial combustion gas flow to increase compressor rotational speed and to boost delivery. The high temperature, high velocity gas is then used to drive the power turbine and generator through a gearbox. The engine has its own on-board lubrication system complete with circulating pumps and a reservoir. The combustion gases then pass through an exhaust volute and to the atmosphere via an exhaust stack.

## 1.2 Project Description & Scope

The gas turbine went in service at Holyrood in 1986. As of December 2010, the unit had a total of approximately 4717 operating hours, +386,000 idle hours, and 2548 starts. Due to the age of the gas turbine and balance of plant, the large number of idle hours, and its exposure to a marine environment, it was necessary to perform a comprehensive condition assessment and life extension study. In general, the unit and balance of plant equipment requires refurbishment or replacement work to continue operating with a high degree of reliability to its required end of life of 2020. The study will identify the measures that need to be taken to ensure reliable operation of the gas turbine (GT) and balance of GT. AMEC Americas Limited (AMEC) was contracted by NL Hydro to conduct a Condition Assessment and Refurbishment/Replacement Study for the Holyrood BlackStart Gas Turbine Generator.

The scope of work consists of an engineering study that will assess the condition of the Holyrood Thermal Generating Station (HTGS) gas turbine and balance of plant and make recommendations for work including cost estimates that will be required to extend its useful life to 2020 with the same high degree of reliability as that experienced in the past. The engineering study will include a Level 2 study as per the guidelines of the Electrical Power Research Institute (EPRI). During the 1970's and 1980's, EPRI developed a three level methodology for performing condition assessment and life extension studies within the utilities industry in which the level of sophistication and detail increases progressively through Level I, Level II, and Level III studies. AMEC shall apply this process to the gas turbine generator and balance of plant equipment.

Part A of the study is primarily a detailed condition assessment and refurbishment study of the existing gas turbine plant located at HTGS with recommendations and cost estimates to extend the life of the gas turbine plant as a highly reliable operation to the year 2020.

Some GT equipment vendors had already issued their condition reports to Hydro. Hydro made these reports available to AMEC. Following an analysis of the reports and consultation with vendors, AMEC shall make recommendations for refurbishment work necessary to extend the life of the gas turbine plant as a highly reliable operation until the year 2020. Cost estimates shall be provided for the recommendations, in addition to giving consideration to the vendor reports.

Part B of the study examines the replacement of the existing gas turbine plant with a new or good used mobile generating plant considering either:

a) A gas turbine plant consisting of two 5 MW mobile/transportable units.
b) A diesel generating plant consisting of five 2 MW diesel units.

If used generating plants are considered, they are required to be relatively new and in good condition.

The new plants are to be able to support start-up block loads up to 3 MW in a smooth and stable manner. The scope would include the decommissioning of the existing plant and removing it from site. The new units would be installed such that uninterrupted black start power availability would be provided to HTGS until new mobile installations are commissioned.

AMEC shall determine the annual operating and maintenance (O&M) cost for each of the alternatives up to the year 2020.

## 1.3 Study Basis

The basis for the study is as follows:

**In-Service:** Summer 2013

**End of Life (EOL):**

- **Holyrood Black Start:** Dec 2020 in Holyrood black start service
- **System Support:** Post 2020 for replacement options - transportable for transmission/ distribution system maintenance to various locations for further 10 to 15 years

**Operating Pattern:**

- **To 2020:** 1 start every 2 weeks to 50%+ load for two hours in winter; 1 start per month in summer; System use – 20 to 40 hrs/year
- **Post 2020:** Maximum 1 month/year operation on transmission line outage support – Maximum 720 hours per year , 6 starts/year

**Capacity Targets:** 10 MW gross peak capacity; Continuous capacity – vendor capacity based on gross peak capacity

**Energy Targets:** No specific energy production targets – Capacity and Operating Pattern define role.

**Reliability Targets:**

| | |
|---|---|
| Start Reliability: | 80% (2nd start – 96%, 3rd start – 99 %) |
| Black Start Ops Reliability: | 98% |
| Peaking Reliability: | 95% |
| Availability: | 93% (Summer maintenance) |

**Health & Safety Target**; Maximum Practically Achievable Safety

- Minimum fire risk
- Minimum catastrophic equipment failure risk

**Environmental & Regulatory Target:** Meet Newfoundland & Labrador environmental and regulatory requirements for the technology and role of the facility

## 1.4 Methodology

### 1.4.1 Part A – Existing Unit Refurbishment

GT equipment vendors previously issued their condition assessment reports to Hydro. Hydro made these reports available to AMEC. An analysis of these reports, and consultation with vendors, forms the basis for AMEC's recommendations for refurbishment work necessary to extend the life of the gas turbine plant as a highly reliable operation until the year 2020. Cost estimates were not provided by the vendors for the recommendations in their assessments. In addition to giving consideration to the vendor reports AMEC shall perform the following tasks in completing the Project.

1. Conduct Equipment Inspections – Balance of Plant (BOP)

AMEC developed a plan, including a schedule, to perform detailed inspections of the remaining gas turbine balance of plant systems and sub systems and identify refurbishment needs. Following the completion of the inspection, AMEC formulated recommendations for refurbishment work complete with cost estimates, including a schedule, that are required to extend the life of the balance of plant systems until the year 2020. The OEM's and other specialists were consulted as required to assist in the study. AMEC contacted OEM's and other specialists to provide this information to AMEC. The remaining gas turbine BOP systems and sub systems addressed by this study included the following:

1. Fuel oil system
    - i. Fuel tanks
    - ii. Fuel oil piping
    - iii. Fuel offloading pumps
    - iv. Valves
    - v. Fuel supply pumps (to the gas turbine)
    - vi. Strainers and filters
    - vii. Fuel flow meter
    - viii. Fire system trip valve
2. Electrical and controls
    - i. Foxboro DCS system
    - ii. DCS logic
    - iii. MCC
    - iv. Switchgear
    - v. Governor system
    - vi. Battery room
3. Compressed air system
    - i. Compressor unit
    - ii. Instrument air dryer
    - iii. Control panel
    - iv. Nitrogen back-up bottle supply
4. Building
    - i. Structure
    - ii. Fire protection system
    - iii. Crane hoist and track system

2. Major Upgrades and Repairs

A number of major upgrades and repairs have been performed on the HTGS gas turbine and balance of plant since it went into service in 1986. AMEC reviewed available plant records pertaining to major equipment upgrades and repairs and evaluate their impact on achieving 2020 service life.

3. Determine Remaining Equipment Life

AMEC assessed the remaining lifetimes of the gas turbine plant major components and systems along with the balance of plant, consulting as required with OEM's and reviewing the historical life cycle information for similar type facilities to assess the requirements to reach an end of life of the gas turbine plant of 2020.

4. Determine Annual Operating and Maintenance Cost

AMEC determined the annual operating and maintenance (O&M) cost for the gas turbine plant up to the year 2020, both with the recommended refurbishments and without completing the recommended refurbishment work. AMEC contacted OEM's and other specialists as required to support development of this information.

### 1.4.2 Part B – Existing Unit Replacement

AMEC developed a scope of work and cost estimate to replace the existing gas turbine plant with a new or good used mobile generating plant considering alternative arrangements as noted below. If used generating plants are considered they are required to be relatively new and in good condition.

a) A gas turbine plant consisting of two 5 MW mobile units.

b) A diesel generating plant consisting of five 2 MW mobile diesel units.

The alternative arrangements were configured such that the new plants would be able to support start-up block loads up to 3 MW in a smooth and stable manner. In addition, cost estimates included decommissioning of the existing plant and removing it from site. The alternatives considered were such that uninterrupted black start power availability would be provided to HTGS until new mobile installations are commissioned.

AMEC determined the annual operating and maintenance (O&M) cost for each of the alternatives up to the year 2020.

The study methodology included the following steps:

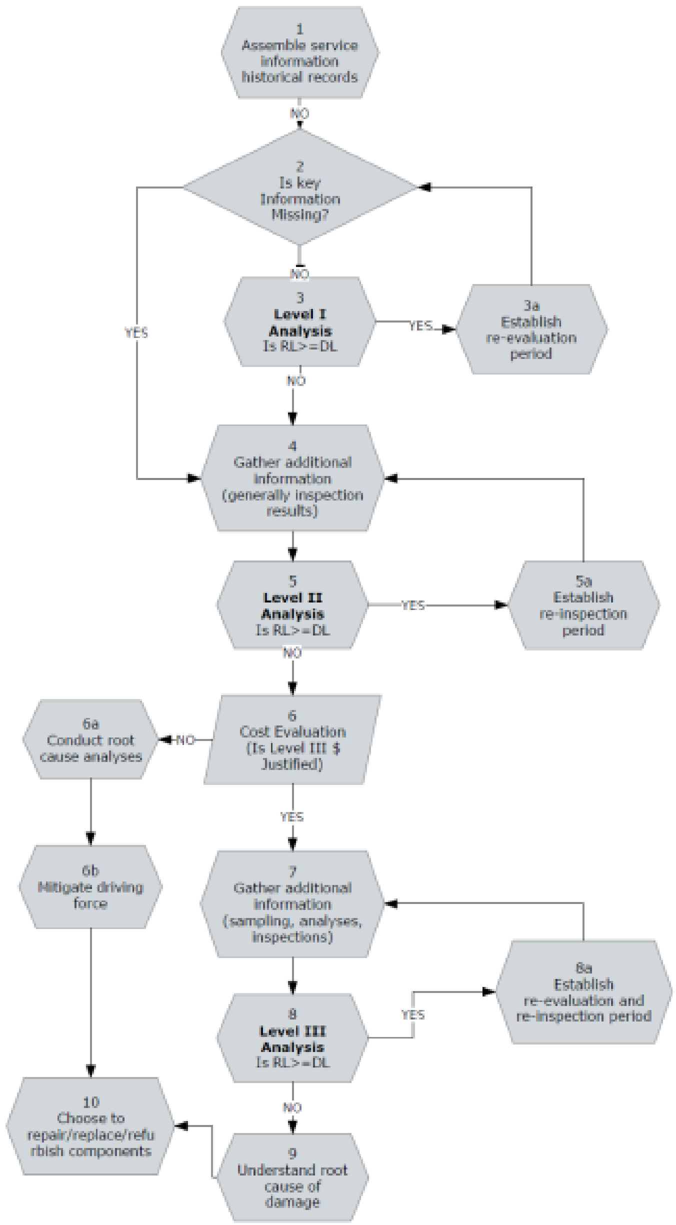
- Initial kick-off meeting and site visit
- Site review and equipment/facility inspections
- Review of the Holyrood Plant Maintenance Program – existing information/background data and staff interviews
- Review and analysis of information and data obtained through:
    2. Existing studies on condition assessment, life expectancy, previous studies of life extension, and the associated costs (capital and O & M) of such programs
    3. Previously noted physical inspection reports of equipment
    4. Equipment lost time analysis data
    5. Interviews and discussions with NL Hydro management
    6. Interviews and discussions with Holyrood Operations and Maintenance personnel
    7. Analysis of power demands vs. Holyrood generation capabilities
- Analysis of the impact and value of capital upgrades and operational and maintenance improvements
    1. Determination of remaining equipment and facility life – using existing information, experience, and OEM consultations as required to develop life cycle curves for major critical equipment and facilities not expected to exceed the 2020 end of life date; and
    2. Conduct equipment risk of failure analysis for major plant components, equipment, systems, and the entire facility which is not expected to exceed the 2020 end of life date.

3. Identify any components or systems that require further investigation; and make recommendations for work that will be required to extend the plant's useful life to 2020 with the same high degree of reliability as experienced in the past.

To the extent practical, the approach followed the intent of the EPRI Condition Assessment Level 2 process or a reasonable alternative approach as determined by individual technology experts. The basic approach consistent with the EPRI Level 2 approach is:

- Examine design or overall service parameters
- Perform Level 2 inspections (physical only, no testing)
- Compare, using conservative considerations, the expected residual life to the required 2020 service period (or the interval to the next inspection whichever is less)
- Incorporate service and measurement information where practical, available and useful including:
  1. Unit running hours
  2. Numbers of starts and stops – hot, warm, cold, trips, ramp rates
  3. Unit load records
  4. Failure history and analyses reports
  5. Maintenance activities
  6. Specifics of past component repairs and replacements
  7. Materials of construction composition checks
  8. Dimensional checks
  9. Design parameters

The generic EPRI condition assessment methodology is illustrated in Figure 1-1. This chart includes step numbers used in the report to identify where in the process various systems and equipment are considered to be.




NOTE: Remaining Life (RL) is the estimated reliable remaining life of a piece of equipment or system based on available inspection and equipment data. Desired Life (DL) is the desired life of the component, but for decision making is the earlier of the desired end of life (EOL) date or the next inspection that can yield date for life assessment purposes.

**FIGURE 1-1 GENERIC EPRI CONDITION ASSESSMENT METHODOLOGY**

For mechanical systems, it considers aspects such as:

| Feature | Level I | Level II | Level III |
|---|---|---|---|
| **Failure History** | Plant records | Plant records | Plant records |
| **Dimensions** | Design or nominal | Measured or nominal | Measured |
| **Condition** | Records or nominal | Inspection | Detailed inspection |
| **Temperature and pressure** | Design or operational | Operational or measured | Measured |
| **Stresses** | Design or operational | Simple calculation | Refined analysis |
| **Material properties** | Minimum | Minimum | Actual material |
| **Material samples required?** | No | No | Yes |

More rigorous assessment →

More accurate operation data required →

More accurate estimate of equipment RL →

**FIGURE 1-2 EPRI METHODOLOGY – INFORMATION REQUIREMENTS**

The Level 2 analysis considers several issues, such as:

- Has the unit component operation exceeded its design parameters (i.e. temperature, pressure) for significant periods of time or by significant amounts?
- Will the required future service requirement exceed significant design parameters (i.e. cycling, two-shifting capacity) without suitable modification?
- Has unit maintenance and reliability shown that the operating philosophy and materials have not been conservative since the units was operational?
- Has the failure history been excessive?

The intent in Level 2 is to address items with insufficient information to make decisions going forward. For example in the chart below, Level 1 allows selection of a number of components to replace, repair or refurbish, but leaves the majority as uncertain. Level 2 further refines the uncertain portion of Level 1.

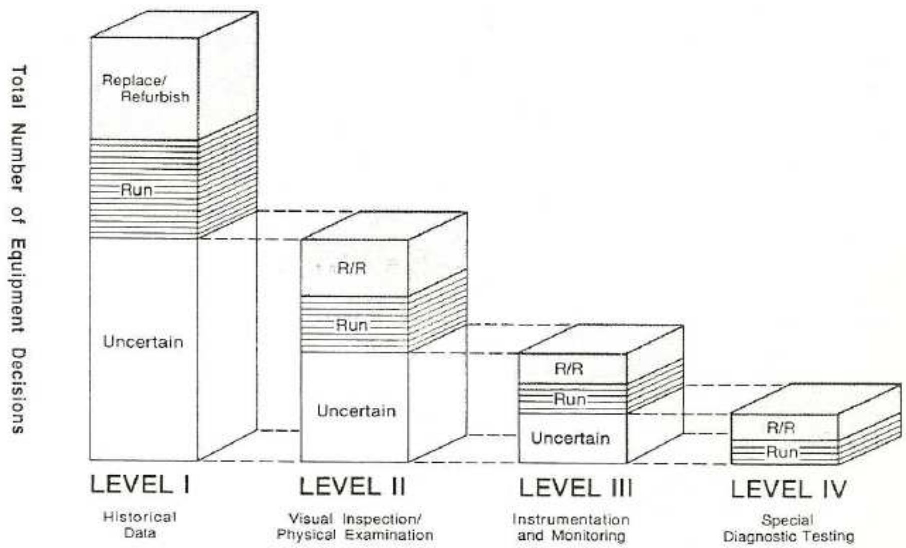



**FIGURE 1-3 FOUR-LEVEL ELECTRICAL COMPONENT LIFE ASSESSMENT**

## 1.5 Background Information and Studies

The key background information and studies included the following:

- Identification of key equipment;
- Identification of recent improvements/changes – fuel, major modifications, etc.;
- Vendor consultation;
- Current/planned station budgets and plans;
- Timing of changes – likelihood;
- Staffing, Operating, Maintenance and Administration (OMA) plans;
- Criteria for operation and operating parameters;
- Major equipment to be considered;
- Present design and operating data – e.g. temperatures, vibration data, cooling water and oil temperatures, etc. at typical load points;
- Facility drawings as required;
- Maintenance data for major pieces of equipment, especially from the last major maintenance outage. Details of known limitations, and operating concerns; and
- Details of major repairs performed on major equipment.

## 1.6 Field Investigation

It was agreed that the scope and results of field investigative work, analyses undertaken, variables examined, and operational considerations would address:

- Operating hrs and cold/warm/hot starts;
- Major outages and associated reports (planned, major maintenance);

- Major plant equipment and system changes (i.e. equipment change-out, major gas turbine modifications and generator modifications) since in-service (particularly in last 10 years) including the scope and timing of the changes;
- Major inspections (and associated reports) on key equipment and systems;
- Unit performance – capacity, heat rate, availability;
- Current budget and business plan information details; and
- Occurrences where the actual operating conditions exceeded the equipment design conditions.

## 1.7 Scope, Key Features and Parameters of Study

The study scope was discussed with NL Hydro during an initial kick-off meeting and it was agreed that:

- AMEC would adapt the Holyrood asset register as the primary index.
- The generic EPRI Condition Assessment approach illustrated in Figure 1-1 is the methodology employed. A more generic approach, using industry and individual expert experience, taking into account Holyrood specific information, was applied in many cases.
- The intent is to provide an assessment of requirements including schedule and cost. Given the stage of and eventual scope of the work, as well as the economic environment, an accuracy of +/- 10-15% is a target typically achieved during detailed quotes on actual work, and the overall costs are practically speaking more of a +10/-25% quality, typical of this stage of the work.

The following key features of the study were identified:

- No new detailed information was developed. The assessment was based on existing information obtained through existing documents and studies, plant interviews, and readily undertaken visual inspections
- The findings of existing studies are taken into account.
- The intent of the EPRI Level 2 methodology is to determine whether a piece of equipment or system can either reach it's intended planned life or reach its next major inspection and overhaul. If it is indeterminable as to whether the equipment can or cannot reach its planned life or next major inspection/overall, then a Level 3 condition assessment is necessary.
- The study focuses primarily on key equipment systems required for black start operation up to 2020
- Inspection and analysis has been done by others on the major gas turbine OEM equipment as per the RFP document. AMEC will use this condition and cost information as the basis for its gas turbine assessment.
- No inspections were required for equipment identified in the Level 1 study as satisfactory – for example: fuel tanks, building siding, recent electronics equipment additions.
- EPRI Level 2 inspections were limited to equipment identified as BOP and for which visible and practical inspections are possible in AMEC's judgment.
- Inspections were only undertaken per above and only on key equipment that is not considered covered under regular OMA, but represented a life limiting issue having a probable and significant impact on the reliable operation of the unit in AMEC's judgment.
- No specific equipment testing was undertaken as a Level 2 exercise.
- Remaining life was determined and reported on for those major systems and pieces of equipment which are expected to fail before 2020 and have a significant reliability impact on the gas turbine unit in AMEC's judgment.

## 1.8 Cost Estimating and Schedule

AMEC developed cost estimates and schedule for both Part A and Part B options - to complete a GT refurbishment as well as to replace the existing gas turbine unit with either 2 x 5 MW gas turbine generators or 5 x 2 MW diesel engine generators. Where practical, the cost estimate targeted an accuracy range of +/- 10-15%. It was identified and agreed that this would not be practical in many cases given the stage of work and the labour and materials marketplace and any key considerations pertinent to completing the cost estimate and schedule provided.

## 1.9 Site Visits

AMEC staff visited Holyrood in May-June 2011:

- A one-week visit by Rupert Merer (GT expert) and Blair Seckington; and
- Various short term visits by several of AMEC St John's office staff with Civil, Structural, Electrical & Controls, and Mechanical expertise.

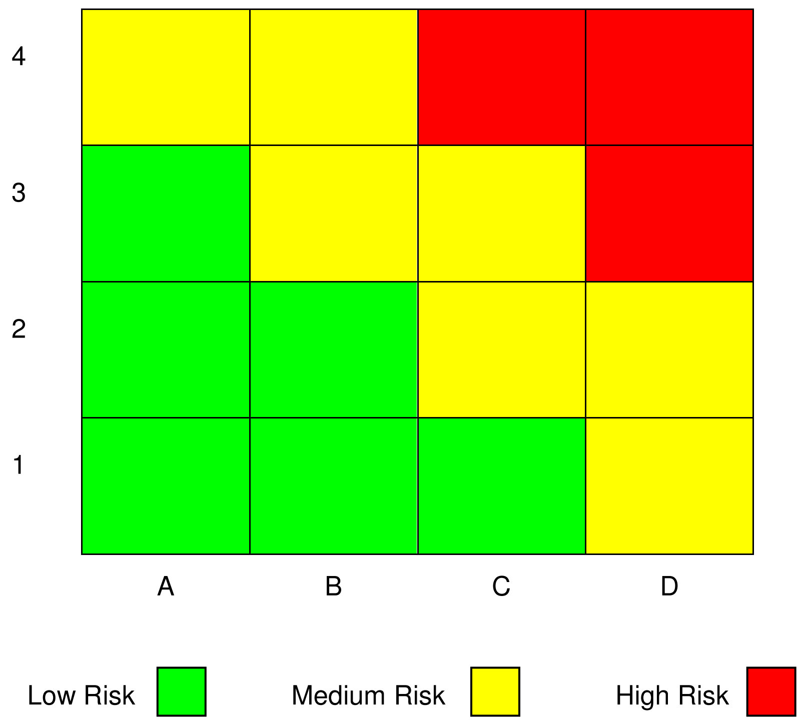
In the course of these visits, meetings and interviews included the following staff:

- Plant management team as a whole – kick-off, scope, areas of responsibility, and general information sharing;
- Terry LeDrew (Plant Manager) – key plant issues and asset history;
- Jeff Vincent (Manager-Long Term Asset Planning) – various plant asset conditions, capital plans, Instrumentation and Controls (I&C), Electrical, and organization;
- Wayne Rice (Manager-Work Execution) – various equipment and system conditions and plant staffing;
- Sean Mullowney (Plant Electrical Engineer) – various technical issues and programs regarding electrical systems, instrumentation, and controls;
- Jamie Curtis (Quality Assurance Engineer) – NDE and test program results;
- Christian Thangasamy (Plant Mechanical Engineer) – various technical issues and programs related to condensers, boilers, synchronous condenser, steam turbine generator, motors, and pumps;
- Mike Manuel (Manager-Environment, Health and Safety) – reliability;
- Alonso Pollard (Performance Specialist) – performance data (reliability and availability);
- Gerard Cochrane (Manager - Operations) – plant and equipment performance issues, plant operations issues;
- Plant Shift Supervisors and Operators (various) – plant operations issues and performance;
    - Ron MacDoanald, Willis Young
- Ron LeDrew (Emergency Response Coordinator) – Emergency Response Team (ERT) activities;

## 1.10 Technological Risk of Failure Analysis

The risk assessment model has been developed based on methods proposed by the American Petroleum Institute (API RP 580), in lieu of a model specific to the power utility industry. The basic concept consists of a 4 x 4 matrix with the consequence measured in cost terms on the base or horizontal axis and the likelihood or frequency of the event on the vertical axis. The study risk of failure analysis was performed using the model illustrated below in Table 1-1.

**TABLE 1-1 TECHNOLOGICAL RISK OF FAILURE ANALYSIS MODEL**




Likelihood of Failure Event:

1. Greater than 10 years
2. 5 to 10 years
3. 1 to 5 years
4. Immanent (< 1 year)

Consequence of Failure Event:

A. Minor ($10k-$100k or derating/1 day outage)
B. Significant ($100k-$1m or 2-14 days outage)
C. Serious ($1m-$10m or 15-30 days outage)
D. Major (>$10m or >1 month outage)

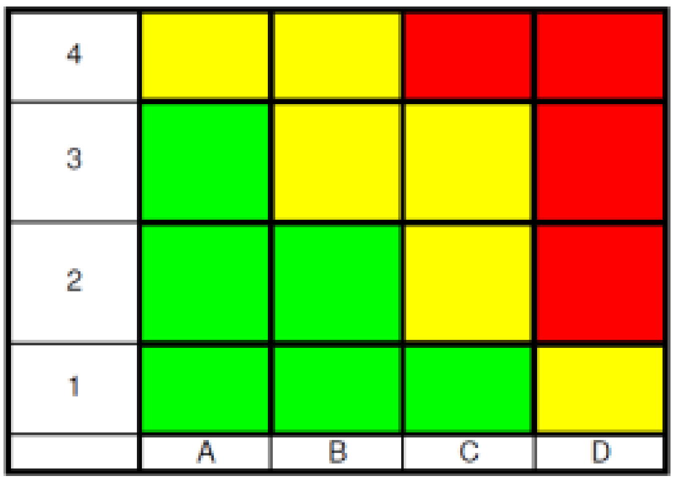
Actions:

- Items that do not apply are not ranked
- Low Risk: Monitor long term (within 5 years)
- Medium Risk: Investigate and monitor short term. Take action where beneficial
- High Risk: Corrective action required short term

### 1.10.1 Safety Risk Failure Analysis

In addition to the technological risk of failure analysis, a preliminary safety risk of failure analysis was undertaken at NL Hydro's request. Its basic format is based on that of the technological risk assessment model above and is somewhat of a hybrid of the more complex "Real Hazard Index" model used by the US Department of Defence. The modified model is presented below in Table 1-2.

**TABLE 1-2 SAFETY RISK FAILURE ANALYSIS MODEL**




Low Risk Medium Risk High Risk

Likelihood of Safety Incident Event:

1. Improbable – so that it can be assumed not to occur
2. Unlikely to occur during life of specific item/process
3. Will occur once during life of specific item/process
4. Likely to occur frequently

Consequence of Safety Incident Event:

A. Minor - will not result in injury, or illness
B. Marginal - may cause minor injury, or illness
C. Critical - may cause severe injury, or illness
D. Catastrophic - may cause death

Actions:

- Items that do not apply are not ranked;
- Low Risk: Monitor, take action where beneficial;
- Medium Risk: Investigate and monitor short term. Take action where beneficial; and
- High Risk: Unacceptable. Corrective action required short term

## 1.11 Priority Rating

A numbered priority was assigned to the various “Recommended Actions”, “Level 3 Inspections”, and “Capital Enhancements” of this report. The scale used was from “1” to “4”. A “1” is the highest priority and essentially means that this activity should definitely be undertaken and where practical in or about the timing identified. A “4” is the lowest priority and essentially means that the item is essentially low risk and low impact and may be much more readily delayed or undertaken in some other fashion. The priority ranking is a subjective relative ranking by AMEC, meant to be an aid to Hydro in allocating resources and assessing trade-offs and program delays.

The priority ranking is not based on a rigorous process, but does take into consideration a number of aspects such as:

1. The impact (likely and worst case) of the item under consideration on achieving the end of life (EOL) goal, on plant operation health and safety, and on environmental and regulatory requirements;
2. The urgency of the need for action on the item under consideration;
3. The degree of certainty of the requirement for the item under consideration;
4. The experience at Holyrood and in the broader industry context with the item;
5. The ability to mitigate or address the issue in other ways;
6. The timing of the recommended response to the item under consideration;
7. The cost of the item under consideration relative to others; and
8. The ability of existing and planned or ongoing actions to address the item in a timely and successful manner.

The priority value of any item should be read in the context of its recommended timing. An item can be a “1”, but be scheduled for a later date if it is deemed that sufficient information exists to be confident of the minimal likely impact of the deferral (usually to tie in with a planned major activity such as an overhaul).

# 2 EXISTING GAS TURBINE CONDITION ASSESSMENT

## 2.1 Gas Turbine Unit and Equipment/Processes

| | |
|---|---|
| Unit #: | GAS TURBINE |
| Asset Class # | BU 1273 Gas Turbine |
| SCI & System: | 7202 Gas Turbine System |
| Sub-Systems: | 7058 GT Power Turbine & G/B<br>7308 GT Avon Jet Engine<br>7309 GT Generator |

### 2.1.1 Description of Holyrood API Gas Turbine

The Holyrood API gas turbine is a 10/12 MW aeroderivative packaged power plant using a Rolls Royce Avon gas generator. It was designed for peaking duty to provide black start capability to the Holyrood Generating Station. The Holyrood unit is the first API produced, and had guaranteed ratings, at ISO conditions, of 12 MW peak and 8.4 MW base load. It was originally installed at Hardwoods, but moved to Holyrood in 1970. In 1986 the plant was removed from its enclosure and re-installed in a custom building with a new exhaust stack with exhaust silencer and inlet filter house.

The gas turbine generator is comprised of a number of components: inlet plenum, AVON 1533-70L power turbine, exhaust system, gearbox, generator, fuel oil system, governor/fuel control and lubricating oil system.

Ambient air enters the intake structure, passes through an intake air filter and enters the inlet air plenum. The air is compressed via a 17- stage axial flow compressor in the forward section of an AVON 1533-70L.gas generator. Fuel is supplied to an eight burner combustion section between the gas generator air compressor section and its turbine section. Combustion of the fuel results in a rapid increase in the temperature and velocity of the axial hot combustion gas flow. A three-stage turbine in the back end of the AVON 1533-70L uses a portion of the axial combustion gas flow to increase compressor rotational speed and to boost delivery. The high temperature, high velocity gas is then used to drive the power turbine and generator through a gearbox. The engine has its own on-board lubrication system complete with circulating pumps and a reservoir. The combustion gases then pass through an exhaust volute and to the atmosphere via an exhaust stack.

The whole unit was re-housed in a custom building in 1986 with new filter house, generator filters, control room and exhaust stack. New stainless steel inlet splitters were installed. A new exhaust silencer and stack were installed with exhaust hoods, a number of control upgrades have been made, and the generator compartment was provided with new filter elements.

**GTG Inlet Plenum**

The inlet plenum is designed to provide approximately 140,000 cubic feet per minute of combustion air to the jet intake. This plenum is constructed of structural steel plate and framing supported by a concrete foundation. To reduce compressor damage and blade fouling, the inlet air must be free of dust and dirt.

Filtration is currently accomplished using a two stage filter. The first stage is designed for water removal, while the second was a high efficiency media type filter. It has 72 high efficiency "Farr" filter assemblies supported on tubular columns above the intake. The inlet silencer consists of acoustical splitters in a steel shell that is designed with round leading edges to create a bell-mouth entry. The trailing edges are tapered to ensure a low pressure drop and uniform flow characteristics. The plenum chamber is built from 10 cm (4 inch) thick noise-shield panels, packed with acoustic fill and secured to a rigid steel frame.

**GTG Gas Generator**

The gas generator employs a Rolls-Royce AVON 1533-70L (#37029) aeroderivative gas turbine manufactured by Associated Electrical Industries (AEI) of Manchester, England. Manufacture of this type generating unit began in the mid 1960's. The unit supplied to the Newfoundland and Labrador Power Commission in 1966 was the first one off the drawing board and was considered to be a development model. The three stage turbine in the aft end of the AVON 1533-70L uses a portion of the axial air flow to increase compressor rpm and boost delivery. The high temperature, high velocity gas exits the jet through an exhaust transition duct which is used to drive the Power Turbine and thus the generator through a gearbox.

The compressor of the Rolls Royce Avon is a single shaft axial compressor unit, with a 17 stage compressor giving a pressure ratio of approximately 10 in industrial service, 8 combustors in an annular arrangement and a 3 stage turbine.

The Rolls Royce Avon gas generator is a single shaft axial unit which was developed in the late 1940s and early 1950s as a prototype axial compressor unit. It is a first generation aero engine, with no bypass. It powered a number of aircraft in the 1950s and early 1960s and very successful adapted as a gas generator, especially in gas compressor drive applications where it established new standards in the late 1960s and 1970s for overhaul life or time between overhauls. TransCanada pipelines, and other North American pipelines, standardized on the Avon until more efficient second generation units became available.

**GTG Power Turbine**

The power turbine is an Associated Electric Industries Ltd. (AEI) design, manufactured in Manchester, England in early 1966. The power turbine is a single stage overhung machine designed for a normal operational speed of approximately 4900 rpm. The power turbine is connected to its generator via a gearbox and its output is converted to 1200 RPM in a vertical pinion and wheel gearbox (ratio of 4:1). The power turbine and gearbox are mounted on the centre section of the unit bedplate with this section also forming the main lubricating oil tank. Auxiliary and emergency oil pumps are mounted on this same base plate. The power turbine casings (volute) were replaced in 1986.

The power turbine uses heavy duty steam turbine construction techniques in contrast to the Avon. The power turbine shaft and disk are solid, although the inner cylinder which constrains the gas flow is fabricated from nimonic materials (nickel based alloys with high temperature tolerance). The power turbine disk is a low alloy ferritic material and it is probable that it has an operating limit of about 535 Deg C. It is cooled by a mixture of bleed air from the Avon and outside air. The power turbine diaphragm and moving blades are nimonic. The power turbine blading is nimonic and uses axially serrated roots, which are now common on modern gas turbines but were only used by AEI in the 1960s for highly stressed locations.

**GTG Gearbox**

The main gearbox was manufactured by AEI in Manchester, England. It is designed to provide an approximate 4:1 speed ratio from the power turbine shaft to the main generator shaft. The power turbine operates at about 4800 RPM and its output is converted to 1200 RPM in a vertical pinion and wheel gearbox. AEI had built quite complex marine and other gearboxes and the API unit was well within their experience. The gear train is fitted to the power turbine rotor by semi-flexible coupling housed within the gearbox. The gears are of the single helical, single reduction type with the pinion mounted directly above the wheel. A removable top cover allows for inspection without disturbing the alignments.

**GTG Exhaust System**

The exhaust casing (volute) is a welded fabrication divided along the horizontal centreline. It turns the combustion gasses transversely to the machine and vertically upwards to the exhaust silencer.

The exhaust stack is constructed of heavy gauge steel plate with light gauge steel cladding on the exterior. The exterior cladding of the lower half of the exhaust stack is constructed of heavy gauge steel plate. This stack was replaced during the 1986 major upgrade. The snow doors on the exhaust stacks are pneumatically actuated and were a new addition in 1986 to reduce corrosion of the volute and power turbine from infiltration of snow and rain water which promoted corrosion within the unit. New limit switches installed on the doors in 2009 indicate the position (opened or closed) of each door at the control station.

**FIGURE 2-1 GTG GAS ENGINE & GENERATOR**

**Generator**

The generator is an air-cooled, 14 MW, 13.8 kV, 3 phase, Type AG 80/100, built by Associated Electric Industries (AEI) of Rugby, England in 1966. It has a rotating-field, salient-pole tube with 6 poles and rotates at 1200 rpm. The brushless exciter eliminates the danger of contamination by carbon dust and minimizes maintenance. Semi-conductor rectifiers rotating within the generator/exciter shaft provide excitation for the main generator field.

**Governor and Fuel Control**

The standard Avon fuel control system is used without alteration as a basis for the API governing and fuel control system. The throttle valve is used as a generator valve and the H.P. cock as a fuel shut-off valve for normal and emergency shut-downs. The governing system is of the sensitive oil type in which fluid pressure is used to transmit the movement of the governor pilot valve to the operating mechanism of the governor valve, in this case the Avon throttle.

The governor is manufactured by Woodward and is driven via gearing from the end of the high speed pinion shaft. The governor is a fly-weight type and carries its own oil supply. Woodward Governor suggests that the present system has a reliability of about 50%. In addition, spare parts for this system are not carried and would have to be fabricated requiring long delivery times.

**Excitation System**

The exciter is a rotating brushless type mounted on a stub to the main rotating shaft. It was designed to ANSI Specification C50-1 3. The AC output from the exciter armature is fed through a set of diodes that are mounted on the rotor and are used to produce a DC voltage. The voltage is fed directly to the field winding of the main generator which is also mounted on the same rotating shaft.

The excitation control system consists of a "Normal" and "Standby" automatic voltage regulator (AVR) backed up by a "Manual" control mode. The AVR controls the strength of the magnetic field in the exciter by varying the amount of current through the stationary exciter field windings.

### 2.1.2 Operating History

| | |
|---|---|
| Original Manufactured/Delivered | 1966 |
| In-Service Date at Hydro | 1970 |
| Rehoused at Holyrood | 1986 |
| End of Planned Life Date | 2020 |
| Last Combustion System Inspection/Overhaul | 2009 |
| Next Major Overhaul/Inspection/Refurbish/Replace | 2012/13 (Recommended) |

The gas turbine generator system at the plant serves as a black start unit for the station. It is occasionally used for system support as well. The hours associated with the unit are provided in Table 2-1 below.

To date, the gas turbine has operated for 4770 hours and 2548 starts. The numbers of hours operated during different phases are shown in the table, below.

**TABLE 2-1 HOLYROOD API OPERATING HISTORY**

| | Hours | Starts | Hours/yr | Starts/yr | Starts/hr | Idle/hr |
|---|---|---|---|---|---|---|
| 1966-1978 | 1749 | 611 | 140 | 47 | 3.0 | 85,000 |
| 1979-1985 | 390 | 185 | 65 | 32 | 2.0 | 85,000 |
| 1986-1995 | 1336 | 644 | 134 | 64 | 2.0 | 85,000 |
| 1996-2005 | 332 | 585 | 33 | 59 | 0.5 | 85,000 |
| 2006-2011 | 961 | 523 | 174 | 87 | 0.5 | 51,600 |
| TOTALS | 4770 | 2548 | | | | 391,600 |

Peaking units traditionally operate for between 500-1000 hours per year, but the Holyrood API has averaged closer to 100 hours per year, and many of these hours, at least in recent years, have come from monthly test runs.

Some parts have been refurbished or replaced. The pattern used for the hours of operation and starts to the end of life date of 2020 is:

**TABLE 2-2 HISTORICAL AND FORECAST OPERATING PATTERN**

| | Year To Dec 31 | GT Ops Hrs | | GT Idle Hrs | | GT Starts | | GT Ops Hrs/Yr | | GT Starts/Yr | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Low | High | Low | High | Low | High | Low | High | Low | High |
| Balance of Plant | 1966 | 0 | | 0 | | 0 | | | | | |
| | 1978 | 1749 | | 85000 | | 611 | | 139.9 | | 48.9 | |
| | 1985 | 2139 | | 170000 | | 796 | | 55.7 | | 26.4 | |
| | 1995 | 3475 | | 256000 | | 1440 | | 133.6 | | 64.4 | |
| | 2005 | 3807 | | 343000 | | 2025 | | 33.2 | | 58.5 | |
| | 2010 | 4717 | | 386000 | | 2548 | | 182.0 | | 104.6 | |
| | 2011 | 4737 | 4737 | 394740 | 394740 | 2558 | 2563 | 20 | 20 | 10 | 15 |
| | 2012 | 4737 | 4737 | 403500 | 403500 | 2558 | 2563 | 0 | 0 | 0 | 0 |
| | 2013 | 4809 | 4887 | 412188 | 412110 | 2585 | 2635 | 72 | 150 | 27 | 72 |
| | 2014 | 4881 | 5037 | 420876 | 420720 | 2612 | 2707 | 72 | 150 | 27 | 72 |
| | 2015 | 4953 | 5187 | 429564 | 429330 | 2639 | 2779 | 72 | 150 | 27 | 72 |
| | 2016 | 5025 | 5337 | 438252 | 437940 | 2666 | 2851 | 72 | 150 | 27 | 72 |
| | 2017 | 5097 | 5487 | 446940 | 446550 | 2693 | 2923 | 72 | 150 | 27 | 72 |
| | 2018 | 5169 | 5637 | 455628 | 455160 | 2720 | 2995 | 72 | 150 | 27 | 72 |
| | 2019 | 5241 | 5787 | 464316 | 463770 | 2747 | 3067 | 72 | 150 | 27 | 72 |
| | 2020 | 5313 | 5937 | 473004 | 472380 | 2774 | 3139 | 72 | 150 | 27 | 72 |
| | | | | | | | | | | | |
| Combustor: | 2020 | 713 | 1337 | | | 1174 | 1539 | 72 | 150 | 27 | 72 |
| PT Volute: | 2020 | 2213 | 3837 | | | 1974 | 2339 | 72 | 150 | 27 | 72 |

The unit has operated for an average of about 100 hours per year and about 50 starts per year, consistent with use for emergency peaking. Although distillate fuel is used resulting in high unit energy costs, little attention has been given to efficiency due to the peaking/emergency roles of the unit. The station operators have demonstrated that they can usually start the unit fairly quickly, although it often takes several attempts. The station does not record starting reliability, which is one of the most important criteria for a normal peaking emergency unit.

One interesting aspect for early Avon units without corrosion protection was that each standby hour may have consumed the equivalent of 0.3 hours of running life. (Maintenance and Support of Mature Gas Turbines – M. Hudson, Siemens 2005)

### 2.1.3 Major Maintenance History

The API unit was originally supplied in its own packaging, but in 1986 the unit was relocated into a custom building with a new inlet filter house and exhaust stack. At that time a GEM80 PLC was installed.

The unit has had significant overhauls/repairs in 1978, 1986, 1991, and 2007.

The following is a summary of significant work completed since 2003. No major overhauls have been completed on the entire machine since 1991. No details of the overhaul work in 1991 (or prior) were available for this study. Limited data on the maintenance of the unit before 1986 was available, with the exception of the Avon.

**16 October 2003**

- Annual boroscope inspection;
- Slight erosion on casing. Re-protect next shop visit;
- Normal amount of carbon build up on nozzle heads;
- Boroscope inspection satisfactory; and
- Intake plenum contained debris, chipped floor and flaking paint. Recommended clean up.

**10 August 2004**

- Annual hot section inspection & failure to start;
- Housing found to have corrosion on struts, will require protective coating next shop visit;
- Air plenum cleaner than last visit, holes still visible in walls;
- Compressor rotor and stator vane blades in dirty condition;
- Normal amount of carbon build up on nozzle heads;
- Slight damage to #7 Combustion Can; and
- Starting motor replaced, due to seizure. (Solved starting issue).

**27 September 2005**

- Annual inspection and boroscope inspection;
- Front Bearing Housing, outer bushes loose;
- Front Bearing Housing, Corrosion/ pitting;
- Corrosion/ Rust found in Plenum;
- HP NGV's have slight erosion of the leading edges and minor cracks in the trailing edges;
- Flame tubes have minor erosion on some of the wiggle strips and some carbon build up within the flame tube, especially around the dish where liquid fuel has collected;
- Normal amount of carbon build up on nozzle heads; and
- Hot gas leakage at Exhaust Transition duct to power turbine.

**13 March 2006**

- Leak in each end of the gearbox at the bearing seals. (Caused fire when oil leaked into insulation around PT and dripped onto top of tank). Greenray discovered turbine shaft/seal modifications, recommended machining and reconditioning.

**13 April 2006**

- Fuel oil leak on underside of gas turbine at IGV Ram, seal deterioration.

**25 May 2007**

- AVON repair and boroscope inspection: IGV ram leak, ignitor failure, hot air leak from #6 burner, bellmouth nuts loose, combustion casing boroscope port bolts loose, bleed valve ducting broken and separated, fuel lag at idle and struggling at speed;
- Significant sparking coming from PT splash plate (rubbing shaft). Suggests bearings are worn and thus damaged seal;
- 2 IGV bushes replaced due to wear in the bush. (Majority of bushes and retaining nuts were replaced as well as the locking bush);
- Rebuild of the intake with securing bolts torque and locked;
- IGV ram replaced due to leak;
- Fuel filter replaced due to feed issues;
- Bolts holding PT seal were not tight, seal incorrectly installed;
- Ignitor, lead and box were replaced;
- High fuel consumption noticed at fuel drain valve, suspect worn seals on FCU and fuel pumps;
- Additional breather recommended for rear of gearbox unit, to reduce leaks;
- Compressor section; front bearing housing, inlet guide vanes have significant corrosion and coating loss;
- Combustion cans show signs of cracking, material loss (could lead to further turbine damage);
- IP nozzle guide vanes and HP nozzle guide vanes show signs of cracking on trailing edges;
- Change PT lube oil filters; and
- Replace/ Repair exhaust snow doors.

**21 May 2008**

- Package filtration inspection;
- Plenum survey;
- Windmill inspection of compressor;
- Boroscope of compressor and VIGV;
- Fuel/oil system: connection, fuel pump/ oil pump, pipelines, oil level & quality, filter and basket removal (replacement consumables);
- On engine review: bleed valves, IGV ram (filter review), gearbox inspection (filters, speed pick up, consumable change), fuel control unit review, oil cooler, fuel filter change, burner removal (ultrasonic cleaning), fuel rail inspection, drain valve operation, thermocouple inspection (terminal cleaning), transition inspection, removal of insulation, rectify leaks, inspect LP blades;
- Boroscope inspection: rear of compressor, snout area, combustion can, HP nozzle guide vanes, cooper beams (crooks washers), turbine section;
- PT and gearbox review; and
- Controls review.

**10 June 2008**

- Water pooling noted in intake plenum along with holes in structure and loose debris;
- Compressor showing significant corrosion and pitting on front bearing housing, inlet guide vanes and compressor stages, physical signs of salt evident;
- Combustion cans need to be replaced due to extensive corrosion, #1 and #2 burners removed for inspection. Seized bolts prevented removal of others;

- Hard impact damage evident in turbine stages, suspect debris from combustion cans and/or intake plenum;
- Suggested unit overhaul for blade recoating etc.; and
- Fuel pump and FCU to be repaired.

**15 October 2009**

- Engine removed and placed on site, in vertical stand for repairs (combustion cans);
- Combustion cans were replaced and FCU and fuel pump repaired;
- Loose discharge nozzles, due to broken brackets (2 off) to be replaced in future;
- PT inspection showed signs of light blade rub, none on stators. Diaphragm free of damage;
- PT inlet cone cranks, to be repaired;
- Thermocouple damage, quick fixed. To be upgraded;
- Exhaust stack needs replacement, lower components noted in good condition. Door opening components to be serviced; and
- Transition duct piston rings seals to be replaced.

**20 November 2009**

- Commissioning;
- Fuel control solenoid valve burnt out and replaced;
- Multiple start trips due to; low fuel pressure, low oil pressure, incomplete start sequence; determined igniter box malfunction, N2 probe incorrectly connected & FCU actuator tuning;
- Exhaust transition lagging replaced due to fuel saturation;
- Split air manifold cracks, to be repaired; and
- Suggest monitoring setup for the 8 EGT thermocouples.

**2011**

In the years 2010 and 2011, NL Hydro undertook a number of activities with vendors that have the Original Equipment Manufacturer (OEM) rights to the gas turbine sections in order to conduct internal inspections of the individual sections and prepare field inspection reports complete with refurbishment estimates.

1. Rolls Wood Group (OEM rights to the Avon gas generator) in 2011 conducted detailed internal inspections of the front end bearing assembly, compressor rotor, compressor casings, combustion assembly, nozzle casing, rear bearing housing, turbine assembly, exhaust unit, and accessory equipment and have prepared a field inspection report. Some refurbishment estimates were provided separately.
2. Greenray Turbines (Lincoln) Limited (OEM rights to the power turbine and gearbox) in 2011 performed detailed internal inspections of the power turbine and the gearbox gears, bearings, and seals.
3. Siemens (OEM rights to 14.150 MW generator including the direct couple cooling fan, the 73.5 KW brushless AC exciter, the AC lube oil pump motor, the DC back-up lube pump motor, and the 25 HP outside fuel off loading pump motor) performed detailed internal inspections and testing of the above noted equipment.

4. Braden Manufacturing is a company that specializes in the design and manufacturing of combustion turbine air filtration systems, air inlet systems, and exhaust systems. They were recently contracted by NL Hydro to perform detailed inspections of the gas turbine air inlet plenum, air filtration system, air inlet plenum support structure, exhaust stack and exhaust stack support structure.

**GTG Inlet Plenum**

When the API gas turbine was constructed, there was little experience of packaging units of this size and the API package was not adequate for the tough marine duty that the unit experienced. The inlet filters, exhaust silencer, exhaust stack and other components corroded quite rapidly and were all replaced in 20 years or less. The original inlet filters were the inertial type which was fairly standard at the time and were still the standard type of filter on TransCanada Pipeline (TCPL) units until the early 1970s. Inertial filters gave good performance in inland locations and places where the dust loading was not excessive. They were not completely satisfactory in icing conditions as the by-pass doors sometimes opened on overpressure, and TCPL suffered a number of cases of ice damage to Avon units. Inertial filters are not capable of handling a high salt content in the inlet air. The original stack had an internal liner which corroded rapidly and did not protect the outer layer against high temperatures. We have limited information on the original silencer splitters but the exhaust unit appears to have corroded very rapidly. We assume that it was not constructed from stainless steel.

The whole unit was re-housed in a custom building in 1986 with new filter house, generator filters, control room and exhaust stack. A new Farr filter building was purchased using a two stage filter- the first stage being designed for water removal while the second was a high efficiency media type filter. This filter was probably quite efficient when new, but with modern experience of high salt environments, largely gained from marine gas turbines, it is clear that its design was not adequate for a location within 200 ft of the ocean, where strong winds are common. Such a location would now require a 3 stage filter with one stage specifically designed for the removal of saline droplets. It is clear that the performance of the filter has deteriorated through time, and in recent years there has been increased evidence of salt ingestion in the Avon. The filter now has air gaps between the filter elements, due to rusting.

New stainless steel inlet splitters were installed and appear to have suffered little deterioration in the subsequent 25 years. A new exhaust silencer and stack were installed with exhaust hoods, and the stack has been severely corroded for a number of years. At the time a number of control upgrades were made, and the generator compartment was provided with new filter elements.

**GTG Gas Generator - Avon**

The early Avons were designed to have a Time Between Overhaul (TBO) of 1500 hours in peaking mode, and 8000 hours or more at base load. Later units achieved much higher base load overhaul intervals, but with some component upgrades. These overhaul intervals probably don't apply for a unit operating for fewer than 200 hours per year, but there is no established criteria for adjusting TBO for long periods of inactivity.

In any case the overhaul life of the Holyrood unit is much more influenced by the high salt atmosphere in which it operates, and the quality of inlet filtration. If the unit had operated entirely at base load in a clean environment, it would probably not require a hot end overhaul or the replacement of any hot end parts in less than 8000 hours.

Between 1966 and 1991, NL Hydro regularly sent the Avon unit to Rolls Royce Canada or other overhaul facilities, at significant expense.

The Avon was overhauled on the dates shown in Table 2-3 below.

TABLE 2-3 HISTORY OF AVON OVERHAULS

| Year | Overhaul By | Overhaul Scope |
|---|---|---|
| 1978 | Not Available | Comp #7,8 replaced Titanium. Compressor recoated. |
| 1986 | Not Available | Overhaul |
| 1991 | GTC Scotland | Overhaul |
| 1993 | RR Canada | Hot End inspection |
| 1997 | RR Canada | Hot End inspection |
| 1998 | RR Canada | Inspection; replace IGV rams |
| 1999 | Onsite TCT | Boroscope and report. Minor work |
| 2001 | Onsite TCT | Boroscope and report. Minor work |
| 2002 | Onsite TCT | Boroscope and report. Minor work |
| 2003 | Onsite TCT | Boroscope and report. Minor work |
| 2004 | Onsite TCT | Boroscope and report. Minor work |
| 2005 | Onsite TCT | Boroscope and report. Minor work |
| 2007 | Onsite Alba | Boroscope and report. Minor work |
| 2008 | Onsite Alba | Boroscope and report. Minor work |
| 2009 | Onsite Alba | Replaced combustor cans. |

The Avon has been inspected at regular intervals, as shown in Table 2-3. It has not been shipped to Rolls Royce or an OEM since 1991.

Since 1991, Hydro has arranged for a boroscope inspection at regular intervals, but the unit has not left the site. On each of the six inspections between 1999 and 2006, the inspection report stated that the unit appeared to be in satisfactory condition. A number of minor repairs have been made since 1991. They included replacement of inlet guide vanes (IGV) bushings and IGV rams, tightening of nuts and replacement of minor components but no major gas path component was replaced until 2009, when the combustor cans were replaced.

In recent years, the Avon has generally operated reliably. However, there is evidence of accelerated corrosion and pitting resulting from deterioration of the inlet filter. The filter is badly corroded and is now allowing unfiltered air to enter the plenum and the engine.

**GTG Power Turbine**

No major maintenance has been done on the power turbine since 1986. Access to the rotor and disk is difficult and until 2010, the only boroscope inspections which were done were performed from the front.

This allowed reasonable inspections of the inlet cones and the diaphragm ring, but not the rear of the turbine disk or the blade roots. In 2010, Greenway obtained a very limited boroscope picture of the power turbine blade roots. We have seen no record of any earlier inspection of the rotor, disk, blade roots or the whole of the moving blades.

**GTG Gear Box**

As early as 1970, the AEI engineers supervising the move of the unit to Holyrood noted several problems with the gearbox. These problems included leakage from the drive end bearing cover on the high speed pinion,) leakage from the generator end low speed shaft, and inadequate gearbox venting. The first of these problems was resolved by machining a groove in the cover plate and inserting an 'O' ring. The second issue was subjected to various adjustments and minor modifications so that the leakage was reduced to an acceptable level. The AEI Engineer's notes refer to components ordered from the factory to further reduce leakage, but the correspondence doesn't indicate what changes were made, and whether the new materials were ever fitted.

We do not have written records of any other gearbox leakage before 2005, but verbal discussions with operators suggest that it has been a growing problem for at least 20 years, and possibly longer. Some time before 2007, it was thought that gearbox oil pooling under the exhaust volute had caused a fire. However, when Alba Power inspected the unit later that year, it was noted that the fire had been the result of leaking fuel oil from failed start attempts on the Avon.

In March 2010, there was a fire under the exhaust stack, and the events following this fire are fully documented in NL Hydro's "Sequence of Events Report" which is included in Appendix 2. The fire caused justifiable safety concern with the operators, and it was reported to the Provincial Department of Occupational Health and Safety, who imposed an operating restriction on the unit.

Alba Power was asked to review and repair the lube oil system and a number of oil leaks were eliminated or reduced:

- Leaks in the auxiliary lube oil piping around the AC, DC and shaft driven pumps were re-gasketed, with the leakage eliminated.
- A new set of seals were manufactured for the generator end of the power turbine gearbox and a large temporary containment dish was installed under this leaking seal. This reduced leakage to what Alba described as "an acceptable level"
- Oil was weeping from the top of the power turbine casing, an instrumentation line and the aux trip bolt mechanism. Repairs eliminated these leaks

After 12 hours of operation at 10 MW, smoke was still seen coming from the top of the gas turbine gearbox in the vicinity of the stack. NL Hydro staff assumed that the seal on the front of the high speed gearbox shaft was also leaking. While a prudent assumption, it is possible that any front end leakage may actually come from another location. The unit has not operated since.

The only conclusions which could be drawn from AMEC's site visit, when the unit was not operating and was fully assembled, were:

- The only visible evidence of fire is a relatively small black charred area above the gearbox on the exhaust volute.
- The existing fire detection equipment is inadequate and did not detect the 2010 fire.
- No ignition source has yet been determined.
- While the new Inergen fire suppression system is safe for operators, it may not be capable of extinguishing an oil fire in the GT compartment, as presently configured, because of the large flow of ventilation air in the compartment. Given that the compartment should be unmanned

during operation, the fire detection and suppression systems should be capable of detecting and controlling fires without the entry of Hydro operating personnel. The overall fire detection and fire protection status of the unit should be reviewed in detail.

At least three or four causes have been suggested for the labyrinth oil seal leakage at the generator end (low speed shaft) and drive end (high speed shaft). There is some evidence to support two of the leakage mechanisms, which may compound each other. The principal causes which have been proposed are:

1. The seal between the power turbine shaft and the front bearing support structure (which is an extension of the gearbox casing) is a double labyrinth which is sealed in the middle by air taken from an Avon compressor bleed. Alba noted, in their May 2007 report, that the pressure in the gearbox (measured by a gauge mounted on the gearboxes casing) rises with load and have suggested that the gearbox is being pressurized by the Avon bleed air. At a load of 10 MW the pressure in the gearbox was 3 inches water gauge. Alba tried to resolve this by adding another oil tank vent, which appeared to reduce the leakage.

   This problem has occurred on other gas turbines and one of the upgrade options offered by GE for their Frame 5 and 6 units, with outputs of 17.5 MW to 40 MW, is to install an oil tank vent blower with coalescer, which maintains a small vacuum in the gearbox and coalesces the oil taken from the tank and returns it via a drain.

2. The bearings may have suffered severe wear due to a number of possible causes (misalignment, gear backlash, or low gearbox oil pressure). In 2008, Alba noted that the splash plate behind the generator end seal was making contact with the shaft, which indicates heavy bearing wear.
3. Misalignment has been proposed as a cause of the leakage, but there is no direct evidence of this.
4. The rear labyrinth seal appears, from the limited data available to us, to be too short. An ideal labyrinth seal should have at least 3 labyrinth sections with oil drains between the sections. The existing seal seems to have only two sections with no oil drain.

**Generator and Exciter**

The Generator, Exciter, AVR and controls were standard at the time of their installation. There has been no major maintenance on the generator or the exciter since 1986. NL Hydro established a draft maintenance procedure in 2009, which included performing insulation integrity tests every second year on both the generator and exciter (resistance to ground, polarization, and resistance phase to phase). The trends of these readings can mean as much as the absolute values, but no figures for them were available before the Siemens tests of 2011.

### 2.1.4 Condition Assessment & Remaining Life

**GTG Gas Generator**

It is now industry practice to specify the overhaul life of a gas turbine in terms of “Hot end overhauls”, during which the high temperature components such as the combustors and turbine blading are refurbished or replaced and “Major maintenance overhauls”, where the hot end and other components are repaired or replaced. The most expensive element of gas turbine maintenance is normally the replacement of high temperature components, and on newer machines this represents up to half of the total cost of a major overhaul. Many high temperature components may have an expected life between refurbishment of over 20,000 hours but can be refurbished one or more times.

The Avon overhaul life was originally established as 1500 hours in peaking mode and up to 8000 hours at base load. With experience, these figures were increased to 4000/5000 for peak load and 25,000/30,000 for base load.

Rolls Royce (RR) now does not directly support older Avon units but there are a number of experienced companies providing support. These companies do not generally differentiate between “Hot end” and “Major” overhauls but offer “Standard overhauls”. It is expected that all of the parts of Avon can be replaced because parts for the Mk-1533 Avon units are plentiful and generally inexpensive. Avon turbine blading has relatively simple metallurgy and cooling arrangements, so it is inexpensive compared to the blading of newer gas turbines.

It is difficult to determine how much of its overhaul life the Avon has expended. All of the recent boroscope reports suggest that it is in reasonable condition, but none of the turbine components have been replaced in the last 20 years, according to our records, and the HP turbine blading and IP vanes have not been replaced or refurbished for over 25 years .

The unit was examined by Rolls-Woods in Nov 2010 and Alba power in 2009 and a summary of their findings is provided below:

- Rolls Woods state that generally the engine appears to be in reasonably good and serviceable condition. The compressor stator components, compressor stators, bleed valves and outer casing were all in reasonably good condition, with most components showing some loss of coating and light corrosion. Components that have deteriorated in the past, such as the front bearing housing and IGV bushings appear to be in good condition. Hot end components also appear to be in good condition with minimal visible damage.
- Alba report that the Avon is in good condition, but are concerned about the loss of coatings, especially on the compressor. It is their opinion that further loss of coating may damage components to the point that they cannot be refurbished.

Normally, the overhaul life of a peaking unit is influenced most by high temperature fatigue while a base load unit is normally limited more by creep, oxidation and corrosion. Boroscope inspections give only limited data on fatigue and creep life expenditure. It is possible that the unit may have operated at its Peak output, earlier in its history, as there are signs of overheating in some of the generator coils (although these could be the result of phase imbalances). Because the engine is rarely washed and has extensive corrosion and pitting, it is likely to have suffered significant performance degradation, which might have reduced its output by up to 10%. (some early US navy gas turbines suffered up to 15% output degradation). The base load output of a degraded unit at high ambient temperatures, would be below 8 MW and the operators may unwittingly have operated at peak, at some time in the unit’s 45 year history.

Our estimate of the Avon’s equivalent operating hours is shown in Table 2-4, below.

The time between overhauls for the existing Avon unit, which are nominally 8,000 hours at peak load and 25,000/30,000 at base load, have to be adjusted for 5 factors, discussed below:

- Between 30 and 40 years ago, Rolls Royce introduced a starts factor making each start equivalent to 10 hours of operation. This factor is somewhat subjective. Most large modern aeroderivative units do not have such a factor, and the manufacturers claim that the number of starts has little effect on overhaul life, if starts are limited to a reasonable number. RR’s current guidance on the Avon is that the equivalence factor is dependent on the type of fuel and the ratio of hours per start. Given that the Holyrood machine burns liquid fuel and has an operating hours to starts ratio of below 3, each start should be counted as ten hours of base load maintenance life.

- The unit operates in a very high salt environment and during the first 19 years of its operating life, and the last five or more years, it has had inadequate inlet filtration. This has affected the compressor blading and casing more than the turbine. There has been a significant loss of compressor coatings.
- The unit operates for very few hours per year. There is little data on how this influences maintenance life, but at Holyrood it seems to have had little effect.
- The unit burns distillate which reduces maintenance life when compared to natural gas.
- The Avon is a very early unit, without many of the later modifications introduced to increase overhaul life.

**TABLE 2-4 CALCULATION OF EQUIVALENT OPERATING HOURS**

| | Equivalent operating hours since 1991 | Total equivalent operating hours |
|---|---|---|
| Components affected | HP vanes, IP turbine blading, misc other | Many components have never been refurbished |
| Operating hours | 2,000 approx | 4,700 |
| Hours equivalent of starts @ 10 hrs per start | 14,000 | 25,000 |
| Discount for oil fuel. Typically 25% adder on other gas turbine types | 4,000 | 7,425 |
| Discount for corrosion | See note below | See note below |
| Approximate totals | 20,000 plus | 38,000 plus |

*Note on Corrosion: Corrosion appears to have affected the compressor blading and casing more than the turbine. Given that compressor components should have a longer operating life than the turbine, corrosion may not be the key factor in determining overhaul life. Also salt appears to have affected the coatings on the compressor more than those of the turbine . The former are designed to protect the blades, while turbine coatings reduce heat flux and protect the rotor and disk from excessive temperatures. We note that the turbine rotor was replaced before 1986.*

The data which is available to AMEC suggests that most of the turbine components are original, with the exception of HP nozzle blades and IP turbine blades. On the Avon the turbine nozzles usually suffer more deterioration than the moving blades. Table 2-4 suggests that, as a minimum, the HP turbine blading and IP nozzles may require refurbishment.

There are many other components on the Avon which cannot be seen during a boroscope inspection, so their condition is unknown.

The Avon requires an overhaul to replace coatings and repair or replace turbine blading and other components which have suffered cracking or other damage. It is expected that when the Avon has been overhauled and the inlet filters replaced, it will not require a further significant overhaul before life end in 2020. In addition, the future annual maintenance costs would be less than $10,000 per year.

**Power Turbine**

The power turbine has received little attention since 1986. A boroscope photograph from 2011 is the only one that we have seen that shows the power turbine blading roots. This shows only a small number of blade roots but the disk material in the axially serrated root appears to be severely corroded. The photos do not show the bulk of the disk itself so we have no way of knowing if this corrosion is present on the remainder of the disk, and whether it is superficial or deep. In the photo, it appears to extend under the root. Steam turbines can suffer from blade root corrosion caused by materials collecting in the root, and it is possible that salt particles have collected in the complex root form. The corrosion may be more serious in highly stressed areas, such as the root. Alternatively, the whole disk may be corroded. In either case, the roots are very vulnerable to stress corrosion cracking.

It should be noted that the turbine cooling air is taken directly from the environment, without filtration. Cooling air passes through an ejector, using Avon bleed air, so that the air reaching the disk is a mixture of filtered air from the Avon and unfiltered air. The disk cooling system has probably operated for 45 years with a significant salt loading.

The Power turbine disk material is a low alloy ferritic steel selected for its high transition temperature. It seems likely that such a material has a service limit of 535 C or lower. The Avon exhaust cone temp (ECT) is close to 640 deg C at the full peak rating, so clearly the design of the API depends on effective disk and blade root cooling. It is probable that the blade root is highly stressed at full load, even with its design cooling. The axially serrated root was the most expensive blade root used by AEI, and so they only used it for highly stressed locations.

Greenray, who now legally represent AEI gas turbines and hold all rights to their technology, do not think that the power turbine should be operated in its present condition, and AMEC agrees with this recommendation.

Based on the information available to AMEC, it appears that the turbine disk should be replaced, using most or all of the existing moving blades. Welding repairs are required on the inlet cones, struts, heat shield, etc and can be used for slightly damaged blades. The cooling air system should be examined carefully as it is essential for the integrity of the power turbine disk and blading. With these measures, there should be no problem operating the power turbine for another ten years or more. The highest risk is the loss of a diaphragm or moving blade.

**Gearbox**

The gearbox pinion and wheel were examined briefly by Alba in 2007 and appeared to be in good condition at that time. A gearbox of this type should operate for many years without problem, and if the bearings and seals are replaced, the gearbox should not present a large risk. The cause of the low oil pressure from the mechanical pump and the oil leak on the low speed drive shaft must be determined and rectified. Although the high speed gearbox shaft has more complex labyrinth seals than those of the generator end, and an air seal, it is probably prudent to assume that this seal is also leaking.

The only conclusions which could be drawn from AMEC's site visit, when the unit was not operating and was fully assembled, were:

- The only visible evidence of fire is a relatively small black charred area above the gearbox on the exhaust volute.
- The existing fire detection equipment is inadequate and did not detect the 2010 fire.
- No ignition source has yet been located.

- While the new Inergen fire suppression system is safe for the operators, it is important to confirm that it is capable of extinguishing an oil fire in the GT compartment, as presently configured, and with all ventilation is shut off in the event of a fire. Given that the compartment should be unmanned during operation, the fire detection and suppression systems should be capable of detecting and controlling fires without the entry of Hydro operating personnel. The overall fire detection and fire protection status of the unit requires a detailed review.

At least three or four causes have been suggested for the labyrinth oil seal leakage at the generator end (low speed shaft) and drive end (high speed shaft). There is some evidence to support two of the leakage mechanisms, which may complement each other. The principal causes which have been proposed are:

a. The seal between the power turbine shaft and the front bearing support structure (which is an extension of the gearbox casing) is a double labyrinth which is sealed in the middle by air taken from an Avon compressor bleed. Alba noted, in their May 2007 report, that the pressure in the gearbox (measured by a gauge mounted on the gearboxes casing) rises with load and they suggested that the gearbox is being pressurized by the Avon bleed air. At a load of 10 MW the pressure in the gearbox was 3 inches water gauge. Alba tried to resolve this by adding another oil tank vent, which appeared to reduce the leakage.

   This problem has occurred on other gas turbines and one of the upgrade options offered by GE for their Frame 5 and 6 units, with outputs of 17.5 MW to 40 MW, is to install an oil tank vent blower with coalescer, which maintains a small vacuum in the gearbox and coalesces the oil taken from the tank and returns it via a drain.

b. The bearings may have suffered severe wear due to a number of possible causes (misalignment, gear backlash, or low gearbox oil pressure). In 2008, Alba noted that the splash plate behind the generator end seal was making contact with the shaft, which indicates heavy bearing wear.
c. Misalignment has been proposed as a cause of the leakage, but there is no direct evidence of this. Another GE upgrade on older gas turbine models is an improved flexible coupling between gas turbine and the load gear.
d. The rear labyrinth seal appears, from the limited data available to us, to be too short. An ideal labyrinth seal should have at least 3 labyrinth sections with oil drains between the sections. The existing seal seems to have only two sections with no oil drain.

Both Alba Power and Greenray, have quoted for the repair of the gearbox, and the bids of both of these companies suggest that the problem can be resolved by restoring the unit to its original design, with better venting. The adequacy of this proposed repair is reinforced by the fact that the Newfoundland Power Commission API unit at Salt Pond has not suffered from oil leaks, and that both Alba and Greenray have experience of other API units.

Since 1991, NL Hydro has arranged for a boroscope inspection at regular intervals, but the unit has not left the site. On each of the six inspections between 1999 and 2006, the inspection reports indicated that the unit appeared satisfactory. A number of minor repairs have been made since 1991, including replacement of IGV bushings and IGV rams, tightening of nuts, and replacement of minor components. However, no major gas path component was replaced until 2009, when the combustor cans were replaced.

**GTG Inlet Plenum**

It is clear that in the high saline atmosphere at Holyrood, operating with an increasingly ineffective inlet filter, the unit has suffered considerable degradation during very few hours of operation. For example, Alba Power reported that between May 2007 and June 2008, the unit had only ran 26 hours with 54 starts and there was considerable degradation of the combustors and other components, which may have corresponded to less than one month of operation in a normal base load unit. The unit is rarely washed because washing is normally performed largely to maintain efficiency. However, it would be beneficial to wash the Holyrood unit because of the buildup of salt on the first stages of the compressor. At present, the engine shows signs of pitting, salt deposition, corrosion and loss of coatings on the Avon gas generator. There is also cracking in the turbine section.

Without replacement, the Avon and PT will degrade rapidly. The inlet air filter/media should be replaced and/or brought back to reasonable condition.

**Generator**

Siemens inspected the generator in 2011 and performed (resistance to ground tests (megger), polarization index of machine windings, and phase to phase resistance measurements. They also visually inspected the stator laminations, windings, and the rotor.

The generator has only 4700 operating hours and NL Hydro records show that in recent years, it has rarely operated at above 10 MW. It is rated 14.15 MW. It should have a design life of over 40 years, but its insulation has suffered from age and possibly from rapid thermal cycling and condensation. The API unit can start and ramp to full load in about 2 minutes and during a fast start, the coils will suffer some thermal stress. Also, the unit experiences large temperature differences between the windings and the cooling air. There are no anti-condensation heaters. If the generator had operated with a high capacity factor for 45 years it would likely require a rewind.

Siemen's report shows that the insulation has deteriorated and there is a phase imbalance on the stator. Siemens recommend rewinding the stator. Table 2-5 compares the measured test results of the generator, exciter and major motors. The polarization readings of the generator stator are reasonable, and considerably better than those of the Exciter stator and the major motors. However the stator phase imbalance is quite high and the cost of a stator rewind has been included in the refurbishment estimate.

**TABLE 2-5 COMPARISON OF SIEMENS TEST RESULTS ON GENERATOR AND MOTORS**

| | Resistance to Ground @ 1 Minute M ohm | Polarization of Windings | Phase to Phase Resistance |
|---|---|---|---|
| Generator Stator | 534 | 1.93 | 30% imbalance |
| Generator Rotor | 2.67 | 1.1 | |
| Exciter Stator | 534 | .96 | |
| Exciter Rotor | 2060 | 2.14 | Within 0.7% |
| AC Oil Pump Motor | 4600 | 1.15 | Within 0.17% |
| DC Oil Pump Motor | 185 | 0.93 | |
| AC Lube Oil Cooler Fan | 5520 | 1.37 | Within 0.67% |
| Fuel Oil Motors | 7920/1250 | 1.56/0.95 | Within 0.18% |

**Generator Exciter**

Siemens recommended an overhaul of the exciter, but there is some concern that an overhaul is not practical because the 45 year old unit is no longer supported by the OEM. Parts may not be available. On the other hand, it may be difficult to support the purchase of a new unit for a 8 year life extension.

**Summary**

In general, the unit is currently in poor condition and overdue for a major overhaul of many components. A tabular summary of the condition assessment of the gas turbine genset is provided below in Table 2-6:

## TABLE 2-6 CONDITION ASSESSMENT – GAS TURBINE GENSETS

| BU # 1 | Asset # 2 | Asset # 3 | Asset # 4 | Asset Level 3 | Description | Detail | Cond. Summ. ID# | Condition | Status Identifier | Original Life (Base Load) Ops Hrs (Yrs) | Current Expected Minimum Remaining Life Years (Subject to Test) | End of Life (EOL) Required | Capability to Reach EOL | In Service |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1273 | 7202 | 0 | 0 | GAS TURBINE SYSTEM | GAS TURBINE SYSTEM | | GTG1 | 44 years old and has accumulated to 2010 about 4,717 hours with 1,548 starts. Four significant overhauls/repairs in 1978, 1986, and 1991 and a combustor replacement in 2007 | 4/10 | 150,000 (30) | 1 | 2020 | No | 1969 |
| 1273 | 7202 | 7308 | 0 | GAS TURBINE AVON JET ENGINE | GAS TURBINE AVON GAS GENERATOR | General | GTG2 | Overall Rolls Wood group inspection in 2010 concluded that the engine appears in reasonably good and serviceable condition.The engine shows signs of pitting, salt deposition, corrosion and loss of coatings on the Avon gas generator. Coatings and some turbine blading and other components have suffered cracking or other damage. Corrosion/cracking from seaside moisture and starts. Buildup of salt on the first stages of the compressor. There is also cracking in the turbine section. Overdue for overhaul.Rear bearing housing in good condition.. | 4/10 | 150,000 (30) | 2 | 2020 | No | 1969 |
| 1273 | 7202 | 7058 | 0 | GAS TURBINE AVON JET ENGINE | GAS TURBINE AVON GAS GENERATOR | Compressor and Intake | GTG3 | Rolls Wood reported: front bearing housing in good condition with medium loss of coating and corrosion,; VIGV bushes in good condition;bleed valves in good condiion, compressor stators in good clean condition with no defects; compressor casing surfaces in reasonably good condition with light to medium loss of coating and corrosion in some areas; compressor outlet casing in good condition with OGV having minor to medium loss of coating and corrosion to most surfaces; | 4/10 | 150,000 (30) | 2 | 2020 | No | 1969 |
| 1273 | 7202 | 7058 | 0 | GAS TURBINE AVON JET ENGINE | GAS TURBINE AVON GAS GENERATOR | Combustor | GTG4 | Rolls Wood reported: carbon deposits on head sections and streaks down flame tube length;All in good conddition. | 4/10 | 150,000 (30) | 10 | 2020 | Yes | 2008 |
| 1273 | 7202 | 7058 | 0 | GAS TURBINE AVON JET ENGINE | GAS TURBINE AVON GAS GENERATOR | Turbine Rotor | GTG5 | Rolls Wood reported: HP,IP andLP turbine blades intact and free of obvious defects. Exhaust assembly in good condition with minor surface corrosion. | 4/10 | 150,000 (30) | 5 | 2020 | No | 1969 |
| 1273 | 7202 | 7058 | 0 | GAS TURBINE POWER TURB & G/B | GAS TURBINE POWER TURBINE | Power Turbine | GTG6 | Received little attention since 1986 with very limited boropscope views of blade roots. Disk material in these limited views in the axially serrated root appears to be severely corroded.No way of knowing if corrosion is present on the remainder of the disk, and whether superficial or deep. Appears to extend under the root. It is possible that salt particles have collected in the complex root form. The corrosion may be more serious in highly stressed areas, such as the root. Alternatively the whole disk may be corroded. In either case the roots are very vulnerable to stress corrosion cracking.Overdue for overhaul. Greenray (legal representive of AEI gas turbines, hold all rights to their technology)do not think that the power turbine should be operated in its present condition. | 4/10 | 150,000 (30) | 2 | 2020 | No | 1969 |
| 1273 | 7202 | 7058 | 0 | GAS TURBINE POWER TURB & G/B | GAS TURBINE POWER TURBINE | Power Turbine | GTG7 | Greenray in its 2011 inspection noted: several circumferential cracks on inlet duct iner cone (previously seen in 2006) - no/limited propogation apparent; weld repairs on cone spokes inner downstream edges may be starting to fail; nozzle blade track corroded, heavily in places, and could cause failure of nozzle segment and shroud; blade tps irregular,possibly rubbed (little other evidence of blade tip rub); geneal corrosion (most light) on blading; rotor disc fir tree posts (for blades) heavily corroded in visible areas highly stressed areas - fialure could lead to catastrophic effect on power turbine components and appear to be propogating under rotor blade shoulder which could cause premature failure.; diffuser/volue generally corroded - effect on volute welding. | 4/10 | 150,000 (30) | 2 | 2020 | No | 1969 |
| 1273 | 7202 | 7058 | 0 | GAS TURBINE POWER TURB & G/B | GAS TURBINE POWER TURBINE | Cooling Air | GTG8 | Turbine cooling air is taken directly from the environment, without filtration. Cooling air passes through an ejector, using Avon bleed air, so that the air reaching the disk is a mixture of filtered air from the Avon and unfiltered air. The disk cooling system has probably operated for 45 years with a significant salt loading. | 4/10 | 150,000 (30) | 2 | 2020 | No | 1969 |
| 1273 | 7202 | 7058 | 0 | GAS TURBINE POWER TURB & G/B | GAS TURBINE POWER GEARBOX | Gearbox | GTG9 | Alba in 2007 indicated gearbox appeared to be in good condition and that if the bearings and seals are replaced the gearbox should not present a large risk. Issues remain on the cause of the low oil pressure from the mechanical pump and the oil leak on the low speed drive shaft and must be determined and rectified. The high speed gearbox shaft seals are leaking and were the cause of a 2010 fire at the power turbine end of the gearbox which has resulted in the unit being limited to emergency use only. At least three or four causes have been suggested for the labyrinth oil seal leakage at the generator end (low speed shaft) and drive end (high speed shaft). Tests on the pressure in the gearbox (measured by a gauge mounted on the gearboxs casing) showed a rise with load and suggested that the gearbox is being pressurized by the Avon bleed air.<br>Greenray 2011 inspection: Gear wheels and internals appeared in pristne condition with normal marks. Outer wiper of leaking low speed gear wheel lube oil gland may be touching top of shaft and have some clearance at bottom (opposite to normal) and may indicate driven machine out of alignment with gearbox output shaft<br>The bearings may have suffered severe wear due to a number of possible causes (misalignment, gear backlash, or low gearbox oil pressure). In 2008 Alba noted that the splash plate behind the generator end seal was making contact with the shaft, which indicates heavy bearing wear.<br>Overdue for overhaul. | 4/10 | 150,000 (30) | 2 | 2020 | No | 1969 |
| 1273 | 7202 | 7309 | 0 | GAS TURBINE GENERATOR | GAS TURBINE GENERATOR | Generator | GTG10 | Siemen's report shows that the insulation has deteriorated and there is a phase inbalance on the stator. The polarization readings of the generator stator are reasonable, and considerably better than those of the Exciter stator and the major motors. However the stator phase inbalance is quite high.<br>The generator compartment was provided with new filter elements which are in good condition, except that there are some holes in the building siding that allows some air to bypass them. | 4/10 | 200000 (40) | 5 | 2020 | No | 1969 |
| 1273 | 7202 | 7309 | 0 | GAS TURBINE GENERATOR | GAS TURBINE GENERATOR | Generator | GTG11 | Siemen's report rotor appears in good condition, that stator iron and wedging in good condition, some stator coil overheating, Stator insulation appeared dregraded, dry and flaking throughout, | 4/10 | 200000 (40) | 5 | 2020 | No | 1969 |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE AUXILIARY SYSTEMS | GAS TURBINE EXHAUST STACK | Exhaust Stack | GTG12 | Severly corroded, leaking,Braden 2011 inspection: exterior significant carbon steel crystallization and peeling of carbon steel; no fatigue/cracking of welds, sulging of stack on south side, several holes in exhaust. Snow hood no apparent issues (some operation issues with functionality). Transition duct (external insulation) not visible for inspection. Expansion joint belt in good condition. reported | 4/10 | (20) | 1 | 2020 | No | 1986 |
| 1273 | 7202 | 7311 | 99003602 | GAS TURBINE AUXILIARY SYSTEMS | GAS TURBINE AIR INLET PLENUM CHAMBER & MEDIA | Filter Material | GTG13 | Inlet housing and filtration system were replaced in 1986. Its stainless steel inlet splitters appear to have suffered little deterioration Water leaking into plenum.Filter media is considered inappropriate for its marine environment. The filter now has air gaps between the filter elements, due to rusting The high saline atmosphere means that the unit is operating with an increasingly ineffective inlet filter and the unit has suffered considerable degradation. | 4/10 | (30) | 2 | 2020 | No | 1986 |
| 1273 | 7202 | 7311 | 99003602 | GAS TURBINE AUXILIARY SYSTEMS | GOVENOR & FUEL CONTROL | | GTG14 | No specific informatioon on govenor and fuel control. Fuel control was an issue in 2007 Alba report with a recommendation to upgrade to address failed starts due to fuel control. Appears to have been completed.. | 4/10 | (30) | 5 | 2020 | No | 1986/2008 |
| 1273 | 7202 | 7311 | 99003602 | GAS TURBINE AUXILIARY SYSTEMS | EXCITATION SYSTEM | | GTG15 | Siemens recommended an overhaul of the exciter and steam cleaning of windings, VPI testing of insulation. There is some concern that it is a 45 year old unit which is not supported. The polarization readings of the Exciter stator are poor. | 4/10 | (30) | 2 | 2020 | No | 1986 |

Notes: 1. A "(bracketed)" value in the "Current Expected Remaining Life" column is a highly probable minimum value that is considered subject to some subsequent verification during further investigation, including at the next test or overhaul. It may be addressed as part of a Level 2 test. A value identified as "(X/Y)" has been included where the recommended minimum value is the lower of the two, but that the higher may be achievable at a higher level of failure risk and/or unreliability.

### 2.1.5 Risk Assessment

**TABLE 2-7 RISK ASSESSMENT – GAS TURBINE GENSETS**

| BU # 1 | Asset # 2 | Asset # 3 | Asset # 4 | Asset Level 3 | Description | Detail | Cond. Summ. ID# | Condition | Major Issues | Remaining Life Years | TECHNO-ECO RISK ASSESS MODEL | | | SAFETY RISK ASSESS MODEL | | | Possible Failure Event | Mitigation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | (Insufficient Info - Inspection Required Within (x) Years) | Likeli--hood | Conse-quence | Risk Level | Likeli-hood | Conse-quence | Safety Risk | | |
| 1273 | 7202 | 0 | 0 | GAS TURBINE SYSTEM | GAS TURBINE SYSTEM | | GTG1 | 44 years old and has accumulated to 2010 about 4,717 hours with 1,548 starts. Four significant overhauls/repairs in 1978, 1986, and 1991 and a combustor replacement in 2007 | Major systems need overhaul | 1/10 | 4 | C | High | 3 | D | High | Major/catastrophic failure of unit or fire | Overhaul or replace |
| 1273 | 7202 | 7308 | 0 | GAS TURBINE AVON JET ENGINE | GAS TURBINE AVON GAS GENERATOR | | GTG2 | Overall Rolls Wood group inspection in 2010 concluded that the engine appears in reasonably good and serviceable condition.The engine shows signs of pitting, salt deposition, corrosion and loss of coatings on the Avon gas generator. Coatings and some turbine blading and other components have suffered cracking or other damage. Corrosion/cracking from seaside moisture and starts. Buildup of salt on the first stages of the compressor. There is also cracking in the turbine section. Overdue for overhaul.Rear bearing housing in good condition.. | Blade failure or material realease causes downstream collateral damage. | 2 | 3 | C | Medium | 1 | D | Medium | Catastrophic failure of downstream equipment | Overhaul or replace |
| 1273 | 7202 | 7058 | 0 | GAS TURBINE POWER TURB & G/B | GAS TURBINE POWER TURBINE | Power Turbine | GTG6/7 | Received little attention since 1986 with very limited boropscope views of blade roots. Disk material in these limited views in the axially serrated root appears to be severely corroded.No way of knowing if corrosion is present on the remainder of the disk, and whether superficial or deep. Appears to extend under the root. It is possible that salt particles have collected in the complex root form. The corrosion may be more serious in highly stressed areas, such as the root. Alternatively the whole disk may be corroded. In either case the roots are very vulnerable to stress corrosion cracking.Overdue for overhaul. Greenray (legal representive of AEI gas turbines, hold all rights to their technology)do not think that the power turbine should be operated in its present condition. | Power turbine rotor disck high stress blade root failure | 2 | 4 | C | High | 3 | D | High | Blade root failure of disk - catastrophic faiure | Replace/repair disk and overhaul unit. |
| 1273 | 7202 | 7058 | 0 | GAS TURBINE POWER TURB & G/B | GAS TURBINE POWER TURBINE | Power Turbine | GTG8 | Turbine cooling air is taken directly from the environment, without filtration. Cooling air passes through an ejector, using Avon bleed air, so that the air reaching the disk is a mixture of filtered air from the Avon and unfiltered air. The disk cooling system has probably operated for 45 years with a significant salt loading. | Corrosion of power turbine blade roots. | 2 | 4 | C | High | 3 | D | High | Blade root failure of disk - catastrophic faiure | Modify air inlet. Replace/repair disk and overhaul unit. |
| 1273 | 7202 | 7058 | 0 | GAS TURBINE POWER TURB & G/B | GAS TURBINE POWER GEARBOX | Gearbox | GTG9 | Alba in 2007 indicated gearbox appeared to be in good condition and that if the bearings and seals are replaced the gearbox should not present a large risk. Issues remain on the cause of the low oil pressure from the mechanical pump and the oil leak on the low speed drive shaft and must be determined and rectified. The high speed gearbox shaft seals are leaking and were the cause of a 2010 fire at the power turbine end of the gearbox which has resulted in the unit being limited to emergency use only. At least three or four causes have been suggested for the labyrinth oil seal leakage at the generator end (low speed shaft) and drive end (high speed shaft). Tests on the pressure in the gearbox (measured by a gauge mounted on the gearboxs casing) showed a rise with load and suggested that the gearbox is being pressurized by the Avon bleed air.<br>Greenray 2011 inspection: Gear wheels and internals appeared in pristne condition with normal marks. Outer wiper of leaking low speed gear wheel lube oil gland may be touching top of shaft and have some clearance at bottom (opposite to normal) and may indicate driven machine out of alignment with gearbox output shaft<br>The bearings may have suffered severe wear due to a number of possible causes (misalignment, gear backlash, or low gearbox oil pressure). In 2008 Alba noted that the splash plate behind the generator end seal was making contact with the shaft, which indicates heavy bearing wear.<br>Overdue for overhaul. | Gearbox oil leaks; gearbox misalignment/wear | 2 | 4 | C | High | 3 | D | High | Lube oil fires. (Gearbox failure (bearings/misalgnment) | Gearbox overhaul - seals, alignment, bearings |
| 1273 | 7202 | 7309 | 0 | GAS TURBINE GENERATOR | GAS TURBINE GENERATOR | | GTG10/11 | Siemen's report shows that the insulation has deteriorated and there is a phase inbalance on the stator. The polarization readings of the generator stator are reasonable, and considerably better than those of the Exciter stator and the major motors. However the stator phase inbalance is quite high.<br>The generator compartment was provided with new filter elements which are in good condition, except that there are some holes in the building siding that allows some air to bypass them. | Generator insulation condiion and potential for failure | 5 | 3 | C | Medium | 3 | C | Medium | Generator winding failure and collateraldamage | Generator overhaul. Rewinds if necessary. |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE AUXILIARY SYSTEMS | GAS TURBINE EXHAUST STACK | Exhaust Stack | GTG12 | Severly corroded, leaking,Braden 2011 inspection: exterior significant carbon steel crystallization and peeling of carbon steel; no fatigue/cracking of welds, sulging of stack on south side, several holes in exhaust. Snow hood no apparent issues (some operation issues with functionality). Transition duct (external insulation) not visible for inspection. Expansion joint belt in good condition. reported | Stack water leakage into power turbine | 1 | 4 | C | High | 3 | C | Medium | Power turbine corrosion/failure. Stack failure | Replace stack |
| 1273 | 7202 | 7311 | 99003602 | GAS TURBINE AUXILIARY SYSTEMS | GAS TURBINE AIR INLET PLENUM CHAMBER & MEDIA | Filter Material | GTG13 | Inlet housing and filtration system were replaced in 1986. Its stainless steel inlet splitters appear to have suffered little deterioration Water leaking into plenum.Filter media is considered inappropriate for its marine environment. The filter now has air gaps between the filter elements, due to rusting The high saline atmosphere means that the unit is operating with an increasingly ineffective inlet filter and the unit has suffered considerable degradation. | Corrosion impact on gas generator and power turbine causing failure | 2 | 3 | C | Medium | 3 | C | Medium | Corrosion of gas generator and power turbine accelerates. | Replace filter media; overhaul/repair housing. |
| 1273 | 7202 | 7311 | 99003602 | GAS TURBINE AUXILIARY SYSTEMS | GOVENOR & FUEL CONTROL | | GTG14 | No specific informatioon on govenor and fuel control. Fuel control was an issue in 2007 Alba report with a recommendation to upgrade to address failed starts due to fuel control. Appears to have been completed.. | Failed starts and speed/load control | 5 | 2 | B | Low | 2 | B | Low | Unit start and control | Check status and refurbish as required as part of overhaul. |
| 1273 | 7202 | 7311 | 99003602 | GAS TURBINE AUXILIARY SYSTEMS | EXCITATION SYSTEM | | GTG15 | Siemens recommended an overhaul of the exciter and steam cleaning of windings, VPI testing of insulation. There is some concern that it is a 45 year old unit which is not supported. The polarization readings of the Exciter stator are poor. | Exciter failure; unit extended outage. | 2 | 3 | C | Medium | 3 | C | Medium | Failure of exciter leads to extended shutdown of unit. | Replace exciter. |

### 2.1.6 Actions

TABLE 2-8 ACTIONS – GAS TURBINE GENSETS

| BU # 1 | Asset # 2 | Asset # 3 | Asset # 4 | Asset Level 3 | Description | Detail | Cond. Summ. ID# | Capital Item | Date | Priority |
|---|---|---|---|---|---|---|---|---|---|---|
| 1273 | 7202 | 0 | 0 | GAS TURBINE SYSTEM | GAS TURBINE SYSTEM | | GTG1 | | | |
| 1273 | 7202 | 7308 | 0 | GAS TURBINE AVON JET ENGINE | GAS TURBINE AVON GAS GENERATOR | General | GTG2 | No specific capital projects - major unit overhaul. | 2012 | 1 |
| 1273 | 7202 | 7308 | 0 | GAS TURBINE AVON JET ENGINE | GAS TURBINE AVON GAS GENERATOR | Compressor and Intake | GTG3 | No specific capital projects - major unit overhaul. | 2012 | 1 |
| 1273 | 7202 | 7308 | 0 | GAS TURBINE AVON JET ENGINE | GAS TURBINE AVON GAS GENERATOR | Combustor | GTG4 | No specific capital projects - major unit overhaul. | 2012 | 1 |
| 1273 | 7202 | 7308 | 0 | GAS TURBINE AVON JET ENGINE | GAS TURBINE AVON GAS GENERATOR | Turbine Rotor | GTG5 | No specific capital projects - major unit overhaul. | 2012 | 1 |
| 1273 | 7202 | 7058 | 0 | GAS TURBINE POWER TURB & G/B | GAS TURBINE POWER TURBINE | Power Turbine | GTG6/7 | Purchase power turbine disk. No other specific capital projects - major unit overhaul. | 2012 | 1 |
| 1273 | 7202 | 7058 | 0 | GAS TURBINE POWER TURB & G/B | GAS TURBINE POWER TURBINE | Cooling Air | GTG8 | Modify cooling air to power turbine to eliminate salt ingress - part of major unit overhaul. | 2012 | 1 |
| 1273 | 7202 | 7058 | 0 | GAS TURBINE POWER TURB & G/B | GAS TURBINE POWER GEARBOX | Gearbox | GTG9 | No specific capital projects - major unit overhaul. | 2012 | 1 |
| 1273 | 7202 | 7309 | 0 | GAS TURBINE GENERATOR | GAS TURBINE GENERATOR | | GTG10/11 | No specific capital projects - major unit overhaul. | 2012 | 1 |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE AUXILIARY SYSTEMS | GAS TURBINE EXHAUST STACK | Exhaust Stack | GTG12 | Replacement stack and installation | 2012 | 1 |
| 1273 | 7202 | 7311 | 99003602 | GAS TURBINE AUXILIARY SYSTEMS | GAS TURBINE AIR INLET PLENUM CHAMBER & MEDIA | Filter Material | GTG13 | No specific capital Requirement - new fiolter media | 2012 | 2 |
| 1273 | 7202 | 7311 | 99003602 | GAS TURBINE AUXILIARY SYSTEMS | GOVENOR & FUEL CONTROL | | GTG14 | None | | |
| 1273 | 7202 | 7311 | 99003602 | GAS TURBINE AUXILIARY SYSTEMS | EXCITATION SYSTEM | | GTG15 | Refurbish exciter (Replace as necessary in refurbishment) | 2012 | 1 |

### 2.1.7 Life Assessment - Life Cycle Curves (Where equipment is not to be overhauled/replaced and life <2020 and has major unit operation impacts.)

The gas turbine *generator unit essentially requires all of its major components to be overhauled* or replaced as soon as practical. After such an overhaul, there should be no further major repairs required before 2020. Given this, no life cycle curves are presented for the gas turbine generator system.

### 2.1.8 Level 3 Inspections Required

The refurbishment of the unit can be done in two ways;

- NL Hydro can disassemble the unit and perform Level 3 inspection assessments on key equipment. After the assessments, NL Hydro will be able to obtain firm bids for replacement components and place orders for them. This will be a lengthy process and it will require Hydro to authorize a two phase investment; the first on disassembly and inspection and reassembly and the second for the purchase and fitting of replacement parts at some future date.
- Once NL Hydro makes a decision to refurbish the existing GT unit instead or replacing it with new GT or diesel generator facilities, those components identified as likely to require replacement should be ordered and the units overhauled. No level 3 inspections will be performed, although detailed inspections when during overhauls may show the need to refurbish other components. Large additional as-found overhaul costs are unlikely since a conservative approach in that any further major items will be required. Under this alternative independent Level 3 assessments are eliminated. This approach is recommended by AMEC.

Generally if the AMEC Recommended Approach is taken, no other “Level 3” inspections/tests are required.

If the first approach is taken, the most important Level 3 assessments are:

- Avon Gas Generator
- Power Turbine blade root condition
- Gearbox bearing wear/alignment and gearbox seals
- Disk cooling system

This approach may result in some savings in the final overhaul, but would require an additional outage and detailed inspections, and possibly additional delay in completing the final overhaul required.

### 2.1.9 Capital Enhancements

TABLE 2-9 SUGGESTED TYPICAL CAPITAL ENHANCEMENTS – GAS TURBINE GENSETS

| BU # 1 | Asset # 2 | Asset # 3 | Asset # 4 | Asset Level 3 | Description | Detail | Cond. Summ. ID# | Capital Item | Date | Priority |
|---|---|---|---|---|---|---|---|---|---|---|
| 1273 | 7202 | 0 | 0 | GAS TURBINE SYSTEM | GAS TURBINE SYSTEM | | GTG1 | | | |
| 1273 | 7202 | 7308 | 0 | GAS TURBINE AVON JET ENGINE | GAS TURBINE AVON GAS GENERATOR | General | GTG2 | No specific capital projects - major unit overhaul. | 2012 | 1 |
| 1273 | 7202 | 7308 | 0 | GAS TURBINE AVON JET ENGINE | GAS TURBINE AVON GAS GENERATOR | Compressor and Intake | GTG3 | No specific capital projects - major unit overhaul. | 2012 | 1 |
| 1273 | 7202 | 7308 | 0 | GAS TURBINE AVON JET ENGINE | GAS TURBINE AVON GAS GENERATOR | Combustor | GTG4 | No specific capital projects - major unit overhaul. | 2012 | 1 |
| 1273 | 7202 | 7308 | 0 | GAS TURBINE AVON JET ENGINE | GAS TURBINE AVON GAS GENERATOR | Turbine Rotor | GTG5 | No specific capital projects - major unit overhaul. | 2012 | 1 |
| 1273 | 7202 | 7058 | 0 | GAS TURBINE POWER TURB & G/B | GAS TURBINE POWER TURBINE | Power Turbine | GTG6/7 | Purchase power turbine disk. No other specific capital projects - major unit overhaul. | 2012 | 1 |
| 1273 | 7202 | 7058 | 0 | GAS TURBINE POWER TURB & G/B | GAS TURBINE POWER TURBINE | Cooling Air | GTG8 | Modify cooling air to power turbine to eliminate salt ingress - part of major unit overhaul. | 2012 | 1 |
| 1273 | 7202 | 7058 | 0 | GAS TURBINE POWER TURB & G/B | GAS TURBINE POWER GEARBOX | Gearbox | GTG9 | No specific capital projects - major unit overhaul. | 2012 | 1 |
| 1273 | 7202 | 7309 | 0 | GAS TURBINE GENERATOR | GAS TURBINE GENERATOR | | GTG10/11 | No specific capital projects - major unit overhaul. | 2012 | 1 |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE AUXILIARY SYSTEMS | GAS TURBINE EXHAUST STACK | Exhaust Stack | GTG12 | Replacement stack and installation | 2012 | 1 |
| 1273 | 7202 | 7311 | 99003602 | GAS TURBINE AUXILIARY SYSTEMS | GAS TURBINE AIR INLET PLENUM CHAMBER & MEDIA | Filter Material | GTG13 | No specific capital Requirement - new fiolter media | 2012 | 2 |
| 1273 | 7202 | 7311 | 99003602 | GAS TURBINE AUXILIARY SYSTEMS | GOVENOR & FUEL CONTROL | | GTG14 | None | | |
| 1273 | 7202 | 7311 | 99003602 | GAS TURBINE AUXILIARY SYSTEMS | EXCITATION SYSTEM | | GTG15 | Refurbish exciter (Replace as necessary in refurbishment) | 2012 | 1 |

### 2.1.10 Capital/Refurbishment and Overhaul Costs (Capital)

The Avon requires an overhaul to replace coatings and repair or replace turbine blading and other components which have suffered cracking or other damage. It is expected that when the Avon has been overhauled and the inlet filters replaced the Avon will not require further significant overhaul before life end in 2020, and that future annual maintenance costs would be less than $10,000 per year.

The first approach whereby limited funding is approved for disassembly and then make a second purchase decision when the equipment is examined is likely to be a slow process and possibly difficult administratively for NL Hydro. AMEC made assumptions based on data available, experience and recommendations from vendors such as Greenray, Alba Power, etc, and prepared an estimate covering all equipment which will probably be required for life extension. This is likely a quicker route to meet the project requirements, but has a risk of purchasing too much equipment.

AMEC received quotations from the following companies.

- Alba Power, Scotland.
- Greenray- the owner of AEI's original technology
- Camfil Farr- supplier of the inlet filter
- Braden - supplier of exhaust stacks
- SS Turbine services Ltd. - a small Canadian aero engine overhaul company.

In addition, AMEC has the quotation provided by 'Rolls Woods to NL Hydro for an Avon overhaul. This 2010 quotation is posted on Newfoundland Power Commission's website.

The pricing provided by Alba Power covers the entire plant, while other companies have only bid for their own equipment. The attached table shows the Alba Power bid, in column 1, with the bids from other companies in column 2. Column's 3 shows AMEC's estimate for the cost of providing a comprehensive rehabilitation to make the unit suitable for another 8 or more years of operation, with minimum risk. The major components, including the Avon, Power turbine, gearbox, generator, inlet filter and exhaust filter would be restored to the same condition as 1986. Column 3 is an amalgamation of the quotations received from the different companies, plus AMEC estimates for some minor costs.

The table assumes an exchange rate of 1.6 for the UK pound, and a modest 10% allowance for duty and freight.

Alba's cost of a complete "Standard Overhaul" of the Avon is included in column 3 but Alba did not include the cost of any required replacement parts. A full standard overhaul by Alba would therefore cost significantly more than the $500,000 which they bid, but it would give the Avon another 20,000 to 30,000 of life. S and S turbine have quoted $450,000 for a full overhaul including parts, which would include a proving test run after completion of the work. Even the work covered by this bid is probably excessive for the 8 year life extension required, but AMEC cannot judge how much work will be needed until the engine is disassembled. We have therefore allowed $500,000 for the Avon overhaul, including transportation.

Alba state that the unit will operate until 2020 with almost no additional cost, if the proposed overhaul is completed. In contrast to the comprehensive overhaul which Alba propose for the Avon, they have proposed simple on-site repairs of the inlet filter and exhaust stack, and a low cost overhaul of the generator and exciter.

### TABLE 2-10 CAPITAL COST ESTIMATE $ 1,000 CDN$

| | Option 1 Alba total package | Option 2 Split supply | Composite estimate | Comments |
|---|---|---|---|---|
| | | Pound @ $1.6 | | |
| **Avon** | 500 | | 500 | Alba estimate is for a complete standard overhaul. O/H reports suggest some of this is not required. (note 1) |
| Replacement components | | | | Woods Rolls estimate $1.3 million for a complete Avon OH |
| | | | | S and S turbine quote $450,000 including parts. |
| **Power Turbine** | 300 | | | |
| Disassemble/reassemble | | 136 | 75 | Greenray estimate is substantially too high |
| New Disk | | 331 | 331 | Alba also have a disk; no quotation provided yet. |
| Moving blades | | See comment | 93 | 1 blade incl Greenway price- See note 1 |
| Rotor rehabilitation | | 282 | 282 | Includes shipment to UK |
| Inlet structure repairs | | | 15 | Small amount of welding is required |
| Thermocouples | | | | excluded from this estimate |
| Diaphragm section | | | 40 | |
| Heat shield | | | | |
| Bearings | | 70 | 70 | |
| Exhaust volute | | | 30 | Allow for minor repairs |
| **Gearbox** | | | | |
| Bearings | | 114 | 114 | |
| Disassemble/reassemble | | | | |
| Inspect, crack detection | | | | |
| Gearbox venting | | | 25 | Contingency against Greenray estimate |
| Contingency; 2nd opinion | | | 25 | Contingency against Greenray estimate |
| **Generator and aux** | 87 | | 900 | Alba confident cleaning & varnishing will improvelife |
| | | | | Rewind estimate requires confirmation. |
| Exciter | | | 50 | Refurbish (Replace as necessary during refurbishment) |
| **Inlet filter** | 30 | 588 | 150 | Camfil Farr est includes SS filter hours & new plenum. |
| | | | | For 8 year life extension new plenum not required, |
| **Exhaust stack** | 34 | 267 | 50 | For 8 year life extens existing stack with refurb adequate. |
| **Oil and fuel** | 45 | | 0 | This item covered by AMEC St Johns as BOP |
| Commission unit | | | 50 | |
| Contingency excl Avon | | | 150 | |
| **TOTAL** | 996 | 1788 | 2951 | |

Note 1. Alba quote $500,000 excluding parts, but overhaul scope is very extensive and can be reduced. S & S turbine is a smaller shop but quote $450,000 including all required parts.
Note 2. New PT blades from Greenray are very expensive. These blades can be welded, and as efficiency is not important we have estimate is based on a total of 4 new blades and weld repairs to others.

Assume 10% duty and shipping

## Schedule

The refurbishment of the unit can be done in two ways:

1. With the first alternative, NL Hydro can disassemble the unit in order to perform level 3 assessments on key equipment. After the Level 3 assessments, NL Hydro will be able to obtain firm bids for replacement components and place orders for them. This will be a lengthy process and it will require Hydro to authorize two separate contracts separated by several months. The first would cover disassembly and inspection and reassembly while the second would cover the purchase and fitting of replacement parts.

2. With the second alternative, AMEC will identify which components are likely to require replacement and that these are ordered if NL Hydro decides to refurbish the unit. Under this alternative, the unit will not receive any level 3 inspections until new components are available. It is possible that the detailed inspections will show the need for other component replacement, but AMEC thinks that it is unlikely that any further major long lead items will be required. The most expensive item which may have to be purchased is the power turbine disk, but NL Hydro will have the choice of purchasing a stock unit from Alba, if it is still available, or a new unit from Greenray.

The most important level 3 assessments are:

- Avon Gas Generator (The actual scope of the overhaul will be adjusted when the unit is inspected at the beginning of the overhaul).
- Gearbox and seals
- Power turbine Disk cooling system
- Power turbine disk
- Diaphragms and diaphragm ring

The schedule suggested by Greenway for the Power Turbine, with some additions identified for the other components, is shown in Table 2-11:

**TABLE 2-11 HOLYROOD GT REFURBISHMENT SCHEDULE**

**Newfoundland and Labrador Hydro. Holyrood GT refurbishment**

| | week | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Manufacture Disc | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | | | | | | |
| Strip and dissassemble plant | | | | | | | | | | | | | | | | | | | | | | ■ | ■ | | | | | | | | | | | | | | | | | | | |
| Ship Rotor to overhaul plant | | | | | | | | | | | | | | | | | | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | | | | | | | | |
| Overhaul and balance Rotor | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ■ | ■ | ■ | ■ | | | | | | | | | |
| Ship Rotor to Holyrood | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | | | |
| Rebuild and commission unit | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ■ | ■ | ■ |
| Avon overhaul | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Generator Refurbish (Rewind as necessary) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

## 2.2 Electrical & Controls Equipment/Processes

| | |
|---|---|
| Unit #: | GAS TURBINE |
| Asset Class # | BU 1273 Gas Turbine |
| SCI & System: | 7202 Gas Turbine System |
| Sub-Systems: | 7310 HRD GT E&C |

### 2.2.1 Description of Existing System

Holyrood GS consists of three thermal units (2x175 MW and 1x150 MW). Each unit supplies its own station service 4160V bus when on line. The Common station service for Unit #1 and #2 is fed from a 69KV/4160V 10.5/14MVA transformer SST-12. The Common station services of Unit #1 are fed from a 69KV/4160V 10.5/14MVA transformer SST-34. When the unit is shutdown (off line) its unit station service bus is transferred to the Common station services source (Reference - Holyrood Single Line Electrical Diagram).

During a total loss of all station service supply the station can be re-started from blackout condition with the 13.5 MW, 13.8 KV Emergency Gas Turbine (GT) connected to the 4160V station service bus through a 10.5 MVA step down transformer (T9). The station service buses all have a ground fault current limited to 1000A by a Neutral Ground Resister (NGR) of 2.4 Ohms.

References:

- NFL Holyrood Single Line Drawing # A)-1403-500-E-001 Rev 16
- IEEE C62.92-1989 Guide for the application of Neutral Grounding in Electrical Utility System Part II Grounding of Synchronous generator system.

Within the GT building, the Electrical and Control systems consist of a rotting brushless exciter, an automatic voltage regulator (AVR), a start rectifier, Distributed Control System (DCS) control modules, motor control centre (MCC), electronic governors, synchronizer, and protection and monitoring equipment.

The brushless exciter, AVR and start rectifier were manufactured by AEI Limited of Manchester, England in the mid-1960's. The governor, synchronizer and monitoring equipment were newly installed in 1986. The exciter and AVR unit controls its stator terminal voltage (13.8 kV) and MVAr delivery. The start rectifier converts station AC current into the high DC current necessary to rotate the jet engine to ignition. The governor consists of two Woodward units: one that controls the jet acceleration on start-up and the second that controls the power turbine/generator during synchronization and megawatt (MW) loading. In 1987, the Gem 80/500 PLC replaced all relay logic, but in 2009 this was again replaced by a Foxboro (Invensys) system which is in communication with the Plant DCS, and is now the primary controlling medium for the gas turbine.

The excitation control system consists of a "Normal" and "Standby" automatic voltage regulator (AVR) backed up by a "Manual" control mode. The AVR controls the strength of the magnetic field in the exciter by varying the amount of current through the stationary exciter field windings.

**Governor and Fuel Control:** The standard Avon fuel control system is used without alteration as a basis for the API governing and fuel control system. The throttle valve is used as a generator valve and the HP cock as a fuel shut-off valve for normal and emergency shut-downs. The governing system is of the sensitive oil type in which fluid pressure is used to transmit the movement of the governor pilot valve to the operating mechanism of the governor valve, in this case the Avon throttle.

The governor is manufactured by Woodward and is driven via gearing from the end of the high speed pinion shaft. The governor is a fly-weight type and carries its own oil supply.

Woodward Governor suggests that the present system has a reliability of about 50%. In addition spare parts for this system are not carried and would have to be fabricated requiring long delivery times.

The governor, synchronizer and monitoring equipment were newly installed in 1986. The governor consists of two Woodward units: one that controls the jet acceleration on start-up and the second that controls the power turbine/generator during synchronization and MW loading.

**Excitation System:** The exciter is a rotating brushless type mounted on a stub to the main rotating shaft. It was designed to ANSI Specification C50-13. The AC output from the exciter armature is fed through a set of diodes that are mounted on the rotor and are used to produce a DC voltage. The voltage is fed directly to the field winding of the main generator which is also mounted on the same rotating shaft.

The excitation control system consists of a “Normal” and “Standby” automatic voltage regulator (AVR) backed up by a “Manual” control mode. The AVR controls the strength of the magnetic field in the exciter by varying the amount of current through the stationary exciter field windings.

**Switchgear:** Primary voltage generated by the GT is 13,300 Volts. The installed GT capacity is 13.5 MW, however based on limiting factors the unit sees normal operation of ~12 MW. Originally this power was fed through a 13.8 kV oil circuit breaker and then through a 13.8 kV fusible switch. The oil circuit breaker is no longer functional but remains installed due to the current transformer (CT’s) in this breaker. These CT’s are essential to the protection of the generator and the 13.8 kV/4.160 14 MVA transformer. Power is then fed from the transformer at 4.160 kV to breaker SSB-2 in station panelboard SB12. Power from the CT or station power also feeds a 13.8 kV fused disconnect switch through a 75 kVA 13.8 kV/575 V transformer that provides power back to the station system.

**600V Standby Power:** GT 600 V standby power for the MCC and auxiliaries is fed from the diesel generator bus DB34 or power centre ‘C’ via a manual transfer switch in the control room. This item feeds into an automatic transfer switch which alternately is fed from the 112 kVA transformer in the previous paragraph.

**Battery Room:** A battery room is located adjacent to the room that contains the MCC and switchgear. The room (approximately 1800mm-2700mm) controls a bank of batteries for the purpose of powering the DC powered emergency lubrication pumps for the GT lubrication system should the shaft driver and the AC driver lubricating pumps fail during operation of the GT. The battery system also provides a source of power to the DC lube oil pump, should the AC power supply from the station Diesel Generators or Utility power to the GT building be lost.

**GTG Control System**

The control system has been incrementally improved through the unit’s life. In 1970, a PLC was installed to improve overall startup and unit control. In 1986, the Gem 80/500 PLC replaced all relay logic and was the primary controlling medium for the gas turbine. In 2009, it was replaced with an Invensys (Foxboro) DCS and the PLC logic was converted to DCS logic. The DCS controls the sequencing functions of the GT as did the PLC. It is set up on the plant DCS network so that the screens can be viewed by the plant operator in the main control room. In 2009, this was replaced by a Foxboro DCS system, which has greatly improved graphics.

**Control Room & MCC/Switchgear Room**

Within the gas turbine building, the electrical and control systems consist of a rotating brushless exciter, an automatic voltage regulator (AVR), a start rectifier, PLC control modules, motor control centre (MCC), electronic governors, synchronizer, and protection and monitoring equipment. The brushless exciter, AVR and start rectifier were manufactured by AEI Limited of Manchester, England in the mid-1960s. The programmable logic controller (PLC), governor, synchronizer and monitoring equipment were newly installed in 1986. The exciter and AVR unit act in combination to supply a controlled DC current to the wound rotor of the main generator which in turn controls its stator terminal voltage (13.8 kV) and MVar delivery. The start rectifier converts station AC current into the high DC current necessary to rotate the jet engine to ignition. The governor consists of two Woodward units: one that controls the jet acceleration on start-up and the second that controls the power turbine/generator during synchronization and MW loading.

**Switchgear**

The primary voltage generated by the GT is 13,300 Volts. The installed GT capacity is 13.5 MW. However, based on limiting factors, the unit sees normal operation of less than 12 MW.

Originally, this power was fed through a 13.8 kV oil circuit breaker and then through a 13.8 kV fusible switch. The oil circuit breaker is no longer functional but remains installed due to the current transformer (CT's) in this breaker. These CT's are essential to the protection of the generator and the 13.8 kV/4.160 14 MVA transformer. Power is then fed from the transformer at 4.160 kV to breaker SSB-2 in station panelboard SB1 2. Power from the CT or station power also feeds a 13.8 kV fused disconnect switch through a 75 kVA 13.8 kV/575 V transformer that provides power back to the station system.

### 2.2.2 Major Maintenance History

In 1987, the original control panel and sequencing system was removed and replaced with a state of the art programmable control and sequence system (Pratt & Whitney). This system was subsequently replaced in 2009 by a Foxboro (Invensys) DCS system. The original AEI/GEC control system was removed and replaced with a Woodward Governor 2301 Control System driving an EGP3 actuator.

Other than the decision to bypass the 13.8kV oil circuit breaker, no major maintenance has been carried out.

The following is a summary of significant work completed since 2003. No major overhauls have been completed on the entire machine.

**25 May 2007**

- Ignitor, lead and box were replaced;

**21 May 2008**

- Controls review.

**10 June 2008**

- Fuel pump and fuel control unit (FCU) to be repaired.

**15 October 2009**

- Thermocouple damage, quick fixed. To be upgraded;

**20 November 2009**

- Commissioning;
- Fuel control solenoid valve burnt out and replaced;
- Multiple start trips due to low fuel pressure, low oil pressure, and incomplete start sequence. Several issues identified - igniter box malfunction, N2 probe incorrectly connected & poor FCU actuator tuning;
- Suggest monitoring setup for the 8 EGT thermocouples.

NL Hydro has since undertaken a number of activities with vendors that have the OEM rights to the GT sections in order to conduct detailed internal inspections of the individual sections and prepare field inspection reports complete with refurbishment estimates. None dealt specifically with the electrical and control (E&C) systems.

### 2.2.3 Condition Assessment & Remaining Life

**TABLE 2-12 CONDITION ASSESSMENT – GT ELECTRICAL & CONTROLS**

| BU # 1 | Asset # 2 | Asset # 3 | Asset # 4 | Asset Level 3 | Description | Detail | Cond. Summ. ID# | Condition | Status Identifier | Original Life (Base Load) Ops Hrs (Yrs) | Current Expected Minimum Remaining Life Years (Subject to Test) | End of Life (EOL) Required | Capability to Reach EOL | In Service |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 7202 | 7310 | 0 | Elect and Control | 800A, 13.8 kV Generator Main Breaker (AEI, Type BRP17 / BVRP17) | 2.3.3.2 a) | EC1 | The breaker has been by-passed, but does not comprimise the protection of the Generator or T9 Transformer, as the protection still disables the excitation and trips SSB-2 on Statron Board SB12, and at the same time removes internal faults on the Generator and T9 Transformer | 4/10 | | N/A | N/A | No | 1969 |
| | 7202 | 7310 | 0 | Elect and Control | 13.8 kV fusible switch (J.G. Statter, Ltd. Type VLMK2) | 2.3.3.2 b) | EC2 | Support and spares are unavailable | 4/10 | | N/A | N/A | No | 1969 |
| | 7202 | 7310 | 0 | Elect and Control | 112 kVa, 13.8 kV: 600V 3ph Transformer (Cart 6 Electrical) | Part of - 2.3.3.2 c) | EC3 | Good Condition | 4/10 | | 10+ | 2020 | Yes | 1969 |
| | 7202 | 7310 | 0 | Elect and Control | 200A, 600V, 3ph manual transfer switch (Square D) | N/A | EC4 | Fair Condition, but no spares available | 4/10 | | 10+ | 2020 | Yes | 1969 |
| | 7202 | 7310 | 0 | Elect and Control | 200A, 600V, 3ph automatic transfer switch (Taylor Industrial Controls) | N/A | EC5 | Fair Condition, but no spares available | 4/10 | | 10+ | 2020 | Yes | 1969 |
| | 7202 | 7310 | 0 | Elect and Control | 600V, 3ph, Dist. Panel | N/A | EC6 | Fair condition, but distribution board and branch breakers are old with no spares available and have been superceeded by up-to-date equipment. | 4/10 | | 0 | 2020 | No | 1969 |
| | 7202 | 7310 | 0 | Elect and Control | 30 kVa, 600V: 230/115V, 1ph lighting transformer (Hammond, Type F Car E70B) | Part of - 2.3.3.2 e) | EC7 | Good Condition | 4/10 | | 10+ | 2020 | Yes | 1969 |
| | 7202 | 7310 | 0 | Elect and Control | MCC (AEI, Type MMC Series 1000) | 2.3.3.2 d) | EC8 | Contains 600V, 3ph, 230V, 3ph and 100V dc bussing. The MCC is not only obsolete, with no spares or documentation available, but also violates CEC C22.1 working space in front of the MCC is less than 1 metre and when a starter is drawn out there is a safety hazard in front of the MCC. | 4/10 | | 0 | 2012 | No | 1969 |
| | 7202 | 7310 | 0 | Elect and Control | 100A, 230V, 3ph lighting panel | N/A | EC9 | Fair condition, but distribution board and branch breakers are old with no spares available and have been superceeded by up-to-date equipment. | 4/10 | | 1 | 2020 | No | 1969 |
| | 7202 | 7310 | 0 | Elect and Control | 120V dc dist. Panel | N/A | EC10 | Fair condition, but distribution board and branch breakers are old with no spares available and have been superceeded by up-to-date equipment. | 4/10 | | 1 | 2020 | No | 1969 |
| | 7202 | 7310 | 0 | Elect and Control | 120V dc motor starters fused disconnect | N/A | EC11 | Part of existing MCC | 4/10 | | 0 | 2020 | No | 1969 |
| | 7202 | 7310 | 0 | Elect and Control | 230V, 3ph, starter and disconnect | N/A | EC12 | Part of existing MCC | 4/10 | | 0 | 2020 | No | 1969 |
| | 7202 | 7310 | 0 | Elect and Control | Battery Charger (SAFT NIFE, Model SLRF 120-30) | N/A | EC13 | Good Condition | 4/10 | | 10+ | 2020 | Yes | 1995 |
| | 7202 | 7310 | 0 | Elect and Control | 129V dc battery bank (C&D technologies) | N/A | EC14 | The battery has a life expectancy of 18-25 years. Being situated in a good environment, not over-stressed and receiving regular maintenance. Product is current with replacement cells and spare parts available. | 4/10 | | 10+ | 2020 | Yes | 1995 |
| | 7202 | 7310 | 0 | Elect and Control | Start rectifier (AEI) | 2.3.3.2 g) | EC15 | No maintenance or servicing has been carried out by the present maintenance staff. | 4/10 | | 0 | 2020 | No | 1969 |
| | 7202 | 7310 | 0 | Elect and Control | Automatic voltage regulator/excitor (AEI) | 2.3.3.2 g) | EC16 | No maintenance or servicing has been carried out by the present maintenance staff. | 4/10 | | 0 | 2020 | No | 1969 |
| | 7202 | 7310 | 0 | Elect and Control | Protection and Controls (Pratt & Whitney) | N/A | EC17 | Very good condition, with spares available for the unforseen future | 4/10 | | 10+ | 2020 | Yes | 1986 |
| | 7202 | 7310 | 0 | Elect and Control | DCS (Foxboro/Invensys) | N/A | EC18 | Good condition - replaces the GEN80 PLC system and communicates direct into the plant DCS. DCS in operation considered "state-of-the-art" and replacement service agreement renders the system current. | 4/10 | | 10+ | 2020 | Yes | 2009 |
| 1325 | 5983 | 5983 | 61-00-69576 | TRANSFORMERS | TRANSFORMER T9 | 13.8 kV | EC19 | Installed in 1970, the unit is at a high level of risk due to its age. No significant issues were identified in Doble tests last done in 2001. Maintenance in 2000, 2004 and 2006 was for various gauges/relays. Silica gel was replaced in 2002 and a Dielectric test performed in 1983. The latest Planned Maintenance was in 2006. Insulating oil tests in 2009 suggests higher power loss when under operation, and also the oil has a higher solubility of polar contaminants and oxidation products. | 4 | (45) | 5+ | 2020 | Yes | 1970 |

### 2.2.4 Risk Assessment/

**TABLE 2-13 RISK ASSESSMENT – GT ELECTRICAL & CONTROLS**

| BU # 1 | Asset # 2 | Asset # 3 | Asset # 4 | Asset Level 3 | Description | Detail | Cond. Summ. ID# | Condition | Major Issues | Remaining Life Years | TECHNO-ECO RISK ASSESS MODEL | | | SAFETY RISK ASSESS MODEL | | | Possible Failure Event | Mitigation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | (Insufficient Info - Inspection Required Within (x) Years) | Likeli-hood | Conse-quence | Risk Level | Likeli-hood | Conse-quence | Safety Risk | | |
| | 7202 | 7310 | 0 | Elect and Control | 800A, 13.8 kV Generator Main Breaker (AEI, Type BRP17 / BVRP17) | 2.3.3.2 a) | EC1 | The breaker has been by-passed, but does not comprimise the protection of the Generator or T9 Transformer, as the protection still disables the excitation and trips SSB-2 on Statron Board SB12, and at the same time removes internal faults on the Generator and T9 Transformer | Arc flash | 0 | 1 | D | Medium | 1 | 4 | Medium | Arc Flash on breaker resulting in potential for serious injury. | Breaker has been by-passed |
| | 7202 | 7310 | 0 | Elect and Control | 13.8 kV fusible switch (J.G. Statter, Ltd. Type VLMK2) | 2.3.3.2 b) | EC2 | Support and spares are unavailable | Not able to maintain | 0 | 4 | A | Low | 4 | 1 | Medium | None likely in current configuration. | replace with new fusible switch |
| | 7202 | 7310 | 0 | Elect and Control | 112 kVa, 13.8 kV: 600V 3ph Transformer (Cart 6 Electrical) | Part of - 2.3.3.2 c) | EC3 | Good Condition | None | 10+ | 1 | B | Low | 1 | C | Low | N/A | Monitor condition. |
| | 7202 | 7310 | 0 | Elect and Control | 200A, 600V, 3ph manual transfer switch (Square D) | N/A | EC4 | Fair Condition, but no spares available | Not able to maintain | 10+ | 1 | A | Low | 1 | A | Low | N/a | Monitor condition. |
| | 7202 | 7310 | 0 | Elect and Control | 200A, 600V, 3ph automatic transfer switch (Taylor Industrial Controls) | N/A | EC5 | Fair Condition, but no spares available | Not able to maintain | 10+ | 1 | A | Low | 1 | A | Low | N/A | Monitor condition. |
| | 7202 | 7310 | 0 | Elect and Control | 600V, 3ph, Dist. Panel | N/A | EC6 | Fair condition, but distribution board and branch breakers are old with no spares available and have been superceeded by up-to-date equipment. | Not able to maintain | 0 | 4 | A | Low | 3 | A | Low | N/A | Monitor condition. |
| | 7202 | 7310 | 0 | Elect and Control | 30 kVa, 600V: 230/115V, 1ph lighting transformer (Hammond, Type F Car FZ9P) | Part of - 2.3.3.2 e) | EC7 | Good Condition | None | 10+ | 1 | B | Low | 1 | C | Low | N/A | Monitor condition. |
| | 7202 | 7310 | 0 | Elect and Control | MCC (AEI, Type MMC Series 1000) | 2.3.3.2 d) | EC8 | Contains 600V, 3ph, 230V, 3ph and 100V dc bussing. The MCC is not only obsolete, with no spares or documentation available, but also violates CEC C22.1 working space in front of the MCC is less than 1 metre and when a starter is drawn out there is a safety hazard in front of the MCC. | Obsolete unable to maintain. Does not conform to Candian Standards Maintance and Arc | 0 | 4 | C | High | 3 | D | High | Arc flash and threat of personell serios injury | Replace the MCC and Re-Cable the 600V, 230V and 110V DC power. |
| | 7202 | 7310 | 0 | Elect and Control | 100A, 230V, 3ph lighting panel | N/A | EC9 | Fair condition, but distribution board and branch breakers are old with no spares available and have been superceeded by up-to-date equipment. | Not able to maintain | 1 | 4 | A | Low | 3 | B | Medium | Lighting failure - staff safety | Replace the Start Rectifier |
| | 7202 | 7310 | 0 | Elect and Control | 120V dc dist. Panel | N/A | EC10 | Fair condition, but distribution board and branch breakers are old with no spares available and have been superceeded by up-to-date equipment. | Not able to maintain | 1 | 4 | C | Medium | 3 | C | Medium | Unit failure to start- extended period. | Replace the Start Rectifier |
| | 7202 | 7310 | 0 | Elect and Control | 120V dc motor starters fused disconnect | N/A | EC11 | Part of existing MCC | Obsolete unable to maintain. Does not conform to Candian Standards Maintance and Arc | 0 | 3 | C | High | 2 | D | High | Arc flash and threat of personell serios injury | Replace the Starter and the Fused Disconnect |
| | 7202 | 7310 | 0 | Elect and Control | 230V, 3ph, starter and disconnect | N/A | EC12 | Part of existing MCC | Obsolete unable to maintain. Does not conform to Candian Standards Maintance and Arc | 0 | 4 | C | High | 3 | D | High | Arc flash and threat of personell serios injury | Replace the Starter and the Fused Disconnect |
| | 7202 | 7310 | 0 | Elect and Control | Battery Charger (SAFT NIFE, Model SLRF 120-30) | N/A | EC13 | Good Condition | None | 10+ | 1 | A | Low | 1 | B | Low | N/A | Monitor condition. |
| | 7202 | 7310 | 0 | Elect and Control | 129V dc battery bank (C&D technologies) | N/A | EC14 | The battery has a life expectancy of 18-25 years. Being situated in a good environment, not over-stressed and receiving regular maintenance. Product is current with replacement cells and spare parts available. | None | 10+ | 1 | A | Low | 1 | B | Low | N/A | Monitor condition. |
| | 7202 | 7310 | 0 | Elect and Control | Start rectifier (AEI) | 2.3.3.2 g) | EC15 | No maintenance or servicing has been carried out by the present maintenance staff. | Not able to maintain | 0 | 1 | C | Medium | 3 | C | Medium | Unit failure to start- extended period. | Replace the Start Rectifier |
| | 7202 | 7310 | 0 | Elect and Control | Automatic voltage regulator/excitor (AEI) | 2.3.3.2 g) | EC16 | No maintenance or servicing has been carried out by the present maintenance staff. | Not able to maintain | 0 | 1 | C | Medium | 3 | C | Medium | Unit failure to start- extended period. | Replace the Automatic Voltage Regulator |
| | 7202 | 7310 | 0 | Elect and Control | Protection and Controls (Pratt & Whitney) | N/A | EC17 | Very good condition, with spares available for the unforseen future | None | 10+ | 1 | A | Low | 1 | B | Low | N/A | Monitor condition. |
| | 7202 | 7310 | 0 | Elect and Control | DCS (Foxboro/Invensys) | N/A | EC18 | Good condition - replaces the GEN80 PLC system and communicates direct into the plant DCS. DCS in operation considered "state-of-the-art" and replacement service agreement renders the system current | None | 10+ | 1 | A | Low | 1 | B | Low | N/A | Monitor condition. |
| 1325 | 5983 | 5983 | 61-00-69576 | TRANSFORMERS | TRANSFORMER T9 | 13.8 kV | EC19 | Installed in 1970, the unit is at a high level of risk due to its age. No significant issues were identified in Doble tests last done in 2001. Maintenance in 2000, 2004 and 2006 was for various gauges/relays. Silica gel was replaced in 2002 and a Dielectric | Transformer failure | 5+ | 2 | C | Medium | 2 | C | Medium | Transformer core failure; oil leak etc. | Monitor condition and gas and oil tests per schedule. |

### 2.2.5 Actions

TABLE 2-14 ACTIONS – GT ELECTRICAL & CONTROLS

| BU # 1 | Asset # 2 | Asset # 3 | Asset # 4 | Asset Level 3 | Description | Detail | Cond. Summ. ID# | Action | Year | Priority |
|---|---|---|---|---|---|---|---|---|---|---|
| | 7202 | 7310 | 0 | Elect and Control | 800A, 13.8 kV Generator Main Breaker (AEI, Type BRP17 / BVRP17) | 2.3.3.2 a) | EC1 | replace 13.8kV breaker, and recommend that a new SSB-2, vacuum interrupting type , 4160V, be installed in station board Sb12, complete with Rm trip and arc flash maintenance reduction switch. | 2012 | 1 |
| | 7202 | 7310 | 0 | Elect and Control | 13.8 kV fusible switch (J.G. Statter, Ltd. Type VLMK2) | 2.3.3.2 b) | EC2 | Replace fusable switch | 2012 | 1 |
| | 7202 | 7310 | 0 | Elect and Control | 112 kVa, 13.8 kV: 600V 3ph Transformer (Cart 6 Electrical) | Part of - 2.3.3.2 c) | EC3 | No recommended action | | |
| | 7202 | 7310 | 0 | Elect and Control | 200A, 600V, 3ph manual transfer switch (Square D) | N/A | EC4 | No recommended action | | |
| | 7202 | 7310 | 0 | Elect and Control | 200A, 600V, 3ph automatic transfer switch (Taylor Industrial Controls) | N/A | EC5 | No recommended action | | |
| | 7202 | 7310 | 0 | Elect and Control | 600V, 3ph, Dist. Panel | N/A | EC6 | Recommend replacing with new dist. Panel and breakers | 2012 | 2 |
| | 7202 | 7310 | 0 | Elect and Control | 30 kVa, 600V: 230/115V, 1ph lighting transformer (Hammond, Type F Car FZ9P) | Part of - 2.3.3.2 e) | EC7 | No reocmmended action | | |
| | 7202 | 7310 | 0 | Elect and Control | MCC (AEI, Type MMC Series 1000) | 2.3.3.2 d) | EC8 | Replace with new MCC for the 600V, 3ph system (also reference items 11 and 12) | 2012 | 1 |
| | 7202 | 7310 | 0 | Elect and Control | 100A, 230V, 3ph lighting panel | N/A | EC9 | Recommend replacing with new lighting panel and breakers | 2012 | 2 |
| | 7202 | 7310 | 0 | Elect and Control | 120V dc dist. Panel | N/A | EC10 | Recommend replacing with new dist. Panel and breakers | 2012 | 1 |
| | 7202 | 7310 | 0 | Elect and Control | 120V dc motor starters fused disconnect | N/A | EC11 | Recommend replacing with a new starter for the Hyd, Gov Pump and new disconnect for the 100V dc panel feed. | 2012 | 1 |
| | 7202 | 7310 | 0 | Elect and Control | 230V, 3ph, motor starter and fused disconnect | | EC12 | Recommend replacing with a new starter for the air compressor and new disconnect for the new ACR controls | 2012 | 1 |
| | 7202 | 7310 | 0 | Elect and Control | battery charger | | EC13 | No recommended action | | |
| | 7202 | 7310 | 0 | Elect and Control | 129V dc battery bank | | EC14 | No recommended action | | |
| | 7202 | 7310 | 0 | Elect and Control | Start rectifier | | EC15 | Recommend replacing with a new system | 2012 | 1 |
| | 7202 | 7310 | 0 | Elect and Control | AVR | | EC16 | Recommend replacing with a new system | 2012 | 1 |
| | 7202 | 7310 | 0 | Elect and Control | Prot. & Controls | | EC17 | No recommended action | | |
| | 7202 | 7310 | 0 | Elect and Control | DCS | | EC18 | No recommended action | | |

### 2.2.6 Life Assessment - Life Cycle Curves (Where Equipment Is Not To Be Overhauled/replaced and Life <2020 and has Major Unit Operation Impacts)

No Life Cycle Curves are presented. The newer equipment (Controls, battery chargers, batteries) can all meet the 2020 end date. The balance (AVR, MCC, etc.) essentially should be replaced as part of any refurbishment program. Post refurbishment in line with the proposals in this report, there should be no further major significant repairs required before 2020.

### 2.2.7 Level 3 Inspections Required

No incremental to refurbishment Level 3 assessments are required.

### 2.2.8 Capital Enhancements

The suggested capital projects for the GT E&C systems are presented in Table 2-15.

**TABLE 2-15 SUGGESTED TYPICAL CAPITAL ENHANCEMENTS – GAS TURBINE ELECTRICAL & CONTROLS**

| Asset # 2 | Asset # 3 | Asset # 4 | Asset Level 3 | Description | Detail | Cond. Summ. ID# | Capital Item | Date | Priority |
|---|---|---|---|---|---|---|---|---|---|
| 7202 | 7310 | 0 | Elect and Control | 800A, 13.8 kV Generator Main Breaker (AEI, Type BRP17 / BVRP17) | 2.3.3.2 a) | EC1 | Removal of existing breaker and installation of new breaker, trays and new JB. Run power cables from new breaker to generator and to T9 tranformer, Termination of existing CT's, PT's and control cables in new JB, and extending new CT, PT and control cables from new JB to the new breaker, Extend grounding as necessary. Function test and commission. | 2012 | 1 |
| 7202 | 7310 | 0 | Elect and Control | 13.8 kV fusible switch (J.G. Statter, Ltd. Type VLMK2) | 2.3.3.2 b) | EC2 | Removal of existing fusible switch and installation of new fusible switch, plus installation of cabling to 112 kVA transformer. Ground as necessary. Function test and commission | 2012 | 1 |
| 7202 | 7310 | 0 | Elect and Control | 112 kVa, 13.8 kV: 600V 3ph Transformer (Cart 6 Electrical) | 2.3.3.2 c) | EC3 | Cable from 112kVA Transformer to new 13.8kV Fusible Switch | 2012 | 1 |
| 7202 | 7310 | 0 | Elect and Control | MCC (AEI, Type MMC Series 1000) | 2.3.3.2 d) | EC8 | Replace the MCC and Re-Cable the 600V, 230V and 110V DC power. | 2012 | 1 |
| 7202 | 7310 | 0 | Elect and Control | 30 kVa, 600V: 230/115V, 1ph lighting transformer (Hammond, Type F Car FZ9P) ; New 230V, 3ph, Auxiliary Distribution Panel | 2.3.3.2 e) | EC7 | Install New 230V, 3ph, Auxiliary Distribution Panel. Relocate 30kVA, 3ph, 550:230V Transformer and Connect to MCC and New 230V, 3ph, Auxiliary Distribution Panel | 2012 | 1 |
| 7202 | 7310 | 0 | Elect and Control | 120V dc motor starters fused disconnect | 2.3.3.2 f) | EC11 | New 110VDC,. NEMA 1 Breaker, new NEMA1 Splitter, new DC Starters, and Existing 100A DC Distribution Panel. New Feeders from Splitter to DC Starters and DC Distribution Panel | 2012 | 1 |
| 7202 | 7310 | 0 | Elect and Control | Start rectifier (AEI) | 2.3.3.2 g) | EC15 | Replace the Start Rectifier | 2012 | 1 |
| 7202 | 7310 | 0 | Elect and Control | Automatic voltage regulator/excitor (AEI) | | EC16 | Replace the Automatic Voltage Regulator | 2012 | 1 |
| 7202 | 7310 | 0 | Elect and Control | Miscellaneous | 2.3.3.2 h) | EC20 | Miscellaneous Hardware, Tray and 4/0 Grounding | 2012 | 1 |
| 7202 | 7310 | 0 | Elect and Control | Commissioning | | EC21 | Commissioning | 2012 | 1 |
| 7202 | 7310 | 0 | Elect and Control | Protection and Controls (Pratt & Whitney) | | EC17 | No Capital Required | | |
| 7202 | 7310 | 0 | Elect and Control | DCS (Foxboro/Invensys) | | EC18 | No Capital Required | | |
| 5983 | 5983 | 61-00-69576 | TRANSFORMERS | TRANSFORMER T9 | | EC19 | No Capital Required | | |
| 7202 | 7310 | 0 | Elect and Control | 200A, 600V, 3ph manual transfer switch (Square D) | | EC4 | No Captial Requirement | | |
| 7202 | 7310 | 0 | Elect and Control | 200A, 600V, 3ph automatic transfer switch (Taylor Industrial Controls) | | EC5 | No Captial Requirement | | |
| 7202 | 7310 | 0 | Elect and Control | 600V, 3ph, Dist. Panel | | EC6 | No Capital Required | | |
| 7202 | 7310 | 0 | Elect and Control | 100A, 230V, 3ph lighting panel | | EC9 | No Captial Requirement | 2012 | 2 |
| 7202 | 7310 | 0 | Elect and Control | 120V dc dist. Panel | | EC10 | No Captial Requirement | 2012 | 2 |
| 7202 | 7310 | 0 | Elect and Control | 120V dc motor starters fused disconnect | | EC11 | Replace the Starter and the Fused Disconnect | 2012 | 1 |
| 7202 | 7310 | 0 | Elect and Control | 230V, 3ph, starter and disconnect | | EC12 | Replace the Starter and the Fused Disconnect | 2012 | 1 |
| 7202 | 7310 | 0 | Elect and Control | Battery Charger (SAFT NIFE, Model SLRF 120-30) | | EC13 | No Capital Required | | |
| 7202 | 7310 | 0 | Elect and Control | 129V dc battery bank (C&D technologies) | | EC14 | No Capital Required | | |

### 2.2.9 Capital/Refurbishment and Overhaul Costs (Capital)

The suggested equipment and installation costs (Refurbishment of Existing Equipment) for the GT E&C systems are presented in Table 2-16.

**TABLE 2-16 CAPITAL COST ESTIMATE – GAS TURBINE ELECTRICAL & CONTROLS**

| Asset #2 | Asset #3 | Asset #4 | Asset Level 3 | Description | Detail | Cond. Summ. ID# | Capital Item | Date | Priority | Desciption | Qty | Unit | Material | Labour | Total | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7202 | 7310 | 0 | Elect and Control | 800A, 13.8 kV Generator Main Breaker (AEI, Type BRP17 / BVRP17) | 2.3.3.2 a) | EC1 | Removal of existing breaker and installation of new breaker, trays and new JB. Run power cables from new breaker to generator and to T9 tranformer, Termination of existing CT's, PT's and control cables in new JB, and extending new CT, PT and control cables from new JB to the new breaker, Extend grounding as necessary. Function test and commission. | 2012 | 1 | Installation of new 800A, 13.8 kV, 3ph, 60Hz Generator Main Breaker | 1 | ea | 126860 | 12800 | 139660 | |
| | | | | | | | | | | Removal of Existing Main Breaker | 1 | lot | - | 1600 | 1600 | |
| | | | | | | | | | | Installation of Cable Tray | 20 | m | 3500 | 1250 | 4750 | |
| | | | | | | | | | | Installation of New Junction Box | 1 | ea | 1000 | 480 | 1480 | |
| | | | | | | | | | | Removal of Existing Power Cables from Existing Breaker to Generator and T9 Transformer | 1 | lot | - | 1600 | 1600 | |
| | | | | | | | | | | Installation of New Power Cables from New Breaker to Generator (2 x 500kcmil) and T9 Transformer (2x500kcmil) | 180 | m | 50,000 | 10,000 | 60,000 | |
| | | | | | | | | | | Connection of Existing and Used CT, PT and Control Cables in New JB, and run the new CT, PT and Control Cables from new JB to new 13.8 kV Main Breaker (4 x 4c10, 1 x 4c12, 1 x 12c12). | 1 | lot | 600 | 1600 | 2200 | |
| 7202 | 7310 | 0 | Elect and Control | 13.8 kV fusible switch (J.G. Statter, Ltd. Type VLMK2) | 2.3.3.2 b) | EC2 | Removal of existing fusible switch and installation of new fusible switch, plus installation of cabling to 112 kVA transformer. Ground as necessary. Function test and commission | 2012 | 1 | Installation of New 13.8kV Fusible Switch | 1 | ea | - | - | | included with cost of 13.8kV |
| | | | | | | | | | | Removal of Existing 13.8 kV Fusible Switch | 1 | lot | - | 1600 | 1600 | |
| 7202 | 7310 | 0 | Elect and Control | 112 kVa, 13.8 kV: 600V 3ph Transformer (Cart 6 Electrical) | 2.3.3.2 c) | EC3 | Cable from 112kVA Transformer to new 13.8kV Fusible Switch | | | Install 3c2AWG, Teeck, 15kV, Cable from 112kVA Transformer to new 13.8kV Fusible Switch | 10 | m | 750 | 300 | 1050 | |
| 7202 | 7310 | 0 | Elect and Control | MCC (AEI, Type MMC Series 1000) | 2.3.3.2 d) | EC8 | Replace the MCC and Re-Cable the 600V, 230V and 110V DC power. | 2012 | 1 | Remove Existing MCC | 1 | ea | - | 8000 | 8000 | |
| | | | | | | | | | | Install New MCC | 1 | ea | 30000 | 8000 | 38000 | |
| | | | | | | | | | | Install Cable Tray | 1 | lot | 1600 | 900 | 2500 | |
| | | | | | | | | | | Install New Incoming and Feeder Cables for 600V Circuits | | | | | | |
| | | | | | | | | | | 3C12, Teck, 1000V, (Seven Circuits) | 280 | m | 1260 | 525 | 1785 | |
| | | | | | | | | | | 3c10, Teck, 1000V, (One Circuit) | 40 | m | 240 | 120 | 360 | |
| | | | | | | | | | | 3c6, Teck, 1000V, (Five Circuits) | 200 | m | 1025 | 350 | 1375 | |
| | | | | | | | | | | 3c2, Teck, 1000V, (One Circuit) | 40 | m | 1040 | 200 | 1240 | |
| 7202 | 7310 | 0 | Elect and Control | 30 kVa, 600V: 230/115V, 1ph lighting transformer (Hammond, Type F Car FZ9P) ; New 230V, 3ph, Auxiliary Distribution Panel | 2.3.3.2 e) | EC7 | Install New 230V, 3ph, Auxiliary Distribution Panel. Relocate 30kVA, 3ph, 550:230V Transformer and Connect to MCC and New 230V, 3ph, Auxiliary Distribution Panel | | | Install New 230V, 3ph, Auxiliary Distribution Panel | 1 | ea | 650 | 350 | 1000 | |
| | | | | | | | | | | Relocate 30kVA, 3ph, 550:230V Transformer and Connect to MCC and New 230V, 3ph, Auxiliary Distribution Panel | 1 | lot | - | 3000 | 3000 | |
| | | | | | | | | | | 3c12, Teck, 1000V (One Circuit) | 40 | m | 180 | 75 | 255 | |
| | | | | | | | | | | 3c10, Teck, 1000V, (Two Circuits) | 40 | m | 120 | 60 | 180 | |
| 7202 | 7310 | 0 | Elect and Control | 120V dc motor starters fused disconnect | 2.3.3.2 f) | EC11 | New 110VDC,. NEMA 1 Breaker, new NEMA1 Splitter, new DC Starters, and Existing 100A DC Distribution Panel. New Feeders from Splitter to DC Starters and DC Distribution Panel | | | Install new 110VDC,. NEMA 1 Breaker, new NEMA1 Splitter, new DC Starters, and Existing 100A DC Distribution Panel | 1 | lot | 31000 | 6400 | 37400 | |
| | | | | | | | | | | Install New Feeders from Splitter to DC Starters and DC Distribution Panel | | | | | | |
| | | | | | | | | | | 3c12, Teck, 1000V (One Circuit) | 40 | m | 180 | 75 | 255 | |
| | | | | | | | | | | 3c10, Teck, 1000V, (One Circuit) | 35 | m | 210 | 120 | 330 | |
| | | | | | | | | | | 3c2, Teck 1000V (One Circuit) | 16 | m | 410 | 140 | 550 | |
| 7202 | 7310 | 0 | Elect and Control | Start rectifier (AEI) | 2.3.3.2 g) | EC15 | Replace the Start Rectifier | 2012 | 1 | Remove Existing AVR/Start Rectifier | 1 | ea | - | 1600 | 1600 | |
| 7202 | 7310 | 0 | Elect and Control | Automatic voltage regulator/excitor (AEI) | | EC16 | Replace the Automatic Voltage Regulator | 2012 | 1 | Install New AVR/Start Rectifier | 1 | ea | 145,000 | 20,000 | 165,000 | |
| 7202 | 7310 | 0 | Elect and Control | Miscellaneous | 2.3.3.2 h) | EC20 | Miscellaneous Hardware, Tray and 4/0 Grounding | 2012 | 1 | Miscellaneous Hardware, Tray and 4/0 Grounding | 1 | lot | 7500 | 7500 | 15000 | |
| 7202 | 7310 | 0 | Elect and Control | Commissioning | | EC21 | Commissioning | 2012 | 1 | Commissioning Costs | | | - | 50,000 | 50000 | |

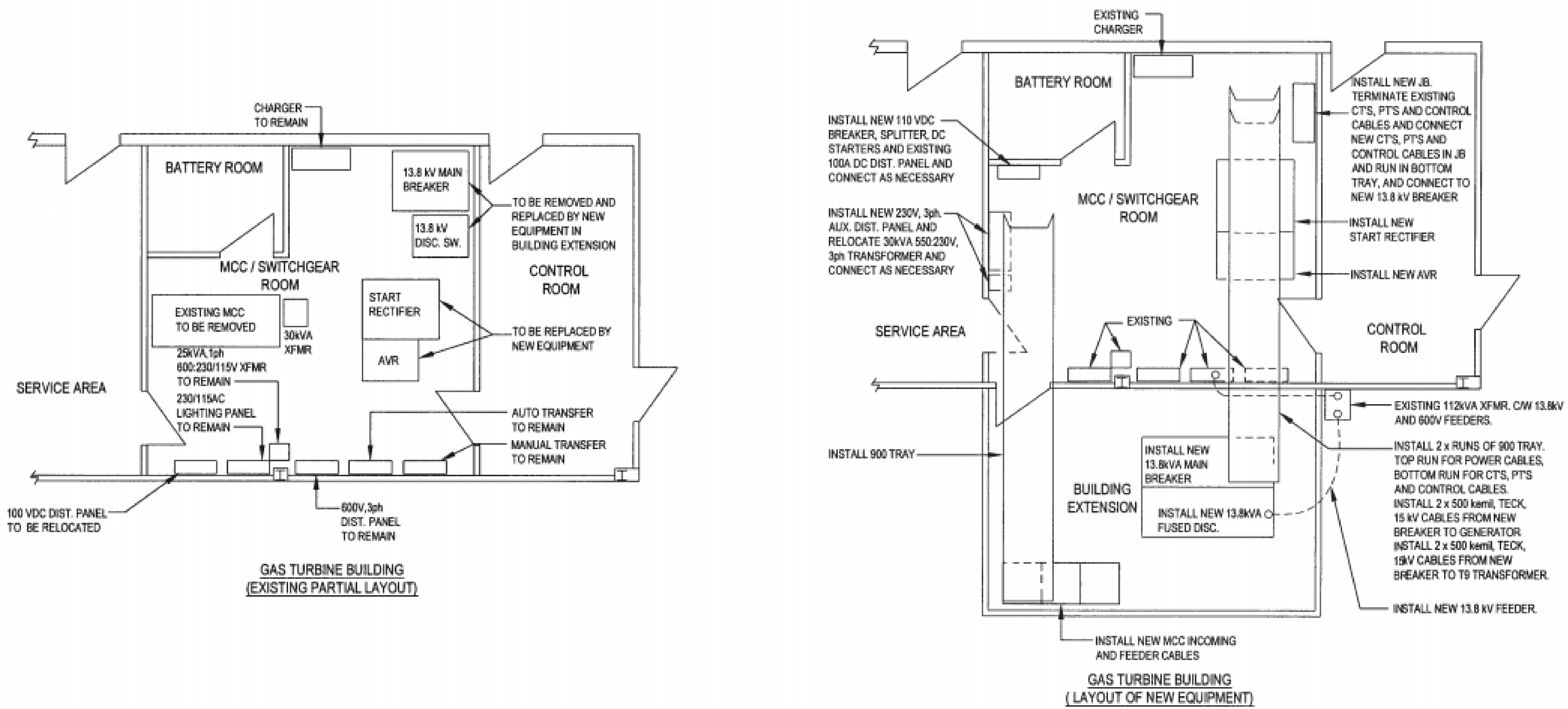



**FIGURE 2-2 GAS TURBINE BUILDING – ELECTRICAL & CONTROLS – CURRENT AND PROPOSED**

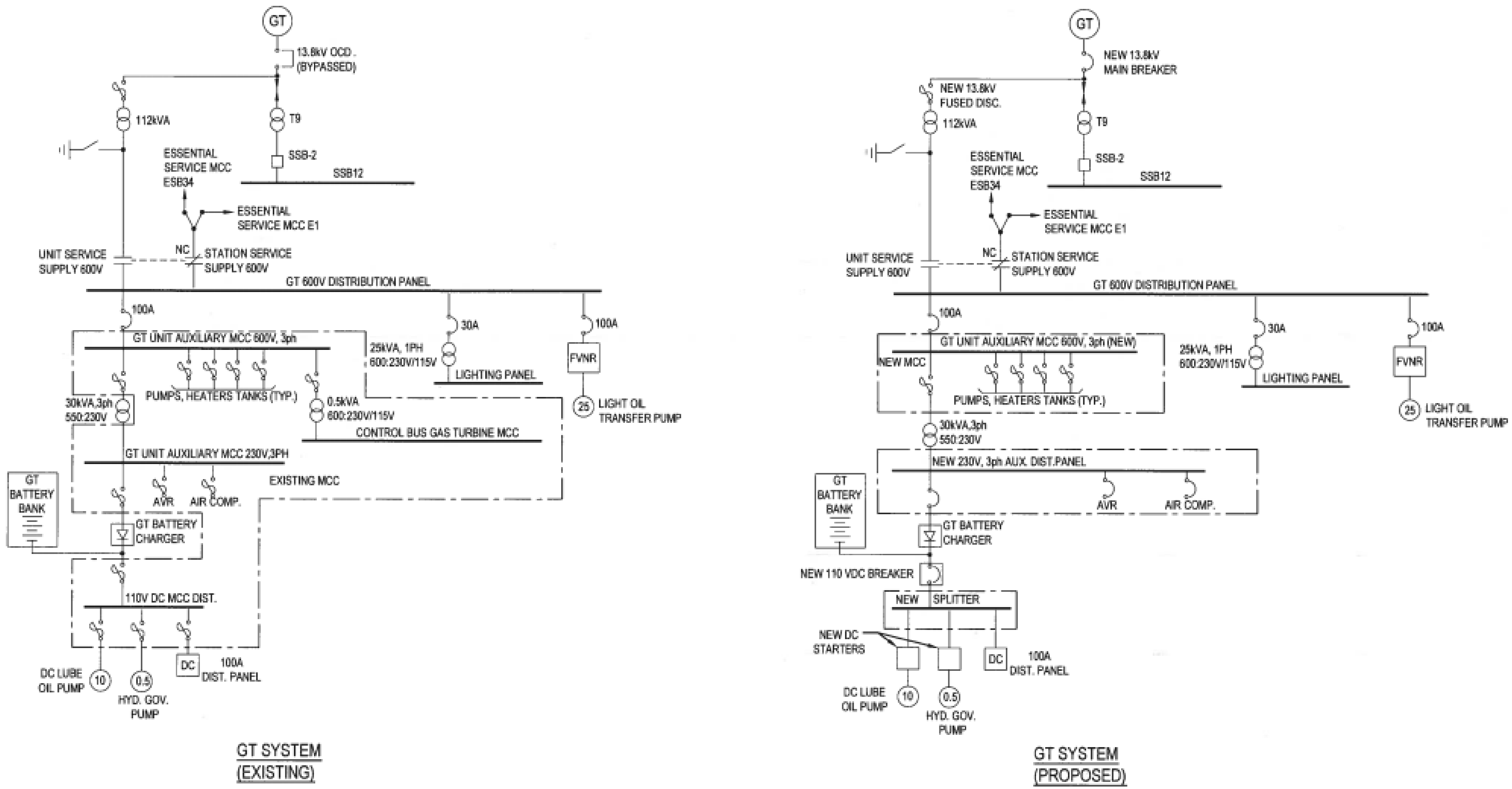



**Figure 2-3 Gas Turbine Single Line Diagrams – Current and Proposed**

## 2.3 Gas Turbine Balance of Plant (BOP) Equipment/Processes

| | |
|---|---|
| Unit #: | GAS TURBINE |
| Asset Class # | BU 1273 Gas Turbine |
| SCI & System: | 7202 Gas Turbine System |
| Sub-Systems: | 7311 GT Aux Systems |

### 2.3.1 Description

**AC Lube Oil Cooler:** The AC Lube Oil Cooler is located outside the GT building. The cooler has experienced a substantial amount of surface corrosion due to the environment. The fan is controlled by temperature logic in the lubricating oil loop. A thermostatically controlled valve is used to circulate sufficient oil flow to the cooler to maintain temperature. From discussions with site personnel the system appears to function adequately. In February 2011, the system was assessed by Siemens who noted in their report that it generally appeared in good condition but recommended some reconditioning.

**Fire Protection System:** The fire system is an Ansul Inergen total-flooding type system that can operate automatically via fire detection or manually via pull stations. The system is comprised of Inergen storage containers, piping, nozzles, control panel, actuators, detection and alarm devices, and pressure relief dampers. It was installed in 2000 to replace the Halon fire system in respect of the ozone depleting substance regulations.

**Compressed Air & Nitrogen System:** The compressed air system consists of a single 600 volt motor/compressor unit, a 310 L (82 gallon) storage tank, a Pall instrument air dryer, and a small control and monitoring panel. The system is designed to supply 700 kPa instrument air to operate the power turbine snow doors, the main generator exhaust and intake louvers, and the jet engine intake and exhaust cooling air louvers. It also has provisions for a four-bottle nitrogen back-up supply in the event of a compressor system failure. The control panel provides pressure indication for the system and a transfer valve to the nitrogen supply.

**Diesel Generators:** The Stage 1 and Stage 2 Diesel Generators and auxiliaries are not located within the GT building and are not part of the scope of this study. Nevertheless, they are critical to the operation of the GT units and are discussed briefly here. Two diesel units located within the main generating facility provide 600 V power for blackstart operation and start of the existing GT. They are anticipated to be required for any replacement black start generator as well.

Both diesel gensets are designed for controlled safe shutdown of the units. They have the necessary auxiliaries to be stand-alone – controls, switchgear, cooling, and lubrication.

The Stage 1 diesel was replaced in the last five years, and the Stage 2 diesel is currently planned to be replaced in 2015.

**FIGURE 2-4 LIGHT OIL RECEIVING & LUBE OIL RADIATOR**

**EXHAUST STACK**

**AIR INTAKE**

**FIGURE 2-5 GTG EXHAUST STACK & AIR INTAKE**

### 2.3.2 Major Maintenance History

The following is a summary of significant work completed since 2003. No major overhauls have been completed on the entire machine.

**16 October 2003**

- Intake plenum contained debris, chipped floor and flaking paint. Recommended clean up.

**10 August 2004**

- Air plenum cleaner than 2003 visit, holes still visible in walls.

**27 September 2005**

- Annual inspection and boroscope inspection;
- Corrosion/ Rust found in Plenum; and
- Hot gas leakage at Exhaust Transition duct to power turbine.

**13 March 2006**

- Leak in each end of the gearbox at the bearing seals. (Caused fire when oil leaked into insulation around PT and dripped onto top of tank). Greenray discovered turbine shaft/seal modifications, recommended machining and reconditioning.

**13 April 2006**

- None

**25 May 2007**

- Rebuild of the intake with securing bolts torque and locked; and
- Replace/ Repair exhaust snow doors.

**21 May 2008**

- Package filtration inspection;
- Plenum survey;
- Fuel/oil system: connection, fuel pump/ oil pump, pipelines, oil level & quality, filter and basket removal (replacement consumables); and
- On engine review: bleed valves, IGV ram (filter review), gearbox inspection (filters, speed pick up, consumable change), fuel control unit review, oil cooler, fuel filter change, burner removal (ultrasonic cleaning), fuel rail inspection, drain valve operation, thermocouple inspection (terminal cleaning), transition inspection, removal of insulation, rectify leaks, inspect LP blades.

**10 June 2008**

- Water pooling noted in intake plenum along with holes in structure and loose debris.

**15 October 2009**

- Exhaust stack needs replacement, lower components noted in good condition. Door opening components to be serviced; and
- Transition duct piston rings seals to be replaced.

**20 November 2009**

- Commissioning;

- Exhaust transition lagging replaced due to fuel saturation; and
- Split air manifold cracks, to be repaired.

**2011**

NL Hydro undertook a number of activities with vendors that have the OEM rights in order to conduct detailed internal inspections of the individual sections and prepare field inspection reports complete with refurbishment estimates.

- Rolls Wood Group has the OEM rights to the front end bearing assembly, compressor rotor, compressor casings, combustion assembly, nozzle casing, rear bearing housing, turbine assembly, exhaust unit, and accessories. They were recently contracted by NL Hydro to conduct detailed internal inspections of the above noted equipment and have prepared a field inspection report complete with refurbishment estimates.
- Braden Manufacturing is a company that specializes in the design and manufacturing of combustion turbine air filtration systems, air inlet systems, and exhaust systems. They were recently contracted by NL Hydro to perform detailed inspections of the GT air inlet plenum, air filtration system, air inlet plenum support structure, exhaust stack and exhaust stack support structure.

### 2.3.3 Condition Assessment & Remaining Life

TABLE 2-17 CONDITION ASSESSMENT – GAS TURBINE BOP

| BU # 1 | Asset # 2 | Asset # 3 | Asset # 4 | Asset Level 3 | Description | Detail | Cond. Summ. ID# | Condition | Status Identifier | Original Life (Base Load) Ops Hrs (Yrs) | Current Expected Minimum Remaining Life Years (Subject to Test) | End of Life (EOL) Required | Capability to Reach EOL | In Service |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1273 | 7202 | 7311 | 0 | GAS TURBINE AUXILIARY SYSTEMS | Fire System | Fire System | BOP1 | Fire system upgraded in 2000 to Ansul Inergen total-flooding type (automatic via fire detection or manually via pull stations). All of existing Inergen system (storage containers, piping, nozzles, control panel, actuators, detection and alarm devices, and pressure relief dampers) are in good condition. Detection and suppression system did not detect 2010 GT gearbox fires - likely require some improvements. | 4/10 | (30) | 10+ | 2020 | Yes | 2000 |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE AUXILIARY SYSTEMS | Lube Oil Cooler/Radiator | Radiator | BOP2 | The cooler has experienced a substantial amount of surface corrosion due to the environment.Motor appears in good condition, but dirty. Corrosion has led to some tube leaks in 2010. Some ice freezing within containment area. Fan thermostatically controlled valve is working adequately. In February 2011 Siemens noted that the system appeared generally in good shape but recommended some reconditioning. | 4 | (20) | 3 | 2020 | No | 1986 |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE AUXILIARY SYSTEMS | Lube Oil System | Lube Oil | BOP3 | Overdue for overhaul. Gearbox lube oil seal leaks and subsequent fires have led to regulatory restriction on unit operation to emergency only. | 4 | (30) | 0 | 2020 | No | 1986 |
| 1273 | 7202 | 7311 | 99003602 | GAS TURBINE AUXILIARY SYSTEMS | Lube Oil Pumps | AC & DC pumps | BOP4 | Siemens indicated AC and DC lube oil pumps in good condition, but no internal inspection or vibration test practical. Plant experienced that lube oil delivery engine driven pump was not maintaining sufficient main pressure, requiring the AC pump to operate continuously. | 4/10 | (30) | 2 | 2020 | No | 1986 |
| 1297 | 7199 | 7205 | 0 | COMPRESSED AIR SYSTEMS | Compressed Air Systems | N/A | BOP5 | The single 600 volt motor/compressor unit, 310 L (82 gallon) storage tank, Pall instrument air dryer and small control and monitoring panel are fairly new and in good condition.The pressure vessels are inspected annually in accordance with government regulations. No indication of any significant degradation. | 4 | 30 | 10+ | 2020 | Yes | 2000 |
| 1297 | 7199 | 7205 | 7231 | COMPRESSED AIR SYSTEMS | Nitrogen(Compressed Air Back-up) System | N/A | BOP6 | The four-bottle nitrogen back-up supply (used in the event of a compressor system failure) and its control panel driven transfer valve are in good operable condition. No issues identified. | 4 | 30 | 10+ | 2020 | Yes | 2000 |

Notes: 1. A "(bracketed)" value in the "Current Expected Remaining Life" column is a highly probable minimum value that is considered subject to some subsequent verification during further investigation, including at the next test or overhaul. It may be addressed as part of a Level 2 test. A value identified as "(X/Y)" has been included for the steam turbine and generator where the recommended minimum value is the lower of the two, but that the higher may be achievable at a higher level of failure risk and/or unreliability.

The current inspection and maintenance program for the diesels is reasonable and should suffice to allow the units to reach their normal end of life. If the existing level II generator replacement is delayed this will impact the reliability of the overall system to operate in black start.

The maintenance required on the AC lube oil cooler recommended by Siemens in the February 2011 report should be completed to ensure reliability.

Review of the information available on the fires on the existing GT does not mention any activation of the Inergen system. It was noted from inspection of the system in the turbine room that there appears to be only one discharge nozzle in which is located above the compressor section of the GT. This was later confirmed during a review of existing drawings. The fires occurred on the opposite side of the room behind the exhaust stack which would likely have reduced the effectiveness of the system in the event of a discharge. The three detectors in the room also appear to be heat detectors and not smoke which is possibly why the system did not react to the fires which have been described as a small amount of flame and smoke. These fires were extinguished by several portable units.

In general, the lube oil system is in poor shape and in need of refurbishment as part of the overhaul. The fire system, while relatively new and capable of lasting beyond 2020, requires modification for functionality reasons. The air compressor and nitrogen systems are relatively new and will last beyond 2020 with reasonable maintenance.

### 2.3.4 Risk Assessment

**TABLE 2-18 RISK ASSESSMENT – GAS TURBINE BOP**

| BU # 1 | Asset # 2 | Asset # 3 | Asset # 4 | Asset Level 3 | Description | Detail | Cond. Summ. ID# | Condition | Major Issues | Remaining Life Years (Insufficient Info - Inspection Required Within (x) Years) | TECHNO-ECO RISK ASSESS MODEL Likeli--hood | TECHNO-ECO RISK ASSESS MODEL Conse-quence | TECHNO-ECO RISK ASSESS MODEL Risk Level | SAFETY RISK ASSESS MODEL Likeli-hood | SAFETY RISK ASSESS MODEL Conse-quence | SAFETY RISK ASSESS MODEL Safety Risk | Possible Failure Event | Mitigation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1273 | 7202 | 7311 | 0 | GAS TURBINE AUXILIARY SYSTEMS | Fire System | Fire System | BOP1 | Fire system upgraded in 2000 to Ansul Inergen total-flooding type (automatic via fire detection or manually via pull stations). All of existing Inergen system (storage containers, piping, nozzles, control panel, actuators, detection and alarm devices, and pressure relief dampers) are in good condition. Detection and suppression system did not detect 2010 GT gearbox fires - likely require some improvements. | Fire detection failure and suppression failure exists. | 10/0 | 4 | C | High | 3 | D | High | Failure to detect and suppress fire | Modify detection and suppression system. In GTG area cameras for external monitoring. |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE AUXILIARY SYSTEMS | Lube Oil Cooler/Radiator | Radiator | BOP2 | The cooler has experienced a substantial amount of surface corrosion due to the environment.Motor appears in good condition, but dirty. Corrosion has led to some tube leaks in 2010. Some ice freezing within containment area. Fan thermostatically controlled valve is working adequately. In February 2011 Siemens noted that the system appeared generally in good shape but recommended some reconditioning. | Lube Oil cooler failure and leak - containment limits risk. Unit 8navailability. | 3 | 3 | B | Medium | 3 | A | Low | Tube failures. Unavailable due to ice freeze up. | Repair/replace with winter icing protection. |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE AUXILIARY SYSTEMS | Lube Oil System | Lube Oil | BOP3 | Overdue for overhaul. Gearbox lube oil seal leaks and subsequent fires have led to regulatory restriction on unit operation to emergency only. | Gearbox seal oil leaks exist and fires have occurred. | 0 | 4 | C | High | 4 | D | High | Fire | New seals; gearbox lube oil air vents; monitor. Improve fire detection and suppression. |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE AUXILIARY SYSTEMS | Lube Oil Pumps | AC & DC pumps | BOP4 | Siemens indicated AC and DC lube oil pumps in good condition, but no internal inspection or vibration test practical. Plant experienced that lube oil delivery engine driven pump was not maintaining sufficient main pressure, requiring the AC pump to operate continuously. | Lube oil system AC pump overuse | 2 | 4 | B | Medium | 4 | A | Low | Pump failure (DC back-up and shutdown) | Repair |
| 1297 | 7199 | 7205 | 0 | COMPRESSED AIR SYSTEMS | Compressed Air Systems | N/A | BOP5 | The single 600 volt motor/compressor unit, 310 L (82 gallon) storage tank, Pall instrument air dryer and small control and monitoring panel are fairly new and in good condition.The pressure vessels are inspected annually in accordance with government regulations. No indication of any significant degradation. | None | 10+ | 1 | D | Low | 1 | A | Low | High pressure air storage failure. Winter stack doors don't open (N2 back-up) | Monitor |
| 1297 | 7199 | 7205 | 7231 | COMPRESSED AIR SYSTEMS | Nitrogen(Compressed Air Back-up) System | N/A | BOP6 | The four-bottle nitrogen back-up supply (used in the event of a compressor system failure) and its control panel driven transfer valve are in good operable condition. No issues identified. | None | 10+ | 1 | D | Low | 1 | A | Low | High pressure N2 storage failure. Winter stack doors don't open | Monitor |

### 2.3.5 Actions

**TABLE 2-19 ACTIONS – GAS TURBINE BOP**

| BU # 1 | Asset # 2 | Asset # 3 | Asset # 4 | Asset Level 3 | Description | Detail | Action Summ. ID# | Action | Year | Priority |
|---|---|---|---|---|---|---|---|---|---|---|
| 1273 | 7202 | 7311 | 0 | GAS TURBINE AUXILIARY SYSTEMS | Fire System | Fire System | BOP1 | Modify fire detection and suppression system. Install GTG room cameras | 2012 | 1 |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE AUXILIARY SYSTEMS | Lube Oil Cooler/Radiator | Radiator | BOP2 | Replace/Repair/refurbish and eliminate icing issues. If re-conditioned, stem clean motor and perform no load and vibration tests. | 2012 | 2 |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE AUXILIARY SYSTEMS | Lube Oil System | Lube Oil | BOP3 | New seals; gearbox lube oil air vents; monitor. Improve fire detection and suppression. | 2012 | 1 |
| 1273 | 7202 | 7311 | 99003602 | GAS TURBINE AUXILIARY SYSTEMS | LUBE OIL PUMPS | | BOP4 | Overhaul AC and DC motors (steam clean). Perform VPI test for insulation. Perform no load and vibration tests. Install anti-condensation heaters. | 2012 | 1 |
| 1297 | 7199 | 7205 | 0 | COMPRESSED AIR SYSTEMS | COMPRESSED AIR SYSTEMS | N/A | BOP5 | None - monitor | | |
| 1297 | 7199 | 7205 | 7231 | COMPRESSED AIR SYSTEMS | NITROGEN (COMPRESSOR BACK-UP) SYSTEM | N/A | BOP6 | None - monitor | | |

### 2.3.6 Life Assessment - Life Cycle Curves (Where Equipment Is Not To Be Overhauled/replaced and Life <2020 and Has Major Unit Operation Impacts)

No Life Cycle Curves are presented. The newer equipment and systems (compressed air, nitrogen) can all meet the 2020 end date with normal maintenance. The lube oil system requires refurbishment and with normal maintenance, should be able to meet the 2020 end date. The AC lube oil cooler fan is recommended to have the repairs recommended by Siemens to maximize the remaining life of the system or be replaced. It will then, with regular intervals of repair and maintenance, last to 2020.

The Stage 1 diesel, not a part of this assessment, but is relatively new and therefore expected to be operational until at least 2020. The Stage 2 diesel is original equipment, installed in 1979. It is at the end of its normal useful life.

### 2.3.7 Level 3 Inspections Required

No incremental to refurbishment Level 3 assessments are required.

### 2.3.8 Capital Enhancements

The suggested capital projects for the GT E&C systems are presented in Table 2-20.

**TABLE 2-20 SUGGESTED TYPICAL CAPITAL ENHANCEMENTS – GAS TURBINE BOP**

| BU # 1 | Asset # 2 | Asset # 3 | Asset # 4 | Asset Level 3 | Description | Detail | Cond. Summ. ID# | Capital Item | Date | Priority |
|---|---|---|---|---|---|---|---|---|---|---|
| 1273 | 7202 | 7311 | 0 | GAS TURBINE AUXILIARY SYSTEMS | Fire System | Fire System | BOP1 | Modification of detection and suppression system for better protection and coverage. New monioring camera system. | 2012 | 1 |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE AUXILIARY SYSTEMS | Lube Oil Cooler/Radiator | Radiator | BOP2 | New lube oil cooler | 2012 | 1 |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE AUXILIARY SYSTEMS | Lube Oil System | Lube Oil | BOP3 | New gear box seals, lube oil venting | 2012 | 1 |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE AUXILIARY SYSTEMS | Lube Oil Pumps | AC & DC pumps | BOP4 | No Captial Requirement | | |
| 1297 | 7199 | 7205 | 0 | COMPRESSED AIR SYSTEMS | Compressed Air Systems | N/A | BOP5 | No Captial Requirement | | |
| 1297 | 7199 | 7205 | 7231 | COMPRESSED AIR SYSTEMS | Nitrogen(Compressed Air Back-up) System | N/A | BOP6 | No Captial Requirement | | |

#### 2.3.8.1 Capital Refurbishment Requirements and Costs

The Stage 2 diesel and its auxiliary systems should be replaced to achieve 2020.

The AC lube oil cooler fan requires refurbishment as recommended by Siemens.

Since there is a likelihood of a fire in the area near the exhaust stack and above the gearbox, it is recommended that additional nozzles be added to the turbine room above the gearbox near the stack, and under the turbine in the vicinity of the origin of the fires to ensure unobstructed effective dispersion of the Inergen gas. It is also recommended that the addition of infrared flame detectors be considered as thermal lag on fixed temperature detectors can delay the activation of the system as can a slowly developing fire on rate of rise detectors. The flame detector effectiveness will depend on the ambient heat radiation from the gas turbine which can decrease its effectiveness.

The suggested typical capital enhancements for the gas turbine BOP include:

**TABLE 2-21 CAPITAL COST –GAS TURBINE BOP**

**Capital cost estimate $ 1,000 Can 2011**

| **BOP Systems** | | Material | Labour | Total | Range |
|---|---|---|---|---|---|
| | Fuel enclosure (See Civil/Structural) | | | | |
| | Fuel piping | $60 | $15 | $75 | $60-$90 |
| | Stack removal | $0 | $30 | $30 | $25-$35 |
| | Inergen system | $7 | $3 | $10 | $7-$15 |
| | Lube oil cooler | $130 | $20 | $150 | $75-$175 |
| | **Sub-Total** | **$197** | **$68** | **$265** | **$150-$320** |
| 10% | **Contingency** | **$20** | **$7** | **$27** | |
| | **TOTAL BOP** | **$217** | **$75** | **$292** | **$180-$350** |

## 2.4 Gas Turbine/Fuel Oil Equipment/Processes

| | |
|---|---|
| Unit #: | Common |
| Asset Class # | BU 1297 - Assets Common |
| SCI & System: | 7199 HRD Common Systems |
| Sub-System | 7209 Light Oil System |
| Components: | To Be Added |
| | |
| | |

### 2.4.1 Description - Gas Turbine Generator Light Fuel Oil System

Light fuel oil (No.2 diesel) is delivered by truck to the unloading skid adjacent to the existing GT generator building. The single 600 volt off-loading pump with local start / stop control is located outdoors at the northwest corner of the gas turbine building and has above-ground piping connecting it to the bulk storage tanks. Power for the motor is supplied from the gas turbine MCC control centre. The two 100,000 litre above-ground fuel tanks were fabricated in 1998 to ULC-S601-93 standards with double wall construction and have a total storage capacity of 200,000 litres. The offloading system is comprised of a single 600 volt pump arrangement with local start / stop control. Power for the motor is supplied from the GT MCC control centre.

The piping installation is typical with a 3 inch Y strainer, isolation valves and piping to the storage tanks. Two 100%, 600 volt, centrifugal forwarding pumps provides low pressure No.2 diesel fuel for the jet engine. The fuel passes through a duplex suction strainer and a 5 micron discharge filter before reaching the jet engine. The fuel line also incorporates a fuel flow/totalizing meter and a fire system trip valve prior to entering the building.

Light oil (No.2 fuel oil) from the light oil fuel oil storage tanks is gravity fed. The light oil pressure at the main units is maintained through constant recirculation back to the light oil storage tanks through a pressure control valve and piping arrangement.

The existing fuel supply system to the GT, fire alarm fuel shut off valve, and fuel offloading system are located adjacent to the GT building and is exposed to a harsh marine environment and as a result, has heavy surface corrosion.

The fuel lines in the dike area are in better condition likely as a result of being at least partially protected from the elements.

Some fuel forwarding pumps are located in a small enclosure to protect them from the elements. The concrete containment system in which the pumps sit was filled with approximately 4 inches of oily water at the time of the inspection.

FIGURE 2-6 LIGHT OIL RECEIVING SYSTEM AND STORAGE TANKS

### 2.4.2 Major Maintenance History

**Light Oil Storage Tanks & Receiving System:** The light oil storage tanks are approximately 13 years old. Aside from the issue that the interstitial pressure was outside its normal design levels, we are not aware of any major maintenance items on these tanks. Inspection information was not considered given the relatively short duration since their in-service date. They are subject to API regulatory inspection.

**Pipelines:** The lines under the roadway have been replaced as part of road repair work carried out in 2007.

### 2.4.3 Condition Assessment & Remaining Life

The condition assessment of the fuel systems (light oil) is illustrated below in Table 2-22.

**TABLE 2-22 CONDITION ASSESSMENT – GAS TURBINE FUEL OIL SYSTEM**

| BU # 1 | Asset # 2 | Asset # 3 | Asset # 4 | Asset Level 3 | Description | Detail | Cond. Summ. ID# | Condition | Status Identifier | Original Life (Base Load) Ops Hrs (Yrs) | Current Expected Minimum Remaining Life Years (Subject to Test) | End of Life (EOL) Required | Capability to Reach EOL | In Service |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1273 | 7202 | 7311 | 0 | GAS TURBINE AUXILIARY SYSTEMS | LIGHT FUEL OIL SYSTEM | | | | | | | | | |
| 1297 | 7199 | 7209 | 0 | LIGHT OIL SYSTEM | GENERAL | General | LFO1 | Exposed receiving and delivery system componets corroded. Build-ups of snow and ice freeze up in containment areas common. | 4 | (40) | (2) | 2020 | No | 1986 |
| 1297 | 7199 | 7209 | 0 | LIGHT OIL SYSTEM | PIPING | N/A | LFO2 | Significant external corrosion and pitting.due to the marine environment, including the lines to the light oil storage tanks. Recent ultrasonic testing (Oct 2010) indicates that the piping is within acceptable wall thickness tolerances despite the external corrosion at the moment. The fuel pumps located in the small enclosures are not readily accessible and would be less so during the winter.significant weather that may prevent emergency repairs on the exposed fuel equipment in the event of a black start requirement. | 4 | (40) | (2) | 2020 | No | 1986 |
| 1297 | 7199 | 7209 | 0 | LIGHT OIL SYSTEM | GT TRANSFER PUMPS AND FILTERS | N/A | LFO3 | The fuel pumps and filters are located in small enclosures are not readily accessible. Siemens indicated that motors appear in fair condition with some surface corrosion. Conduit appeared in good condition. A full assessment was not possible due to accessibility. The enclosures still fill somewhat with water and snow. The concrete containment system in which the pumps sit was filled approximately 4" with oily water at the time of the visit. THis may freeze in winter and snow makes them less accessible during the winter which may prevent emergency repairs on the exposed fuel equipment in the event of a black start requirement. | 4 | (40) | (2) | 2020 | No | 1986 |
| 1297 | 7199 | 7209 | 0 | LIGHT OIL SYSTEM | FUEL RECEIVING/FORWARDING PUMPS | N/A | LFO4 | The fuel receiving/transfer pumps, fire alarm fuel shut off valve, and fuel offloading system are located adjacent to the Gas Turbine Building and exposed to a harsh marine environment and have heavy surface corrosion as a result. Snow and ice in winter makes them less accessible and may prevent emergency repairs on the exposed fuel equipment in the event of a black start requirement. | 4 | (40) | (2) | 2020 | No | 1986 |
| 1297 | 7199 | 7209 | 99034713 | LIGHT OIL SYSTEM | OIL STORAGE TANK | General | LFO5 | Relatively new, about 13 years. No inspections that station are aware of. | 3a | (40) | 10+ | 2020 | Yes | 1998 |
| 1297 | 7199 | 7209 | 99034713 | LIGHT OIL SYSTEM | OIL STORAGE TANK | N/A | LFO6 | Interstitial vacuum pressure on both tanks are -35 and -38 mm Hg. Very faded warning stickers on the tanks indicated if the vacuum pressure was less than – 42 mm Hg the manufacturer should be contacted. While the gauges still indicate a high vacuum in each tank, there is a concern tahta Holyrood management acknowledged this as an ongoing issue with the tanks that they were aware of. | 3a | (40) | 10+ | 2020 | Yes | 1998 |
| 1297 | 7199 | 7209 | 99034713 | LIGHT OIL SYSTEM | OIL STORAGE TANK | N/A | LFO7 | Fuel oil tank penetrations on the top of the tank are showing heavy corrosion. No other data available. | 3a | (40) | 10+ | 2020 | Yes | 1998 |

Notes: 1. A "(bracketed)" value in the "Current Expected Remaining Life" column is a highly probable minimum value that is considered subject to some subsequent verification during further investigation, including at the next test or overhaul. It may be addressed as part of a Level 2 test. A value identified as "(X/Y)" has been included for the steam turbine and generator where the recommended minimum value is the lower of the two, but that the higher may be achievable at a higher level of failure risk and/or unreliability.

A review of the 2006 SGE Acres report "Evaluation of Fuel Oil Storage Tanks, Associated Pipelines and dike Drainage System Holyrood Thermal Generating Station" was used to determine the existing condition of the tanks in conjunction with a walkthrough of the tank farm. During examination of the two light oil tanks, it was noted that the interstitial vacuum pressure on both tanks are -35 and -38 mm HG . Very faded warning stickers on the tanks indicated if the vacuum pressure was less than 42 mm hg the manufacture should be contacted. While the gauges still indicate a high vacuum in each tank, the concern was brought forward to Holyrood management and was acknowledged as an ongoing issue with the tanks that they were aware of.

It was also noted that the fuel oil tank penetrations on the top of the tank are showing heavy corrosion. Since these tanks are critical to the operation of diesel gensets, the black start gas turbine, and main unit ignition it is recommended that this corrosion be addressed through regular maintenance.

The light oil receiving, pumping and piping system located at the gas turbine building is operational, but have experienced significant external corrosion due to the marine environment, including the lines to the light oil storage tanks and to the powerhouse ignition oil system. Some data was made available on ultrasonic testing of the lines from October 2010, it appears from preliminary review of the results that the piping is within acceptable wall thickness tolerances despite the external corrosion at the moment. The fuel pumps located in the small enclosures are not readily accessible and would be less so during the winter.

The piping exterior is in poor condition due to its prolonged exposure to the marine environment. Extreme weather may prevent emergency repairs on the exposed fuel equipment during a black start event. Given their exposure to the harsh marine environment, the existing fuel supply system to the gas turbine, the fire alarm fuel shut off valve, and the fuel offloading system located adjacent to the G Building is not expected to continue to 2020. While the majority of the components are fairly standard and off the shelf, a failure of the Gas Turbine fuel system during black start would be costly both financially and in terms of time.

### 2.4.4 Risk Assessment

**TABLE 2-23 RISK ASSESSMENT – GAS TURBINE FUEL OIL SYSTEM**

| BU # 1 | Asset # 2 | Asset # 3 | Asset # 4 | Asset Level 3 | Description | Detail | Cond. Summ. ID# | Condition | Major Issues | Remaining Life Years | TECHNO-ECO RISK ASSESS MODEL | | | SAFETY RISK ASSESS MODEL | | | Possible Failure Event | Mitigation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | (Insufficient Info - Inspection Required Within (x) Years) | Likeli-hood | Conse-quence | Risk Level | Likeli-hood | Conse-quence | Safety Risk | | |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE AUXILIARY SYSTEMS | LIGHT FUEL OIL SYSTEM | | | | | | | | | | | | | |
| 1297 | 7199 | 7209 | 0 | LIGHT OIL SYSTEM | GENERAL | General | LFO1 | Exposed receiving and delivery system componets corroded. Build-ups of snow and ice freeze up in containment areas common. | Oil Leak; failure to operate and access easily. | (2) | 3 | A | Low | 4 | A | Medium | Modest oil spill within containment; inability to start unit until ice cleared | Install new fuel receing/handling shed |
| 1297 | 7199 | 7209 | 0 | LIGHT OIL SYSTEM | PIPING | N/A | LFO2 | Significant external corrosion and pitting.due to the marine environment, including the lines to the light oil storage tanks. Recent ultrasonic testing (Oct 2010) indicates that the piping is within acceptable wall thickness tolerances despite the external corrosion at the moment. The fuel pumps located in the small enclosures are not readily accessible and would be less so during the winter.significant weather that may prevent emergency repairs on the exposed fuel equipment in the event of a black start requirement. | Oil Leak; failure to operate and access easily. | (2) | 3 | A | Low | 4 | A | Medium | Modest oil spill within containment; inability to start unit until ice cleared | Install new fuel receing/handling shed |
| 1297 | 7199 | 7209 | 0 | LIGHT OIL SYSTEM | GT TRANSFER PUMPS AND FILTERS | N/A | LFO3 | The fuel pumps and filters are located in small enclosures are not readily accessible. The enclosures still fill somewhat with water and snow. The concrete containment system in which the pumps sit was filled approximately 4" with oily water at the time of the visit. THis may freeze in winter and snow makes them less accessible during the winter which may prevent emergency repairs on the exposed fuel equipment in the event of a black start requirement. | Oil Leak; failure to operate and access easily. | (2) | 3 | A | Low | 4 | A | Medium | Modest oil spill within containment; inability to start unit until ice cleared | Install new fuel receing/handling shed |
| 1297 | 7199 | 7209 | 0 | LIGHT OIL SYSTEM | FUEL RECEIVING/FORWARDING PUMPS | N/A | LFO4 | The fuel receiving/transfer pumps, fire alarm fuel shut off valve, and fuel offloading system are located adjacent to the Gas Turbine Building and exposed to a harsh marine environment and have heavy surface corrosion as a result. Snow and ice in winter makes them less accessible and may prevent emergency repairs on the exposed fuel equipment in the event of a black start requirement. | Oil Leak; failure to operate and access easily. | (2) | 3 | A | Low | 4 | A | Medium | Modest oil spill within containment; inability to start unit until ice cleared | Install new fuel receing/handling shed |
| 1297 | 7199 | 7209 | 99034713 | LIGHT OIL SYSTEM | OIL STORAGE TANK | General | LFO5 | Relatively new, about 13 years. No inspections that station are aware of. | Regulatory out of complince. | 10+ | 2 | A | Low | 2 | B | Medium | Ensure regulatoy inspection compliance undertaken. | Tank inspection. |
| 1297 | 7199 | 7209 | 99034713 | LIGHT OIL SYSTEM | OIL STORAGE TANK | N/A | LFO6 | Interstitial vacuum pressure on both tanks are -35 and -38 mm Hg. Very faded warning stickers on the tanks indicated if the vacuum pressure was less than – 42 mm Hg the manufacturer should be contacted. While the gauges still indicate a high vacuum in each tank, there is a concern tahta Holyrood management acknowledged this as an ongoing issue with the tanks that they were aware of. | Operating outside vendor recommended limits. Leak.. | 10+ | 3 | A | Low | 2 | B | Medium | Modest oil spill within containment; inability to start unit until ice cleared | Investigate rezson and repair. Replace warning stickers. |

### 2.4.5 Actions

**TABLE 2-24 ACTIONS – GAS TURBINE FUEL OIL SYSTEM**

| BU # 1 | Asset # 2 | Asset # 3 | Asset # 4 | Asset Level 3 | Description | Detail | Action Summ. ID# | Action | Year | Priority |
|---|---|---|---|---|---|---|---|---|---|---|
| 1273 | 7202 | 7311 | 0 | GAS TURBINE AUXILIARY SYSTEMS | LIGHT FUEL OIL SYSTEM | | | | | |
| 1297 | 7199 | 7209 | 0 | LIGHT OIL SYSTEM | GENERAL | General | LFO1 | | | |
| 1297 | 7199 | 7209 | 0 | LIGHT OIL SYSTEM | PIPING | N/A | LFO2 | Replace fuel piping downstream of filters with stainless. Refurbsih remaining piping, vales etc. Enclose building related equipment in fuel shed. | 2012 | 2 |
| 1297 | 7199 | 7209 | 0 | LIGHT OIL SYSTEM | GT TRANSFER PUMPS AND FILTERS | N/A | LFO3 | Replace fuel receiving and transfer piping. Enclose in fuel shed. | 2012 | 1 |
| 1297 | 7199 | 7209 | 0 | LIGHT OIL SYSTEM | FUEL RECEIVING/FORWARDING PUMPS | N/A | LFO4 | Replace fuel receiving and transfer piping. Enclose in fuel shed. | 2012 | 1 |
| 1297 | 7199 | 7209 | 99034713 | LIGHT OIL SYSTEM | OIL STORAGE TANK | General | LFO5 | | | |
| 1297 | 7199 | 7209 | 99034713 | LIGHT OIL SYSTEM | OIL STORAGE TANK | N/A | LFO6 | Inspect per regulatory and maintain | 2012 | 1 |
| 1297 | 7199 | 7209 | 99034713 | LIGHT OIL SYSTEM | OIL STORAGE TANK | N/A | LFO7 | Investigate interstial vacuum difference and repair. Replace warning stickers. | 2012 | 2 |

### 2.4.6 Life Assessment - Life Cycle Curves (Where Equipment Is Not To Be Overhauled/Replaced and Life <2020 and Has Major Unit Operation Impacts)

No Life Cycle Curves are presented. The system should be capable of meeting the 2020 end date with reasonable maintenance. Modifications including stainless steel piping from filters to the GT, and the installation of a fuel shed and replacement of system to address winter weather impacts. The issue is primarily problems resulting from extreme weather impacts and less with the equipment itself. The oil storage tanks should with maintenance and regulatory inspection make the 2020 end date.

### 2.4.7 Level 3 Inspections Required

Given the condition historical data reviewed and recommended changes, no Level 3 analyses are necessary.

### 2.4.8 Capital Enhancements

The suggested capital projects for the GT E&C systems are presented in Table 2-25.

TABLE 2-25 SUGGESTED TYPICAL CAPITAL ENHANCEMENTS – GAS TURBINE FUEL OIL SYSTEM

| BU # 1 | Asset # 2 | Asset # 3 | Asset # 4 | Asset Level 3 | Description | Detail | Cond. Summ. ID# | Capital Item | Date | Priority |
|---|---|---|---|---|---|---|---|---|---|---|
| 1273 | 7202 | 7311 | 0 | GAS TURBINE AUXILIARY SYSTEMS | LIGHT FUEL OIL SYSTEM | | | | | |
| 1297 | 7199 | 7209 | 0 | LIGHT OIL SYSTEM | GENERAL | General | LFO1 | New fuel shed. | 2012 | 1 |
| 1297 | 7199 | 7209 | 0 | LIGHT OIL SYSTEM | PIPING | N/A | LFO2 | New stainless steel piping from filters to GTG | 2012 | 1 |
| 1297 | 7199 | 7209 | 0 | LIGHT OIL SYSTEM | GT TRANSFER PUMPS AND FILTERS | N/A | LFO3 | New system | 2012 | 1 |
| 1297 | 7199 | 7209 | 0 | LIGHT OIL SYSTEM | FUEL RECEIVING/FORWARDING PUMPS | N/A | LFO4 | New system | 2012 | 1 |
| 1297 | 7199 | 7209 | 99034713 | LIGHT OIL SYSTEM | OIL STORAGE TANK | General | LFO5 | No Captial Requirement | | |
| 1297 | 7199 | 7209 | 99034713 | LIGHT OIL SYSTEM | OIL STORAGE TANK | N/A | LFO6 | No Captial Requirement | | |
| 1297 | 7199 | 7209 | 99034713 | LIGHT OIL SYSTEM | OIL STORAGE TANK | N/A | LFO7 | No Captial Requirement | | |

### 2.4.9 Capital/Refurbishment and Overhaul Costs (Capital)

It is recommended that the fuel system, fire alarm fuel shut off valve and fuel offloading system be refurbished/replaced and be enclosed in a full sized shelter. This will help protect the exposed equipment and allow for safe operation and repairs unhindered by weather and enclosures too small to work in.

The suggested equipment and installation costs (refurbishment of existing equipment) for the system are presented in Table 2-26.

**TABLE 2-26 CAPITAL COST ESTIMATE – GAS TURBINE FUEL OIL SYSTEM**

| Item | Cost |
|---|---|
| Fuel enclosure | $40,000 |
| Fuel piping | $75,000 |
| Stack removal | $ 30,000 |
| Inergen system | $10,000 |
| Lube oil cooler | $150,000 |

## 2.5 Building and Structural/Civil Equipment

| | |
|---|---|
| Unit #: | COMMON |
| Asset Class # | BU 1297 – Assets Common |
| SCI & System: | 7255 HRD Buildings & Site |
| Sub-Systems: | 272255 HRD Buildings |
| Components: | 7307 HRD Gas Turbine Building |
| Sub-Components: | 7307 HRD Gas Turbine Building |

### 2.5.1 Description

The GT building at the plant houses the GT that is used in the event of a black start. The existing gas turbine building was constructed in 1986. The building is of pre-engineered, galvanized metal-panel construction, 40 ft in width and 50 ft in length with R20 exterior wall insulation. The foundation is of conventional reinforced concrete pier/wall and floor slab construction and incorporates the original turbine and module slabs. A full height concrete block partition wall was installed to completely separate the turbine/generator sections from the remaining building area. It houses a one tonne hoist/track provision to move equipment to the service area. The electrical area is divided into a battery room, a control room and an MCC/switchgear section. It has an oil drain provision for both the service and turbine rooms complete with a reinforced concrete trap. A rolling service door between the turbine and work area is provided for fire containment but easily removed for heavy equipment.

#### 2.5.1.1 Gas Turbine Building Asbestos

Pinchin Leblanc undertook an “Asbestos Materials Re-Assessment” study of Holyrood for NL Hydro in 2010 (Pinchin Leblanc Project 02-02-004-01, November 19, 2010).

The study was not exhaustive and rather a review of areas identified previously, some of which had been addressed. It did not appear to address the GT building specifically, but did indicate that the metal sheet siding of some of the out buildings on the site were made of a material called Galbestos which had a backing of non-friable tarpaper containing chrysotile asbestos. The study indicated that this siding material should be repaired or removed following Type 1 (low risk) asbestos abatement procedures.

Given that the GT building was installed at the Holyrood site in 1986, it is unlikely that the siding material was Galbestos. Nevertheless, before any modification work is undertaken on the siding or other building components, the presence or absence of asbestos should be verified.

No cost or time has been allowed for asbestos evaluation or removal in this assessment, as the likelihood of its presence is low and the risk associated with its removal is identified by the report as being low.

### 2.5.2 Major Maintenance History

No inspection records specific to the turbine building were identified. A visual walkthrough of the gas turbine building was performed to gauge the existing condition of the building.

**Structural:** The structural systems that comprise the building are in excellent condition with very little corrosion found and no major structural deficiencies noted. There was significant surface corrosion found on the structural members located below the exhaust stack that sits on the roof of the building over the turbine.

**Roofs & Siding:** The siding and roof of the gas turbine building, specifically in the area around the stack, at the roofliner, and at the base of the building, show evidence of significant corrosion.

**Exhaust Stack:** The exhaust stack is extensively corroded with leaks into the building and into the turbine, and should be replaced.

Picture shows corroded exhaust stack

Picture shows corroded exhaust stack

Picture shows corroded exhaust stack

Picture shows corroded exhaust stack

**FIGURE 2-7 CORRODED EXHAUST STACK (GAS TURBINE PLANT**

### 2.5.3 Condition Assessment & Remaining Life

The condition assessment of the buildings and building M and E system is illustrated below in Table 2-27.

**TABLE 2-27 CONDITION ASSESSMENT – GAS TURBINE BUILDINGS AND BUILDING M AND E SYSTEM**

| BU # 1 | Asset # 2 | Asset # 3 | Asset # 4 | Asset Level 3 | Description | Detail | Cond. Summ. ID# | Condition | Status Identifier | Original Life (Base Load) Ops Hrs (Yrs) | Current Expected Minimum Remaining Life Years (Subject to Test) | End of Life (EOL) Required | Capability to Reach EOL | In Service |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1297 | 7255 | 272255 | 7307 | BUILDINGS | GAS TURBINE BUILDING | N/A | BLDG1 | Generally in good condition with modest corrosion and no significant structural deficiencies noted, except where related to gas turbine intake and exhaust. Some surface corrosion on structural members located below the exhaust stack. Sidings and roofs of the Gas Turbine Building have some corrosion requiring repair. | 4 | (40) | 10+ | 2020 | Yes | 1986 |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Structure - General | Structure | BLDG2 | The structural systems that comprise the building are in excellent condition with very little corrosion found and no major structural deficiencies noted. There was significant surface corrosion found on the structural members in the turbine room located immediately below the exhaust stack that sits on the roof of the building over the turbine. | 4/10 | (20) | 10+ | 2020 | Yes | 1986 |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Service Room: | Service Room: | BLDG3 | Visible structural steel in service room is in excellent condition with paint covering the members and no signs of corrosion or major structural deficiencies. The masonry wall dividing the service room and turbine room is in excellent condition on this side. | 4/10 | (20) | 10+ | 2020 | Yes | 1986 |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Turbine Room | Turbine Room | BLDG4 | Structural steel is in good condition except in the immediate vicinity of the exhaust stack. The steel members in this area have moderate corrosion owing to water infiltration around the stack. The masonry wall dividing the service room and turbine room is in excellent condition on this side. | 4/10 | (20) | 10+ | 2020 | Yes | 1986 |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Generator Room | Generator Room | BLDG5 | Visible structural steel in generator room is in good condition except in the immediate vicinity of the exhaust stack. Steel members directly surrounding the exhaust ducting has minor corrosion owing to water infiltration at the roof. This evidenced by rust running down the side of the ducting. | 4/10 | (20) | 10+ | 2020 | Yes | 1986 |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Battery Room /MCC Room /Control Room | Battery Room | BLDG6 | These rooms have their own infill structure that is covered by finishes. There does not appear to be any structural deficiencies in these areas. The building structural steel above these rooms is somewhat visible from the Service Room and looks to be in the same good condition as the steel in that room. | 4/10 | (20) | 10+ | 2020 | Yes | 1986 |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Roofing | Roofing | BLDG7 | The roof of the gas turbine building, specifically in the area around the stack, at the roof liner, shows evidence of moderate corrosion. Unless these areas are repaired there is a risk the deterioration might accelerate and begin to affect the primary structural members. (ie. columns, beams) | 4/10 | (20) | 10/1 | 2020 | No | 1986 |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Siding | Siding | BLDG8 | The siding of the gas turbine building, specifically at the base of the building, show evidence of significant corrosion. Unless these areas are repaired there is a risk the deterioration might accelerate and begin to affect the primary structural members. (ie. columns, beams) | 4/10 | (20) | 10/1 | 2020 | No | 1986 |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Hoists / Lifting | Hoists / Lifting | BLDG9 | There is a main monorail which spans between the Service Room and Turbine Room. This monorail is excellent condition with no signs of corrosion or structural deficiencies. There are two minor lifting beams between the power generator and power turbine. These monorails are in good condition with only minor surface corrosion and no major structural deficiencies. There is a monorail in the generator room which is in excellent conditions with no signs of corrosion or structural deficiencies. | 4/10 | (20) | 10+ | 2020 | Yes | 1986 |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Exhaust Stack Structure | Exhaust Stack Structure | BLDG10 | The steel support frame is good condition with only moderate corrosion, with paint covering the majority of the frame surface and no sign of major structural deficiencies. The structural frame holding up the exhaust cannot be assessed visually as it rests above the main structure obscured from view inside and above the roofline it is covered in flashing. The lifting lugs are in good condition with no signs of major corrosion. The sealant used to weather proof the connection of the frame to the roof is cracking and it should be assumed the frame exhibits similar corrosion as the primary structural steel inside. While not technically a structural item, the exhaust stack itself is extensively corroded above the roof line allowing water to leak into the building causing corrosion. | 4/10 | (20) | 10/0 | 2020 | No | 1986 |

Notes: 1. A "(bracketed)" value in the "Current Expected Remaining Life" column is a highly probable minimum value that is considered subject to some subsequent verification during further investigation, including at the next test or overhaul. It may be addressed as part of a Level 2 test. A value identified as "(X/Y)" has been included for the steam turbine and generator where the recommended minimum value is the lower of the two, but that the higher may be achievable at a higher level of failure risk and/or unreliability.

**Newfoundland and Labrador Hydro a NALCOR Energy Co.**
**Holyrood Thermal Generating Station**
**Gas Turbine Condition Assessment**

## 2.5.4 Risk Assessment

### TABLE 2-28 RISK ASSESSMENT – GAS TURBINE BUILDINGS AND BUILDING M AND E SYSTEM

| BU # 1 | Asset # 2 | Asset # 3 | Asset # 4 | Asset Level 3 | Description | Detail | Cond. Summ. ID# | Condition | Major Issues | Remaining Life Years | TECHNO-ECO RISK ASSESS MODEL | | | SAFETY RISK ASSESS MODEL | | | Possible Failure Event | Mitigation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | (Insufficient Info - Inspection Required Within (x) Years) | Likeli-hood | Conse-quence | Risk Level | Likeli-hood | Conse-quence | Safety Risk | | |
| 1297 | 7255 | 272255 | 7307 | BUILDINGS | GAS TURBINE BUILDING | | | | | | | | | | | | | |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Structure - General | Structure | BLDG1 | The structural systems that comprise the building are in excellent condition with very little corrosion found and no major structural deficiencies noted. There was significant surface corrosion found on the structural members in the turbine room located immediately below the exhaust stack that sits on the roof of the building over the turbine. | Stack leaks causing structural member surface corrosion. | 10+ | 1 | B | Low | 1 | C | Medium | Structural steel member sigifican corrosion. Stack support failure. | Monitor. Replace/repair leaks in area of stack and check support. |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Service Room: | Service Room: | BLDG2 | Visible structural steel in service room is in excellent condition with paint covering the members and no signs of corrosion or major structural deficiencies. The masonry wall dividing the service room and turbine room is in excellent condition on this side. | None | 10+ | 1 | A | Low | A | B | LOW | None expected. | Monitor |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Turbine Room | Turbine Room | BLDG3 | Structural steel is in good condition except in the immediate vicinity of the exhaust stack. The steel members in this area have moderate corrosion owing to water infiltration around the stack. The masonry wall dividing the service room and turbine room is in excellent condition on this side. | Stack support failure 9eventual). | 10+ | 3 | B | Medium | 1 | C | Medium | Structural steel member sigifican corrosion. Stack support failure. | Monitor. Replace/repair leaks in area of stack and check support. |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Generator Room | Generator Room | BLDG4 | Visible structural steel in generator room is in good condition except in the immediate vicinity of the exhaust stack. Steel members directly surrounding the exhaust ducting has minor corrosion owing to water infiltration at the roof. This evidenced by rust running down the side of the ducting. | Stack support failure 9eventual). | 10+ | 3 | B | Medium | 1 | C | Medium | Structural steel member sigifican corrosion. Stack support failure. | Monitor. Replace/repair leaks in area of stack and check support. |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Battery Room /MCC Room /Control Room | Battery Room | BLDG5 | These rooms have their own infill structure that is covered by finishes. There does not appear to be any structural deficiencies in these areas. The building structural steel above these rooms is somewhat visible from the Service Room and looks to be in the same good condition as the steel in that room. MCC Requirements require more space. | Regulatory compliance re MCC's and other electrical equipment spacing. | 1-Oct | 3 | B | Medium | 3 | C | Medium | Electrtical equipment failure in limited space. Regulatory non-compliance. | Increase space when replacing MCC's and/or other electrical room equipment. |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Roofing | Roofing | BLDG6 | The roof of the gas turbine building, specifically in the area around the stack, at the roof liner, shows evidence of moderate corrosion. Unless these areas are repaired there is a risk the deterioration might accelerate and begin to affect the primary structural members. (ie. columns, beams) | Roof failure. Water damage in gas turbine causing major damage. | 10/1 | 4 | C | High | 3 | C | Medium | Power turbine water in-leakage causing failure. Stack support failure. | Replace/repair leaks in area of stack and check support. Replace stack. |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Siding | Siding | BLDG7 | The siding of the gas turbine building, specifically at the base of the building, show evidence of significant corrosion. Unless these areas are repaired there is a risk the deterioration might accelerate and begin to affect the primary structural members. (ie. columns, beams) | Inleakage of marine salt laden air causing increased corrosion. | 10/1 | 4 | A | Medium | 4 | a | Medium | Structural steel member sigifican corrosion. Stack support failure. | Repair existing holes and sections. Check for asbestos. |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Hoists / Lifting | Hoists / Lifting | BLDG8 | There is a main monorail which spans between the Service Room and Turbine Room. This monorail is excellent condition with no signs of corrosion or structural deficiencies. There are two minor lifting beams between the power generator and power turbine. These monorails are in good condition with only minor surface corrosion and no major structural deficiencies. There is a monorail in the generator room which is in excellent conditions with no signs of corrosion or structural deficiencies. | None | 10+ | 1 | C | Low | 1 | C | LOW | Failure during GT part lift. | Monitor |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Exhaust Stack Structure | Exhaust Stack Structure | BLDG9 | The steel support frame is good condition with only moderate corrosion, with paint covering the majority of the frame surface and no sign of major structural deficiencies. The structural frame holding up the exhaust cannot be assessed visually as it rests above the main structure obscured from view inside and above the roofline it is covered in flashing. The lifting lugs are in good condition with no signs of major corrosion. The sealant used to weather proof the connection of the frame to the roof is cracking and it should be assumed the frame exhibits similar corrosion as the primary structural steel inside. While not technically a structural item, the exhaust stack itself is extensively corroded above the roof line allowing water to leak into the building causing corrosion. | Water inleakage into power turbine and gearbox area. | 10/0 | 4 | C | High | 3 | C | Medium | Power turbine failure. Stack support failure. | Replace stack and repair roof leaks. |

### 2.5.5 Actions

TABLE 2-29 ACTIONS – GAS TURBINE BUILDINGS AND BUILDING M AND E SYSTEM

| BU # 1 | Asset # 2 | Asset # 3 | Asset # 4 | Asset Level 3 | Description | Detail | Action Summ. ID# | Action | Year | Priority |
|---|---|---|---|---|---|---|---|---|---|---|
| 1297 | 7255 | 272255 | 7307 | BUILDINGS | GAS TURBINE BUILDING | N/A | BLDG1 | Generally repair areas of moisture penetration and air leaks. | 2012 | 2 |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Structure - General | Structure | BLDG2 | Maintain and monitor | 2012 | 2 |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Service Room: | Service Room: | BLDG3 | Maintain and monitor | 2012 | 4 |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Turbine Room | Turbine Room | BLDG4 | Fix roof near stack and stack | 2012 | 1 |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Generator Room | Generator Room | BLDG5 | Fix roof near stack and stack | 2012 | 1 |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Battery Room /MCC Room /Control Room | Battery Room & MCC Room /Control Room | BLDG6 | Expand room per current codes when replacing equipment | 2012 | 1 |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Roofing | Roofing | BLDG7 | Repair roofing around stack. Inspect and maintain balance. | 2012 | 1 |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Siding | Siding | BLDG8 | Repair current corrosion areas | 2012 | 2 |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Hoists / Lifting | Hoists / Lifting | BLDG9 | None - Inspect and monitor ongoing | | |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Exhaust Stack Structure | Exhaust Stack Structure | BLDG10 | Fix roof near stack and stack | 2012 | 1 |

### 2.5.6 Life Assessment - Life Cycle Curves (Where Equipment Is Not To Be Overhauled/replaced and Life <2020 and Has Major Unit Operation Impacts)

No Life Cycle Curves are presented. The building with the recommended modifications and repairs can all meet the 2020 end date.

### 2.5.7 Level 3 Inspections Required

A higher level of inspection is required to confirm the lifting capability of the existing expansion joint / skid which exhaust fan is framed into. It was not confirmed if the existing building contains asbestos. If the roof is disturbed to service/replace the exhaust duct testing should be completed to determine if there is any asbestos in the roofing materials.

Removal of small sections of interior paneling and insulation in areas where corrosion exists in the turbine and power generator rooms should be carried out determine the condition of steel columns in areas where exterior siding has corroded through. These are considered outside of the scope of this assessment and part of the GT overhaul or facility asbestos program,

### 2.5.8 Capital Enhancements

The suggested capital projects for the GT building and building M and E systems are presented in Table 2-30.

**TABLE 2-30 SUGGESTED TYPICAL CAPITAL ENHANCEMENTS – GAS TURBINE BUILDINGS AND BUILDING M AND E SYSTEM**

| BU # 1 | Asset # 2 | Asset # 3 | Asset # 4 | Asset Level 3 | Description | Detail | Cond. Summ. ID# | Capital Item | Date | Priority |
|---|---|---|---|---|---|---|---|---|---|---|
| 1297 | 7255 | 272255 | 7307 | BUILDINGS | GAS TURBINE BUILDING | N/A | BLDG1 | Expansion of building for electrical system requirements and for fuel oil shed. | 2012 | 1 |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Structure - General | Structure | BLDG2 | No Captial Requirement | | |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Service Room: | Service Room: | BLDG3 | No Captial Requirement | | |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Turbine Room | Turbine Room | BLDG4 | No Captial Requirement | | |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Generator Room | Generator Room | BLDG5 | No Captial Requirement | | |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Battery Room /MCC Room /Control Room | Battery Room /MCC Room /Control Room | BLDG6 | Expansion of building for electrical system requirements. | 2012 | 1 |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Roofing | Roofing | BLDG7 | No Captial Requirement | | |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Siding | Siding | BLDG8 | No Captial Requirement | | |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Hoists / Lifting | Hoists / Lifting | BLDG9 | No Captial Requirement | | |
| 1273 | 7202 | 7311 | 0 | GAS TURBINE BUILDING | Exhaust Stack Structure | Exhaust Stack Structure | BLDG10 | New stack | 2012 | 1 |

### 2.5.9 Capital/Refurbishment Requirements and Costs

The following are the requirements for the complete refurbishment of the building:

- Repair sections of roofing and siding that are corroded and allowing water infiltration. Cost = Approximately $5,000;
- The addition of a building extension to shelter the turbine fuel line mechanical equipment from the elements, likely single span pre-engineered lean-to. Cost = Approximately $40,000;
- Addition of electrical building Cost = Approximately $40,000

## 2.6 Existing Unit De-Commissioning and Demolition in 2020

No significant incremental costs were identified for existing unit de-commissioning and/or demolition. It was felt that the value of the materials derived from the demolition could offset the cost to the contractor. If required as a sensitivity, then a value such as $40,000 (2011$) might be used, but this would not be expected to either sway the selection of a preferred option, nor impact the overall cost but rather be part of an overall project contingency regardless of any option selected.

## 2.7 Project Engineering and Management, Owner's Costs

It was assumed that the facility implementation would be undertaken largely as an engineer, procure, construct (EPC) external contract. NL Hydro would be responsible for getting the project approved and the necessary environmental and regulatory approvals. It may be necessary to maintain a schedule for NL Hydro to either procure a power turbine disk or at least a manufacturing slot for the materials and manufacturing pending an EPC which would be free-issued the same (with some guarantee provision exclusions likely).

**EPC Costs**

For the EPC contractor, the project engineering and management costs are based on the total project costs and a percentage for engineering and for management. For the purposes of this estimate, the engineering costs are estimated to be about 8% of direct costs. The project management and commissioning costs (excluding fuel, NL Hydro staff costs) are estimated to be 8% of direct costs.

**Owner's Costs**

Owner's costs are not included in the estimates, but are likely to be comparable regardless of the selected option. NL Hydro is assumed to undertake all the necessary environmental and regulatory permitting entirely internally or with some measure of external support (i.e. environmental modeling and engineering support, or full external scope). This cost is also not included but likely on the order of $55,000.

For the actual project implementation, the assumption is that NL Hydro would assume its own costs of this initial development and then assign a project manager for the life of the project to monitor and assure its successful completion. These and other NL Hydro costs (insurance, legal, supply chain, interest, owners' contingency, Holyrood station participation, commissioning fuel, commissioning labour) are not identified or included herein. It is likely that the Owner costs could amount to in the order of 1.5% of directs or about $150,000.

## 2.8 Existing GTG Refurbishment - Total Cost Estimate

The total existing GT refurbishment cost estimate is shown in Table 2-31. Details are provided in Appendix 7.

**TABLE 2-31 EXISTING GTG REFURBISHMENT COST ESTIMATE**

**Capital cost estimate $1,000 Can 2011**

| **Option Number** | **0** |
|---|---|
| **Option** | **Existing GT Refurb** |
| GT/Diesel Cost | $2,950 |
| Civil Works | $224 |
| Electrical Works | $541 |
| BOP Systems | $330 |
| Existing Unit Demolition & Removal | $0 |
| **Sub-Total - Directs and Indirects** | $4,046 |
| Project Engineering | $324 |
| Project Management | $283 |
| Total | $4,652 |

| | |
|---|---|
| + Standby = Total | $4,825 |
| | |
| + New Rental Stdby = Total | $9,421 |

Owner's costs were not included, but are expected to be in the order of about 1.5% of direct and indirect cost, plus any taxes and interest where applicable. It should be noted that it may be possible to obtain a used power turbine disk and refurbish it, as opposed to buying a new disk. This may slightly reduce the overall cost slightly. The availability of other parts is considered to be relatively good, but uncertain until a formal tender is issued.

### 2.8.1 Schedule

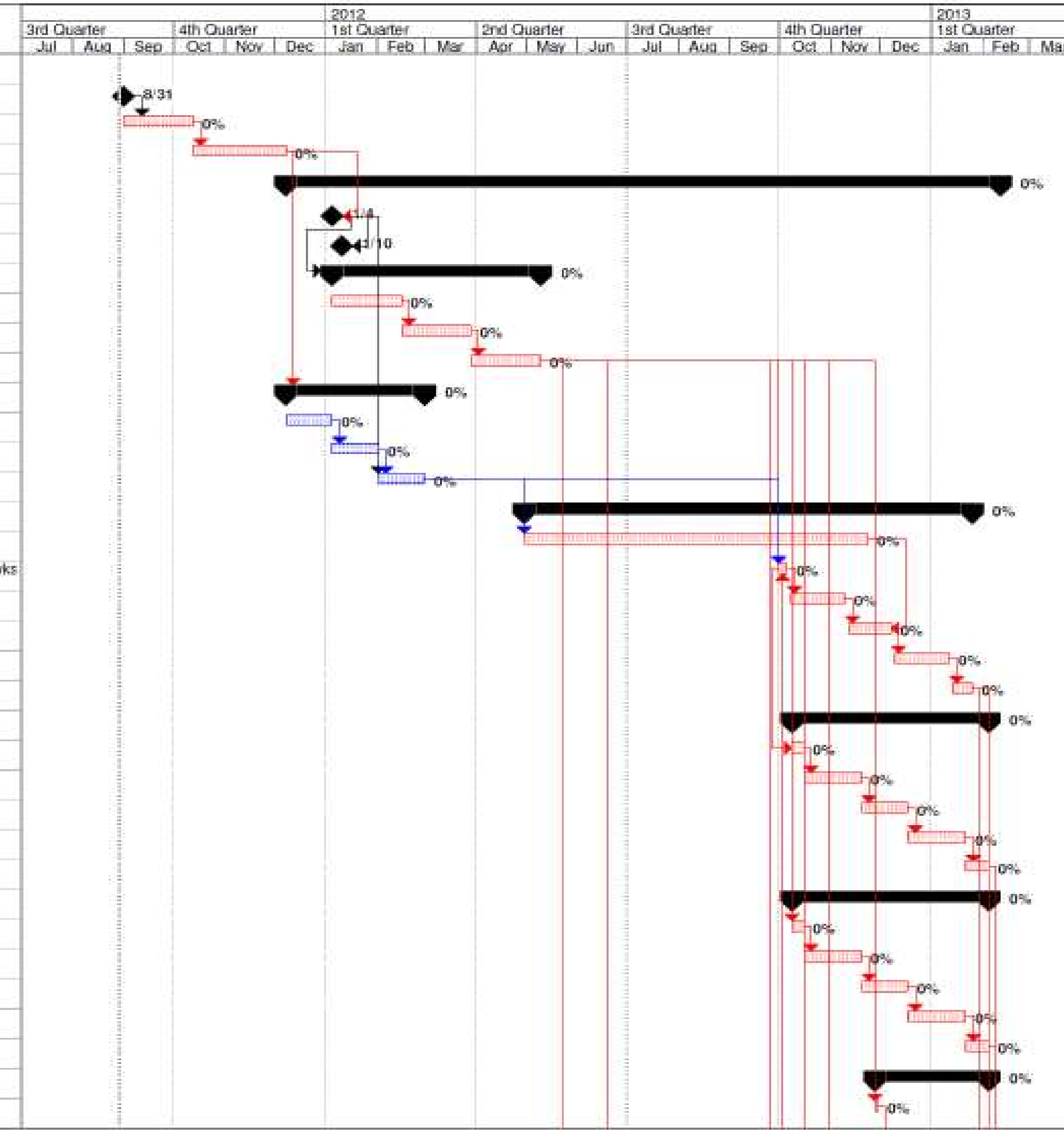
The basic "earliest return to service" schedule for the existing GTG unit refurbishment is shown in Figure 2-8 below. Its in-service date is in February 2013. It assumes no replacement unit in six month outage window from September 2012 to February 2013. It is based on an EPC RFP, with the exception of the procurement of a Power Turbine disk which is then free-issued to the EPC contractor.

The outage occurs when Holyrood is normally required to operate. It is likely that the schedule would be allowed to slip to an in-service date in Oct 2013 to have the outage in April to Oct 2013.

**Newfoundland and Labrador Hydro a NALCOR Energy Co.**
**Holyrood Thermal Generating Station**
**Gas Turbine Condition Assessment & Options Study**

**FIGURE 2-8 EXISTING GTG REFURBISHMENT – BASE SCHEDULE (NO OUTAGE REPLACEMENT CAPACITY)**

| ID | | Task Name | Duration | Start | Finish | Constraint Type | Predecessors |
|---|---|---|---|---|---|---|---|
| 1 | | | | | | | |
| 2 | | Condition Assessment Study | 0 wks | Wed 8/31/11 | Wed 8/31/11 | ish No Earlier Than | |
| 3 | | Hydro Internal Capital Budget Proposal Development | 6 wks | Thu 9/1/11 | Wed 10/12/11 | .s Soon As Possible | 2 |
| 4 | | Submission - Public Utilities Board & Approval | 6 wks | Thu 10/13/11 | Wed 12/7/11 | .s Soon As Possible | 3 |
| 5 | | **Refurbish Unit** | **308 days** | **Thu 12/8/11** | **Mon 2/11/13** | **Soon As Possible** | |
| 6 | | Project Limited Notice to proceed (LNTP) Approval | 0 days | Wed 1/4/12 | Wed 1/4/12 | .s Soon As Possible | 4FF+4 wks |
| 7 | | Project Full Notice to proceed (NTP) | 0 days | Tue 1/10/12 | Tue 1/10/12 | .s Soon As Possible | 6FF+4 days |
| 8 | | **Request for Proposal (RFP) - Engineer/Procure/Co** | **90 days** | **Thu 1/5/12** | **Wed 5/9/12** | **Soon As Possible** | 6 |
| 9 | | Prepare | 30 days | Thu 1/5/12 | Wed 2/15/12 | .s Soon As Possible | |
| 10 | | Bid | 30 days | Thu 2/16/12 | Wed 3/28/12 | .s Soon As Possible | 9 |
| 11 | | Award | 30 days | Thu 3/29/12 | Wed 5/9/12 | .s Soon As Possible | 10 |
| 12 | | **RFP for Power Turbine Disc Manufacture** | **60 days** | **Thu 12/8/11** | **Wed 2/29/12** | **Soon As Possible** | 4 |
| 13 | | Prepare | 20 days | Thu 12/8/11 | Wed 1/4/12 | .s Soon As Possible | |
| 14 | | Bid | 20 days | Thu 1/5/12 | Wed 2/1/12 | .s Soon As Possible | 13 |
| 15 | | Award | 20 days | Thu 2/2/12 | Wed 2/29/12 | .s Soon As Possible | 14,6 |
| 16 | | **Power Turbine** | **195 days** | **Mon 4/30/12** | **Fri 1/25/13** | **Soon As Possible** | |
| 17 | | Manufacture Disc | 30 wks | Mon 4/30/12 | Fri 11/23/12 | As Late As Possible | 15 |
| 18 | | Strip and dissassemble plant | 1 wk | Mon 10/1/12 | Fri 10/5/12 | .s Soon As Possible | 15,42,11FS+2 wks |
| 19 | | Ship Rotor to overhaul plant | 5 wks | Mon 10/8/12 | Fri 11/9/12 | .s Soon As Possible | 18 |
| 20 | | Overhaul and balance Rotor | 4 wks | Mon 11/12/12 | Fri 12/7/12 | .s Soon As Possible | 17FF+2 wks,19 |
| 21 | | Ship Rotor to Holyrood | 5 wks | Mon 12/10/12 | Fri 1/11/13 | .s Soon As Possible | 20 |
| 22 | | Rebuild and commission unit | 2 wks | Mon 1/14/13 | Fri 1/25/13 | .s Soon As Possible | 21 |
| 23 | | **Gear Box Overhaul** | **85 days** | **Tue 10/9/12** | **Mon 2/4/13** | **Soon As Possible** | |
| 24 | | Strip and dissassemble plant | 1 wk | Tue 10/9/12 | Mon 10/15/12 | As Late As Possible | 18SS |
| 25 | | Ship to overhaul plant | 5 wks | Tue 10/16/12 | Mon 11/19/12 | As Late As Possible | 24 |
| 26 | | Overhaul and balance Rotor | 4 wks | Tue 11/20/12 | Mon 12/17/12 | As Late As Possible | 25 |
| 27 | | Ship to Holyrood | 5 wks | Tue 12/18/12 | Mon 1/21/13 | .s Soon As Possible | 26 |
| 28 | | Rebuild and commission unit | 2 wks | Tue 1/22/13 | Mon 2/4/13 | .s Soon As Possible | 27 |
| 29 | | **Avon Gas Generator Overhaul** | **85 days** | **Tue 10/9/12** | **Mon 2/4/13** | **Soon As Possible** | |
| 30 | | Strip and dissassemble plant | 1 wk | Tue 10/9/12 | Mon 10/15/12 | As Late As Possible | 11FS+2 wks |
| 31 | | Ship Rotor to overhaul plant | 5 wks | Tue 10/16/12 | Mon 11/19/12 | As Late As Possible | 30 |
| 32 | | Overhaul and balance Rotor | 4 wks | Tue 11/20/12 | Mon 12/17/12 | As Late As Possible | 31 |
| 33 | | Ship Rotor to Holyrood | 5 wks | Tue 12/18/12 | Mon 1/21/13 | .s Soon As Possible | 32 |
| 34 | | Rebuild and commission unit | 2 wks | Tue 1/22/13 | Mon 2/4/13 | .s Soon As Possible | 33 |
| 35 | | **Generator Rewind** | **49 days** | **Wed 11/28/12** | **Mon 2/4/13** | **Soon As Possible** | |
| 36 | | Strip and dissassemble plant | 2 days | Wed 11/28/12 | Thu 11/29/12 | As Late As Possible | 11FS+2 wks |




Project: Project1 Exist r1.mpp
Date: Mon 8/29/11

Critical · Critical Split · Critical Progress · Task · Split · Task Progress · Baseline · Baseline Split · Baseline Milestone · Milestone · Summary Progress · Summary · Project Summary · External Tasks · External Milestone · Deadline

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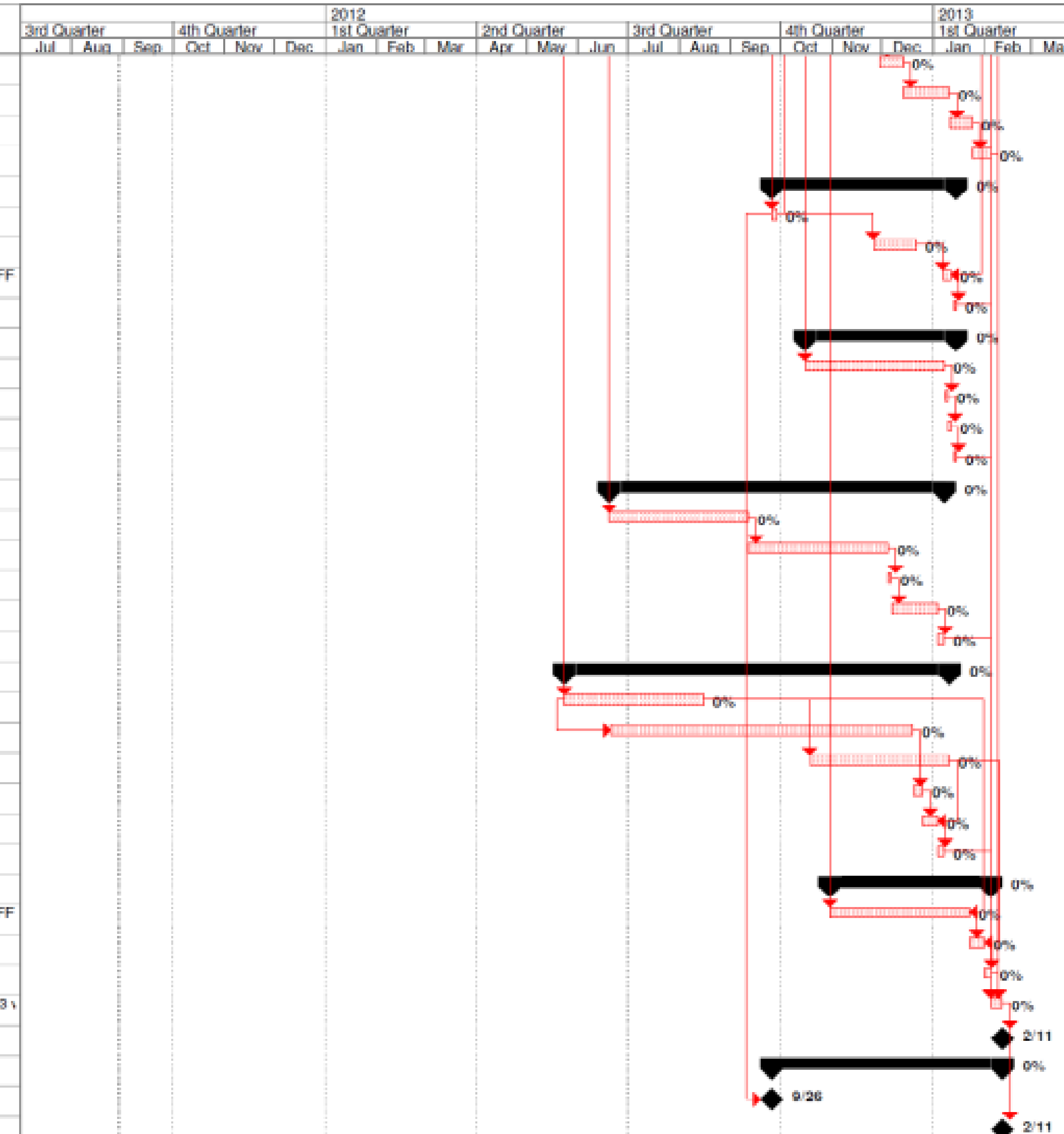
**Newfoundland and Labrador Hydro a NALCOR Energy Co.**
**Holyrood Thermal Generating Station**
**Gas Turbine Condition Assessment & Options Study**

| ID | | Task Name | Duration | Start | Finish | Constraint Type | Predecessors |
|---|---|---|---|---|---|---|---|
| 37 | | Ship Rotor to overhaul plant | 2 wks | Fri 11/30/12 | Thu 12/13/12 | As Late As Possible | 36 |
| 38 | | Overhaul, rewind, and balance Rotor | 4 wks | Fri 12/14/12 | Thu 1/10/13 | As Late As Possible | 37 |
| 39 | | Ship Rotor to Holyrood | 2 wks | Fri 1/11/13 | Thu 1/24/13 | s Soon As Possible | 38 |
| 40 | | Rebuild and commission unit | 7 days | Fri 1/25/13 | Mon 2/4/13 | s Soon As Possible | 39 |
| 41 | | **Exhaust Stack** | **79 days** | **Wed 9/26/12** | **Mon 1/14/13** | **Soon As Possible** | |
| 42 | | Remove | 3 days | Wed 9/26/12 | Fri 9/28/12 | As Late As Possible | 11FS+2 wks |
| 43 | | Repair/Replace | 4 wks | Mon 11/26/12 | Fri 12/21/12 | As Late As Possible | 42 |
| 44 | | Re-install | 5 days | Mon 1/7/13 | Fri 1/11/13 | As Late As Possible | 43FS+2 wks,22FF |
| 45 | | Commission unit | 1 day | Mon 1/14/13 | Mon 1/14/13 | s Soon As Possible | 44 |
| 46 | | **Intake media** | **65 days** | **Tue 10/16/12** | **Mon 1/14/13** | **Soon As Possible** | |
| 47 | | Order & Manufacture Filter media | 12 wks | Tue 10/16/12 | Mon 1/7/13 | As Late As Possible | 11FS+2 wks |
| 48 | | Remove | 2 days | Tue 1/8/13 | Wed 1/9/13 | As Late As Possible | 47 |
| 49 | | Repair/Replace | 2 days | Thu 1/10/13 | Fri 1/11/13 | As Late As Possible | 48 |
| 50 | | Commission unit | 1 day | Mon 1/14/13 | Mon 1/14/13 | s Soon As Possible | 49 |
| 51 | | **Fuel System Refurbishments** | **144 days** | **Wed 6/20/12** | **Mon 1/7/13** | **Soon As Possible** | |
| 52 | | Engineer | 12 wks | Wed 6/20/12 | Tue 9/11/12 | As Late As Possible | 11FS+2 wks |
| 53 | | Order, Manufacture, Deliver | 12 wks | Wed 9/12/12 | Tue 12/4/12 | As Late As Possible | 52 |
| 54 | | Remove | 2 days | Wed 12/5/12 | Thu 12/6/12 | As Late As Possible | 53 |
| 55 | | Repair/Replace | 4 wks | Fri 12/7/12 | Thu 1/3/13 | As Late As Possible | 54 |
| 56 | | Commission unit | 2 days | Fri 1/4/13 | Mon 1/7/13 | s Soon As Possible | 55 |
| 57 | | **Electrical & Control Systmes** | **166 days** | **Thu 5/24/12** | **Thu 1/10/13** | **Soon As Possible** | |
| 58 | | Engineer | 12 wks | Thu 5/24/12 | Wed 8/15/12 | As Late As Possible | 11FS+2 wks |
| 59 | | Order & Manufacture Elect & Control Equip | 26 wks | Thu 6/21/12 | Wed 12/19/12 | As Late As Possible | 58SS+4 wks |
| 60 | | GT Building Addition | 12 wks | Fri 10/19/12 | Thu 1/10/13 | As Late As Possible | 58 |
| 61 | | Remove Existing | 4 days | Thu 12/20/12 | Tue 12/25/12 | As Late As Possible | 59 |
| 62 | | Install New System | 7 days | Wed 12/26/12 | Thu 1/3/13 | As Late As Possible | 61,60FF-1 wk |
| 63 | | Commission unit | 2 days | Fri 1/4/13 | Mon 1/7/13 | s Soon As Possible | 62 |
| 64 | | **Building & Systmes** | **69 days** | **Wed 10/31/12** | **Mon 2/4/13** | **Soon As Possible** | |
| 65 | | Engineer | 12 wks | Wed 10/31/12 | Tue 1/22/13 | As Late As Possible | 11FS+2 wks,58FF |
| 66 | | Modify and Refurbish | 7 days | Wed 1/23/13 | Thu 1/31/13 | As Late As Possible | 65,60FF |
| 67 | | Commission unit | 2 days | Fri 2/1/13 | Mon 2/4/13 | s Soon As Possible | 66 |
| 68 | | Complete Unit Test | 5 days | Tue 2/5/13 | Mon 2/11/13 | s Soon As Possible | 34,40,22,45FS+3 v |
| 69 | | Gas Turbine (GT) In-service (I/S) | 0 days | Mon 2/11/13 | Mon 2/11/13 | s Soon As Possible | 68 |
| 70 | | **UNIT OUTAGE** | **99 days** | **Wed 9/26/12** | **Mon 2/11/13** | **Soon As Possible** | |
| 71 | | Unit Outage Start | 0 days | Wed 9/26/12 | Wed 9/26/12 | s Soon As Possible | 42SS |
| 72 | | Unit Outage End | 0 days | Mon 2/11/13 | Mon 2/11/13 | s Soon As Possible | 68 |




Project: Project1 Exist r1.mpp
Date: Mon 8/29/11

| | | | | |
|---|---|---|---|---|
| Critical | Task | Baseline | Milestone | Project Summary | 
| Critical Split | Split | Baseline Split | Summary Progress | External Tasks |
| Critical Progress | Task Progress | Baseline Milestone | Summary | External Milestone |

Deadline

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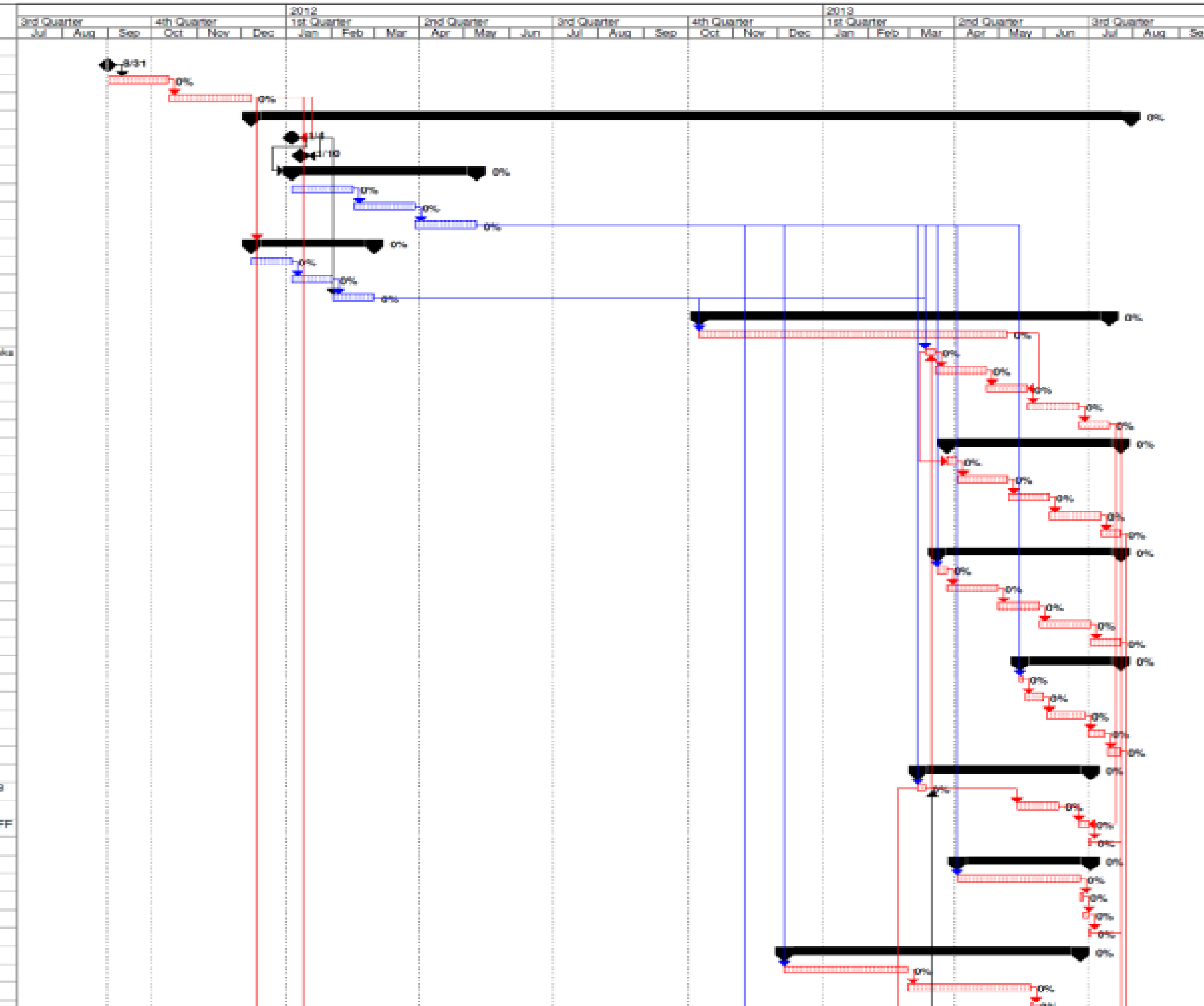
Figure 2-9 presents a variation of the basic "earliest return to service" schedule for the existing GTG unit refurbishment. It includes a replacement nearly new 2 x 5 MW GT during the outage window of the existing unit. The nearly new units would be in-service in March 2013. The resulting existing unit in-service date is end of July 2013, with a five month existing unit outage window from March to July 2013. It also is based on an EPC RFP, with the exception of the procurement of a Power Turbine disk which is free-issued to the EPC contractor. There is no significant period when black start capability is not available. A new 2 x 5MW unit would increase the schedule by about two months.

**FIGURE 2-9 EXISTING GTG REFURBISHMENT – ALTERNATE SCHEDULE 1 (NEARLY NEW 2 X 5 MW GT REPLACEMENT DURING OUTAGE)**

| ID | | Task Name | Duration | Start | Finish | Constraint Type | Predecessors |
|---|---|---|---|---|---|---|---|
| 1 | | | | | | | |
| 2 | | Condition Assessment Study | 0 wks | Wed 8/31/11 | Wed 8/31/11 | Finish No Earlier Than | |
| 3 | | Hydro Internal Capital Budget Proposal Development | 6 wks | Thu 9/1/11 | Wed 10/12/11 | As Soon As Possible | 2 |
| 4 | | Submission - Public Utilities Board & Approval | 8 wks | Thu 10/13/11 | Wed 12/7/11 | As Soon As Possible | 3 |
| 5 | | **Refurbish Unit** | **429 days** | **Thu 12/8/11** | **Tue 7/30/13** | **As Soon As Possible** | |
| 6 | | Project Limited Notice to proceed (LNTP) Approval | 0 days | Wed 1/4/12 | Wed 1/4/12 | As Soon As Possible | 4FF+4 wks |
| 7 | | Project Full Notice to proceed (NTP) | 0 days | Tue 1/10/12 | Tue 1/10/12 | As Soon As Possible | 6FF+4 days |
| 8 | | **Request for Proposal (RFP) - Engineer/Procure/Cor** | **90 days** | **Thu 1/5/12** | **Wed 5/9/12** | **As Soon As Possible** | **6** |
| 9 | | Prepare | 30 days | Thu 1/5/12 | Wed 2/15/12 | As Soon As Possible | |
| 10 | | Bid | 30 days | Thu 2/16/12 | Wed 3/28/12 | As Soon As Possible | 9 |
| 11 | | Award | 30 days | Thu 3/29/12 | Wed 5/9/12 | As Soon As Possible | 10 |
| 12 | | **RFP for Power Turbine Disc Manufacture** | **60 days** | **Thu 12/8/11** | **Wed 2/29/12** | **As Soon As Possible** | **4** |
| 13 | | Prepare | 20 days | Thu 12/8/11 | Wed 1/4/12 | As Soon As Possible | |
| 14 | | Bid | 20 days | Thu 1/5/12 | Wed 2/1/12 | As Soon As Possible | 13 |
| 15 | | Award | 20 days | Thu 2/2/12 | Wed 2/29/12 | As Soon As Possible | 14,6 |
| 16 | | **Power Turbine** | **200 days** | **Tue 10/9/12** | **Mon 7/15/13** | **As Soon As Possible** | |
| 17 | | Manufacture Disc | 30 wks | Tue 10/9/12 | Mon 5/6/13 | As Late As Possible | 15 |
| 18 | | Strip and disassemble plant | 1 wk | Tue 3/12/13 | Mon 3/18/13 | As Late As Possible | 15,42,11FS+2 wks |
| 19 | | Ship Rotor to overhaul plant | 5 wks | Tue 3/19/13 | Mon 4/22/13 | As Late As Possible | 18 |
| 20 | | Overhaul and balance Rotor | 4 wks | Tue 4/23/13 | Mon 5/20/13 | As Late As Possible | 17FF+2 wks,19 |
| 21 | | Ship Rotor to Holyrood | 5 wks | Tue 5/21/13 | Mon 6/24/13 | As Soon As Possible | 20 |
| 22 | | Rebuild and commission unit | 3 wks | Tue 6/25/13 | Mon 7/15/13 | As Soon As Possible | 21 |
| 23 | | **Gear Box Overhaul** | **85 days** | **Wed 3/27/13** | **Tue 7/23/13** | **As Soon As Possible** | |
| 24 | | Strip and disassemble plant | 1 wk | Wed 3/27/13 | Tue 4/2/13 | As Late As Possible | 18SS |
| 25 | | Ship to overhaul plant | 5 wks | Wed 4/3/13 | Tue 5/7/13 | As Late As Possible | 24 |
| 26 | | Overhaul and balance Rotor | 4 wks | Wed 5/8/13 | Tue 6/4/13 | As Late As Possible | 25 |
| 27 | | Ship to Holyrood | 5 wks | Wed 6/5/13 | Tue 7/9/13 | As Soon As Possible | 26 |
| 28 | | Rebuild and commission unit | 2 wks | Wed 7/10/13 | Tue 7/23/13 | As Soon As Possible | 27 |
| 29 | | **Avon Gas Generator Overhaul** | **90 days** | **Wed 3/20/13** | **Tue 7/23/13** | **As Soon As Possible** | |
| 30 | | Strip and disassemble plant | 1 wk | Wed 3/20/13 | Tue 3/26/13 | As Late As Possible | 11FS+2 wks |
| 31 | | Ship Rotor to overhaul plant | 5 wks | Wed 3/27/13 | Tue 4/30/13 | As Late As Possible | 30 |
| 32 | | Overhaul and balance Rotor | 4 wks | Wed 5/1/13 | Tue 5/28/13 | As Late As Possible | 31 |
| 33 | | Ship Rotor to Holyrood | 5 wks | Wed 5/29/13 | Tue 7/2/13 | As Soon As Possible | 32 |
| 34 | | Rebuild and commission unit | 3 wks | Wed 7/3/13 | Tue 7/23/13 | As Soon As Possible | 33 |
| 35 | | **Generator Rewind** | **49 days** | **Thu 5/16/13** | **Tue 7/23/13** | **As Soon As Possible** | |
| 36 | | Strip and disassemble plant | 2 days | Thu 5/16/13 | Fri 5/17/13 | As Late As Possible | 11FS+2 wks |
| 37 | | Ship Rotor to overhaul plant | 2 wks | Mon 5/20/13 | Fri 5/31/13 | As Late As Possible | 36 |
| 38 | | Overhaul, rewind, and balance Rotor | 4 wks | Mon 6/3/13 | Fri 6/28/13 | As Late As Possible | 37 |
| 39 | | Ship Rotor to Holyrood | 2 wks | Mon 7/1/13 | Fri 7/12/13 | As Soon As Possible | 38 |
| 40 | | Rebuild and commission unit | 7 days | Mon 7/15/13 | Tue 7/23/13 | As Soon As Possible | 39 |
| 41 | | **Exhaust Stack** | **84 days** | **Thu 3/7/13** | **Tue 7/2/13** | **As Soon As Possible** | |
| 42 | | Remove | 3 days | Thu 3/7/13 | Mon 3/11/13 | As Late As Possible | 11FS+2 wks,108 |
| 43 | | Repair/Replace | 4 wks | Tue 5/14/13 | Mon 6/10/13 | As Late As Possible | 42 |
| 44 | | Re-install | 5 days | Tue 6/25/13 | Mon 7/1/13 | As Late As Possible | 43FS+2 wks,22FF |
| 45 | | Commission unit | 1 day | Tue 7/2/13 | Tue 7/2/13 | As Soon As Possible | 44 |
| 46 | | **Intake media** | **65 days** | **Wed 4/3/13** | **Tue 7/2/13** | **As Soon As Possible** | |
| 47 | | Order & Manufacture Filter media | 12 wks | Wed 4/3/13 | Tue 6/25/13 | As Late As Possible | 11FS+2 wks |
| 48 | | Remove | 2 days | Wed 6/26/13 | Thu 6/27/13 | As Late As Possible | 47 |
| 49 | | Repair/Replace | 2 days | Fri 6/28/13 | Mon 7/1/13 | As Late As Possible | 48 |
| 50 | | Commission unit | 1 day | Tue 7/2/13 | Tue 7/2/13 | As Soon As Possible | 49 |
| 51 | | **Fuel System Refurbishments** | **144 days** | **Thu 12/6/12** | **Tue 6/25/13** | **As Soon As Possible** | |
| 52 | | Engineer | 12 wks | Thu 12/6/12 | Wed 2/27/13 | As Late As Possible | 11FS+2 wks |
| 53 | | Order, Manufacture, Deliver | 12 wks | Thu 2/28/13 | Wed 5/22/13 | As Late As Possible | 52 |
| 54 | | Remove | 2 days | Thu 5/23/13 | Fri 5/24/13 | As Late As Possible | 53 |



Project: Project1 Exist & Repla near ne
Date: Wed 8/31/11

Critical | Critical Split | Critical Progress | Task | Split | Task Progress | Baseline | Baseline Split | Baseline Milestone | Milestone | Summary Progress | Summary | Project Summary | External Tasks | External Milestone | Deadline

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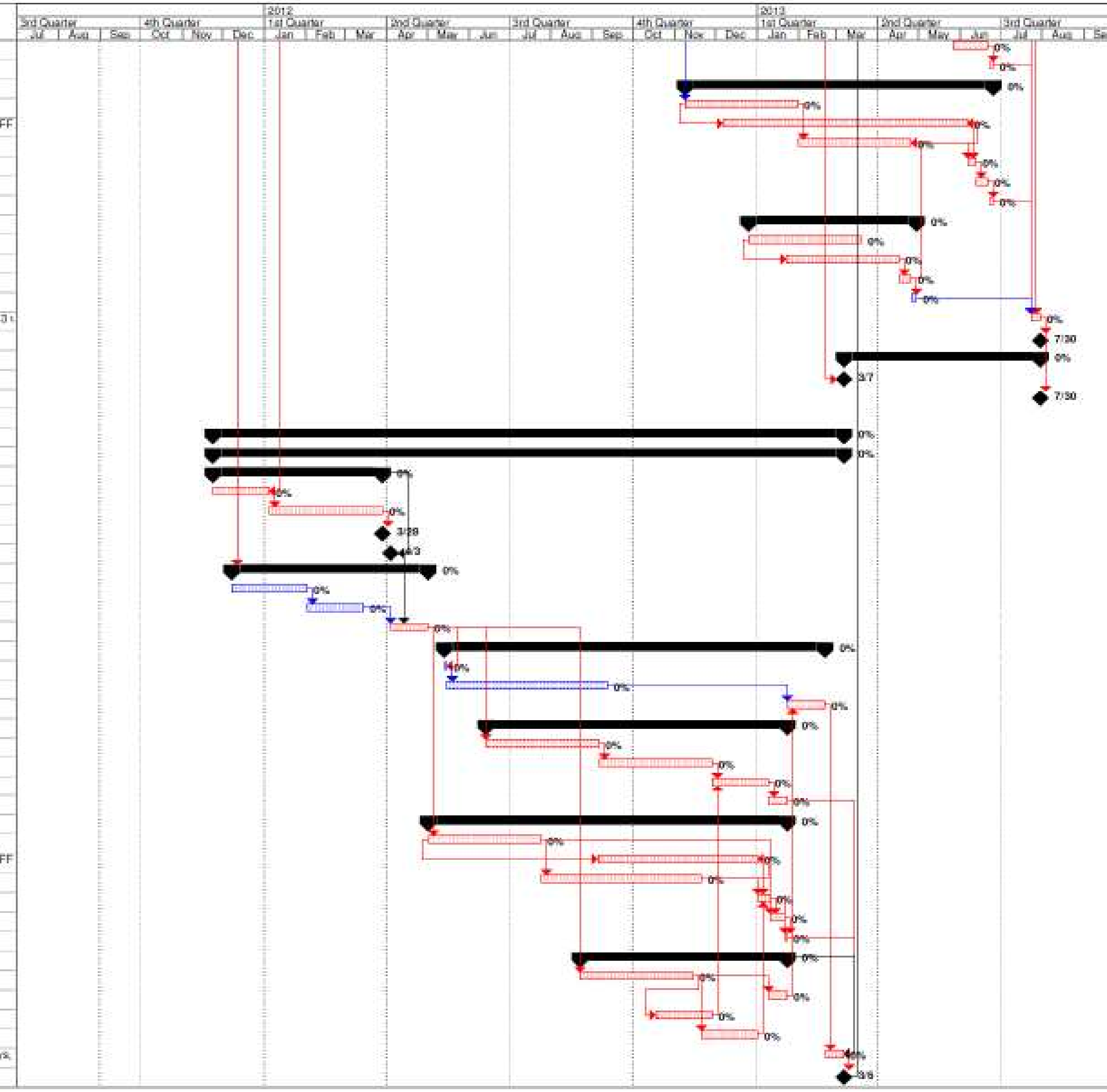
**Newfoundland and Labrador Hydro a NALCOR Energy Co.**
**Holyrood Thermal Generating Station**
**Gas Turbine Condition Assessment & Options Study**

| ID | Task Name | Duration | Start | Finish | Constraint Type | Predecessors |
|---|---|---|---|---|---|---|
| 55 | Repair/Replace | 4 wks | Mon 5/27/13 | Fri 6/21/13 | As Late As Possible | 54 |
| 56 | Commission unit | 2 days | Mon 6/24/13 | Tue 6/25/13 | As Soon As Possible | 55 |
| 57 | **Electrical & Control Systmes** | **163 days** | **Fri 11/9/12** | **Tue 6/25/13** | **As Soon As Possible** | |
| 58 | Engineer | 12 wks | Fri 11/9/12 | Thu 1/31/13 | As Late As Possible | 11FS+2 wks |
| 59 | Order & Manufacture Elect & Control Equip | 26 wks | Fri 12/7/12 | Thu 6/6/13 | As Late As Possible | 58SS+4 wks,60FF |
| 60 | GT Building Addition | 12 wks | Fri 2/1/13 | Thu 4/25/13 | As Late As Possible | 58,67FF |
| 61 | Remove Existing | 4 days | Fri 6/7/13 | Wed 6/12/13 | As Late As Possible | 60,59 |
| 62 | Install New System | 7 days | Thu 6/13/13 | Fri 6/21/13 | As Late As Possible | 61 |
| 63 | Commission unit | 2 days | Mon 6/24/13 | Tue 6/25/13 | As Soon As Possible | 62 |
| 64 | **Building & Systmes** | **89 days** | **Wed 12/26/12** | **Mon 4/29/13** | **As Soon As Possible** | |
| 65 | Engineer | 12 wks | Wed 12/26/12 | Tue 3/19/13 | As Late As Possible | |
| 66 | Order & Manufacture Elect & Control Equip | 12 wks | Wed 1/23/13 | Tue 4/16/13 | As Late As Possible | 65SS+4 wks |
| 67 | Modify and Refurbish | 7 days | Wed 4/17/13 | Thu 4/25/13 | As Late As Possible | 66 |
| 68 | Commission unit | 2 days | Fri 4/26/13 | Mon 4/29/13 | As Soon As Possible | 67 |
| 69 | Complete Unit Test | 5 days | Wed 7/24/13 | Tue 7/30/13 | As Soon As Possible | 34,40,22,45FS-3 ( |
| 70 | Gas Turbine (GT) In-service (I/S) | 0 days | Tue 7/30/13 | Tue 7/30/13 | As Soon As Possible | 69 |
| 71 | **UNIT OUTAGE** | **104 days** | **Thu 3/7/13** | **Tue 7/30/13** | **As Soon As Possible** | |
| 72 | Unit Outage Start | 0 days | Thu 3/7/13 | Thu 3/7/13 | As Soon As Possible | 42SS |
| 73 | Unit Outage End | 0 days | Tue 7/30/13 | Tue 7/30/13 | As Soon As Possible | 69 |
| 74 | | | | | | |
| 75 | **REPLACEMENT UNIT** | **335 days** | **Thu 11/24/11** | **Wed 3/6/13** | **As Soon As Possible** | |
| 76 | **Nearly New gas Turbine (GT) Generator Units** | **335 days** | **Thu 11/24/11** | **Wed 3/6/13** | **As Soon As Possible** | |
| 77 | **Project Environmental & Regulatory Approvals** | **90 days** | **Thu 11/24/11** | **Wed 3/28/12** | **As Soon As Possible** | |
| 78 | Prepare Dispersion Modelling & Submission | 30 days | Thu 11/24/11 | Wed 1/4/12 | As Soon As Possible | 4FF+4 wks |
| 79 | Regulatory Review and Approval | 60 days | Thu 1/5/12 | Wed 3/28/12 | As Soon As Possible | 78 |
| 80 | Environmental Approval | 0 days | Wed 3/28/12 | Wed 3/28/12 | As Soon As Possible | 79 |
| 81 | Project Full Release | 0 days | Tue 4/3/12 | Tue 4/3/12 | As Soon As Possible | 77FF+4 days |
| 82 | **Request for Proposal (RFP) for Engineer/Proc** | **104 days** | **Thu 12/8/11** | **Tue 5/1/12** | **As Soon As Possible** | 4 |
| 83 | Prepare | 40 days | Thu 12/8/11 | Wed 2/1/12 | As Soon As Possible | |
| 84 | Bid | 6 wks | Thu 2/2/12 | Wed 3/14/12 | As Soon As Possible | 83 |
| 85 | Award | 20 days | Wed 4/4/12 | Tue 5/1/12 | As Soon As Possible | 81,84 |
| 86 | **Nearly New GT or Diesel Engine Generator** | **203 days** | **Mon 5/14/12** | **Wed 2/20/13** | **As Soon As Possible** | |
| 87 | Award GT/Diesel Engine Contract | 2 days | Mon 5/14/12 | Tue 5/15/12 | As Soon As Possible | 85FF+10 days |
| 88 | Manufacture & Deliver Transportable Engine | 17 wks | Wed 5/16/12 | Tue 9/11/12 | As Soon As Possible | 87 |
| 89 | Install and Commission | 4 wks | Thu 1/24/13 | Wed 2/20/13 | As Soon As Possible | 88,104 |
| 90 | **Fuel System** | **160 days** | **Thu 6/14/12** | **Wed 1/23/13** | **As Soon As Possible** | |
| 91 | Engineer | 12 wks | Thu 6/14/12 | Wed 9/5/12 | As Late As Possible | 85 |
| 92 | Order, Manufacture, Deliver | 12 wks | Thu 9/6/12 | Wed 11/28/12 | As Late As Possible | 91 |
| 93 | Install new fuel lines and receiving system | 6 wks | Thu 11/29/12 | Wed 1/9/13 | As Late As Possible | 92,105 |
| 94 | Commission System | 2 wks | Thu 1/10/13 | Wed 1/23/13 | As Late As Possible | 93 |
| 95 | **Electrical & Control Systmes** | **191 days** | **Wed 5/2/12** | **Wed 1/23/13** | **As Soon As Possible** | |
| 96 | Engineer | 12 wks | Wed 5/2/12 | Tue 7/24/12 | As Late As Possible | 85 |
| 97 | Order & Manufacture Elect & Control (E&C) E | 17 wks | Wed 9/5/12 | Tue 1/1/13 | As Late As Possible | 96SS+4 wks,98FF |
| 98 | Electrical Building Manufacture, Delivery, Ins | 17 wks | Wed 7/25/12 | Tue 11/20/12 | As Late As Possible | 96 |
| 99 | Install New System | 7 days | Wed 1/2/13 | Thu 1/10/13 | As Late As Possible | 97,98,106 |
| 100 | RE-align Existing Plant Systems | 7 days | Fri 1/11/13 | Mon 1/21/13 | As Late As Possible | 96,99 |
| 101 | Commission unit | 2 days | Tue 1/22/13 | Wed 1/23/13 | As Soon As Possible | 99,100 |
| 102 | **Site Civil Work** | **110 days** | **Thu 8/23/12** | **Wed 1/23/13** | **As Soon As Possible** | |
| 103 | Engineer | 12 wks | Thu 8/23/12 | Wed 11/14/12 | As Late As Possible | 85 |
| 104 | Generator area clearing and civil | 2 wks | Thu 1/10/13 | Wed 1/23/13 | As Late As Possible | 103FS-6 wks |
| 105 | Fuel line civil work | 6 wks | Thu 10/18/12 | Wed 11/28/12 | As Late As Possible | 103FS-4 wks |
| 106 | Electrical an contro cable civil work | 6 wks | Wed 11/21/12 | Tue 1/1/13 | As Late As Possible | 103FS-2 wks |
| 107 | Complete Unit Test | 10 days | Thu 2/21/13 | Wed 3/6/13 | As Soon As Possible | 89,94FF+30 days, |
| 108 | GT In-Service (I/S) | 0 days | Wed 3/6/13 | Wed 3/6/13 | As Soon As Possible | 107 |




Project: Project1 Exist & Repla near ne
Date: Wed 8/31/11

Critical | Critical Split | Critical Progress | Task | Split | Task Progress | Baseline | Baseline Split | Baseline Milestone | Milestone | Summary Progress | Summary | Project Summary | External Tasks | External Milestone | Deadline

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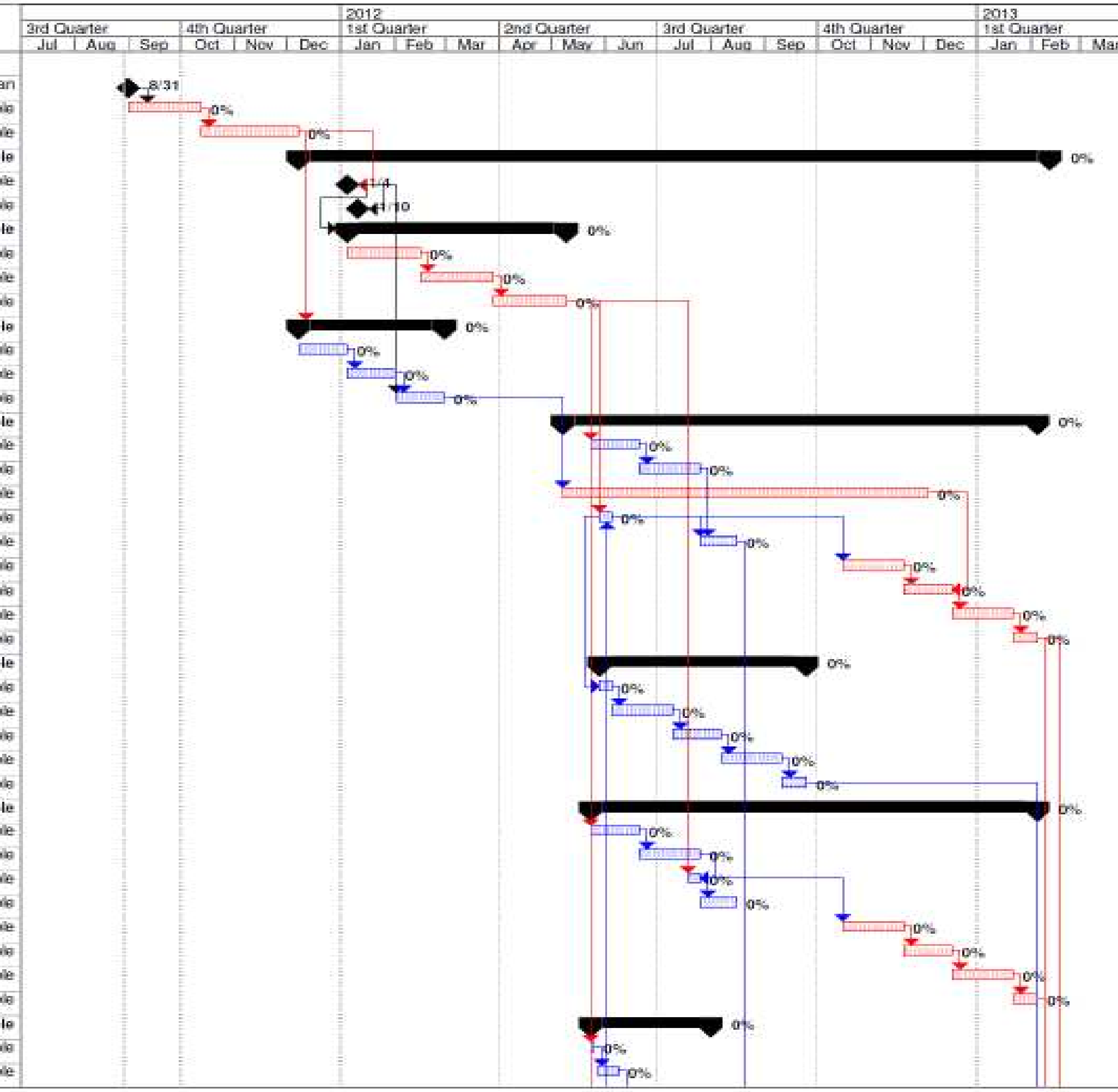
Figure 2-10 presents a second variation of the basic "earliest return to service" schedule for the existing GTG unit refurbishment. It assumes leased used replacements parts for the existing GT unit (the gas generator, the power turbine) to minimize the outage window, but does not. The in-service date is still February 2013, but with a longer outage window of 9 months from May 2012 to February 2013. The outage also occurs when Holyrood is normally required to operate, and given its duration would not be impacted by schedule shifting.

**FIGURE 2-10 EXISTING GTG REFURBISHMENT – ALTERNATE SCHEDULE 2 (LEASED USED GAS GENERATOR AND POWER TURBINE DURING OUTAGE)**

| ID | | Task Name | Duration | Start | Finish | Constraint Type |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | | Condition Assessment Study | 0 wks | Wed 8/31/11 | Wed 8/31/11 | Finish No Earlier Than |
| 3 | | Hydro Internal Capital Budget Proposal Development | 6 wks | Thu 9/1/11 | Wed 10/12/11 | As Soon As Possible |
| 4 | | Submission - Public Utilities Board & Approval | 8 wks | Thu 10/13/11 | Wed 12/7/11 | As Soon As Possible |
| 5 | | **Refurbish Unit** | **308 days** | **Thu 12/8/11** | **Mon 2/11/13** | **As Soon As Possible** |
| 6 | | Project Limited Notice to proceed (LNTP) Approval | 0 days | Wed 1/4/12 | Wed 1/4/12 | As Soon As Possible |
| 7 | | Project Full Notice to proceed (NTP) | 0 days | Tue 1/10/12 | Tue 1/10/12 | As Soon As Possible |
| 8 | | **Request for Proposal (RFP) - Engineer/Procure/Construct (I** | **90 days** | **Thu 1/5/12** | **Wed 5/9/12** | **As Soon As Possible** |
| 9 | | Prepare | 30 days | Thu 1/5/12 | Wed 2/15/12 | As Soon As Possible |
| 10 | | Bid | 30 days | Thu 2/16/12 | Wed 3/28/12 | As Soon As Possible |
| 11 | | Award | 30 days | Thu 3/29/12 | Wed 5/9/12 | As Soon As Possible |
| 12 | | **RFP for Power Turbine Disc Manufacture** | **60 days** | **Thu 12/8/11** | **Wed 2/29/12** | **As Soon As Possible** |
| 13 | | Prepare | 20 days | Thu 12/8/11 | Wed 1/4/12 | As Soon As Possible |
| 14 | | Bid | 20 days | Thu 1/5/12 | Wed 2/1/12 | As Soon As Possible |
| 15 | | Award | 20 days | Thu 2/2/12 | Wed 2/29/12 | As Soon As Possible |
| 16 | | **Power Turbine** | **195 days** | **Tue 5/8/12** | **Mon 2/4/13** | **As Soon As Possible** |
| 17 | | Procure Lease Disc and PT Assembly | 4 wks | Thu 5/24/12 | Wed 6/20/12 | As Soon As Possible |
| 18 | | Refurbish PT Replacement | 5 wks | Thu 6/21/12 | Wed 7/25/12 | As Soon As Possible |
| 19 | | Manufacture NEW PT Disc | 30 wks | Tue 5/8/12 | Mon 12/3/12 | As Late As Possible |
| 20 | | Strip and dissassemble plant | 1 wk | Tue 5/29/12 | Mon 6/4/12 | As Soon As Possible |
| 21 | | Rebuild and commission unit - Lease part | 3 wks | Thu 7/26/12 | Wed 8/15/12 | As Soon As Possible |
| 22 | | Ship Rotor to overhaul plant | 5 wks | Tue 10/16/12 | Mon 11/19/12 | As Late As Possible |
| 23 | | Overhaul and balance Rotor | 4 wks | Tue 11/20/12 | Mon 12/17/12 | As Late As Possible |
| 24 | | Ship Rotor to Holyrood | 5 wks | Tue 12/18/12 | Mon 1/21/13 | As Soon As Possible |
| 25 | | Replace lease part, rebuild and commission unit | 2 wks | Tue 1/22/13 | Mon 2/4/13 | As Soon As Possible |
| 26 | | **Gear Box Overhaul** | **85 days** | **Tue 5/29/12** | **Mon 9/24/12** | **As Soon As Possible** |
| 27 | | Strip and dissassemble plant | 1 wk | Tue 5/29/12 | Mon 6/4/12 | As Soon As Possible |
| 28 | | Ship to overhaul plant | 5 wks | Tue 6/5/12 | Mon 7/9/12 | As Soon As Possible |
| 29 | | Overhaul and balance Rotor | 4 wks | Tue 7/10/12 | Mon 8/6/12 | As Soon As Possible |
| 30 | | Ship to Holyrood | 5 wks | Tue 8/7/12 | Mon 9/10/12 | As Soon As Possible |
| 31 | | Rebuild and commission unit | 2 wks | Tue 9/11/12 | Mon 9/24/12 | As Soon As Possible |
| 32 | | **Avon Gas Generator Overhaul** | **183 days** | **Thu 5/24/12** | **Mon 2/4/13** | **As Soon As Possible** |
| 33 | | Procure Lease Disc and PT Assembly | 4 wks | Thu 5/24/12 | Wed 6/20/12 | As Soon As Possible |
| 34 | | Refurbish PT Replacement | 5 wks | Thu 6/21/12 | Wed 7/25/12 | As Soon As Possible |
| 35 | | Strip and dissassemble plant | 1 wk | Thu 7/19/12 | Wed 7/25/12 | As Soon As Possible |
| 36 | | Rebuild and commission unit - Lease part | 3 wks | Thu 7/26/12 | Wed 8/15/12 | As Soon As Possible |
| 37 | | Ship Rotor to overhaul plant | 5 wks | Tue 10/16/12 | Mon 11/19/12 | As Late As Possible |
| 38 | | Overhaul and balance Rotor | 4 wks | Tue 11/20/12 | Mon 12/17/12 | As Late As Possible |
| 39 | | Ship Rotor to Holyrood | 5 wks | Tue 12/18/12 | Mon 1/21/13 | As Soon As Possible |
| 40 | | Replace lease part, rebuild and commission unit | 2 wks | Tue 1/22/13 | Mon 2/4/13 | As Soon As Possible |
| 41 | | **Generator Rewind** | **49 days** | **Thu 5/24/12** | **Tue 7/31/12** | **As Soon As Possible** |
| 42 | | Strip and dissassemble plant | 2 days | Thu 5/24/12 | Fri 5/25/12 | As Soon As Possible |
| 43 | | Ship Rotor to overhaul plant | 2 wks | Mon 5/28/12 | Fri 6/8/12 | As Soon As Possible |




Project: Project1 Exist & Repla Lease
Date: Mon 8/29/11

Critical | Critical Split | Critical Progress | Task | Split | Task Progress | Baseline | Baseline Split | Baseline Milestone | Milestone | Summary Progress | Summary | Project Summary | External Tasks | External Milestone | Deadline

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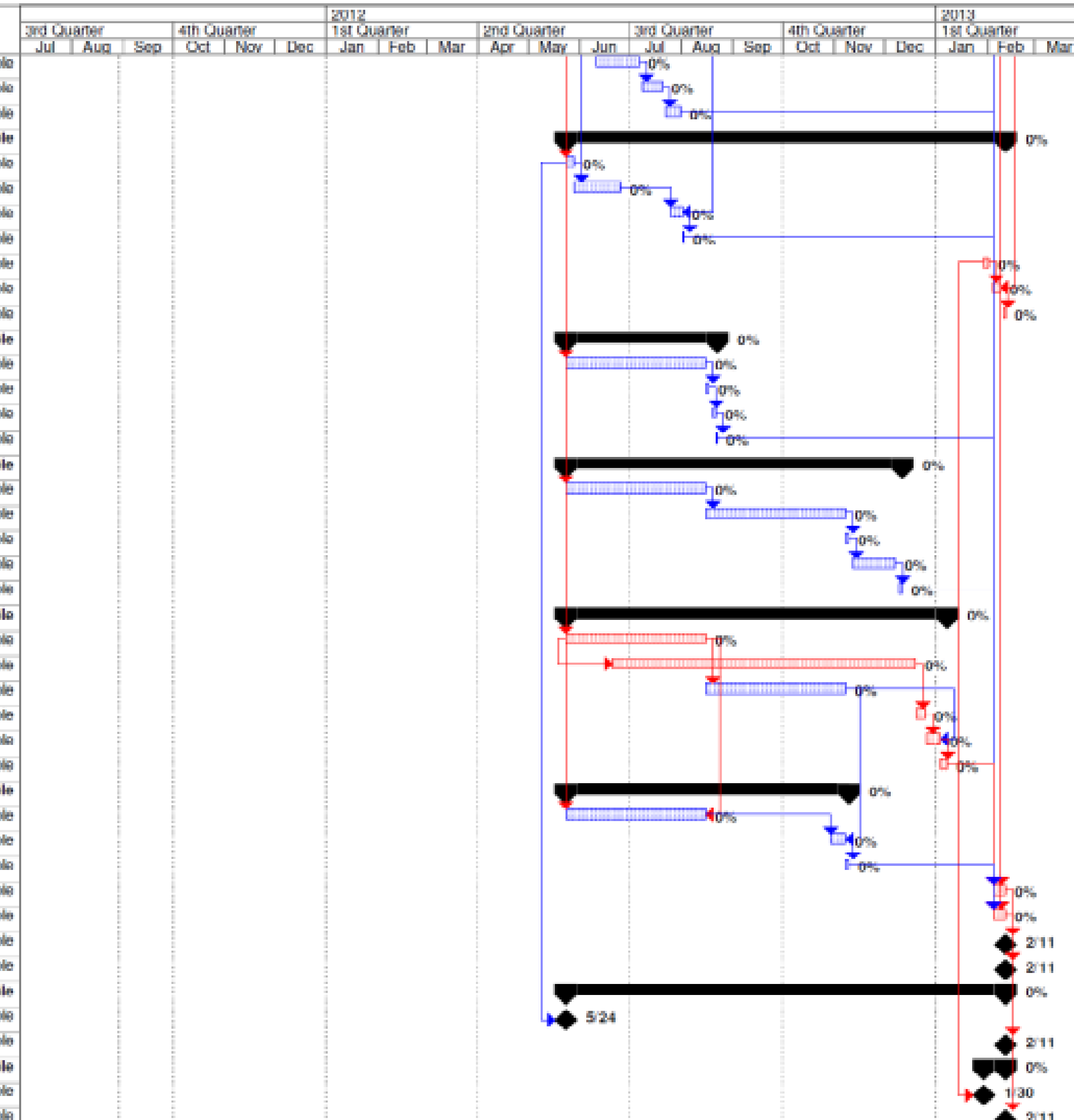
| ID | | Task Name | Duration | Start | Finish | Constraint Type |
|---|---|---|---|---|---|---|
| 44 | | Overhaul, rewind, and balance Rotor | 4 wks | Mon 6/11/12 | Fri 7/6/12 | As Soon As Possible |
| 45 | | Ship Rotor to Holyrood | 2 wks | Mon 7/9/12 | Fri 7/20/12 | As Soon As Possible |
| 46 | | Rebuild and commission unit | 7 days | Mon 7/23/12 | Tue 7/31/12 | As Soon As Possible |
| 47 | | **Exhaust Stack** | **188 days** | **Thu 5/24/12** | **Mon 2/11/13** | **As Soon As Possible** |
| 48 | | Remove | 3 days | Thu 5/24/12 | Mon 5/28/12 | As Soon As Possible |
| 49 | | Repair/Replace | 4 wks | Tue 5/29/12 | Mon 6/25/12 | As Soon As Possible |
| 50 | | Re-install | 5 days | Thu 7/26/12 | Wed 8/1/12 | As Soon As Possible |
| 51 | | Commission unit | 1 day | Thu 8/2/12 | Thu 8/2/12 | As Soon As Possible |
| 52 | | Remove new stack | 3 days | Wed 1/30/13 | Fri 2/1/13 | As Late As Possible |
| 53 | | Re-install | 5 days | Mon 2/4/13 | Fri 2/8/13 | As Late As Possible |
| 54 | | Commission unit | 1 day | Mon 2/11/13 | Mon 2/11/13 | As Soon As Possible |
| 55 | | **Intake media** | **65 days** | **Thu 5/24/12** | **Wed 8/22/12** | **As Soon As Possible** |
| 56 | | Order & Manufacture Filter media | 12 wks | Thu 5/24/12 | Wed 8/15/12 | As Soon As Possible |
| 57 | | Remove | 2 days | Thu 8/16/12 | Fri 8/17/12 | As Soon As Possible |
| 58 | | Repair/Replace | 2 days | Mon 8/20/12 | Tue 8/21/12 | As Soon As Possible |
| 59 | | Commission unit | 1 day | Wed 8/22/12 | Wed 8/22/12 | As Soon As Possible |
| 60 | | **Fuel System Refurbishments** | **144 days** | **Thu 5/24/12** | **Tue 12/11/12** | **As Soon As Possible** |
| 61 | | Engineer | 12 wks | Thu 5/24/12 | Wed 8/15/12 | As Soon As Possible |
| 62 | | Order, Manufacture, Deliver | 12 wks | Thu 8/16/12 | Wed 11/7/12 | As Soon As Possible |
| 63 | | Remove | 2 days | Thu 11/8/12 | Fri 11/9/12 | As Soon As Possible |
| 64 | | Repair/Replace | 4 wks | Mon 11/12/12 | Fri 12/7/12 | As Soon As Possible |
| 65 | | Commission unit | 2 days | Mon 12/10/12 | Tue 12/11/12 | As Soon As Possible |
| 66 | | **Electrical & Control Systmes** | **163 days** | **Thu 5/24/12** | **Mon 1/7/13** | **As Soon As Possible** |
| 67 | | Engineer | 12 wks | Thu 5/24/12 | Wed 8/15/12 | As Soon As Possible |
| 68 | | Order & Manufacture Elect & Control Equip | 26 wks | Thu 6/21/12 | Wed 12/19/12 | As Soon As Possible |
| 69 | | GT Building Addition | 12 wks | Thu 8/16/12 | Wed 11/7/12 | As Soon As Possible |
| 70 | | Remove Existing | 4 days | Thu 12/20/12 | Tue 12/25/12 | As Soon As Possible |
| 71 | | Install New System | 7 days | Wed 12/26/12 | Thu 1/3/13 | As Soon As Possible |
| 72 | | Commission unit | 2 days | Fri 1/4/13 | Mon 1/7/13 | As Soon As Possible |
| 73 | | **Building & Systmes** | **122 days** | **Thu 5/24/12** | **Fri 11/9/12** | **As Soon As Possible** |
| 74 | | Engineer | 12 wks | Thu 5/24/12 | Wed 8/15/12 | As Soon As Possible |
| 75 | | Modify and Refurbish | 7 days | Tue 10/30/12 | Wed 11/7/12 | As Soon As Possible |
| 76 | | Commission unit | 2 days | Thu 11/8/12 | Fri 11/9/12 | As Soon As Possible |
| 77 | | Complete Unit Test - Lease Parts | 5 days | Tue 2/5/13 | Mon 2/11/13 | As Soon As Possible |
| 78 | | Complete Unit Test - Original Replacement | 5 days | Tue 2/5/13 | Mon 2/11/13 | As Soon As Possible |
| 79 | | Gas Turbine (GT) In-service (I/S) - Lease Parts | 0 days | Mon 2/11/13 | Mon 2/11/13 | As Soon As Possible |
| 80 | | Gas Turbine (GT) In-service (I/S) - Original | 0 days | Mon 2/11/13 | Mon 2/11/13 | As Soon As Possible |
| 81 | | **UNIT OUTAGE -Lease Parts** | **188 days** | **Thu 5/24/12** | **Mon 2/11/13** | **As Soon As Possible** |
| 82 | | Unit Outage Start | 0 days | Thu 5/24/12 | Thu 5/24/12 | As Soon As Possible |
| 83 | | Unit Outage End | 0 days | Mon 2/11/13 | Mon 2/11/13 | As Soon As Possible |
| 84 | | **UNIT OUTAGE - Original** | **9 days** | **Wed 1/30/13** | **Mon 2/11/13** | **As Soon As Possible** |
| 85 | | Unit Outage Start | 0 days | Wed 1/30/13 | Wed 1/30/13 | As Soon As Possible |
| 86 | | Unit Outage End | 0 days | Mon 2/11/13 | Mon 2/11/13 | As Soon As Possible |




Project: Project1 Exist & Repla Lease
Date: Mon 8/29/11

Critical | Critical Split | Critical Progress | Task | Split | Task Progress | Baseline | Baseline Split | Baseline Milestone | Milestone | Summary Progress | Summary | Project Summary | External Tasks | External Milestone | Deadline

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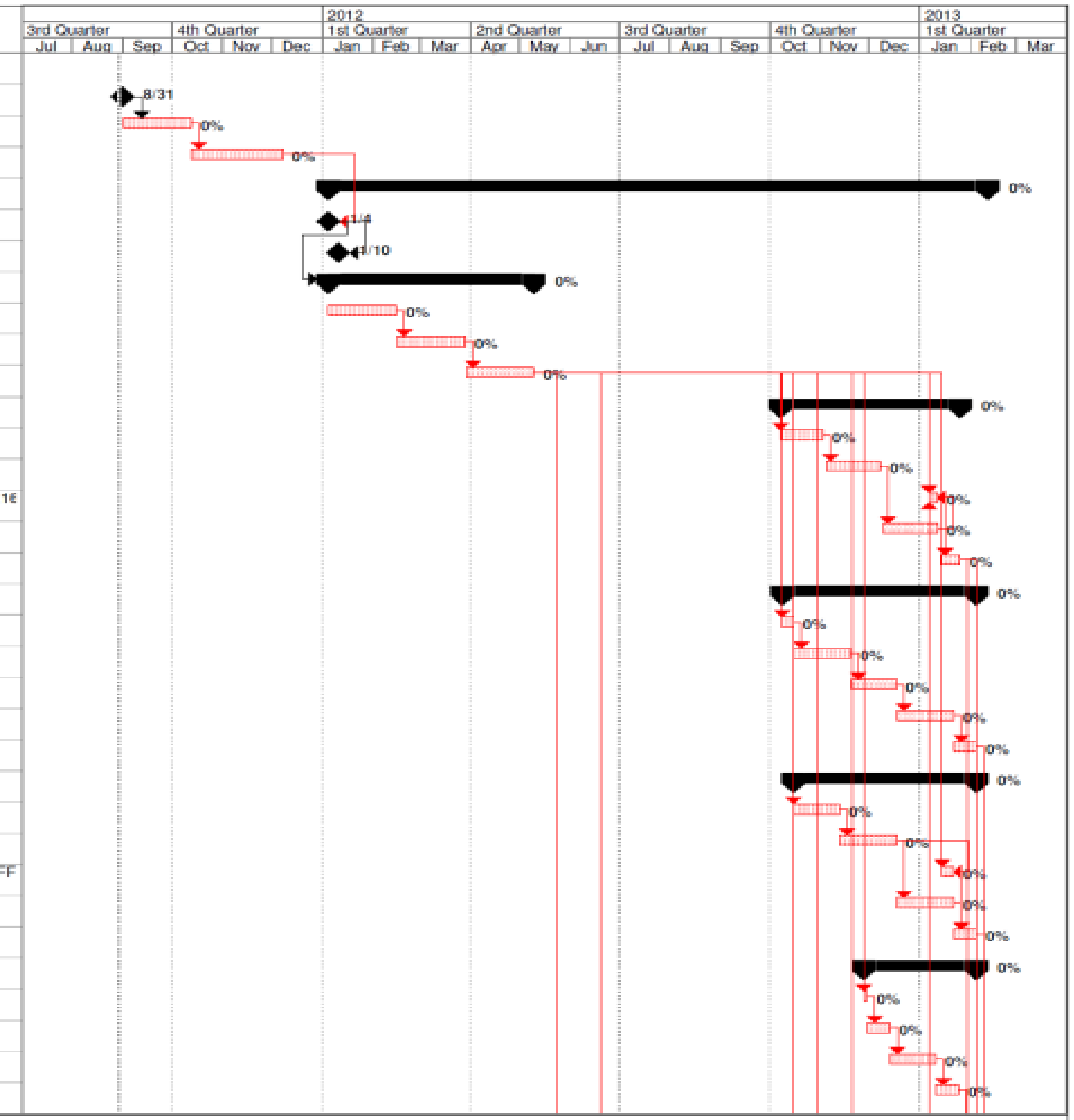
Figure 2-11 presents a third variation of the basic "earliest return to service" schedule for the existing GTG unit refurbishment. It assumes the purchase and refurbishment for use of used replacements parts for the existing GT unit (the gas generator, the power turbine) to minimize the outage window. Its in-service date is February 2013, but with an outage window of only four months from November 2012 to February 2013. The outage also occurs when Holyrood is normally required to operate, and the actual schedule would likely be shifted six months to allow for a May 2013 to August 2013 outage and August 2013 in-service.

**FIGURE 2-11 EXISTING GTG REFURBISHMENT – ALTERNATE SCHEDULE 3 (USE OF PROCURED AND REFURBISHED GAS GENERATOR AND POWER TURBINE DURING OUTAGE)**

| ID | | Task Name | Duration | Start | Finish | Constraint Type | Predecessors |
|---|---|---|---|---|---|---|---|
| 1 | | | | | | | |
| 2 | | Condition Assessment Study | 0 wks | Wed 8/31/11 | Wed 8/31/11 | Finish No Earlier Than | |
| 3 | | Hydro Internal Capital Budget Proposal Development | 6 wks | Thu 9/1/11 | Wed 10/12/11 | As Soon As Possible | 2 |
| 4 | | Submission - Public Utilities Board & Approval | 8 wks | Thu 10/13/11 | Wed 12/7/11 | As Soon As Possible | 3 |
| 5 | | **Refurbish Unit** | **288 days** | **Wed 1/4/12** | **Mon 2/11/13** | **As Soon As Possible** | |
| 6 | | Project Limited Notice to proceed (LNTP) Approval | 0 days | Wed 1/4/12 | Wed 1/4/12 | As Soon As Possible | 4FF+4 wks |
| 7 | | Project Full Notice to proceed (NTP) | 0 days | Tue 1/10/12 | Tue 1/10/12 | As Soon As Possible | 6FF+4 days |
| 8 | | **Request for Proposal (RFP) - Engineer/Procure/Co** | **90 days** | **Thu 1/5/12** | **Wed 5/9/12** | **As Soon As Possible** | 6 |
| 9 | | Prepare | 30 days | Thu 1/5/12 | Wed 2/15/12 | As Soon As Possible | |
| 10 | | Bid | 30 days | Thu 2/16/12 | Wed 3/28/12 | As Soon As Possible | 9 |
| 11 | | Award | 30 days | Thu 3/29/12 | Wed 5/9/12 | As Soon As Possible | 10 |
| 12 | | **Power Turbine (PT)** | **80 days** | **Mon 10/8/12** | **Fri 1/25/13** | **As Soon As Possible** | |
| 13 | | Procure Refurbished Disc and PT Assembly | 4 wks | Mon 10/8/12 | Fri 11/2/12 | As Late As Possible | 11 |
| 14 | | Refurbish PT Replacement | 5 wks | Mon 11/5/12 | Fri 12/7/12 | As Late As Possible | 13 |
| 15 | | Strip and dissassemble plant | 1 wk | Mon 1/7/13 | Fri 1/11/13 | As Late As Possible | 37,11FS+2 wks,16 |
| 16 | | Ship Rotor to Holyrood | 5 wks | Mon 12/10/12 | Fri 1/11/13 | As Soon As Possible | 14 |
| 17 | | Rebuild and commission unit | 2 wks | Mon 1/14/13 | Fri 1/25/13 | As Soon As Possible | 16,15 |
| 18 | | **Gear Box Overhaul** | **85 days** | **Tue 10/9/12** | **Mon 2/4/13** | **As Soon As Possible** | |
| 19 | | Strip and dissassemble plant | 1 wk | Tue 10/9/12 | Mon 10/15/12 | As Late As Possible | 11FS+4 wks |
| 20 | | Ship to overhaul plant | 5 wks | Tue 10/16/12 | Mon 11/19/12 | As Late As Possible | 19 |
| 21 | | Overhaul and balance Rotor | 4 wks | Tue 11/20/12 | Mon 12/17/12 | As Late As Possible | 20 |
| 22 | | Ship to Holyrood | 5 wks | Tue 12/18/12 | Mon 1/21/13 | As Soon As Possible | 21 |
| 23 | | Rebuild and commission unit | 2 wks | Tue 1/22/13 | Mon 2/4/13 | As Soon As Possible | 22 |
| 24 | | **Avon Gas Generator Overhaul** | **80 days** | **Tue 10/16/12** | **Mon 2/4/13** | **As Soon As Possible** | |
| 25 | | Procure Refurbished Disc and PT Assembly | 4 wks | Tue 10/16/12 | Mon 11/12/12 | As Late As Possible | 11 |
| 26 | | Refurbish PT Replacement | 5 wks | Tue 11/13/12 | Mon 12/17/12 | As Late As Possible | 25 |
| 27 | | Strip and dissassemble plant | 1 wk | Tue 1/15/13 | Mon 1/21/13 | As Late As Possible | 11FS+2 wks,26FF |
| 28 | | Ship Rotor to Holyrood | 5 wks | Tue 12/18/12 | Mon 1/21/13 | As Soon As Possible | 26 |
| 29 | | Rebuild and commission unit | 2 wks | Tue 1/22/13 | Mon 2/4/13 | As Soon As Possible | 28,27 |
| 30 | | **Generator Rewind** | **49 days** | **Wed 11/28/12** | **Mon 2/4/13** | **As Soon As Possible** | |
| 31 | | Strip and dissassemble plant | 2 days | Wed 11/28/12 | Thu 11/29/12 | As Late As Possible | 11FS+2 wks |
| 32 | | Ship Rotor to overhaul plant | 2 wks | Fri 11/30/12 | Thu 12/13/12 | As Late As Possible | 31 |
| 33 | | Overhaul, rewind, and balance Rotor | 4 wks | Fri 12/14/12 | Thu 1/10/13 | As Late As Possible | 32 |
| 34 | | Ship Rotor to Holyrood | 2 wks | Fri 1/11/13 | Thu 1/24/13 | As Soon As Possible | 33 |




Project: Project1 Exist Repla GT parts
Date: Mon 8/29/11

Critical | Task | Baseline | Milestone | Project Summary | Deadline
Critical Split | Split | Baseline Split | Summary Progress | External Tasks
Critical Progress | Task Progress | Baseline Milestone | Summary | External Milestone

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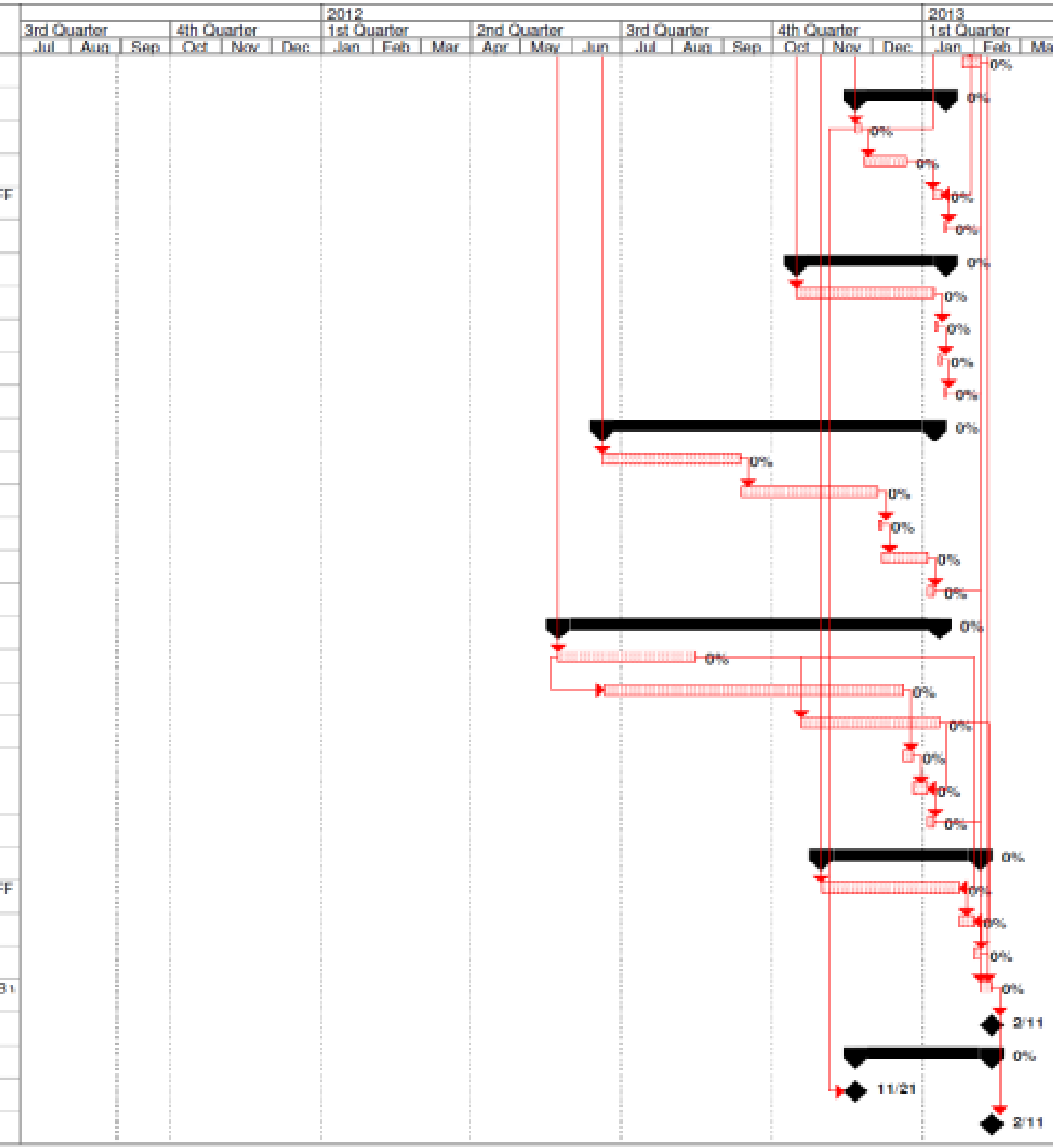
| ID | | Task Name | Duration | Start | Finish | Constraint Type | Predecessors |
|---|---|---|---|---|---|---|---|
| 35 | | Rebuild and commission unit | 7 days | Fri 1/25/13 | Mon 2/4/13 | As Soon As Possible | 34 |
| 36 | | **Exhaust Stack** | **39 days** | **Wed 11/21/12** | **Mon 1/14/13** | **As Soon As Possible** | |
| 37 | | Remove | 3 days | Wed 11/21/12 | Fri 11/23/12 | As Late As Possible | 11FS+2 wks |
| 38 | | Repair/Replace | 4 wks | Mon 11/26/12 | Fri 12/21/12 | As Late As Possible | 37 |
| 39 | | Re-install | 5 days | Mon 1/7/13 | Fri 1/11/13 | As Late As Possible | 38FS+2 wks,17FF |
| 40 | | Commission unit | 1 day | Mon 1/14/13 | Mon 1/14/13 | As Soon As Possible | 39 |
| 41 | | **Intake media** | **65 days** | **Tue 10/16/12** | **Mon 1/14/13** | **As Soon As Possible** | |
| 42 | | Order & Manufacture Filter media | 12 wks | Tue 10/16/12 | Mon 1/7/13 | As Late As Possible | 11FS+2 wks |
| 43 | | Remove | 2 days | Tue 1/8/13 | Wed 1/9/13 | As Late As Possible | 42 |
| 44 | | Repair/Replace | 2 days | Thu 1/10/13 | Fri 1/11/13 | As Late As Possible | 43 |
| 45 | | Commission unit | 1 day | Mon 1/14/13 | Mon 1/14/13 | As Soon As Possible | 44 |
| 46 | | **Fuel System Refurbishments** | **144 days** | **Wed 6/20/12** | **Mon 1/7/13** | **As Soon As Possible** | |
| 47 | | Engineer | 12 wks | Wed 6/20/12 | Tue 9/11/12 | As Late As Possible | 11FS+2 wks |
| 48 | | Order, Manufacture, Deliver | 12 wks | Wed 9/12/12 | Tue 12/4/12 | As Late As Possible | 47 |
| 49 | | Remove | 2 days | Wed 12/5/12 | Thu 12/6/12 | As Late As Possible | 48 |
| 50 | | Repair/Replace | 4 wks | Fri 12/7/12 | Thu 1/3/13 | As Late As Possible | 49 |
| 51 | | Commission unit | 2 days | Fri 1/4/13 | Mon 1/7/13 | As Soon As Possible | 50 |
| 52 | | **Electrical & Control Systmes** | **166 days** | **Thu 5/24/12** | **Thu 1/10/13** | **As Soon As Possible** | |
| 53 | | Engineer | 12 wks | Thu 5/24/12 | Wed 8/15/12 | As Late As Possible | 11FS+2 wks |
| 54 | | Order & Manufacture Elect & Control Equip | 26 wks | Thu 6/21/12 | Wed 12/19/12 | As Late As Possible | 53SS+4 wks |
| 55 | | GT Building Addition | 12 wks | Fri 10/19/12 | Thu 1/10/13 | As Late As Possible | 53 |
| 56 | | Remove Existing | 4 days | Thu 12/20/12 | Tue 12/25/12 | As Late As Possible | 54 |
| 57 | | Install New System | 7 days | Wed 12/26/12 | Thu 1/3/13 | As Late As Possible | 56,55FF-1 wk |
| 58 | | Commission unit | 2 days | Fri 1/4/13 | Mon 1/7/13 | As Soon As Possible | 57 |
| 59 | | **Building & Systems** | **69 days** | **Wed 10/31/12** | **Mon 2/4/13** | **As Soon As Possible** | |
| 60 | | Engineer | 12 wks | Wed 10/31/12 | Tue 1/22/13 | As Late As Possible | 11FS+2 wks,53FF |
| 61 | | Modify and Refurbish | 7 days | Wed 1/23/13 | Thu 1/31/13 | As Late As Possible | 60,55FF |
| 62 | | Commission unit | 2 days | Fri 2/1/13 | Mon 2/4/13 | As Soon As Possible | 61 |
| 63 | | Complete Unit Test | 5 days | Tue 2/5/13 | Mon 2/11/13 | As Soon As Possible | 29,35,17,40FS+3 |
| 64 | | Gas Turbine (GT) In-service (I/S) | 0 days | Mon 2/11/13 | Mon 2/11/13 | As Soon As Possible | 63 |
| 65 | | **UNIT OUTAGE** | **59 days** | **Wed 11/21/12** | **Mon 2/11/13** | **As Soon As Possible** | |
| 66 | | Unit Outage Start | 0 days | Wed 11/21/12 | Wed 11/21/12 | As Soon As Possible | 37SS |
| 67 | | Unit Outage End | 0 days | Mon 2/11/13 | Mon 2/11/13 | As Soon As Possible | 63 |




Project: Project1 Exist Repla GT parts
Date: Mon 8/29/11

Critical | Critical Split | Critical Progress | Task | Split | Task Progress | Baseline | Baseline Split | Baseline Milestone | Milestone | Summary Progress | Summary | Project Summary | External Tasks | External Milestone | Deadline

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## 2.9 Annual OMA Cost Estimate to 2020

### 2.9.1 Historical OMA

Historical operations, maintenance and administration (OMA) data was obtained from the station cost database for the period 2000 to 2011. Information prior to that was not available. Also provided were several recent purchase order invoices from Alba Power for recent boroscope and physical inspections that are assumed to be included in the work order totals, but which may be somewhat out of synchronization. Copies of the "Cost Report by Work Order/Asset" are attached in Appendix 3.

**TABLE 2-32 HISTORICAL OMA COST ASSUMPTIONS**

**OMA**

| | Maintenance | | Fueling | Ops | Total |
|---|---|---|---|---|---|
| Year | Work Order k$/Yr OMA | PO Data k$/Yr OMA | k$/Yr Fuel | PO Data k$/Yr OMA | Work Order k$/Yr OMA |
| 2000-2002 | $10 | | | | |
| 2003 | $14 | | $37 | $33 | $83 |
| 2004 | $31 | | $37 | $33 | $100 |
| 2005 | $19 | | $37 | $33 | $89 |
| 2006 | $129 | $100 | $201 | $59 | $388 |
| 2007 | $34 | $74 | $201 | $59 | $293 |
| 2008 | $45 | $15 | $201 | $59 | $304 |
| 2009 | $283 | $182 | $201 | $59 | $542 |
| 2010 | $45 | $50 | $201 | $59 | $304 |
| 2011 | $182 | | $22 | $8 | $212 |
| Av/Yr Hist | $68 | $84 | $126 | $44 | $257 |

Most of the historical costs are for relatively minor repairs and do not include major changes such as controls change outs or other major capital modifications. These major costs are not particularly relevant to the OMA analyses going forward.

Several interesting issues arose during the period:

- Ice and snow blockage of parts of lube oil cooler and fuel oil system (led to enclosure of pumps and filters) identified beginning in 2004 and beyond
- GT generator vibration checks (issue) in 2007
- Leak and pressure check on GT gearbox in 2006. Filter not cleaned regularly. Issue in 2003 (last cleaned filter). Fittings change. Gearbox drain valve change -
- Modify/Addition of gear box lube oil vent to relieve pressure in 2007 and 2008
- Lube oil at gearbox cleanup in 2008, 2009, Attempt to fix by Alba 2010; Increase generator end gearbox bearing drain. Fire 2010/2011.
- Several issues in recent years with snow doors operation and rusting, annual checks done
- 2008 lube oil radiator leak

Several major systems had been replaced/modified: controls (twice), gearbox seals, lube oil radiator

### 2.9.2 Estimated Future OMA

Operating and maintenance (O&M) costs going forward for completely refurbished or new units are not significantly relevant given their level of operation. Most such O&M costs will be for ongoing annual inspection costs. Significant maintenance costs as have been seen recently with the existing unit should not occur if regular inspection and maintenance is undertaken. For completeness, the costs were assumed to include the ongoing maintenance costs (annual inspections, repairs, etc.), the operations costs (costs to run the unit on test), the fuelling costs (fuel costs to run the tests), and an electricity value credit.

The operating costs are shown for both a refurbished case and a non-refurbished case. The assumptions used for fuel, operations, and electricity value are illustrated in Table 2-33. The "electricity value" is a revenue stream premised on recovering fuelling costs plus marginal operating and maintenance costs. The maintenance costs are based on historical maintenance data and information from vendors. The fuelling and electricity prices are intended as representative and based on running the units 150 hours per year, whereas actual hours could be as half of this.. The actual values (average run capacity, sent out heat rate (SOHR) and hence fuel and electricity depend on how the testing is actually done.

**TABLE 2-33 EXISTING GTG – FUTURE OMA COST ASSUMPTIONS**

**Assumptions**

| | | Fuelling |
|---|---|---|
| #2 Oil Fuel Price (A) | $/MMBTU | $21.47 |
| Unit Efficiency (B) | BTU/kWh | 13,656 |
| Average Running Capacity (C) | MW | 4 |
| Average Running Cost (D) = AxBxC/1000 | $/Hr | $1,173 |
| Electricity Value (E) = AxB/1000 + $50 Mtce | $/MWh | $343 |
| Electricity Value (F) = E*C | $/Hr OP | $1,373 |

| Operations | |
|---|---|
| 2 | Persons/Start (U) |
| 4 | Hrs/Start (V) |
| $70 | $/PersonHr (W) |
| $560 | $/Start (Z) = UxVxW |

The following OMA costs have been assumed going forward. The non-refurbished case includes an assumption of an equipment failure with modest consequential damage in 2016. "Electricity value" is a revenue stream for electricity sold during testing.

**TABLE 2-34 EXISTING GTG – FUTURE OMA COSTS**

**Existing Unit**
**1000's Cnd $ - 2011/Yr**

| | Maintenance | | Operations | | Fuelling | | Sub-Total | | Electricity Value | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | With Rehab | Without Rehab | With Rehab | Without Rehab | With Rehab | Without Rehab | With Rehab | Without Rehab | With Rehab | Without Rehab | With Rehab | Without Rehab |
| 2012 | $15 | $15 | $0 | $0 | $0 | $0 | $15 | $15 | $0 | $0 | $15 | $15 |
| 2013 | $20 | $15 | $40 | $0 | $176 | $0 | $236 | $15 | ($206) | $0 | $30 | $15 |
| 2014 | $20 | $15 | $40 | $0 | $176 | $0 | $236 | $15 | ($206) | $0 | $30 | $15 |
| 2015 | $20 | $15 | $40 | $0 | $176 | $0 | $236 | $15 | ($206) | $0 | $30 | $15 |
| 2016 | $20 | $1,500 | $40 | $1 | $176 | $88 | $236 | $1,589 | ($206) | ($103) | $30 | $1,486 |
| 2017 | $20 | $15 | $40 | $0 | $176 | $0 | $236 | $15 | ($206) | $0 | $30 | $15 |
| 2018 | $20 | $15 | $40 | $0 | $176 | $0 | $236 | $15 | ($206) | $0 | $30 | $15 |
| 2019 | $20 | $15 | $40 | $0 | $176 | $0 | $236 | $15 | ($206) | $0 | $30 | $15 |
| 2020 | $0 | $0 | $40 | $0 | $176 | $0 | $216 | $0 | ($206) | $0 | $10 | $0 |
| TOTAL | $155 | $1,605 | $323 | $1 | $1,408 | $88 | $1,885 | $1,694 | ($1,648) | ($103) | $238 | $1,591 |

The actual maintenance costs going forward can be expected to vary widely and could easily be twice those noted, depending on the actual operation of the unit. The costs for operations and for fuel, as well as fuel value are comparable in value or larger.

# 3 TASK B – REPLACEMENT OPTIONS ASSESSMENT

## 3.1 Task Details

Mobile/transportable GT and diesel generators were evaluated for their ability to provide Holyrood Thermal Generating Station with black start capability until the year 2020. Following 2020, it is expected the Holyrood plant will no longer be operating as a generating facility**.** The mobile/transportable gas turbine and diesel generators would be available post-2020 for other temporary power uses within NL Hydro's system, and possibly for similar uses prior to 2020 as warranted.

## 3.2 Assessment Basis

The assessment will be based on an evaluation of Hydro and vendor supplied information regarding the existing Holyrood infrastructure, and new or nearly new transportable power generation units which will either be GT or diesel.

**TABLE 3-1 ASSESSMENT CRITERIA**

| Criteria | Description |
|---|---|
| Generator | 1) Gas Turbine Gen Set 5 MW X 2 – new or nearly new/used<br>2) Diesel Gen Set 2 MW X5 – new or nearly new/used |
| Transportability | Transportability - system must be capable of being set up within a week, to ensure that the system can be used elsewhere as needed, particularly after its service has ended at Holyrood. Must comply with local road regulations. |
| Footprint | Minimize space site requirement of the generator. Set selected must be able to fit on the parking lot adjacent to the emergency response building. This site was selected through discussions with Nalcor personnel. |
| Electrical output | The system must be able to generate at 13.8 KV, combined system output to be approximately 10 MW peak, with a block load of about 3 to 3.5 MW. |
| Black Start | Systems must be capable of black start function for the plant and require no more than 600 volt 316 kW for black start |
| Fuel Type | Must use No. 2 fuel oil |
| Site Preparation | Unit trailers must be self levelling and require no concrete foundation. |
| Certification | CSA Certification |
| Emissions | **Diesel Gensets**: The equipment is assumed to be classified as stationary. The province has jurisdiction, and all existing regulations apply. (In Ontario, the generally accepted practice is that a unit is considered to be stationary if it remains within the same municipal boundaries for 12 continuous months regardless if it's mounted on wheels or not.)<br>Regulations require a dispersion model be prepared to demonstrate compliance with regulations of ground level concentrations of pollutants at the property boundaries or nearest critical receptor. The key parameter is oxides of nitrogen (NOx) and the permitted concentration limit is, for non-emergency generation, |

| | |
|---|---|
| | 400 micro-grams per cubic meter of air.<br>The emergency generator limit permitted in NL is not readily identifiable (Ontario $NO_x$ concentration limit for emergency generators is 1880 mg/m3 of air).<br>Newfoundland & Labrador air emissions regulations do require Best Available Control Technology (BACT), but provide for reasonable economics and also for Ministerial exemptions. This would need to be addressed in environmental regulatory approvals.<br>**GT Gensets:** Canadian Council of Ministers of the Environment (CCME) 1992 National Emission Guidelines for Stationary Combustion Turbines may be followed. They do not apply to "Emergency" or "Standby GT" (a unit not normally required for the supply of energy or motive power to meet normal system operational requirements. A "Peaking GT" is a unit ordinarily used to supply electric or motive power in periods of high demand but typically has restricted hours (<3000 hours over 5 years in summer; <7500 hours over 5 years total). The GT Emission Guideline values for diesel fuel are as follows. These units may, however, still have to meet ground level concentration limits, assumed to be 400 ug/$m^3$ of air, based on dispersion modeling.<br>Peaking — Emergency<br>$NO_X$ — 530 g/GJ — Exempt<br>Notes:<br>g/GJ = grams of NOx as nitrogen dioxide (NO2) per gigajoule (GJ) of net electrical energy output (where 1 megawatthour (MWh) of electricity = 3.6 GJ.<br>AMEC has assessed the diesel emission regulations and considers that the installation would be considered a "stationary source". It is likely to also be considered an emergency unit. |

## 3.3 Options 2 – 2 x 5 MW GT (New, Nearly-New)

### 3.3.1 Description

In this option, two 5 MW units would be utilized to provide black start capability. Sizing at 5 MW each would allow the units to be more transportable than larger units. Both units would be required to operate simultaneously to provide sufficient power for black start. Vendor information was received from TOROMONT CAT, PETERSON Power Systems CAT, Solar Turbines, and Rolls Royce/Allison Turbine.

These will be mobile units supplied by a vendor and will not require a GT building. Several items will however be required, such as:

- Turbine trailers area with site work to ensure sufficient ground support for the mobile turbines.
- A pre-engineered shelter for electrical equipment, including concrete foundation and floor slab. Approximately 30 ft x 30 ft.
- A reinforced concrete pipe/trench for cables running from the turbines to the main building and from the turbines to the existing fuel lines.
- Electrical and I&C connections to the existing plant facilities

### 3.3.2 Performance Characteristics

The performance characteristics are based on information from Solar Turbines Taurus 60, (**APPENDIX 4).** Vendors are Peterson, Toromont, and Solar. Peterson also sells used Taurus 60 gen packages.

**TABLE 3-2 TURBINE PERFORMANCE CRITERIA**

| Criteria | Value |
|---|---|
| KW Gross Output @ ISO Conditions | 5,510kW |
| Voltage | 13.8 KV |
| Site Ambient Temperature for Performance Analysis: | 15 C (59 F) |
| Site Elevation for Performance Analysis: | 320 Feet |
| Site Ambient Relative Humidity for Performance Analysis: | 60% |
| Turbine Inlet Pressure Loss: | 4" H20 (inches of water gauge pressure) |
| Turbine Outlet Pressure Loss: | 4"H20 |
| Turbine Fuel Consumption @ specified site conditions (Lower Heating value(LHV) | 59 MBTU/hr (Millions of British Thermal Units Per Hour) |
| KW Gross Output @ specified site conditions: | 5,301 kW |
| Turbine Auxiliary Power Consumption: | 15 kW |
| Net Turbine Power Production | 5,286 kW |
| Black Start kW Requirement (Turbine Generator Set Only) | A 250kW, 480VAC, 3 phase, Black Start Generator is required for turbine starting in the event 13.8kV power is not available. |
| Fuel Consumption | 8.0 gallons per minute (gpm) (30 Liters/min (L/min)). This implies for black start with two units running there would be a total of 16 gpm (60 L/min) and assuming a 24 hour period would require almost 24,000 gallons (90,849 L) of fuel. The current fuel oil tanks as previously noted are 26,417 gallons (100,000 L) each. |
| Inlet Filter Media | Suitable for Marine Environment |

#### 3.3.2.1 Emission Requirements

For a peaking GT unit on oil emission limits would be:

| | |
|---|---|
| $NO_x$ (Oxides of Nitrogen (NO,$NO_2$): | 530 g ($NO_x$ as $NO_2$)/ GJ electric energy (1 MWh = 3.6 GJ). |
| $SO_2$ (Sulphur dioxide): | 970 g $SO_2$/GJ of electric output. Current 0.2% sulphur (S) in oil (specification) = approximately1572 grams as $NO_2$/GJ output |
| CO (Carbon Monoxide): | 50 ppm at full load (corrected to 15% O2, dry basis) |

Operating time limits could be placed on peaking units. An emergency unit for black start only might be exempt, but could thereby limit its future.

No specific GT applicable Newfoundland air pollution regulations were identified. There is however a general requirement for Best Available Control Technology (BACT), with provisions for an exemption based on economics and on a Ministerial exemption for practical purposes. The typical emission performance for Solar GT units on diesel oil is presented in Table 3-3.

**TABLE 3-3 SOLAR GT TYPICAL EMISSIONS**

| Exhaust Emissions At Stack (Solar) | Measurement | Per Unit |
|---|---|---|
| $NO_x$ | parts per million (ppm) @ 15% O2 in flue gas | 74 |
| | lb/MMBTU, HHV (Pounds/Million BTU, Higher Heating Value) | 0.284 |
| | Pounds/Hour (lb/hr) | 17.8 |
| | tons/year | 78 |
| CO (Carbon Monoxide) | ppm @ 15% O2 | 25 |
| | lb/MMBTU, HHV | 0.058 |
| | lb/hr | 3.7 |
| | tons/year | 16 |
| UHC (Unburnt Hydrocarbons | ppm @ 15% O2 | 25 |
| | lb/MMBTU, HHV | 0.033 |
| | lb/hr | 2.1 |
| | tons/year | 9.2 |
| VOC Volatile Organic Compounds | ppm @ 15% O2 | 25 |
| | lb/MMBTU, HHV | 0.033 |
| | lb/hr | 2.1 |
| | tons/year | 9.2 |
| $PM_{10}/PM_{2.5}$ (Particulate Matter – Less than 10 and 2.5 microns in size) | lb/hr | 2.4 |
| | lb/MMBTU, HHV | 0.039 |
| | tons/year | 10.7 |
| $SO_2$ | lb/hr | 12.91 |
| | lb/MMBTU, HHV | 0.20555 |
| | tons/year | 56.5 |
| Greenhouse Gas Emissions | lbs of carbon dioxide ($CO_2$)/MMBTU (HHV) | 162 |

$SO_2$ emissions depend upon the fuel's sulfur content. The $SO_2$ estimate is based upon the assumption of 100% conversion of fuel sulphur to $SO_2$, using assumed values for various fuels that may not reflect actual fuel composition.

#### 3.3.2.2 Transition

The existing GT system is to remain active while new system is independently installed. A short outage will be required during a transition period during which final connections to the electrical, instrumentation and controls, and fuel systems are made.

#### 3.3.2.3 Decommissioning

The existing GT unit will be decommissioned, including those parts of the fuel system and electrical connections not required for the new units. This will occur once the new transportable units are in place and operational. A modified fuel offloading/receiving system will remain.

### 3.3.3 General Arrangement Sketch

See attached GA sketch based on dimensional information provided by Solar Turbines located in Appendix 4.

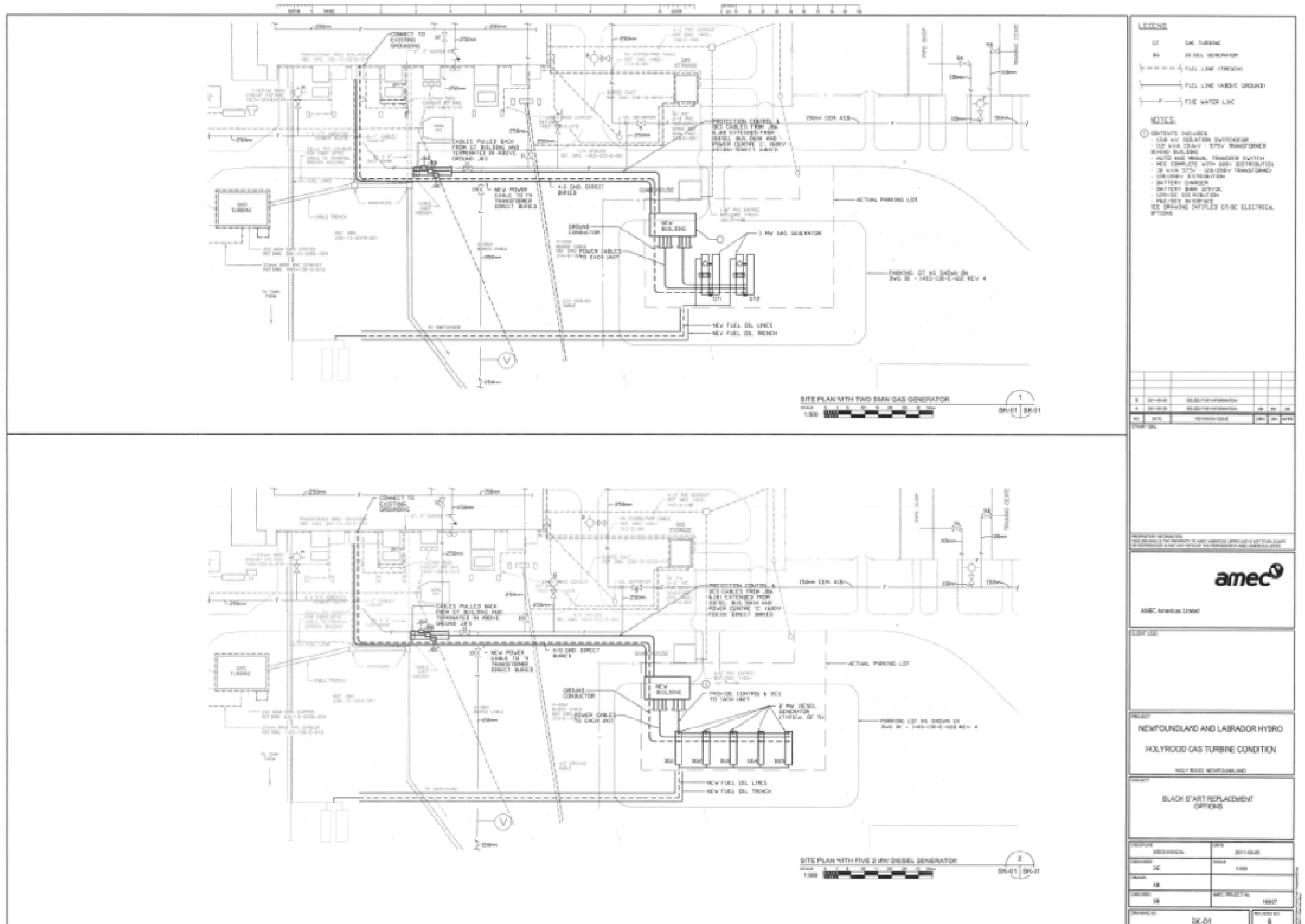



**FIGURE 3-1 GENERAL ARRANGEMENT - 2 X 5 MW GAS TURBINE GENERATORS**

### 3.3.4 Capital Cost Estimate

The following estimates are based on budgetary information provided by Solar Turbines (Details in Appendix 4) and Peterson Power Systems (Details in Appendix 5), and Rolls Royce (details in Appendix 6). Following a review of the vendor information, it appears that used units can be available much quicker than a new purchase. The vendors contacted noted that they did not typically have many of these systems available and that they are sold fairly quickly. On Power Inc who use the Rolls Royce 501 turbine noted that they have 4 units being refurbished for sale which may be able to convert to a mobile configuration. The price would be approximately $ 1 M less than a new package.

Note that Peterson Power Systems deals with the rental and sale of used Taurus mobiles whereas Solar Turbines deals with the sale only of new Taurus mobiles. Rolls Royce has indicated that they would require about 1 year for delivery.

There is not expected to be a significant difference in price between the New and Nearly New options, the advantage between these options is the possibility that a Nearly New set of units will be available and lead/delivery times are significantly reduced.

**TABLE 3-4 SOLAR TURBINE QUOTE FOR NEW TRANSPORTABLE GTG**

| Item | Description | Unit Price | Quantity | Cost |
|---|---|---|---|---|
| 1. | Liquid Fuel TAURUS 60-7901S Mobile Power Unit Turbine Generator Set (New) Solar Quote **APPENDIX 4** | $4,535,000.00 | 2 | $9,070,000.00 |
| 2. | Commissioning Parts, Start-up, and Site Testing | $70,000 | 2 | $140,000 |
| 3 | Shipping | $92,100 | 2 | $184,200 |
| 4 | 6% Balance of Plant Contingency | $5,500 | 2 | $11,000 |
| 5 | Estimation of cost per ISO rating kilowatt for selected equipment | $853 | | $0 |
| 6* | Training* | $9720 | 1 | $29,160 |
| 7 | Mobile Winterization Package (-40 C) | $219,000 | 2 | $438,000 |
| 8 | Marine Grade Inlet Air filter | $12,000 | 2 | $24,000 |
| | | | | $9,896,360 |

- Duties and taxes not included in estimate.
- This quote is provided for budgetary purposes only and does not represent a firm quote.
- Based on Peterson rates.

**TABLE 3-5 ROLLS ROYCE QUOTE FOR NEW TRANSPORTABLE GTG**

| Item | Description | Unit Price | Quantity | Cost |
|---|---|---|---|---|
| 1. | Rolls Royce Allison 501-KB7 mobile GenSet, **APPENDIX 6** | $4,300,000.00 | 2 | $8,600,000.00 |
| 2. | Commissioning Parts, Startup, and Site Testing | $70,00.00 | 2 | $140,000.00 |
| 3 | Shipping | $92,100.00 | 2 | $184,200.00 |
| 4 | 6% Balance of Plant Contingency | $5,500.00 | 2 | $11,000.00 |
| 5 | Estimation of cost per ISO rating kilowatt for selected equipment | $853.00 | | $0.00 |
| 6 | Training | $9720.00 | 3 | $29,160.00 |
| 7 | Mobile Winterization Package (-40 C) | $219,000.00 | 2 | $438,000.00 |
| 8 | Marine Grade Inlet Air filter | $12,000.00 | 2 | $24,000.00 |
| | | | | $9,426,360.00 |

**TABLE 3-6 PETERSON QUOTE FOR NEARLY NEW/USED GT'S**

| Item | Description | Unit Price | Quantity | Cost |
|---|---|---|---|---|
| 1. | Liquid Fuel TAURUS T60 Mobile Power Unit Turbine Generation I Generator Set (Used) Peterson Quote (APPENDIX 5) | $3,800,000.00 | | $7,600,000 |
| 2. | Commissioning Parts, Startup, and Site Testing | $ 63,900.00 | | $127,800 |
| 3 | Shipping | $ 92,100.00 | | $184,200 |
| 4 | 6% Balance of Plant Contingency | $ 5,500.00 | | $11,000 |
| 5 | Estimation of cost per ISO rating kilowatt for selected equipment | $ 853.00 | | $0 |
| 6 | Training | $ 9,720.00 | | $29,160 |
| 7 | Mobile Winterization Package (-40 C) | $ 219,000.00 | | $438,000 |
| 8 | Marine Grade Inlet Air filter | $ 12,000.00 | | $24,000 |
| | | | | $8,414,160 |

### 3.3.4.1 Gas Turbine Trailer Units

For consideration under this project, GT packaged trailer systems shall have the following systems and items included with the gas turbine trailer or support trailer. The following is based on information provided by Solar Turbine (Appendix 4).

**TABLE 3-7 TRANSPORTABLE GAS TURBINE PACKAGE COMPONENTS**

| Component | Description |
|---|---|
| Turbine MODULE: | 5.2 MW Output, 13.8 Kilovolts, 60 Hertz, Direct drive starter and lube system, Lube oil cooler, Turbine Weatherproof acoustic enclosure, Power control room weatherproof acoustic enclosure, Fuel oil filter, High Temperature Detection and Alarm, Auxiliary Systems, Lights, On Crank and On Line Water Wash, Ventilation Silencers and Fans, CO2 Fire Suppression System, Fire Detection and Gas Monitoring System, High Efficiency Combustion Air Barrier Filter and Silencer, Trailer mounted exhaust stack and silencer, Control System with local and remote interface and monitoring. |
| TURBINE TRAILER (Model TK95LCS) | Tri-Axle Transport Trailer with Two Axle Pivoting Booster Length 48' + 14'1" Booster (removable at site) Width 8'6", 9'0" across trailer axles 133" Swing Clearance 49" 5th wheel Height (loaded) Air Ride Suspension and Air Raise and Lowering Kit Steel Disc Wheels with 275/70R x 22.5 Tire Three Tail Light Package Landing Gear (2) 6 Additional Landing Gears with Soil Bearing Plates for Levelling/Stabilization at Site Overall transport height: 14'2" Approximate transport weight: 118,000 lbs (without tractor) |
| POWER CONTROL MODULE (consists of the following): | Power Control Room (PCR) mounted on Two Axle Transport Trailer, Power Control Room HVAC system, Generator Main Circuit Breaker, Single interface point to power grid, Auxiliary Transformer Feeder Circuit Breaker, Bus PTs, Feeder CTs, Metering CTs and PTs, Beckwith M-3425 Protective Relay Module with the following relays:- Impedance (21), Reverse Power Protection (32), Loss of Field Protection (40), Negative Phase Sequence Protection (46), PT Blown Fuse Protection (60), Time Overcurrent Protection (50/51 V), Neutral Overcurrent Protection (51 N) – utilized in grounded site design, Bus Ground Fault Detection (59N) – utilized in ungrounded site design, Generator Differential Fault Protection (87 G), One High Speed Tripping Relay (86) for Circuit Breaker Trip, Lockout, and Turbine Shutdown Settings, Programming, and Testing, Lightning Arrestor and Surge Capacitor, Motor Control Center. Serves Turbine Generator Auxiliary Loads, 120VDC Turbine Generator Battery System with Charger, Dedicated 120VDC Switchgear Battery System with Charger, Start Motor Variable Frequency Drive (VFD), DC Backup Lube Oil Pump Contactor, Interior Lighting, Photocell Controlled Exterior Lighting at Access Doors, Emergency Eyewash Station, Ancillary Equipment. Installed onto the Power Control Room Module are the following: Gas Turbine Lube Oil Cooler, Neutral Ground Resistor, Auxiliary Load Transformer |
| Power Control Room Trailer (Model TK70LCS) | Two Axle Transport Trailer, Trailer Length 46' Overall, Width 8'6", 49" 5th wheel Height (loaded), Air Ride Suspension and Air Raise and Lower Kit, Steel Disc Wheels with 255/70R x 22.5 Tires, Three Tail Light Package, Landing Gear, 4 Additional Landing Gears with Soil Bearing Plates for Levelling/Stabilization at Site, Overall Transport Height: 14'0", Approximate transport weight: 48,000 lbs. (without tractor) |

#### 3.3.4.2 Site Civil Works

Site/civil works requirements are primarily related to the gas turbine generator trailer site, and to electrical and fuel connections. The major costs are expected to be:

- Confirming the bearing capacity of soil = $4,000
- Pre-engineered shelter for elec. equipment = $45,000
- Concrete cable trench = $70,000

Oil piping excavation is included in the cost of the piping.

#### 3.3.4.3 Gas Turbine Generator Unit Modifications

For this application, the gas turbine units should be provided with air filter media suitable for use in a marine environment as well as have coatings on external components designed for such environments.

#### 3.3.4.4 New Gas Turbine Generator Mechanical Requirements

Aside from fuel oil supply, it is expected that the gas turbine units would be self contained and not require any additional mechanical equipment. If required for the water wash system, a water line would be provided.

**Connection and Changes to Existing Oil System**

From supplier information, each turbine at its maximum output would consume fuel at a rate of about 8.0 gpm (30 L/min). This implies for black start with two units running there would be a total of 16 gpm (60 L/min). For a 24 hour period, the fuel oil storage requirement would be about 24,000 gallons (90,849 L) of fuel. The current Fuel oil tanks as previously noted are 26,417 gal (100,000 L) each.

The fuel requirement makes portable tanks impractical for the 8 year solution and this will also have to be considered in the gas turbine transportability consideration. The new gas turbine units will be located approximately 160 m from the existing GT building and will require new fuel oil supply and return piping from the existing system. Since two gas turbines would be provided under this option it is anticipated that only two line connections would be required. Piping could be routed through a trenched containment system.

**TABLE 3-8 NEW GTG – MECHANICAL SYSTEM COSTS**

| Item | Cost |
|---|---|
| 3" supply and return fuel line | $77,100.00 |
| Project Engineering Costs Mechanical | $17,000.00 |

### 3.3.5 New Gas Turbine Option – Electrical, Instrumentation, and Control Requirements

Option 1 is 2 x 5 MW gas turbine generators rated at 13.8 kV. This option involves the replacement of the existing GTG with two (2) GT units rated at 5 MW. Each has a generator output voltage of 13.8kV and is connected to the delta primary of the existing T9 transformer.

#### 3.3.5.1.1 Connections to the Existing Electrical and Control System

Each GT unit will be a completely self contained capable of operating in 'isochronous' or 'droop' mode, having its own main breaker (52), AVR, control and protection, synchronizing, load sharing, paralleling, monitoring and ability to connect to the existing station DCS.

All these functions will connect to a new building. Each generator breaker will be cabled to an item of isolating switchgear. The isolating switchgear will consist of two (2) 13.8kV disconnect switches, one (1) fused disconnect for auxiliaries, and one disconnect for connection of the zig-zag grounding transformer.

An isolation switch allows the individual GT unit to be taken out of service at any time. Each generator breaker (52) is synchronized for connection to the station service bus through the 13.8kV:4160V transformer T9, either individually or as a pair of generators.

The two GT units will be designed with high resistance grounding consisting of a grounding transformer and NGR to limit the ground fault current to less than 10A as normal standard.

The governor and voltage regulation control of the two units is common in utilities. Another advantage is the reliability of the emergency supply source and it is felt the probability of successful starts of one of the two units is better than one GT. For essential auxiliaries loads it requires only one unit running to secure the station during total loss of AC power (black-out).

The 13.8kV fused disconnect FSWI will feed a 112 kVA, 13.8 kV:575 V, 3 phase transformer to provide 600 V service via a new 600 A, 600 V, 3 phase, 60 Hz, 3 W MCC. The MCC will typically provide starters or fused disconnects for pumps, heating, 120/208 V distribution via a 30 kVA transformer and the battery charger. The battery charger supplies the 129 VDC battery and distribution.

Alternative supplies to the MCC will be via an automatic transfer switch (ATS) and a manual transfer switch (MTS), and will be from the diesel bus DB34 and power centre 'C', both in the powerhouse.

Protection and Control/DCS (P&C/DCS) interfaces will combine the requirements of the new units with the requirements of the existing T9 transformer and 4160V breaker SSB2.

#### 3.3.5.1.2 Changes to existing El and C System

The existing protection, control and DCS cables entering the present GT building will be pulled back and terminated in a weatherproof Junction Box (JB). New teck cables will be connected to these existing cables and direct-buried from the JB to the P&C/DCS interface in the new building.

Similarly, the 600 V feeds from the diesel bus DB34 and power centre 'C' will be pulled-back and terminated in weatherproof JB's. New teck cables will be connected to these existing cables and direct-buried from the JB's to the manual transfer switch (MTS) in the new 'building'.

All new weatherproof JB's will be mounted above ground.

Power cables from the common bus of the isolating switchgear to the existing T9 transformer will replace the existing cables, and will be direct-buried from T9 transformer to the switchgear.

Changes will be made as necessary to the P&C located in Panel 13 (in the powerhouse) and also in Panel 2 (in the powerhouse). Screens will be reconfigured in the control room involving the two new units and their monitoring, control, indication, and alarm functions.

Each unit will be capable of operating in parallel when connected to an isolated 4160 V bus through a transformer (T9 Step-down), i.e. isochronous mode load sharing.

Each unit will be capable of energizing step-down transformer T9 to pick-up essential loads on the 4160 V bus.

The two unit operation will be controlled through a master controller to direct which unit is to pick-up dead-bus, and which unit is to synchronize with the other unit.

The start/stop commands are given from the master controller for auto-operation or manually from the control room.

**Voltage Drop on the 4160 V Bus**

The voltage drop on the 4160 V bus during starting the largest MV motor - 3000 horsepower (hp) boiler feed pump (BFP) motor under the condition of both 5 MW units running (in islanded mode) is about 10% below the recommended minimum of 80% by NEMA MGI. At the same time, starting of a 3000 hp BFP with isolation transformer was found to be unacceptable following preliminary simulation calculations from ETAP. Therefore a detailed procedure must be prepared for the black-start of MV motors.

### 3.3.5.2 4160 V Generator Voltage Option

The 2 x 5 MW generators with outputs at 4160 V are no longer considered for the following reasons:

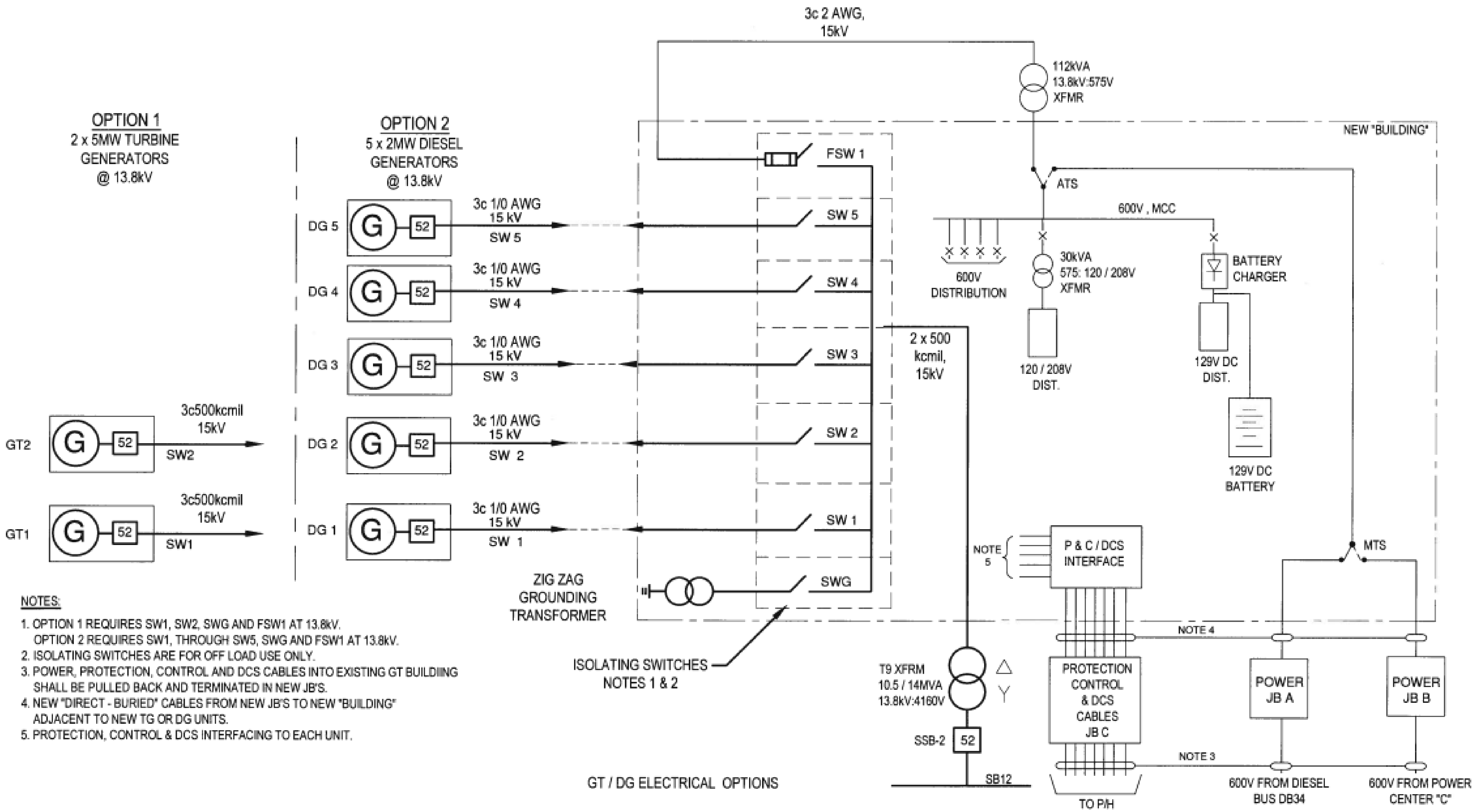
1. The 4160 V generator characteristics are not suitable for large motor starting, even without the step-down transformer.

2. The distance between the generators and the 4160 V bus is long (+200 M), therefore the voltage drop will be more, which results in costly power cables.

3. The existing ground fault current of the 4160 V bus is 1000 A, therefore the generators must have the generator neutral current of 1000 A. With low grounding resistance there is the possibility of third harmonic current circulating from one generator to another. The 4160 V diesel gensets submitted by the vendor cannot be connected to 4160 V because of them being unable to withstand the 1000 A ground fault on the 4160 V bus.

4. With generator connected directly to the 4160 V bus which is normally fed from the grid, three-phase short circuit current contribution from the grid (to the internal fault near the line end of the generator winding), is significant which results in more damage to the generator windings.

In conclusion, this option is not preferred compared to the other option of 2 x 5 MW units.




NOTES:

1. OPTION 1 REQUIRES SW1, SW2, SWG AND FSW1 AT 13.8kV. OPTION 2 REQUIRES SW1, THROUGH SW5, SWG AND FSW1 AT 13.8kV.
2. ISOLATING SWITCHES ARE FOR OFF LOAD USE ONLY.
3. POWER, PROTECTION, CONTROL AND DCS CABLES INTO EXISTING GT BUILDING SHALL BE PULLED BACK AND TERMINATED IN NEW JB'S.
4. NEW "DIRECT - BURIED" CABLES FROM NEW JB'S TO NEW "BUILDING" ADJACENT TO NEW TG OR DG UNITS.
5. PROTECTION, CONTROL & DCS INTERFACING TO EACH UNIT.

**FIGURE 3-2 SINGLE LINE SKETCH – NEW GAS TURBINE GENSET**

TABLE 3-9 ELECTRICAL & CONTROL EQUIPMENT AND INSTALLATION COSTS (OPTION 1) 2 X 5MW TG'S

| Item # | Desciption | Qty | Unit | Material | Labour | Total | Comments |
|---|---|---|---|---|---|---|---|
| 1 | 3c500 kemil, Teck 15kV cable (2 runs) | 550 | m | 112,750 | 10000 | 122,750 | Power from T9 to switchgear and to generators |
| 2 | 13.8kV isolating switchgear (3+1 fused switch) | 1 | ea | 95,000 | 10,000 | 105,000 | |
| 3 | P&C/DCS interface | 1 | ea | 55,000 | 10,000 | 65,000 | Will contain interfacing requirements of the new units to T9 and SSB2. |
| 4 | 10 x 3c12AWG, Teck, 1000V cable | 250 | m | 960 | 2250 | 3210 | from P&C/DCS interface to GTI and GT2 for protection and control |
| 5 | 2 x 25c16AWG, Teck, 1000V cable | 350 | m | 8505 | 3150 | 11655 | Cables from P&C/DCS interface to junction box JBC |
| | 4 x 4c12AWG, Teck, 1000V cable | 700 | m | 3290 | 6300 | 9590 | Cable from FSWI to 112kV transformer |
| | 1 x 12C12AWG, Teck, 1000V cable | 175 | m | 2240 | 1575 | 3815 | Cable ATS to MTS and JBA/JBB to MTS |
| 6 | 3c2AWG, Teck, 15kV cable | 15 | m | 945 | 250 | 1195 | |
| 7 | 2 x 3c1/0, Teck, 1000V cable | 125 | m | 4500 | 1125 | 5625 | |
| 8 | 112kVA, 13.8kV:575V, 3ph, 60Hz transformer | 1 | ea | 30000 | 3000 | 33000 | |
| 9 | 200A, 600V, 3ph, 60Hz automatic transfer switch | 1 | ea | 5336 | 1500 | 6836 | |
| 10 | 200A, 600V, 3ph, 60Hz manual transfer switch | 1 | ea | 2000 | 1000 | 3000 | |
| 11 | MCC, 600A, 600V, 3ph, 3W | 1 | ea | 30000 | 5000 | 35000 | |
| 12 | 30kVA, 575:120/280V, 3ph, 60Hz transformer | 1 | ea | 1000 | 500 | 1500 | |
| 13 | 129VDC distribution panel, motor starters and disconnects | 1 | ea | 35000 | 6500 | 41500 | |
| 14 | 100A, 120/208V, 3ph, 60Hz distribution panel c/w breakers | 1 | ea | 1418 | 350 | 1768 | |
| 15 | 600V, battery charger, 129VDC output | 1 | ea | 16,000 | 3220 | 19,220 | |
| 16 | 129VDC battery bank | 1 | ea | 39,000 | 7500 | 46,500 | |
| 17 | All interconnecting cabling | 1 | lot | 16000 | 12000 | 28000 | Includes MCC feeders, heating and lighting |
| 18 | Miscellaneous 4/0 ground wire, conducts trays and hardware | 1 | lot | 16000 | 9000 | 25000 | |
| 19 | Reconfiguration of DCS screens, and existing system | 1 | lot | | 25,000 | 25000 | |
| 20 | 25kVA, 13.8kV, 3ph, 60Hz, zig-zag grounding transformer | 1 | ea | 31,000 | 2,000 | 33,000 | |
| | Commissioning | | | - | 63,000 | 63,000 | |
| | Totals | | | 505,944 | 184220 | 690,164 | |

### 3.3.6 Existing Unit De-Commissioning and Demolition

No significant incremental costs were identified for existing unit de-commissioning and/or demolition. It was felt that the value of the materials derived from the demolition could offset the cost to the contractor. If required as sensitivity, then a value such as $40,000 might be used, but this would not be expected to either sway the selection of a preferred option, or impact the overall cost but rather be part of an overall project contingency regardless of any option selected.

### 3.3.7 Project Engineering and Management, Owner's Costs

It was assumed that the facility implementation would be undertaken largely as an engineer, procure, construct (EPC) external contract. Hydro would be responsible for getting the project approved and the necessary environmental and regulatory approvals.

**EPC Costs**

For the EPC contractor, the project engineering and management costs are based on the total project costs and a percentage for engineering and for management. For the purposes of this estimate, the engineering costs are estimated to be 5% of direct costs of the GT or diesel package and 10% of the balance of plant. The project management and commissioning costs (excluding fuel, Hydro staff costs) are estimated to be 7% of total direct costs. .

**Owner's Costs**

Owner's costs are not included in the estimates, but are likely to be comparable regardless of the selected option. NL Hydro is assumed to undertake the early steps to get its Public Utilities Board (PUB) approvals as part of its ongoing operations cost. Hydro is also assumed to undertake all the necessary environmental and regulatory permitting entirely internally or with some measure of external support (i.e. environmental modeling and engineering support, or full external scope). This cost is also not included but likely on the order of $55,000.

For the actual project implementation, the assumption is that NL Hydro would assume its own costs of this initial development and then assign a project manager for the life of the project to monitor and assure its successful completion. These and other NL Hydro costs (insurance, legal, supply chain, interest, owners' contingency, Holyrood station participation, commissioning fuel, commissioning labour) are not identified or included herein. It is likely that Owner costs could amount to on the order of 1.5% of directs or about $150,000.

### 3.3.8 Total New and Nearly New 2 x 5MW GTG Capital Cost Estimate

The total New and Nearly New 2 x 5 MW GTG cost estimate is as follows. The difference in the New and Nearly New is mostly in the capital costs. It should be noted that there may be some additional costs required to retrofit nearly new units to meet the same or required standards as the new units that are designed to meet Holyrood requirements.

**TABLE 3-10 CAPITAL COST ESTIMATE – TRANSPORTABLE GTG**

**Capital Cost Comparison**

**Capital cost estimate $1,000 Can 2011**

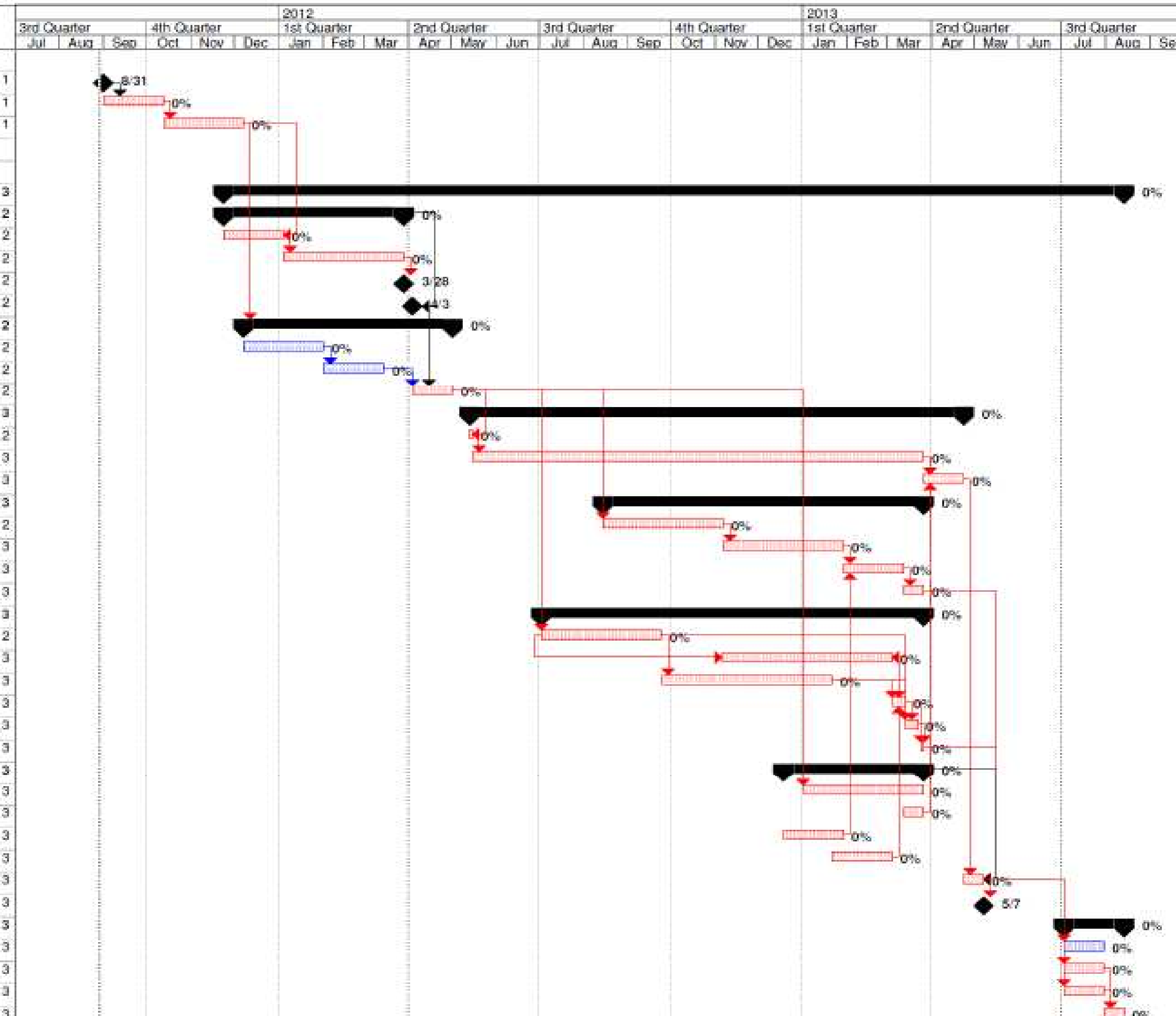
| Option Number | 1 | 1A |
|---|---|---|
| **Option** | **New 2 x 5 MW GT** | **Used 2 x 5 MW GT** |
| GT/Diesel Cost | $10,865 | $9,234 |
| Civil Works | $131 | $131 |
| Electrical Works | $759 | $759 |
| BOP Systems | $129 | $129 |
| Existing Unit Demolition & Removal | $7 | $7 |
| **Sub-Total - Directs and Indirects** | $11,891 | $10,260 |
| Project Engineering | $625 | $544 |
| Project Management | $832 | $718 |
| Total | $13,348 | $11,522 |

### 3.3.9 Schedule

The schedules for the new and nearly new 2 X 5 MW GTG are illustrated below. The basic schedule highlights are as follows:

| Task | New GT | Nearly New GT |
|---|---|---|
| Review of Options Report | Sept 2011 | |
| Project Approvals and Release | Sept 2011 - Dec 2011 | |
| Engineer, Procure, Construct Contract | May 2012 | |
| In-Service of New 2 x 5 MW GT | May 2013 | March 2013 |
| Decommission Existing GT | Aug/Dec 2013 | Aug/Dec 2013 |

| ID | | Task Name | Duration | Start | Finish |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | Condition Assessment Study | 0 wks | Wed 8/31/11 | Wed 8/31/11 |
| 3 | | Hydro Internal Capital Budget Proposal Development | 6 wks | Thu 9/1/11 | Wed 10/12/11 |
| 4 | | Submission - Public Utilities Board & Approval | 8 wks | Thu 10/13/11 | Wed 12/7/11 |
| 5 | | | | | |
| 6 | | | | | |
| 7 | | **New GT or Diesel Units** | **449 days** | **Thu 11/24/11** | **Tue 8/13/13** |
| 8 | | **Project Environmental & Regulatory Approvals** | **90 days** | **Thu 11/24/11** | **Wed 3/28/12** |
| 9 | | Prepare Dispersion Modelling & Submission | 30 days | Thu 11/24/11 | Wed 1/4/12 |
| 10 | | Regulatory Review and Approval | 60 days | Thu 1/5/12 | Wed 3/28/12 |
| 11 | | Environmental Approval | 0 days | Wed 3/28/12 | Wed 3/28/12 |
| 12 | | Project Full Release | 0 days | Tue 4/3/12 | Tue 4/3/12 |
| 13 | | **Request for Proposal (RFP) for Engineer/procure/Cons** | **104 days** | **Thu 12/8/11** | **Tue 5/1/12** |
| 14 | | Prepare | 40 days | Thu 12/8/11 | Wed 2/1/12 |
| 15 | | Bid | 6 wks | Thu 2/2/12 | Wed 3/14/12 |
| 16 | | Award | 20 days | Wed 4/4/12 | Tue 5/1/12 |
| 17 | | **New Gas Turbien or Diesel Engine Generator** | **247 days** | **Mon 5/14/12** | **Tue 4/23/13** |
| 18 | | Award Gas Turbine (GT)/Engine Contract | 2 days | Mon 5/14/12 | Tue 5/15/12 |
| 19 | | Manufacture & Deliver Transportable Engines | 45 wks | Wed 5/16/12 | Tue 3/26/13 |
| 20 | | Install and Commission | 4 wks | Wed 3/27/13 | Tue 4/23/13 |
| 21 | | **Fuel System** | **160 days** | **Wed 8/15/12** | **Tue 3/26/13** |
| 22 | | Engineer | 12 wks | Wed 8/15/12 | Tue 11/6/12 |
| 23 | | Order, Manufacture, Deliver | 12 wks | Wed 11/7/12 | Tue 1/29/13 |
| 24 | | Install new fuel lines and receiving system | 6 wks | Wed 1/30/13 | Tue 3/12/13 |
| 25 | | Commission System | 2 wks | Wed 3/13/13 | Tue 3/26/13 |
| 26 | | **Electrical & Control Systmes** | **191 days** | **Tue 7/3/12** | **Tue 3/26/13** |
| 27 | | Engineer | 12 wks | Tue 7/3/12 | Mon 9/24/12 |
| 28 | | Order & Manufacture Elect & Control (E&C) Equip | 17 wks | Tue 11/6/12 | Mon 3/4/13 |
| 29 | | Electrical Building Manufacture, Delivery, Install | 17 wks | Tue 9/25/12 | Mon 1/21/13 |
| 30 | | Install New System | 7 days | Tue 3/5/13 | Wed 3/13/13 |
| 31 | | RE-align Existing Plant Systems | 7 days | Thu 3/14/13 | Fri 3/22/13 |
| 32 | | Commission unit | 2 days | Mon 3/25/13 | Tue 3/26/13 |
| 33 | | **Site Civil Work** | **70 days** | **Wed 12/19/12** | **Tue 3/26/13** |
| 34 | | Engineer | 12 wks | Wed 1/2/13 | Tue 3/26/13 |
| 35 | | Generator area clearing and civil | 2 wks | Wed 3/13/13 | Tue 3/26/13 |
| 36 | | Fuel line civil work | 6 wks | Wed 12/19/12 | Tue 1/29/13 |
| 37 | | Electrical an contro cable civil work | 6 wks | Tue 1/22/13 | Mon 3/4/13 |
| 38 | | Complete Unit Test | 10 days | Wed 4/24/13 | Tue 5/7/13 |
| 39 | | Gas Turbine (GT) In-Service (I/S) | 0 days | Tue 5/7/13 | Tue 5/7/13 |
| 40 | | **Decommission Existing GT** | **30 days** | **Wed 7/3/13** | **Tue 8/13/13** |
| 41 | | Fuel delivery system | 4 wks | Wed 7/3/13 | Tue 7/30/13 |
| 42 | | Electrical & Controls | 4 wks | Wed 7/3/13 | Tue 7/30/13 |
| 43 | | GT | 4 wks | Wed 7/3/13 | Tue 7/30/13 |
| 44 | | Building | 2 wks | Wed 7/31/13 | Tue 8/13/13 |




Project: Project1 New.mpp
Date: Mon 8/29/11

| | | | | | |
|---|---|---|---|---|---|
| Critical | Task | Baseline | Milestone | Project Summary | Deadline |
| Critical Split | Split | Baseline Split | Summary Progress | External Tasks | |
| Critical Progress | Task Progress | Baseline Milestone | Summary | External Milestone | |

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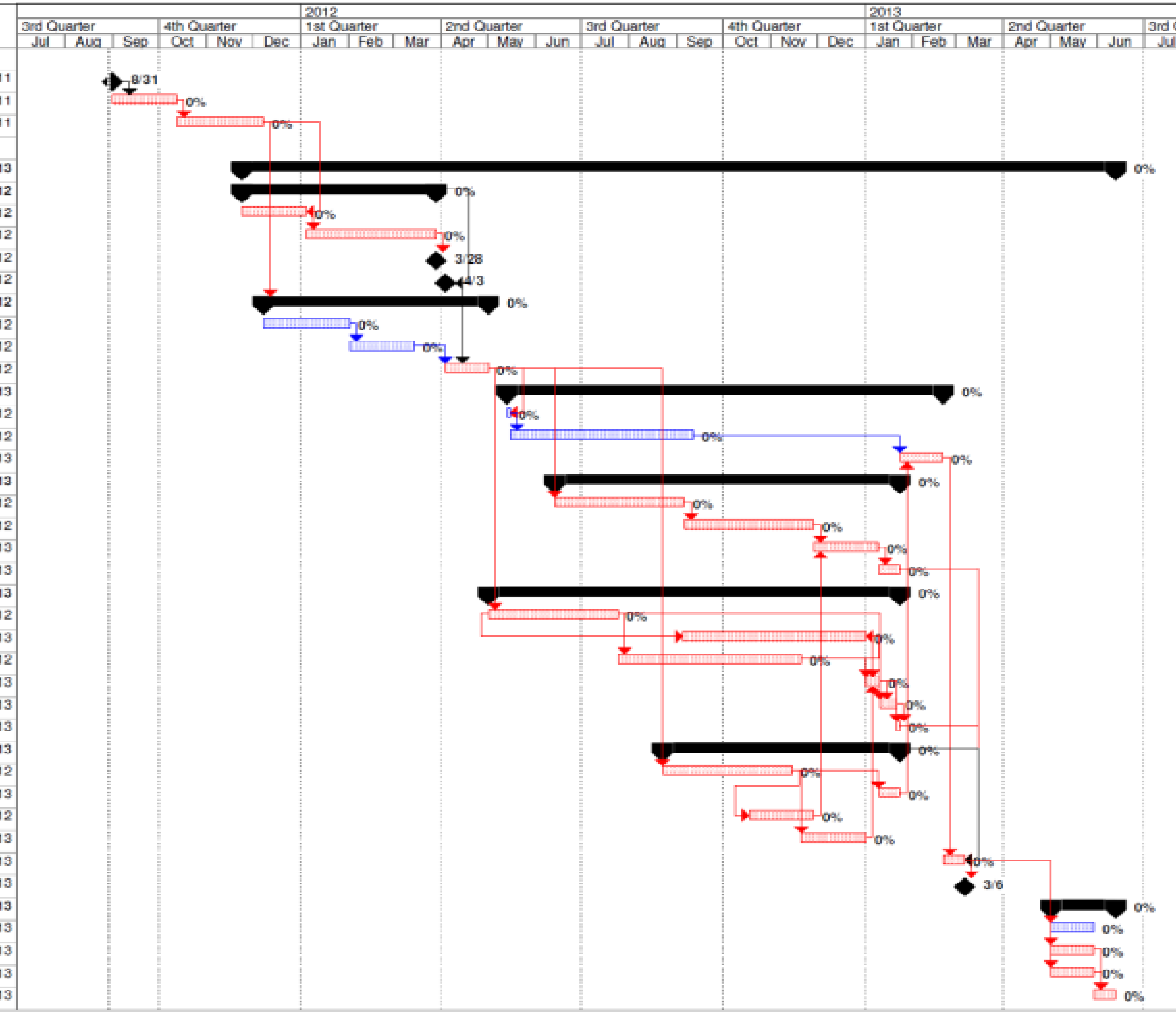
**FIGURE 3-3 SCHEDULE – NEW TRANSPORTABLE 2 X 5 MW GTG**

**Newfoundland and Labrador Hydro a NALCOR Energy Co.**
**Holyrood Thermal Generating Station**
**Gas Turbine Condition Assessment & Options Study**

| ID | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 1 | | | | |
| 2 | Condition Assessment Study | 0 wks | Wed 8/31/11 | Wed 8/31/11 |
| 3 | Hydro Internal Capital Budget Proposal Development | 6 wks | Thu 9/1/11 | Wed 10/12/11 |
| 4 | Submission - Public Utilities Board & Approval | 8 wks | Thu 10/13/11 | Wed 12/7/11 |
| 5 | | | | |
| 6 | **Nearly New gas Turbine (GT) or Diesel Generator Units** | **405 days** | **Thu 11/24/11** | **Wed 6/12/13** |
| 7 | **Project Environmental & Regulatory Approvals** | **90 days** | **Thu 11/24/11** | **Wed 3/28/12** |
| 8 | Prepare Dispersion Modelling & Submission | 30 days | Thu 11/24/11 | Wed 1/4/12 |
| 9 | Regulatory Review and Approval | 60 days | Thu 1/5/12 | Wed 3/28/12 |
| 10 | Environmental Approval | 0 days | Wed 3/28/12 | Wed 3/28/12 |
| 11 | Project Full Release | 0 days | Tue 4/3/12 | Tue 4/3/12 |
| 12 | **Request for Proposal (RFP) for Engineer/Procure/Construct (** | **104 days** | **Thu 12/8/11** | **Tue 5/1/12** |
| 13 | Prepare | 40 days | Thu 12/8/11 | Wed 2/1/12 |
| 14 | Bid | 6 wks | Thu 2/2/12 | Wed 3/14/12 |
| 15 | Award | 20 days | Wed 4/4/12 | Tue 5/1/12 |
| 16 | **Nearly New GT or Diesel Engine Generator** | **203 days** | **Mon 5/14/12** | **Wed 2/20/13** |
| 17 | Award GT/Diesel Engine Contract | 2 days | Mon 5/14/12 | Tue 5/15/12 |
| 18 | Manufacture & Deliver Transportable Engines | 17 wks | Wed 5/16/12 | Tue 9/11/12 |
| 19 | Install and Commission | 4 wks | Thu 1/24/13 | Wed 2/20/13 |
| 20 | **Fuel System** | **160 days** | **Thu 6/14/12** | **Wed 1/23/13** |
| 21 | Engineer | 12 wks | Thu 6/14/12 | Wed 9/5/12 |
| 22 | Order, Manufacture, Deliver | 12 wks | Thu 9/6/12 | Wed 11/28/12 |
| 23 | Install new fuel lines and receiving system | 6 wks | Thu 11/29/12 | Wed 1/9/13 |
| 24 | Commission System | 2 wks | Thu 1/10/13 | Wed 1/23/13 |
| 25 | **Electrical & Control Systmes** | **191 days** | **Wed 5/2/12** | **Wed 1/23/13** |
| 26 | Engineer | 12 wks | Wed 5/2/12 | Tue 7/24/12 |
| 27 | Order & Manufacture Elect & Control (E&C) Equip | 17 wks | Wed 9/5/12 | Tue 1/1/13 |
| 28 | Electrical Building Manufacture, Delivery, Install | 17 wks | Wed 7/25/12 | Tue 11/20/12 |
| 29 | Install New System | 7 days | Wed 1/2/13 | Thu 1/10/13 |
| 30 | RE-align Existing Plant Systems | 7 days | Fri 1/11/13 | Mon 1/21/13 |
| 31 | Commission unit | 2 days | Tue 1/22/13 | Wed 1/23/13 |
| 32 | **Site Civil Work** | **110 days** | **Thu 8/23/12** | **Wed 1/23/13** |
| 33 | Engineer | 12 wks | Thu 8/23/12 | Wed 11/14/12 |
| 34 | Generator area clearing and civil | 2 wks | Thu 1/10/13 | Wed 1/23/13 |
| 35 | Fuel line civil work | 6 wks | Thu 10/18/12 | Wed 11/28/12 |
| 36 | Electrical an contro cable civil work | 6 wks | Wed 11/21/12 | Tue 1/1/13 |
| 37 | Complete Unit Test | 10 days | Thu 2/21/13 | Wed 3/6/13 |
| 38 | GT In-Service (I/S) | 0 days | Wed 3/6/13 | Wed 3/6/13 |
| 39 | **Decommission Existing GT** | **30 days** | **Thu 5/2/13** | **Wed 6/12/13** |
| 40 | Fuel delivery system | 4 wks | Thu 5/2/13 | Wed 5/29/13 |
| 41 | Electrical & Controls | 4 wks | Thu 5/2/13 | Wed 5/29/13 |
| 42 | GT | 4 wks | Thu 5/2/13 | Wed 5/29/13 |
| 43 | Building | 2 wks | Thu 5/30/13 | Wed 6/12/13 |




Project: Project1 Nearly New.mpp
Date: Mon 8/29/11

Critical | Critical Split | Critical Progress | Task | Split | Task Progress | Baseline | Baseline Split | Baseline Milestone | Milestone | Summary Progress | Summary | Project Summary | External Tasks | External Milestone | Deadline

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**FIGURE 3-4 SCHEDULE – NEARLY NEW/USED TRANSPORTABLE 2 X 5 MW GTG**

### 3.3.10 OMA Cost Estimate to 2020

Operating costs were assumed to include the ongoing maintenance costs (annual inspections, repairs, etc.), the operations costs (costs to run the unit on test), the fuelling costs (fuel costs to run the tests), and an electricity value credit. The operating costs shown are the same for both the new and nearly new cases. For the type of operation required, peak and emergency operation (typically <=60 Hrs/Yr, the GT packages normally would require only an annual service and inspection by qualified service personnel. Most utilities would exercise the equipment once a month to verify proper operation.

The costs were assumed to include the ongoing maintenance costs (annual inspections, repairs, etc.), the operations costs (costs to run the unit on test), the fuelling costs (fuel costs to run the tests), and an electricity value credit. The vendor indicated that for the 6 month inspection the cost was to be $10,000 and for the yearly it was $18,000 and that these costs would be the same for both new and nearly new. A lower value was actually used reflecting their very limited use – essentially an annual inspection similar to what is done now.

The assumptions used for fuel, operations, and electricity value are illustrated below. The electricity value is premised on receiving the same value per MWh as the existing units would if they were to recover their fuelling costs plus marginal operating and maintenance costs. The fuelling and electricity prices are intended as representative and based on running the units 150 hours per year, whereas actual hours could be as half of this.. The actual values (average run capacity, sent out heat rate (SOHR) and hence fuel and electricity depend on how the testing is actually done.

The assumptions used for fuel, operations, and electricity value are illustrated below. The electricity value is premised on recovering fuelling costs plus marginal operating costs.

**TABLE 3-11 NEW GTG OMA COST ASSUMPTIONS**

**Assumptions**

| | | |
|---|---|---|
| #2 Oil Fuel Price (A) | $/MMBTU | $21.47 |
| Unit Efficiency (B) | BTU/kWh | 12,000 |
| Average Running Capacity (C) | MW | 4 |
| Average Running Cost (D) = AxBxC/1000 | $/Hr | $1,031 |
| Electricity Value (E) = Value for existing GT | $/MWh | $343.25 |
| Electricity Value (F) = E*C | $/Hr OP | $1,373 |

| | |
|---|---|
| 2 | Persons/Start (U) |
| 4 | Hrs/Start (V) |
| $70 | $/PersonHr (W) |
| $560 | $/Start (Z) = UxVxW |

**TABLE 3-12 NEW GTG OMA COSTS**

New/Near New GT
1000's Cnd $ - 2011/Yr

| | Maintenance | Operations | Fuelling | Sub-Total | Electricity Value | | Total |
|---|---|---|---|---|---|---|---|
| 2012 | $15 | $0 | $0 | $15 | $0 | | $15 |
| 2013 | $20 | $40 | $155 | $215 | ($206) | | $9 |
| 2014 | $20 | $40 | $155 | $215 | ($206) | | $9 |
| 2015 | $20 | $40 | $155 | $215 | ($206) | | $9 |
| 2016 | $20 | $40 | $155 | $215 | ($206) | | $9 |
| 2017 | $20 | $40 | $155 | $215 | ($206) | | $9 |
| 2018 | $20 | $40 | $155 | $215 | ($206) | | $9 |
| 2019 | $20 | $40 | $155 | $215 | ($206) | | $9 |
| 2020 | $0 | $40 | $155 | $195 | ($206) | | ($11) |
| TOTAL | $155 | $323 | $1,237 | $1,714 | ($1,648) | | $67 |

## 3.4 Option 2 – 5 x 2 MW Diesel Engine Generator (DG) at 13.8kV (New and Nearly New Option)

### 3.4.1 Description

In this option, five 2 MW diesel engine generator units would be utilized to provide black start capability. Sizing at 2 MW each would allow the units to be more transportable than larger units. In addition, this is approximately the maximum size available for portable units. With this arrangement, all five of the units would be required to operate simultaneously to provide sufficient power for black start. A generator voltage of 13.8 kV connected to the delta primary of the existing T9 transformer would be utilized. Other units from Cummins Diesel are available as packaged two 1 MW units. However, NL Hydro expressed reliability and operational concerns with 10 diesel units and they have not been considered further.

Vendor information was received from TOROMONT CAT. These will be mobile units supplied by a vendor and will not require a diesel building. Several items will however be required, such as:

- Turbine trailers areas with site work to ensure sufficient ground support for the mobile diesel genset units.
- A pre-engineered shelter for electrical equipment, including concrete foundation and floor slab. Approximately 30 ft x 30 ft.
- A reinforced concrete pipe/trench for cables running from the diesel gensets to the main building and from the diesel gensets to the existing fuel lines.
- Electrical and I&C connections to the existing plant facilities

### 3.4.2 Connections to the Existing E and C System

Each diesel/generator unit will be a completely self contained unit capable of operating in isochronous or droop mode, having its own main breaker (52), AVR, control and protection, synchronizing, load sharing, paralleling, monitoring and ability to connect to the existing station DCS.

All these functions will connect to a new building. Each generator output breaker will be cabled to an item of isolating switchgear. The isolating switchgear will consist of five (5) 13.8 kV disconnect switches, one (1) fused disconnect for auxiliaries, and one disconnect for connection of the zig-zag grounding transformer.

An isolation switch allows the individual GT unit to be taken out of service at any time. Each generator breaker (52) is synchronized for connection to the station service bus through the 13.8 kV:4160 V transformer (T9), either individually or as any combination of generators.

The five DG units will be designed with high resistance grounding consisting of a grounding transformer and NGR to limit the ground fault current to less than 10 A as normal standard.

The 13.8KV fused disconnect fused switch #1 (FSWI) will feed a 112 kVA, 13.8 kV:575 V, 3 phase transformer to provide 600 V service via a new 600 A, 600 V, 3phase, 60 Hz, 3 W MCC. The MCC will typically provide starters or fused disconnects for pumps, hearing, 120/208 V distribution via a 30 kVA transformer and the battery charger. The battery charger supplies the 129 VDC battery and distribution.

Alternative supplies to the MCC will be via an automatic transfer switch (ATS) and a manual transfer switch (MTS) and will be from the diesel bus DB34 and power center 'C', both located in the powerhouse.

Protection & Control/DCS interfaces will combine the requirements of the new units with the requirements of the existing T9 transformer and 4160 V breaker SSB2.

#### 3.4.2.1.1 Changes to Existing EI&C Systems

The existing protection, control and DCS cables entering the present GT building will be pulled-back and terminated in a weatherproof JB. New teck cables will be connected to these existing cables and direct-buried from the JB to the P&C/DCS interface in the new building.

Similarly the 600 V feeds from the diesel bus DB34 and power centre 'C' will be pulled-back and terminated in weatherproof JB's. New teck cables will be connected to these existing cables and direct-buried from the JB's to the MTS in the new 'building'.

All new weatherproof JB's will be mounted above ground.

Power cable from the common bus of the isolating switchgear to the existing T9 transformer will replace the existing cables, and will be direct-buried from T9 to the switchgear.

Changes will be made as necessary to P&C in Panel 13 (in the powerhouse) and also in Panel 2 (in the powerhouse). Screens will be reconfigured in the control room involving the five new units and their monitoring, control, indication, and alarm functions.

### 3.4.3 Performance Characteristics

Diesel gensets have several ratings.

> Standby – Applicable for supplying continuous electrical power (at variable load) in the event of a utility power failure. No overload is permitted on these ratings. The generator on the generator set is peak prime rated (as defined in ISO8528-3) at 30°C (86°F).
>
> Prime – Applicable for supplying continuous electrical power (at variable load) in lieu of commercially purchased power. There is no limitation to the annual hours of operation and the generator set can supply 10% overload power for 1 hour in 12 hours.

NL Hydro noted that for blackstart only, their requirement is for the standby rating. Information on prime is provided for comparison.

TABLE 3-13 DIESEL PERFORMANCE CRITERIA

| Generator Set Technical Data | Units | 60 Hz Prime | 60 Hz Standby |
|---|---|---|---|
| Performance Specification | | DM8264 | DM8264 |
| Power Rating | kW (kVA) | 1825 (2281) | 2000 (2500) |
| Lubricating System<br>Oil pan capacity | L (gal) | 401.3 (106) | 401.3 (106) |
| Fuel System<br>Fuel Consumption<br>100% load<br>75 % load<br>50 %load<br>Fuel tank capacity<br>Running time @ 75% rating | L (gal)<br>L (gal)<br>L (gal)<br><br>L (gal)<br>Hours | 483.2 (127.6)<br>380 (100.4)<br>270.5 (71.5)<br>4731 (1,250)<br>12.5 | 525.7 (138.9<br>408.2 (107.8)<br>294.2 (77.7)<br>4731 (1,250)<br>11.5 |
| Cooling System<br>Radiator coolant capacity<br>including engine | L (gal) | 630 (166) | 630 (166) |
| Air Requirements<br>Combustion air flow<br>Maximum air cleaner restriction<br>Generator cooling air | m3/min (cfm)<br>kPa (in H2O)<br>m3/min (cfm) | 174.7 (6169)<br>6.2 (24.9)<br>168 (4,995) | 180.3 (6367)<br>6.2 (24.9)<br>168 (4,995) |
| Exhaust System<br>Exhaust flow at rated kW<br>Exhaust stack temperature at<br>rated kW dry exhaust | m3/min (cfm)<br>°C (°F) | 404 (14,260)<br>387 (728) | 428.6 (15,137)<br>405 (762) |
| Noise Rating (with enclosure)<br>@ 7 meters (23 feet)<br>@15 meters (50 feet) | dB(A)<br>dB(A) | 78<br>74 | 79<br>75 |

### 3.4.3.1 Emission Requirements

For new diesel units on oil, the requirement is uncertain. In the United States, the United States Environmental protection Agency (USEPA) is clearly moving to even tighter diesel genset limits. Canada has only adopted those for mobile (on-road) sources, not stationary sources. There is also the issue of emergency use (black-start would apply) and non-emergency (distribution support, grid support is likely to apply):

- For stationary (including transportable genset units) in emergency use (i.e. black start only)
    - In US would likely be a USEPA Tier 2 (a diesel requiring advanced combustion systems)
    - In Canada, no specific regulations could be identified. Diesel units are likely similar to those required in the US, or comparable to the Canadian guideline requirement for gas turbines above

- For stationary (including transportable genset) in a non-emergency use (i.e. distribution support).
    - In the US, a USEPA Tier 4 (a diesel unit required to have advanced combustion and post combustion control such as selective catalytic reduction (SCR) using ammonia or urea and would also require ultralow sulphur diesel fuel (15 ppm sulphur)
    - In Canada, no specific regulations identified – the study assumes for the role required that Tier 2 would suffice. A question may arise where the plan is for their use in distribution system support. This should likely be considered an emergency role and not result in more onerous restrictions. At worst, assuming a requirement comparable to that for gas turbines above for peaking purposes is reasonable.

Operating time limits could be placed on peaking units. An emergency unit for black start only might be exempt, but could thereby limit its future.

No specific diesel genset applicable to Newfoundland air pollution regulations were identified. There is however a general requirement for BACT, with provisions for an exemption based on economics and on a ministerial exemption for practical purposes.

In emergency and non-emergency applications, dispersion modeling is likely required to demonstrate ground level concentrations are acceptable.

#### 3.4.3.2 Transition

The existing gas turbine system is to remain active while the new system is independently installed. A short outage will be required during a transition period during which final connections to the electrical, instrumentation and controls, and fuel systems are made.

#### 3.4.3.3 Decommissioning

The existing GT unit will be decommissioned, including those parts of the fuel system and electrical connections not required for the new units. This will occur once the new transportable units are in place and operational. A modified fuel offloading/receiving system will remain.

### 3.4.4 General Arrangement Sketch

See attached GA sketch based on dimensional information provided by TOROMONT CAT (APPENDIX 3).

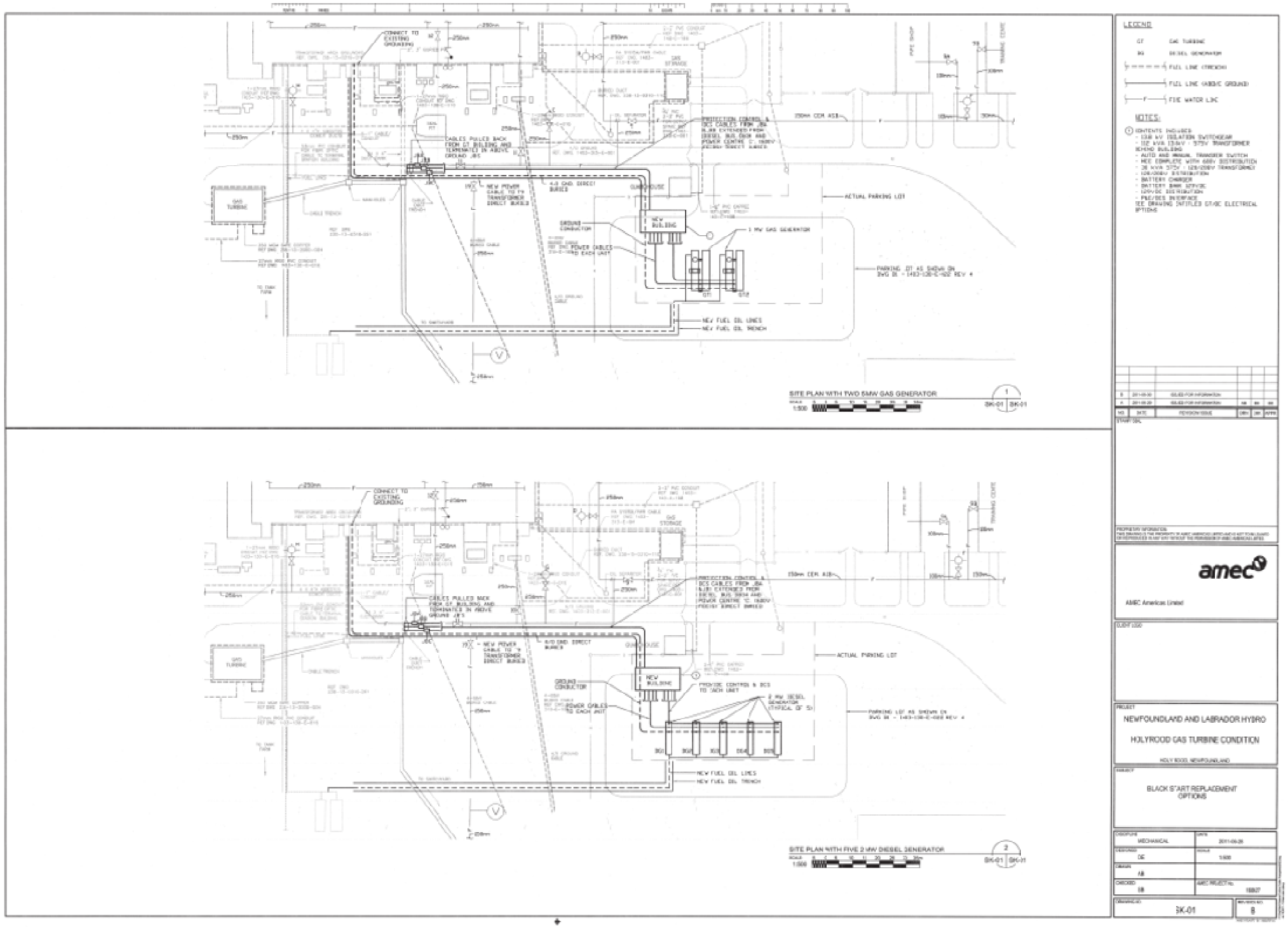



**FIGURE 3-5 GENERAL ARRANGEMENT – 5 X 2 MW DIESEL GENSETS**

### 3.4.5 Capital Cost Estimate (Differentiate New and Nearly New Option)

Budget pricing supplied by CAT indicated that the transportable diesel genset cost would be in the order of $1,500,000.00 per unit. However, there could be a 50% increase in price if the units are required to meet more stringent emission limits in emission regulations likely to be adopted soon by the federal government. AMEC has requested this information but as not received any additional details on these requirements, and their applicability to this application for black start capability and short term distribution system maintenance support.

There is not expected to be a significant difference in price between the New and Nearly New options. The advantage between these options is the possibility that a Nearly New set of units will be available and lead/delivery times are significantly reduced.

**TABLE 3-14 DIESEL GENSET CAPITAL COST**

| Item | Description | Unit Price | Quantity | Cost |
|---|---|---|---|---|
| 1. | XQ2000 with 13.8kv output $1.5m per unit (x5) under current emissions rules. | $1,500,000 | 5 | $7,500,000 |
| 2. | Commissioning Parts, Start-up, and Site Testing | $20,000 | 5 | $100,000 |
| 4 | Shipping | $25,000 | 5 | $125,000 |
| 5 | Training | $5,000 | 5 | $25,000 |
| 6 | Marine Grade Filter (Included) | | | |
| | | | | $7,750,000 |

- Duties and taxes not included in estimate.
- This quote is provided for budgetary purposes only and does not represent a firm quote.

#### 3.4.5.1 Diesel Trailer Units

**TABLE 3-15 DIESEL PACKAGE COMPONENTS**

| Component | Description |
|---|---|
| Engine | ▪ EPA approved Tier 2 3516C Caterpillar engine<br>▪ Heavy duty air cleaner with service indicator<br>▪ 60-Amp charging alternator<br>▪ Fuel filters – primary and duplex secondary with integral water separator and change-over valve<br>▪ Lubricating oil system with spin-on, full flow oil filters and water cooled oil cooler<br>▪ Oil drain lines routed to engine rail<br>▪ Jacket water heater<br>▪ Fuel cooler and priming pump<br>▪ Electronic ADEM™ A3 controls<br>▪ 24V electric starting motors with battery rack and cables |

| Component | Description |
|---|---|
| | ▪ 110% spill containment of onboard engine fluids |
| Generator | ▪ SR-4B brushless, permanent magnet excited, three-phase with Caterpillar digital voltage regulator (CDVR),space heater, 6-lead design, Class H insulation operating at Class F temperature for extended life,<br>▪ winding temperature detectors and anti-condensation space heaters (120/240 V 1.2 kW) |
| Containerized Module | ▪ 40' ISO high cube container, CSC certified<br>▪ 3-axle, 40' ISO container chassis<br>▪ Seven (7) sound attenuated air intake louvers and 4 lockable personnel doors with panic release<br>▪ Side bus bar access door, external access load connection bus bars<br>▪ Shore power connection via distribution block connections for jacket water heater, battery charger, space heaters, and generator condensate heaters<br>▪ Standard lighting 3 AC/4 DC, one (1) single duplex service receptacle, 2 external break-glass emergency stop push buttons<br>▪ 1,250 gal fuel tank, UL listed, double wall, 9 hr runtime @ prime rating<br>▪ Sound attenuated 75 dB(A) @ 50 ft<br>▪ Spill containment 110% of all engine fluids<br>▪ Four (4) oversized maintenance-free batteries, battery rack and 20-Amp battery charger<br>▪ Hospital grade, internally insulated, rectangular exhaust silencer with vertical discharge<br>▪ Vibration isolators, corrosion resistant hardware and hinges<br>▪ External drain access to standard fluids<br>▪ Fire extinguishers (Qty 2)<br>▪ Standard Cat rental decals and painted standard Cat power module white<br>▪ Interior walls and ceilings insulated with 100 mm of acoustic paneling<br>▪ Floor of container insulated with acoustic glass and covered with galvanized steel |
| Cooling | ▪ Standard cooling provides 43° C ambient capability (60 Hz) at prime +10% rating<br>▪ Vertically mounted, separate ATAAC and JW cores with vertical air discharge |

| Component | Description |
|---|---|
| Generator Paralleling Control | ▪ Custom switchgear control with EMCP 3.3 genset mounted controller and wall mounted paralleling controls Provides single unit and/or multi-unit/utility paralleling components. Standby, load sense/load demand, import, export, and base load modes. Comes standard with Basler Utility Multi-function Relay IPS-100.<br>▪ Exclusive Caterpillar Digital Voltage Regulator (CDVR) Three-phase sensing and adjustable Volts-per- Hertz regulation give precise control, excellent block loading, and constant voltage in the normal operating range.<br>▪ Automatic start/stop with cool down timer<br>▪ Protections: 25, 27/59, 40, 32, 81 O/U<br>▪ Utility multi-function relay protections: 25,27/59, 32, 47, 50/51, 62, 67, 81 O/U<br>▪ UMR is IEEE1547-2003 compliant in most applications<br>▪ Reverse compatibility module provided for interface to legacy power modules<br>▪ Touch screen controls with event log<br>▪ Multi-mode operation (island, multi-island and utility parallel), load sharing (multi-unit only)<br>▪ Import & export control (utility parallel only), manual and automatic paralleling capability<br>▪ Touch screen display (status and alarms)<br>▪ Metering display: voltage, current, frequency, power factor, kW, WHM, kVAR, and synchroscope |
| Quality | ▪ Standard genset and package factory tested<br>▪ UL, NEMA, ISO and IEEE standards |
| Other | |

### 3.4.5.2 Site Civil Works – Trailer Site and Electrical & Gas Connections

Site/civil works requirements are primarily related to the diesel generator trailer site, and to electrical and fuel connections. The major costs are expected to be:

- Confirming the bearing capacity of soil = $4,000
- Pre-engineered shelter for elec. equipment = $45,000
- Concrete cable trench = $70,000

Oil piping excavation is included in the cost of the piping.

### 3.4.5.3 Existing Gas Turbine Generator Unit Modifications

For this application the gas turbine units should be provided with air filter media suitable for use in a marine environment as well as have coatings on external components designed for such environments.

#### 3.4.5.4 New Diesel Genset Mechanical Requirements

Aside from fuel oil supply, it is expected that the diesel genset units would be self contained and not require any additional mechanical equipment. Specific to diesel engine trailers, each trailer must have 15.6 m clearance on both sides to ensure adequate ventilation and combustion airflow.

**Connection to Fuel Oil System and Changes to Existing Oil System**

From supplier information each turbine at its maximum output would consume fuel at a rate of 2.3 gpm (8.7 L/min). This implies for black start with five units running there would be a total of 11.5 gpm (43.5 L/min). For a 24 hour period, the fuel oil storage requirement would be about 16,500 gallons (62, 459 L) of fuel. The current fuel oil tanks as previously noted are 26,417 gal (100,000 L) each.

The new diesel units will be located approximately 160 m away from the existing GT building and will require new fuel oil supply and return piping from the existing system. Since five diesels would be provided under this option, it is anticipated that five connections would be required. Due to spacing requirements of the diesels gen sets this manifold system would be quite extensive. Piping could be routed through a trenched containment system. Preliminary sizing indicates that the supply and return lines would be 3 inch with a total length of 130 m each.

**TABLE 3-16 DIESEL GENSET – MECHANICAL SYSTEM COSTS**

| Item | Cost |
|---|---|
| 3” supply and return fuel line | $77,100.00 |
| Project Engineering Costs Mechanical | $15,000.00 |

### 3.4.6 New Diesel Genset Option – Electrical, Instrumentation, and Control Requirements

With generators connected directly to the 4160 V bus which is normally fed from the grid, the three-phase short circuit current contribution from the grid (to the internal fault near the line end of the generator winding) is significant which results in more damage to the generator windings.

With the 5 X 2 MW generators, the calculated voltage drop at the 4160 V bus results are improved, but potential drawbacks are expected as follows:

1. The starting reliability of 5 generators (following total loss of station AC supply) is questionable. The successful starting of 5 units is not easy to achieve. With our experience of multiple diesel starting at once, there is a high probability that 100% success is not easily achieved compared to two 5 MW units on the assumption that one 5 MW unit is suitable for plant essential loads.

2. The isochronous load sharing of 5 units requires 5 electronic governors and a complicated master controller. This is necessary to manage the paralleling operation of 5 units during isochronous mode, particularly during starting of MV motors. This will cost more.

3. With the same contribution of fault current from the grid through the l0 MVA step-down transformer, may exceed the damaging level of the 2 MW generator for internal fault of the stator (close to line end of windings).

4. The 13.8 kV switchgear line-up would be much larger than the 2 X 5 MW option.

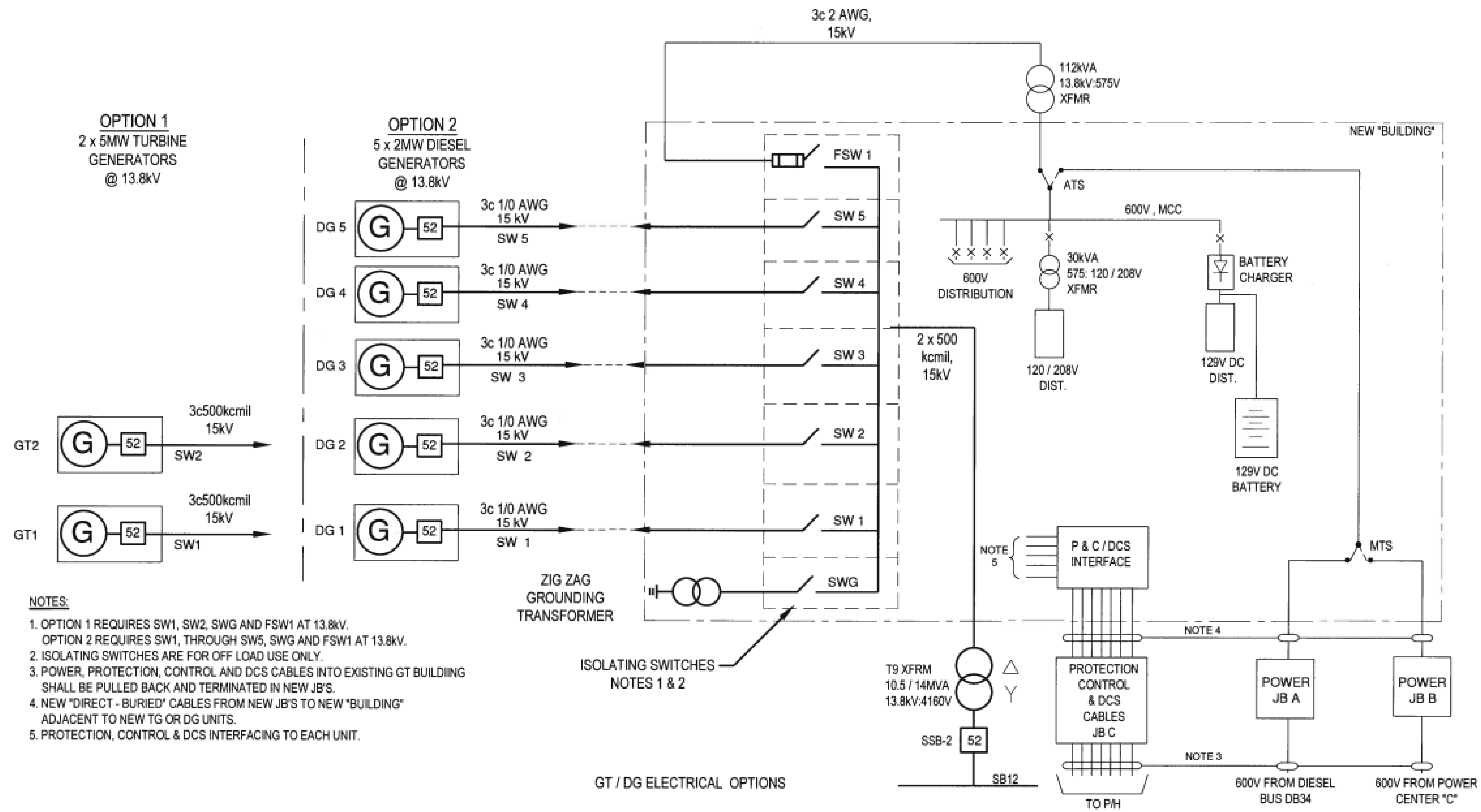



**FIGURE 3-6 SINGLE LINE SKETCH – NEW DIESEL GENSET**

### 3.4.6.1 Equipment & Installation Costs – Electrical & Controls

**TABLE 3-17 ELECTRICAL & CONTROL EQUIPMENT AND INSTALLATION COSTS (OPTION 2) – 5 X 2 MW TGS @ 4160 V.**

| Item # | Desciption | Qty | Unit | Material | Labour | Total | Comments |
|---|---|---|---|---|---|---|---|
| 1 | 3c500 kemil, Teck 15kV cable (2 runs) | 440 | m | 90,200 | 10,000 | 100,200 | Power from switchgear to generators T9 and grounding transformer |
| 2 | 3C 1/0 AWG Teck 15kV cable | 300 | M | 10,800 | 4,000 | 14,800 | |
| 3 | 13.8kV isolating switchgear (6+1 fused switch) | 1 | ea | 144700 | 15000 | 159,700 | |
| 4 | P&C/DCS interface | 1 | ea | 65,000 | 10,000 | 75,000 | Will contain interfacing requirements of the new units to T9 and SSB2 |
| 5 | 10 x 3c12AWG, Teck, 1000V cable | 500 | m | 1920 | 4500 | 6420 | from P&C/DCS interface to DG1 through DG5 for protection and control |
| 6 | 2 x 24c16AWG, Teck, 1000V cable | 350 | m | 8505 | 3150 | 11,655 | Cables from P&C/DCS interface to junction box JBC |
| 7 | 4 x 4c12AWG, Teck, 1000V cable | 700 | m | 3290 | 6300 | 9590 | Cable from FSWI to 112kV transformer |
| 8 | 1 x 12C12AWG, Teck, 1000V cable | 175 | m | 2240 | 1575 | 3815 | Cable ATS to MTS and JBA/JBB to MTS |
| 9 | 3c2AWG, Teck, 15kV cable | 15 | m | 945 | 135 | 1080 | |
| 10 | 2 x 3c1/0, Teck, 1000V cable | 125 | m | 4500 | 1125 | 5625 | |
| 11 | 112kVA, 13.8kV:575V, 3ph, 60Hz transformer | 1 | ea | 30000 | 3000 | 33000 | |
| 12 | 200A, 600V, 3ph, 60Hz automatic transfer switch | 1 | ea | 5336 | 1500 | 6836 | |
| 13 | 200A, 600V, 3ph, 60Hz manual transfer switch | 1 | ea | 2000 | 1000 | 3000 | |
| 14 | MCC, 600A, 600V, 3ph, 3W | 1 | ea | 30000 | 5000 | 35000 | |
| 15 | 30kVA, 575:120/280V, 3ph, 60Hz transformer | 1 | ea | 1,000 | 500 | 1,500 | |
| 16 | 129VDC distribution panel, motor starters and disconnects | 1 | ea | 35000 | 6500 | 41500 | |
| 17 | 100A, 120/208V, 3ph, 60Hz distribution panel c/w breakers | 1 | ea | 1418 | 350 | 1768 | |
| 18 | 600V, battery charger, 129VDC output | 1 | ea | 16,000 | 3220 | 19,220 | |
| 19 | 129VDC battery bank | 1 | ea | 39,000 | 7500 | 46,500 | |
| 20 | All interconnecting cabling | 1 | lot | 16000 | 12000 | 28000 | Includes MCC feeders, heating and lighting |
| 21 | Miscellaneous 4/0 ground wire, tray and hardware | 1 | lot | 16000 | 9000 | 25,000 | |
| 22 | Reconfiguration of DCS screens, and existing system | 1 | lot | - | 25,000 | 25,000 | |
| 23 | 25 kVA, 13.8kV, 3ph, 60Hz, zig-zag grounding transformer | 1 | ea | 31,000 | 2,000 | 33,000 | |
| 24 | Commissioning | | | - | 69,000 | 69,000 | |
| | Totals | | | 554,854 | 201,355 | 756,209 | |

### 3.4.7 Existing Unit De-Commissioning and Demolition

No significant incremental costs were identified for existing unit de-commissioning and/or demolition. It was felt that the value of the materials derived from the demolition could offset the cost to the contractor. If required as a sensitivity, then a value such as $40,000 might be used. This would not be expected to either sway the selection of a preferred option or impact the overall cost. It should be considered as part of an overall project contingency regardless of any option selected.

### 3.4.8 Project Engineering and Management, Owner's Costs

It was assumed that the facility implementation would be undertaken largely as an engineer, procure, construct (EPC) external contract. NL Hydro would be responsible for getting the project approved and the necessary environmental and regulatory approvals.

**EPC Costs**

For the EPC contractor, the project engineering and management costs are based on the total project costs and a percentage for engineering and for management. For the purposes of this estimate, the engineering costs are estimated to be 5% of direct costs of the GT or diesel package and 10% of the balance of plant. The project management and commissioning costs (excluding fuel, Hydro staff costs) are estimated to be 7% of total direct costs. .

**Owner's Costs**

Owner's costs are not included in the estimates, but are likely to be comparable regardless of the selected option. NL Hydro is also assumed to undertake all the necessary environmental and regulatory permitting entirely internally or with some measure of external support (i.e. environmental modeling and engineering support, or full external scope). This cost is also not included but likely on the order of $55,000.

For the actual project implementation, the assumption is that NL Hydro would assume its own costs of this initial development and then assign a project manager for the life of the project to monitor and assure its successful completion. These and other NL Hydro costs (insurance, legal, supply chain, interest, owners' contingency, Holyrood station participation, commissioning fuel, commissioning labour) are not identified or included herein. It is likely that Owner costs could amount to on the order of 1.5% of directs or about $150,000.

### 3.4.9 Total New and Nearly New 5 x 2MW Diesel Generator Capital Cost Estimate

The total New and Nearly New 5 x 2 MW diesel generator cost estimate is as follows. The difference in the New and Nearly New is mostly in the capital costs. It should be noted that there may be some additional costs required to retrofit nearly new units to meet the same or required standards as the new units that are designed to meet Holyrood requirements.

TABLE 3-18 CAPITAL COST ESTIMATE – TRANSPORTABLE DIESEL GENSET

**Capital Cost Comparison**

**Capital cost estimate $1,000 Can 2011**

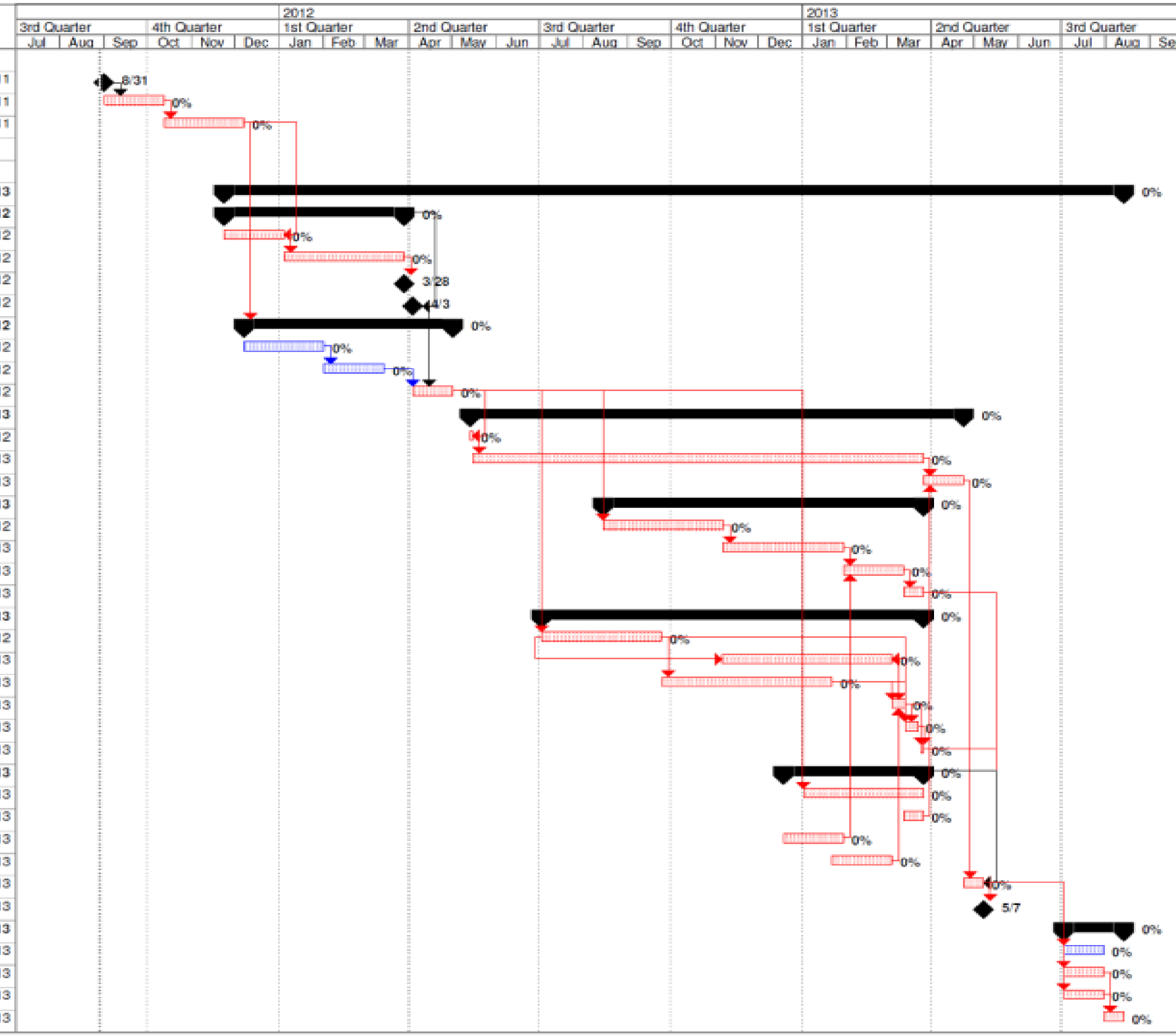
| Option Number | 2 | 2A |
|---|---|---|
| **Option** | **New 5 x 2 MW Diesel** | **Used 5 x 2 MW Diesel** |
| GT/Diesel Cost | $8,553 | $7,453 |
| Civil Works | $131 | $131 |
| Electrical Works | $801 | $801 |
| BOP Systems | $129 | $129 |
| Existing Unit Demolition & Removal | $7 | $7 |
| **Sub-Total - Directs and Indirects** | $9,620 | $8,520 |
| Project Engineering | $513 | $458 |
| Project Management | $673 | $596 |
| Total | $10,807 | $9,575 |

### 3.4.10 Schedule

The schedules for the new and nearly new five 2 MW diesel generator are illustrated below. The basic schedule highlights are as follows:

| Task | New Diesel Genset | Nearly New Diesel Genset |
|---|---|---|
| Review of Options Report | Sept 2011 | |
| Project Approvals and Release | Sept 2011 - Dec 2011 | |
| Engineer, Procure, Construct Contract | May 2012 | |
| In-Service of New 2 x 5 MW GT | May 2013 | March 2013 |
| Decommission Existing GT | Aug/Dec 2013 | Aug/Dec 2013 |

| ID | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 1 | | | | |
| 2 | Condition Assessment Study | 0 wks | Wed 8/31/11 | Wed 8/31/11 |
| 3 | Hydro Internal Capital Budget Proposal Development | 6 wks | Thu 9/1/11 | Wed 10/12/11 |
| 4 | Submission - Public Utilities Board & Approval | 8 wks | Thu 10/13/11 | Wed 12/7/11 |
| 5 | | | | |
| 6 | | | | |
| 7 | **New GT or Diesel Units** | **449 days** | **Thu 11/24/11** | **Tue 8/13/13** |
| 8 | **Project Environmental & Regulatory Approvals** | **90 days** | **Thu 11/24/11** | **Wed 3/28/12** |
| 9 | Prepare Dispersion Modelling & Submission | 30 days | Thu 11/24/11 | Wed 1/4/12 |
| 10 | Regulatory Review and Approval | 60 days | Thu 1/5/12 | Wed 3/28/12 |
| 11 | Environmental Approval | 0 days | Wed 3/28/12 | Wed 3/28/12 |
| 12 | Project Full Release | 0 days | Tue 4/3/12 | Tue 4/3/12 |
| 13 | **Request for Proposal (RFP) for Engineer/procure/Cons** | **104 days** | **Thu 12/8/11** | **Tue 5/1/12** |
| 14 | Prepare | 40 days | Thu 12/8/11 | Wed 2/1/12 |
| 15 | Bid | 6 wks | Thu 2/2/12 | Wed 3/14/12 |
| 16 | Award | 20 days | Wed 4/4/12 | Tue 5/1/12 |
| 17 | **New Gas Turbien or Diesel Engine Generator** | **247 days** | **Mon 5/14/12** | **Tue 4/23/13** |
| 18 | Award Gas Turbine (GT)/Engine Contract | 2 days | Mon 5/14/12 | Tue 5/15/12 |
| 19 | Manufacture & Deliver Transportable Engines | 45 wks | Wed 5/16/12 | Tue 3/26/13 |
| 20 | Install and Commission | 4 wks | Wed 3/27/13 | Tue 4/23/13 |
| 21 | **Fuel System** | **160 days** | **Wed 8/15/12** | **Tue 3/26/13** |
| 22 | Engineer | 12 wks | Wed 8/15/12 | Tue 11/6/12 |
| 23 | Order, Manufacture, Deliver | 12 wks | Wed 11/7/12 | Tue 1/29/13 |
| 24 | Install new fuel lines and receiving system | 6 wks | Wed 1/30/13 | Tue 3/12/13 |
| 25 | Commission System | 2 wks | Wed 3/13/13 | Tue 3/26/13 |
| 26 | **Electrical & Control Systmes** | **191 days** | **Tue 7/3/12** | **Tue 3/26/13** |
| 27 | Engineer | 12 wks | Tue 7/3/12 | Mon 9/24/12 |
| 28 | Order & Manufacture Elect & Control (E&C) Equip | 17 wks | Tue 11/6/12 | Mon 3/4/13 |
| 29 | Electrical Building Manufacture, Delivery, Install | 17 wks | Tue 9/25/12 | Mon 1/21/13 |
| 30 | Install New System | 7 days | Tue 3/5/13 | Wed 3/13/13 |
| 31 | RE-align Existing Plant Systems | 7 days | Thu 3/14/13 | Fri 3/22/13 |
| 32 | Commission unit | 2 days | Mon 3/25/13 | Tue 3/26/13 |
| 33 | **Site Civil Work** | **70 days** | **Wed 12/19/12** | **Tue 3/26/13** |
| 34 | Engineer | 12 wks | Wed 1/2/13 | Tue 3/26/13 |
| 35 | Generator area clearing and civil | 2 wks | Wed 3/13/13 | Tue 3/26/13 |
| 36 | Fuel line civil work | 6 wks | Wed 12/19/12 | Tue 1/29/13 |
| 37 | Electrical an contro cable civil work | 6 wks | Tue 1/22/13 | Mon 3/4/13 |
| 38 | Complete Unit Test | 10 days | Wed 4/24/13 | Tue 5/7/13 |
| 39 | Gas Turbine (GT) In-Service (I/S) | 0 days | Tue 5/7/13 | Tue 5/7/13 |
| 40 | **Decommission Existing GT** | **30 days** | **Wed 7/3/13** | **Tue 8/13/13** |
| 41 | Fuel delivery system | 4 wks | Wed 7/3/13 | Tue 7/30/13 |
| 42 | Electrical & Controls | 4 wks | Wed 7/3/13 | Tue 7/30/13 |
| 43 | GT | 4 wks | Wed 7/3/13 | Tue 7/30/13 |
| 44 | Building | 2 wks | Wed 7/31/13 | Tue 8/13/13 |




Project: Project1 New.mpp
Date: Mon 8/29/11

Critical | Task | Baseline | Milestone | Project Summary | Deadline
Critical Split | Split | Baseline Split | Summary Progress | External Tasks
Critical Progress | Task Progress | Baseline Milestone | Summary | External Milestone

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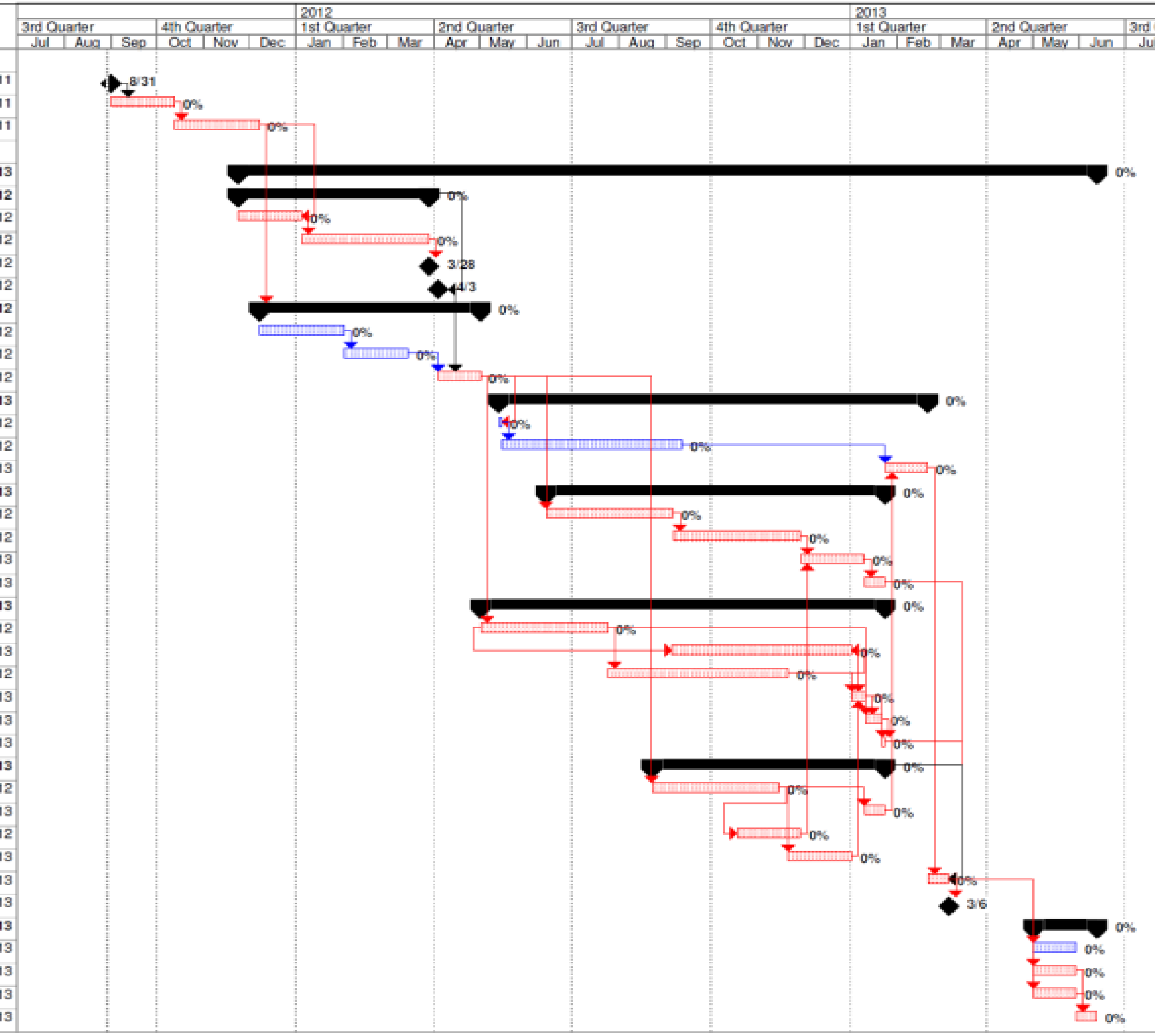
**Figure 3-7 Schedule – New Diesel Genset**

| ID | | Task Name | Duration | Start | Finish |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | Condition Assessment Study | 0 wks | Wed 8/31/11 | Wed 8/31/11 |
| 3 | | Hydro Internal Capital Budget Proposal Development | 6 wks | Thu 9/1/11 | Wed 10/12/11 |
| 4 | | Submission - Public Utilities Board & Approval | 8 wks | Thu 10/13/11 | Wed 12/7/11 |
| 5 | | | | | |
| 6 | | **Nearly New gas Turbine (GT) or Diesel Generator Units** | **405 days** | **Thu 11/24/11** | **Wed 6/12/13** |
| 7 | | **Project Environmental & Regulatory Approvals** | **90 days** | **Thu 11/24/11** | **Wed 3/28/12** |
| 8 | | Prepare Dispersion Modelling & Submission | 30 days | Thu 11/24/11 | Wed 1/4/12 |
| 9 | | Regulatory Review and Approval | 60 days | Thu 1/5/12 | Wed 3/28/12 |
| 10 | | Environmental Approval | 0 days | Wed 3/28/12 | Wed 3/28/12 |
| 11 | | Project Full Release | 0 days | Tue 4/3/12 | Tue 4/3/12 |
| 12 | | **Request for Proposal (RFP) for Engineer/Procure/Construct (** | **104 days** | **Thu 12/8/11** | **Tue 5/1/12** |
| 13 | | Prepare | 40 days | Thu 12/8/11 | Wed 2/1/12 |
| 14 | | Bid | 6 wks | Thu 2/2/12 | Wed 3/14/12 |
| 15 | | Award | 20 days | Wed 4/4/12 | Tue 5/1/12 |
| 16 | | **Nearly New GT or Diesel Engine Generator** | **203 days** | **Mon 5/14/12** | **Wed 2/20/13** |
| 17 | | Award GT/Diesel Engine Contract | 2 days | Mon 5/14/12 | Tue 5/15/12 |
| 18 | | Manufacture & Deliver Transportable Engines | 17 wks | Wed 5/16/12 | Tue 9/11/12 |
| 19 | | Install and Commission | 4 wks | Thu 1/24/13 | Wed 2/20/13 |
| 20 | | **Fuel System** | **160 days** | **Thu 6/14/12** | **Wed 1/23/13** |
| 21 | | Engineer | 12 wks | Thu 6/14/12 | Wed 9/5/12 |
| 22 | | Order, Manufacture, Deliver | 12 wks | Thu 9/6/12 | Wed 11/28/12 |
| 23 | | Install new fuel lines and receiving system | 6 wks | Thu 11/29/12 | Wed 1/9/13 |
| 24 | | Commission System | 2 wks | Thu 1/10/13 | Wed 1/23/13 |
| 25 | | **Electrical & Control Systmes** | **191 days** | **Wed 5/2/12** | **Wed 1/23/13** |
| 26 | | Engineer | 12 wks | Wed 5/2/12 | Tue 7/24/12 |
| 27 | | Order & Manufacture Elect & Control (E&C) Equip | 17 wks | Wed 9/5/12 | Tue 1/1/13 |
| 28 | | Electrical Building Manufacture, Delivery, Install | 17 wks | Wed 7/25/12 | Tue 11/20/12 |
| 29 | | Install New System | 7 days | Wed 1/2/13 | Thu 1/10/13 |
| 30 | | RE-align Existing Plant Systems | 7 days | Fri 1/11/13 | Mon 1/21/13 |
| 31 | | Commission unit | 2 days | Tue 1/22/13 | Wed 1/23/13 |
| 32 | | **Site Civil Work** | **110 days** | **Thu 8/23/12** | **Wed 1/23/13** |
| 33 | | Engineer | 12 wks | Thu 8/23/12 | Wed 11/14/12 |
| 34 | | Generator area clearing and civil | 2 wks | Thu 1/10/13 | Wed 1/23/13 |
| 35 | | Fuel line civil work | 6 wks | Thu 10/18/12 | Wed 11/28/12 |
| 36 | | Electrical an contro cable civil work | 6 wks | Wed 11/21/12 | Tue 1/1/13 |
| 37 | | Complete Unit Test | 10 days | Thu 2/21/13 | Wed 3/6/13 |
| 38 | | GT In-Service (I/S) | 0 days | Wed 3/6/13 | Wed 3/6/13 |
| 39 | | **Decommission Existing GT** | **30 days** | **Thu 5/2/13** | **Wed 6/12/13** |
| 40 | | Fuel delivery system | 4 wks | Thu 5/2/13 | Wed 5/29/13 |
| 41 | | Electrical & Controls | 4 wks | Thu 5/2/13 | Wed 5/29/13 |
| 42 | | GT | 4 wks | Thu 5/2/13 | Wed 5/29/13 |
| 43 | | Building | 2 wks | Thu 5/30/13 | Wed 6/12/13 |




Project: Project1 Nearly New.mpp
Date: Mon 8/29/11

Critical | Critical Split | Critical Progress | Task | Split | Task Progress | Baseline | Baseline Split | Baseline Milestone | Milestone | Summary Progress | Summary | Project Summary | External Tasks | External Milestone | Deadline

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FIGURE 3-8 SCHEDULE – NEW DIESEL GENSET

### 3.4.11 OMA Cost Estimate to 2020

Operating costs were assumed to include the ongoing maintenance costs (annual inspections, repairs, etc.), the operations costs (costs to run the unit on test), the fuelling costs (fuel costs to run the tests), and an electricity value credit. The operating costs shown are the same for both the new and nearly new cases. For the kind of operation required, peak and emergency operation (typically <=60 Hrs/Yr, the diesel packages normally would require only an annual service and inspection by qualified service personnel. Most utilities would exercise the equipment once a month to verify proper operation.

The costs were assumed to include the ongoing maintenance costs (annual inspections, repairs, etc.), the operations costs (costs to run the unit on test), the fuelling costs (fuel costs to run the tests), and an electricity value credit. The assumptions used for fuel, operations, and electricity value are illustrated below. The electricity value is premised on receiving the same value per MWh as the existing units would if they were to recover their fuelling costs plus marginal operating and maintenance costs. The fuelling and electricity prices are intended as representative and based on running the units 150 hours per year, whereas actual hours could be as half of this.. The actual values (average run capacity, sent out heat rate (SOHR) and hence fuel and electricity depend on how the testing is actually done.

**TABLE 3-19 NEW DIESEL GENSET – OMA COST ASSUMPTION**

**Assumptions**

| | | Fuelling |
|---|---|---|
| #2 Oil Fuel Price (A) | $/MMBTU | $21.47 |
| Unit Efficiency (B) | BTU/kWh | 13,656 |
| Average Running Capacity (C) | MW | 4 |
| Average Running Cost (D) = AxBxC/1000 | $/Hr | $1,173 |
| Electricity Value (E) = Value for existing GT | $/MWh | $343 |
| Electricity Value (F) = E*C | $/Hr OP | $1,373 |

| Operations | |
|---|---|
| 2 | Persons/Start (U) |
| 4 | Hrs/Start (V) |
| $70 | $/PersonHr (W) |
| $560 | $/Start (Z) = UxVxW |

The resulting costs are:

**TABLE 3-20 NEW DIESEL GENSET – OMA COSTS**

New/Near New Diesel
1000's Cnd $ - 2011/Yr

| | Maintenance | Operations | Fuelling | Sub-Total | Electricity Value | Total |
|---|---|---|---|---|---|---|
| 2012 | $15 | $0 | $0 | $15 | $0 | $15 |
| 2013 | $20 | $40 | $155 | $215 | ($206) | $9 |
| 2014 | $20 | $40 | $155 | $215 | ($206) | $9 |
| 2015 | $20 | $40 | $155 | $215 | ($206) | $9 |
| 2016 | $20 | $40 | $155 | $215 | ($206) | $9 |
| 2017 | $20 | $40 | $155 | $215 | ($206) | $9 |
| 2018 | $20 | $40 | $155 | $215 | ($206) | $9 |
| 2019 | $20 | $40 | $155 | $215 | ($206) | $9 |
| 2020 | $0 | $40 | $155 | $195 | ($206) | ($11) |
| TOTAL | $155 | $323 | $1,237 | $1,714 | ($1,648) | $67 |

# 4 COMPARATIVE ANALYSIS OF OPTIONS

## 4.1 Economic Assumptions

### 4.1.1 Economic Parameters

The economic parameter values used for escalation rate (general, fuel, electricity rate), and discount rate (escalated and unescalated) are illustrated below, as well as the associated cumulative factors.

**TABLE 4-1 ECONOMIC FACTORS**

| | Escalation | | Discount Rate (Escalated $) | | Real Discount Rate (UnEscalated $) | | Fuel Escalation | | Electricity Value Escalation | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | Escalation | Cumulative Escalation Factor | Discount Rate (Escalated $) | Discount Factor (Escalated $) | Discount Rate (UnEscalated $) | Discout Factor (Unescalated $) | Fuel Escalation Rate | Cumulative Fuel Escalation Factor | Electricity Value Escalation Rate | Cumulative Electricity Value Factor |
| | "A" | "B" = Previous B x (1+A) | "C" | "D" = Previous D x 1/(1+C) | "E" = "C"-"A" | "F" =Previous F x 1/(1+E) | "G" | "H" = Previous H x (1+G) | "I" | "J" = Previous J x (1+I) |
| **2011** | 0.00% | 1.000 | 10.00% | 1.000 | 7.50% | 1.000 | 0.00% | 1.000 | 0.00% | 1.000 |
| **2012** | 2.50% | 1.025 | 10.00% | 0.909 | 7.50% | 0.930 | 3.00% | 1.030 | 3.00% | 1.030 |
| **2013** | 2.50% | 1.051 | 10.00% | 0.826 | 7.50% | 0.865 | 3.00% | 1.061 | 3.00% | 1.061 |
| **2014** | 2.50% | 1.077 | 10.00% | 0.751 | 7.50% | 0.805 | 3.00% | 1.093 | 3.00% | 1.093 |
| **2015** | 2.50% | 1.104 | 10.00% | 0.683 | 7.50% | 0.749 | 3.00% | 1.126 | 3.00% | 1.126 |
| **2016** | 2.50% | 1.131 | 10.00% | 0.621 | 7.50% | 0.697 | 3.00% | 1.159 | 3.00% | 1.159 |
| **2017** | 2.50% | 1.160 | 10.00% | 0.564 | 7.50% | 0.648 | 3.00% | 1.194 | 3.00% | 1.194 |
| **2018** | 2.50% | 1.189 | 10.00% | 0.513 | 7.50% | 0.603 | 3.00% | 1.230 | 3.00% | 1.230 |
| **2019** | 2.50% | 1.218 | 10.00% | 0.467 | 7.50% | 0.561 | 3.00% | 1.267 | 3.00% | 1.267 |
| **2020** | 2.50% | 1.249 | 10.00% | 0.424 | 7.50% | 0.522 | 3.00% | 1.305 | 3.00% | 1.305 |

### 4.1.2 Economic Values - Failure to Operate

The analysis assumed a relative difference in the relative probability of failure to perform as required (with Option 1 – the New 2 x 5 MW GTG as the base against which the others are compared). This is based on the reasons provided previously.

**TABLE 4-2 ECONOMIC VALUES – FAILURE TO OPERATE ASSUMPTION**

| **Failure To Operate** | | % Probability once over 2013-2020 | Value of Hr Shutdown | # Hrs Per Shutdown | Probable $/Incident |
|---|---|---|---|---|---|
| | | % (A) | MM$/Hr (B) | Hrs (C) | MM$ (D) = AxBxC |
| Option 0 | Refurbished Unit | 10% | $5 | 20 | $10 |
| Option1 & 1A | New/Used 2 x 5 MW GT | 0% | $5 | 20 | $0 |
| Option 2 & 2A | New/Used 5x2 MW Diesel | 4% | $5 | 20 | $4 |

**Notes:**
Value/ Hr Shutdown = $5 MM (Impact to Newfoundland Economy)
Probability risk is relative to the new 2 x 5MW GT option
One occurrence assumed nominally in 2016
Probable $/incident increases proportional to (A), (B), or (C)

### 4.1.3 Economic Values –Terminal Values

Each of the options has a "terminal value" at the end of the 2020 period. The amount is a function of both the age and condition and market value of the units at that time, and/or of its internal value for redeployment for other uses within Hydro post 2020 (i.e. regional distribution line outage/maintenance support). Potential short term alternative uses prior to 2020 may also have value, but were not assessed. The terminal values assumed for the study are shown in Table 4-4.

**TABLE 4-3 OPTION TERMINAL VALUES IN 2020**

| Option | Purchased Equipment Cost M$ | System Terminal Value in 2020 M$ | Comment |
|---|---|---|---|
| Option 0 - Refurbished Existing Unit | $3.0 | $0 | Terminal value covers cost for demolition |
| Option 1 - New 2 x 5 MW GT | $10.9 | $7.0 | Low use, essentially new condition. |
| Option 1A - Nearly New 2 x 5 MW GT | $9.2 | $4.0 | Lower percent recovery than new given prior use. |
| Option 2 - New 5 x 2 MW Diesel Genset | $8.6 | $5.0 | Lower market value – more available. |
| Option 2A - Nearly New 5 x 2 MW Diesel Genset | $7.5 | $3.0 | Lower percent recovery than new given prior use. |

## 4.2 Capital Cost Comparison

Table 4-4 provides an overview of the total capital cost of the options.

<u>**Option 0, Existing GTG Unit**</u>

For Option 0, the existing GT Unit refurbishment, there are three relevant values.

- The base total ($4.462M) does not address the replacement of the unit's capacity during its extensive overhaul outage (12 to 22 weeks).
- The second case ("+ standby") is based on the assumption that a "replacement gas generator and power turbine" are leased and substituted for the current equipment during the overhaul outage. There is a strong likelihood that this is possible. It is assumed that other issues (gearbox oil leaks etc are fixed in relatively short time on site). It is unlikely that other major equipment such as a gearbox could be leased.
- The third option ("+ Rental Stby") assumes that two new 5 MW trailer mounted gas turbines are leased for the outage period and the necessary facilities to connect them installed. This is a very expensive option and auxiliary systems will have limited useful life. It is also likely to significantly extend the schedule. It is not seen as a viable option to pursuing Option 1 or 1A.

<u>**Options 1 and 2, New and Nearly New, Used Gas Turbine Generator and Diesel Generator Units**</u>

The difference in the New and Nearly New is mostly in the capital costs. It should be noted that there may be some additional costs required to retrofit nearly new units to meet the same or required standards as the new units that are designed to meet Holyrood requirements.

**TABLE 4-4 CAPITAL COST COMPARISON OF OPTIONS**

**Capital Cost Comparison**
**Capital cost estimate $1,000 Can 2011**

| **Option Number** | **0** | **1** | **1A** | **2** | **2A** |
|---|---|---|---|---|---|
| **Option** | **Existing GT Refurb** | **New 2 x 5 MW GT** | **Used 2 x 5 MW GT** | **New 5 x 2 MW Diesel** | **Used 5 x 2 MW Diesel** |
| GT/Diesel Cost | $2,950 | $10,865 | $9,234 | $8,553 | $7,453 |
| Civil Works | $224 | $131 | $131 | $131 | $131 |
| Electrical Works | $541 | $759 | $759 | $801 | $801 |
| BOP Systems | $330 | $129 | $129 | $129 | $129 |
| Existing Unit Demolition & Removal | $0 | $7 | $7 | $7 | $7 |
| **Sub-Total - Directs and Indirects** | $4,046 | $11,891 | $10,260 | $9,620 | $8,520 |
| Project Engineering | $324 | $625 | $544 | $513 | $458 |
| Project Management | $283 | $832 | $718 | $673 | $596 |
| Total | $4,652 | $13,348 | $11,522 | $10,807 | $9,575 |

| | |
|---|---|
| + Standby = Total | $4,825 |
| | |
| + New Rental Stdby = Total | $9,421 |

## 4.3 Operating Cost Comparison

Operating costs were assumed to include the ongoing maintenance costs (annual inspections, repairs, etc.), the operations costs (costs to run the unit on test), the fuelling costs (fuel costs to run the tests), and an electricity value credit.

**For Option 0, Existing GTG Unit**

The operating costs are shown for both a refurbished case and a non-refurbished case. The assumptions used for fuel, operations, and electricity value are illustrated below. The electricity value is premised on recovering fuelling costs plus marginal operating costs.

**TABLE 4-5 OMA ASSUMPTIONS – OPTION 0, EXISTING GTG**

**Assumptions**

| | | Fuelling |
|---|---|---|
| #2 Oil Fuel Price (A) | $/MMBTU | $21.47 |
| Unit Efficiency (B) | BTU/kWh | 13,656 |
| Average Running Capacity (C) | MW | 4 |
| Average Running Cost (D) = AxBxC/1000 | $/Hr | $1,173 |
| Electricity Value (E) = AxB/1000 + $50 Mtce | $/MWh | $343 |
| Electricity Value (F) = E*C | $/Hr OP | $1,373 |

| Operations | |
|---|---|
| 2 | Persons/Start (U) |
| 4 | Hrs/Start (V) |
| $70 | $/PersonHr (W) |
| $560 | $/Start (Z) = UxVxW |

The non-refurbished case includes an assumption of an equipment failure with modest consequential damage in 2016.

**TABLE 4-6 OMA COSTS – OPTION 0, EXISTING GTG**

Existing Unit
1000's Cnd $ - 2011/Yr

| | Maintenance | | Operations | | Fuelling | | Sub-Total | | Electricity Value | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | With Rehab | Without Rehab | With Rehab | Without Rehab | With Rehab | Without Rehab | With Rehab | Without Rehab | With Rehab | Without Rehab | With Rehab | Without Rehab |
| 2012 | $15 | $15 | $0 | $0 | $0 | $0 | $15 | $15 | $0 | $0 | $15 | $15 |
| 2013 | $20 | $15 | $40 | $0 | $176 | $0 | $236 | $15 | ($206) | $0 | $30 | $15 |
| 2014 | $20 | $15 | $40 | $0 | $176 | $0 | $236 | $15 | ($206) | $0 | $30 | $15 |
| 2015 | $20 | $15 | $40 | $0 | $176 | $0 | $236 | $15 | ($206) | $0 | $30 | $15 |
| 2016 | $20 | $1,500 | $40 | $1 | $176 | $88 | $236 | $1,589 | ($206) | ($103) | $30 | $1,486 |
| 2017 | $20 | $15 | $40 | $0 | $176 | $0 | $236 | $15 | ($206) | $0 | $30 | $15 |
| 2018 | $20 | $15 | $40 | $0 | $176 | $0 | $236 | $15 | ($206) | $0 | $30 | $15 |
| 2019 | $20 | $15 | $40 | $0 | $176 | $0 | $236 | $15 | ($206) | $0 | $30 | $15 |
| 2020 | $0 | $0 | $40 | $0 | $176 | $0 | $216 | $0 | ($206) | $0 | $10 | $0 |
| TOTAL | $155 | $1,605 | $323 | $1 | $1,408 | $88 | $1,885 | $1,694 | ($1,648) | ($103) | $238 | $1,591 |

## For Option 1 and 1A – New and Nearly New 2 x 5MW GTG

The operating costs shown are the same for both the new and nearly new cases. The difference in the New and Nearly New is mostly in the capital costs. The vendor indicated that for the 6 month inspection the cost was to be 10,000 and for the yearly it was 18,000 and that these costs would be the same for both new and nearly new.

The assumptions used for fuel, operations, and electricity value are illustrated below. The electricity value is premised on recovering fuelling costs plus marginal operating costs.

**TABLE 4-7 OMA ASSUMPTIONS – OPTION 1, NEW TRANSPORTABLE GTG**

**Assumptions**

| | | |
|---|---|---|
| #2 Oil Fuel Price (A) | $/MMBTU | $21.47 |
| Unit Efficiency (B) | BTU/kWh | 12,000 |
| Average Running Capacity (C) | MW | 4 |
| Average Running Cost (D) = AxBxC/1000 | $/Hr | $1,031 |
| Electricity Value (E) = Value for existing GT | $/MWh | $343.25 |
| Electricity Value (F) = E*C | $/Hr OP | $1,373 |

| | |
|---|---|
| 2 | Persons/Start (U) |
| 4 | Hrs/Start (V) |
| $70 | $/PersonHr (W) |
| $560 | $/Start (Z) = UxVxW |

The resulting costs are:

**TABLE 4-8 OMA COSTS – OPTION 1, NEW TRANSPORTABLE GTG**

New/Near New GT
1000's Cnd $ - 2011/Yr

| | Maintenance | Operations | Fuelling | Sub-Total | Electricity Value | | Total |
|---|---|---|---|---|---|---|---|
| 2012 | $15 | $0 | $0 | $15 | $0 | | $15 |
| 2013 | $20 | $40 | $155 | $215 | ($206) | | $9 |
| 2014 | $20 | $40 | $155 | $215 | ($206) | | $9 |
| 2015 | $20 | $40 | $155 | $215 | ($206) | | $9 |
| 2016 | $20 | $40 | $155 | $215 | ($206) | | $9 |
| 2017 | $20 | $40 | $155 | $215 | ($206) | | $9 |
| 2018 | $20 | $40 | $155 | $215 | ($206) | | $9 |
| 2019 | $20 | $40 | $155 | $215 | ($206) | | $9 |
| 2020 | $0 | $40 | $155 | $195 | ($206) | | ($11) |
| TOTAL | $155 | $323 | $1,237 | $1,714 | ($1,648) | | $67 |

**For Option 2 and 2A – New and Nearly New 5 x 2MW Diesel Engine Generators**

The operating costs shown are the same for both the new and nearly new cases. The difference in the New and Nearly New is mostly in the capital costs.

The assumptions used for fuel, operations, and electricity value are illustrated below. The electricity value is premised on recovering fuelling costs plus marginal operating costs.

**TABLE 4-9 OMA ASSUMPTIONS – OPTION 2, NEW DIESEL GENSET**

**Assumptions**

| | | Fuelling |
|---|---|---|
| #2 Oil Fuel Price (A) | $/MMBTU | $21.47 |
| Unit Efficiency (B) | BTU/kWh | 13,656 |
| Average Running Capacity (C) | MW | 4 |
| Average Running Cost (D) = AxBxC/1000 | $/Hr | $1,173 |
| Electricity Value (E) = Value for existing GT | $/MWh | $343 |
| Electricity Value (F) = E*C | $/Hr OP | $1,373 |

| Operations | |
|---|---|
| 2 | Persons/Start (U) |
| 4 | Hrs/Start (V) |
| $70 | $/PersonHr (W) |
| $560 | $/Start (Z) = UxVxW |

The resulting costs are:

**TABLE 4-10 OMA COSTS – OPTION 2, NEW DIESEL GENSET**

New/Near New Diesel
1000's Cnd $ - 2011/Yr

| | Maintenance | Operations | Fuelling | Sub-Total | Electricity Value | Total |
|---|---|---|---|---|---|---|
| 2012 | $15 | $0 | $0 | $15 | $0 | $15 |
| 2013 | $20 | $40 | $155 | $215 | ($206) | $9 |
| 2014 | $20 | $40 | $155 | $215 | ($206) | $9 |
| 2015 | $20 | $40 | $155 | $215 | ($206) | $9 |
| 2016 | $20 | $40 | $155 | $215 | ($206) | $9 |
| 2017 | $20 | $40 | $155 | $215 | ($206) | $9 |
| 2018 | $20 | $40 | $155 | $215 | ($206) | $9 |
| 2019 | $20 | $40 | $155 | $215 | ($206) | $9 |
| 2020 | $0 | $40 | $155 | $195 | ($206) | ($11) |
| TOTAL | $155 | $323 | $1,237 | $1,714 | ($1,648) | $67 |

## 4.4 Life Cycle Cost Comparison

Table 4-11 presents a summary of the life cycle cost comparison of the options in 1) un-escalated non-discounted (not present worthed), 2) un-escalated discounted (present worthed), 3) escalated non-discounted (not present worthed), and 4) escalated discounted (present worthed) costs.

The existing unit refurbishment option costs include the lower cost standby option, assuming that a replacement gas generator and power turbine are leased and installed while the existing units are sent out for refurbishment. This adds only about $200,000 to the base cost.

The existing unit refurbishment option costs assuming the standby option using a complete, installed 2 x 5 MW nearly new GT leased option would add an additional $4.6 M.

The options include a cost for differences in the likelihood of a failure occurring once during the period – an additional $10 million in 2016 for the existing GTG and $3 to 4 million for the 5 x 2 MW diesel options.

### TABLE 4-11 LIFE CYCLE COST COMPARISON SUMMARY

| | | Refurbished Unit, Use of Spare Gas Generator & Power Turbine | | | | | |
|---|---|---|---|---|---|---|---|
| | | Capital Cost | OMA | Fuel | Sub-Total | Elect Value | Total |
| 1 | UNESCALATED | $14,825 | $1,885 | $1,408 | $18,118 | ($1,648) | $16,470 |
| 2 | UNESCALATED, DISCOUTED CASHFLOW | $11,454 | $1,291 | $959 | $13,704 | ($1,122) | $12,582 |
| 3 | ESCALATED CASHFLOW | $16,260 | $2,159 | $1,660 | $20,079 | ($1,943) | $18,136 |
| 4 | ESCALATED, DISCOUTED CASHFLOW | $11,521 | $1,302 | $992 | $13,815 | ($1,161) | $12,654 |

| | | Option 1 New 2x5 MW GT | | | | | |
|---|---|---|---|---|---|---|---|
| | | Capital Cost | OMA | Fuel | Sub-Total | Elect Value | Total |
| 1 | UNESCALATED | $6,348 | $1,714 | $1,237 | $9,300 | ($1,648) | $7,652 |
| 2 | UNESCALATED, DISCOUTED CASHFLOW | $8,766 | $1,175 | $842 | $10,783 | ($1,122) | $9,661 |
| 3 | ESCALATED CASHFLOW | $4,940 | $1,963 | $1,459 | $8,362 | ($1,943) | $6,419 |
| 4 | ESCALATED, DISCOUTED CASHFLOW | $8,731 | $1,185 | $871 | $10,787 | ($1,161) | $9,626 |

| | Option 1A Used 2x5 MW GT | | | | | |
|---|---|---|---|---|---|---|
| | Capital Cost | OMA | Fuel | Sub-Total | Elect Value | Total |
| 1 | $7,522 | $1,714 | $1,237 | $10,473 | ($1,648) | $8,826 |
| 2 | $8,632 | $1,175 | $842 | $10,649 | ($1,122) | $9,527 |
| 3 | $6,815 | $1,963 | $1,459 | $10,236 | ($1,943) | $8,294 |
| 4 | $8,618 | $1,185 | $871 | $10,674 | ($1,161) | $9,513 |

| | | Option 2 New 5x2MW Diesel | | | | | |
|---|---|---|---|---|---|---|---|
| | | Capital Cost | OMA | Fuel | Sub-Total | Elect Value | Total |
| 1 | UNESCALATED | $9,807 | $323 | $1,237 | $11,366 | ($1,648) | $9,719 |
| 2 | UNESCALATED, DISCOUTED CASHFLOW | $10,231 | $220 | $842 | $11,293 | ($1,122) | $10,171 |
| 3 | ESCALATED CASHFLOW | $9,358 | $370 | $1,459 | $11,187 | ($1,943) | $9,244 |
| 4 | ESCALATED, DISCOUTED CASHFLOW | $10,232 | $222 | $871 | $11,325 | ($1,161) | $10,164 |

| | Option 2A Used 5x2MW Diesel | | | | | |
|---|---|---|---|---|---|---|
| | Capital Cost | OMA | Fuel | Sub-Total | Elect Value | Total |
| 1 | $10,575 | $323 | $1,237 | $12,134 | ($1,648) | $10,487 |
| 2 | $10,128 | $220 | $842 | $11,190 | ($1,122) | $10,068 |
| 3 | $10,593 | $370 | $1,459 | $12,422 | ($1,943) | $10,479 |
| 4 | $10,143 | $222 | $871 | $11,236 | ($1,161) | $10,075 |

The details of the un-escalated non-discounted (not present worthed) and unescalated discounted (present worthed) tables for the options, using the assumption in Section 4.1, are as follows:

**TABLE 4-12 LIFE CYCLE COST COMPARISON (UNESCALATED, NOT-DISCOUNTED AND DISCOUNTED)**

**UNESCALATED, NOT DISCOUNTED CASHFLOW**

Refurbished Unit, Use of Spare Gas Generator & Power Turbine

| | Capital Cost | OMA | Fuel | Sub-Total | Elect Value | Total |
|---|---|---|---|---|---|---|
| 2011 | | $0 | $0 | $0 | $0 | $0 |
| 2012 | $4,825 | $15 | $0 | $4,840 | $0 | $4,840 |
| 2013 | | $236 | $176 | $412 | ($206) | $206 |
| 2014 | | $236 | $176 | $412 | ($206) | $206 |
| 2015 | | $236 | $176 | $412 | ($206) | $206 |
| 2016 | $10,000 | $236 | $176 | $10,412 | ($206) | $10,206 |
| 2017 | | $236 | $176 | $412 | ($206) | $206 |
| 2018 | | $236 | $176 | $412 | ($206) | $206 |
| 2019 | | $236 | $176 | $412 | ($206) | $206 |
| 2020 | $0 | $216 | $176 | $392 | ($206) | $186 |
| Total | $14,825 | $1,885 | $1,408 | $18,118 | ($1,648) | $16,470 |

Option 1 New 2x5 MW GT

| | Capital Cost | OMA | Fuel | Sub-Total | Elect Value | Total |
|---|---|---|---|---|---|---|
| 2011 | | $0 | $0 | $0 | $0 | $0 |
| 2012 | $13,348 | $15 | $0 | $13,363 | $0 | $13,363 |
| 2013 | | $215 | $155 | $370 | ($206) | $164 |
| 2014 | | $215 | $155 | $370 | ($206) | $164 |
| 2015 | | $215 | $155 | $370 | ($206) | $164 |
| 2016 | $0 | $215 | $155 | $370 | ($206) | $164 |
| 2017 | | $215 | $155 | $370 | ($206) | $164 |
| 2018 | | $215 | $155 | $370 | ($206) | $164 |
| 2019 | | $215 | $155 | $370 | ($206) | $164 |
| 2020 | ($7,000) | $195 | $155 | ($6,650) | ($206) | ($6,856) |
| Total | $6,348 | $1,714 | $1,237 | $9,300 | ($1,648) | $7,652 |

Option 1A Used 2x5 MW GT

| | Capital Cost | OMA | Fuel | Sub-Total | Elect Value | Total |
|---|---|---|---|---|---|---|
| 2011 | | $0 | $0 | $0 | $0 | $0 |
| 2012 | $11,522 | $15 | $0 | $11,537 | $0 | $11,537 |
| 2013 | | $215 | $155 | $370 | ($206) | $164 |
| 2014 | | $215 | $155 | $370 | ($206) | $164 |
| 2015 | | $215 | $155 | $370 | ($206) | $164 |
| 2016 | $0 | $215 | $155 | $370 | ($206) | $164 |
| 2017 | | $215 | $155 | $370 | ($206) | $164 |
| 2018 | | $215 | $155 | $370 | ($206) | $164 |
| 2019 | | $215 | $155 | $370 | ($206) | $164 |
| 2020 | ($4,000) | $195 | $155 | ($3,650) | ($206) | ($3,856) |
| Total | $7,522 | $1,714 | $1,237 | $10,473 | ($1,648) | $8,826 |

Option 2 New 5 x 2 MW Diesel

| | Capital Cost | OMA | Fuel | Sub-Total | Elect Value | Total |
|---|---|---|---|---|---|---|
| 2011 | | $0 | $0 | $0 | $0 | $0 |
| 2012 | $10,807 | $0 | $0 | $10,807 | $0 | $10,807 |
| 2013 | | $40 | $155 | $195 | ($206) | ($11) |
| 2014 | | $40 | $155 | $195 | ($206) | ($11) |
| 2015 | | $40 | $155 | $195 | ($206) | ($11) |
| 2016 | $4,000 | $40 | $155 | $4,195 | ($206) | $3,989 |
| 2017 | | $40 | $155 | $195 | ($206) | ($11) |
| 2018 | | $40 | $155 | $195 | ($206) | ($11) |
| 2019 | | $40 | $155 | $195 | ($206) | ($11) |
| 2020 | ($5,000) | $40 | $155 | ($4,805) | ($206) | ($5,011) |
| Total | $9,807 | $323 | $1,237 | $11,366 | ($1,648) | $9,719 |

Option 2A used 5 x 2 MW Diesel

| | Capital Cost | OMA | Fuel | Sub-Total | Elect Value | Total |
|---|---|---|---|---|---|---|
| 2011 | | $0 | $0 | $0 | $0 | $0 |
| 2012 | $9,575 | $0 | $0 | $9,575 | $0 | $9,575 |
| 2013 | | $40 | $155 | $195 | ($206) | ($11) |
| 2014 | | $40 | $155 | $195 | ($206) | ($11) |
| 2015 | | $40 | $155 | $195 | ($206) | ($11) |
| 2016 | $4,000 | $40 | $155 | $4,195 | ($206) | $3,989 |
| 2017 | | $40 | $155 | $195 | ($206) | ($11) |
| 2018 | | $40 | $155 | $195 | ($206) | ($11) |
| 2019 | | $40 | $155 | $195 | ($206) | ($11) |
| 2020 | ($3,000) | $40 | $155 | ($2,805) | ($206) | ($3,011) |
| Total | $10,575 | $323 | $1,237 | $12,134 | ($1,648) | $10,487 |

**UNESCALATED, DISCOUTED CASHFLOW**

Refurbished Unit, Use of Spare Gas Generator & Power Turbine

| | Capital Cost | OMA | Fuel | Sub-Total | Elect Value | Total |
|---|---|---|---|---|---|---|
| 2011 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2012 | $4,489 | $14 | $0 | $4,502 | $0 | $4,502 |
| 2013 | $0 | $204 | $152 | $357 | ($178) | $178 |
| 2014 | $0 | $190 | $142 | $332 | ($166) | $166 |
| 2015 | $0 | $177 | $132 | $309 | ($154) | $154 |
| 2016 | $6,966 | $165 | $123 | $7,253 | ($143) | $7,109 |
| 2017 | $0 | $153 | $114 | $267 | ($133) | $134 |
| 2018 | $0 | $142 | $106 | $248 | ($124) | $124 |
| 2019 | $0 | $132 | $99 | $231 | ($115) | $116 |
| 2020 | $0 | $113 | $92 | $205 | ($107) | $97 |
| Total | $11,454 | $1,291 | $959 | $13,704 | ($1,122) | $12,582 |

Option 1 New 2x5 MW GT

| | Capital Cost | OMA | Fuel | Sub-Total | Elect Value | Total |
|---|---|---|---|---|---|---|
| 2011 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2012 | $12,417 | $14 | $0 | $12,431 | $0 | $12,431 |
| 2013 | $0 | $186 | $134 | $320 | ($178) | $142 |
| 2014 | $0 | $173 | $124 | $297 | ($166) | $132 |
| 2015 | $0 | $161 | $116 | $277 | ($154) | $123 |
| 2016 | $0 | $150 | $108 | $257 | ($143) | $114 |
| 2017 | $0 | $139 | $100 | $239 | ($133) | $106 |
| 2018 | $0 | $130 | $93 | $223 | ($124) | $99 |
| 2019 | $0 | $121 | $87 | $207 | ($115) | $92 |
| 2020 | ($3,651) | $102 | $81 | ($3,469) | ($107) | ($3,576) |
| Total | $8,766 | $1,175 | $842 | $10,783 | ($1,122) | $9,661 |

Option 1A Used 2x5 MW GT

| | Capital Cost | OMA | Fuel | Sub-Total | Elect Value | Total |
|---|---|---|---|---|---|---|
| 2011 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2012 | $10,718 | $14 | $0 | $10,732 | $0 | $10,732 |
| 2013 | $0 | $186 | $134 | $320 | ($178) | $142 |
| 2014 | $0 | $173 | $124 | $297 | ($166) | $132 |
| 2015 | $0 | $161 | $116 | $277 | ($154) | $123 |
| 2016 | $0 | $150 | $108 | $257 | ($143) | $114 |
| 2017 | $0 | $139 | $100 | $239 | ($133) | $106 |
| 2018 | $0 | $130 | $93 | $223 | ($124) | $99 |
| 2019 | $0 | $121 | $87 | $207 | ($115) | $92 |
| 2020 | ($2,086) | $102 | $81 | ($1,904) | ($107) | ($2,011) |
| Total | $8,632 | $1,175 | $842 | $10,649 | ($1,122) | $9,527 |

Option 2 New 5 x 2 MW Diesel

| | Capital Cost | OMA | Fuel | Sub-Total | Elect Value | Total |
|---|---|---|---|---|---|---|
| 2011 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2012 | $10,053 | $0 | $0 | $10,053 | $0 | $10,053 |
| 2013 | $0 | $35 | $134 | $169 | ($178) | ($10) |
| 2014 | $0 | $32 | $124 | $157 | ($166) | ($9) |
| 2015 | $0 | $30 | $116 | $146 | ($154) | ($8) |
| 2016 | $2,786 | $28 | $108 | $2,922 | ($143) | $2,779 |
| 2017 | $0 | $26 | $100 | $126 | ($133) | ($7) |
| 2018 | $0 | $24 | $93 | $117 | ($124) | ($7) |
| 2019 | $0 | $23 | $87 | $109 | ($115) | ($6) |
| 2020 | ($2,608) | $21 | $81 | ($2,506) | ($107) | ($2,614) |
| Total | $10,231 | $220 | $842 | $11,293 | ($1,122) | $10,171 |

Option 2A used 5 x 2 MW Diesel

| | Capital Cost | OMA | Fuel | Sub-Total | Elect Value | Total |
|---|---|---|---|---|---|---|
| 2011 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2012 | $8,907 | $0 | $0 | $8,907 | $0 | $8,907 |
| 2013 | $0 | $35 | $134 | $169 | ($178) | ($10) |
| 2014 | $0 | $32 | $124 | $157 | ($166) | ($9) |
| 2015 | $0 | $30 | $116 | $146 | ($154) | ($8) |
| 2016 | $2,786 | $28 | $108 | $2,922 | ($143) | $2,779 |
| 2017 | $0 | $26 | $100 | $126 | ($133) | ($7) |
| 2018 | $0 | $24 | $93 | $117 | ($124) | ($7) |
| 2019 | $0 | $23 | $87 | $109 | ($115) | ($6) |
| 2020 | ($1,565) | $21 | $81 | ($1,463) | ($107) | ($1,570) |
| Total | $10,128 | $220 | $842 | $11,190 | ($1,122) | $10,068 |

Based on escalated cost assumptions in Section 4.1, the escalated non-discounted (not present worthed) and escalated discounted (present worthed) tables are as follows.

**TABLE 4-13 LIFE CYCLE COST COMPARISON (ESCALATED, NOT DISCOUNTED AND DISCOUNTED, PRESENT VALUED)**

**ESCALATED, NOT DISCOUNTED CASHFLOW**

Refurbished Unit, Use of Spare Gas Generator & Power Turbine

| | Capital Cost | OMA | Fuel | Sub-Total | Elect Value | Total |
|---|---|---|---|---|---|---|
| 2011 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2012 | $4,946 | $15 | $0 | $4,961 | $0 | $4,961 |
| 2013 | $0 | $248 | $187 | $435 | ($218) | $216 |
| 2014 | $0 | $254 | $192 | $447 | ($225) | $222 |
| 2015 | $0 | $261 | $198 | $459 | ($232) | $227 |
| 2016 | $11,314 | $267 | $204 | $11,785 | ($239) | $11,547 |
| 2017 | $0 | $274 | $210 | $484 | ($246) | $238 |
| 2018 | $0 | $281 | $216 | $497 | ($253) | $244 |
| 2019 | $0 | $288 | $223 | $511 | ($261) | $250 |
| 2020 | $0 | $270 | $230 | $500 | ($269) | $231 |
| Total | $16,260 | $2,159 | $1,660 | $20,079 | ($1,943) | $18,136 |

Option 1 New 2x5 MW GT

| | Capital Cost | OMA | Fuel | Sub-Total | Elect Value | Total |
|---|---|---|---|---|---|---|
| 2011 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2012 | $13,682 | $15 | $0 | $13,697 | $0 | $13,697 |
| 2013 | $0 | $226 | $164 | $390 | ($218) | $171 |
| 2014 | $0 | $231 | $169 | $400 | ($225) | $175 |
| 2015 | $0 | $237 | $174 | $411 | ($232) | $179 |
| 2016 | $0 | $243 | $179 | $422 | ($239) | $184 |
| 2017 | $0 | $249 | $185 | $434 | ($246) | $188 |
| 2018 | $0 | $255 | $190 | $446 | ($253) | $192 |
| 2019 | $0 | $262 | $196 | $458 | ($261) | $197 |
| 2020 | ($8,742) | $243 | $202 | ($8,297) | ($269) | ($8,566) |
| Total | $4,940 | $1,963 | $1,459 | $8,362 | ($1,943) | $6,419 |

Option 1A Used 2x5 MW GT

| | Capital Cost | OMA | Fuel | Sub-Total | Elect Value | Total |
|---|---|---|---|---|---|---|
| 2011 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2012 | $11,810 | $15 | $0 | $11,826 | $0 | $11,826 |
| 2013 | $0 | $226 | $164 | $390 | ($218) | $171 |
| 2014 | $0 | $231 | $169 | $400 | ($225) | $175 |
| 2015 | $0 | $237 | $174 | $411 | ($232) | $179 |
| 2016 | $0 | $243 | $179 | $422 | ($239) | $184 |
| 2017 | $0 | $249 | $185 | $434 | ($246) | $188 |
| 2018 | $0 | $255 | $190 | $446 | ($253) | $192 |
| 2019 | $0 | $262 | $196 | $458 | ($261) | $197 |
| 2020 | ($4,995) | $243 | $202 | ($4,550) | ($269) | ($4,819) |
| Total | $6,815 | $1,963 | $1,459 | $10,236 | ($1,943) | $8,294 |

Option 2 New 5 x 2 MW Diesel

| | Capital Cost | OMA | Fuel | Sub-Total | Elect Value | Total |
|---|---|---|---|---|---|---|
| 2011 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2012 | $11,077 | $0 | $0 | $11,077 | $0 | $11,077 |
| 2013 | $0 | $42 | $164 | $206 | ($218) | ($12) |
| 2014 | $0 | $43 | $169 | $212 | ($225) | ($13) |
| 2015 | $0 | $45 | $174 | $219 | ($232) | ($13) |
| 2016 | $4,526 | $46 | $179 | $4,750 | ($239) | $4,512 |
| 2017 | $0 | $47 | $185 | $231 | ($246) | ($15) |
| 2018 | $0 | $48 | $190 | $238 | ($253) | ($15) |
| 2019 | $0 | $49 | $196 | $245 | ($261) | ($16) |
| 2020 | ($6,244) | $50 | $202 | ($5,992) | ($269) | ($6,261) |
| Total | $9,358 | $370 | $1,459 | $11,187 | ($1,943) | $9,244 |

Option 2A used 5 x 2 MW Diesel

| | Capital Cost | OMA | Fuel | Sub-Total | Elect Value | Total |
|---|---|---|---|---|---|---|
| 2011 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2012 | $9,814 | $0 | $0 | $9,814 | $0 | $9,814 |
| 2013 | $0 | $42 | $164 | $206 | ($218) | ($12) |
| 2014 | $0 | $43 | $169 | $212 | ($225) | ($13) |
| 2015 | $0 | $45 | $174 | $219 | ($232) | ($13) |
| 2016 | $4,526 | $46 | $179 | $4,750 | ($239) | $4,512 |
| 2017 | $0 | $47 | $185 | $231 | ($246) | ($15) |
| 2018 | $0 | $48 | $190 | $238 | ($253) | ($15) |
| 2019 | $0 | $49 | $196 | $245 | ($261) | ($16) |
| 2020 | ($3,747) | $50 | $202 | ($3,494) | ($269) | ($3,763) |
| Total | $10,593 | $370 | $1,459 | $12,422 | ($1,943) | $10,479 |

**ESCALATED, DISCOUTED CASHFLOW**

Refurbished Unit, Use of Spare Gas Generator & Power Turbine

| | Capital Cost | OMA | Fuel | Sub-Total | Elect Value | Total |
|---|---|---|---|---|---|---|
| 2011 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2012 | $4,496 | $14 | $0 | $4,510 | $0 | $4,510 |
| 2013 | $0 | $205 | $154 | $359 | ($181) | $179 |
| 2014 | $0 | $191 | $144 | $336 | ($169) | $167 |
| 2015 | $0 | $178 | $135 | $313 | ($158) | $155 |
| 2016 | $7,025 | $166 | $127 | $7,318 | ($148) | $7,170 |
| 2017 | $0 | $155 | $119 | $273 | ($139) | $134 |
| 2018 | $0 | $144 | $111 | $255 | ($130) | $125 |
| 2019 | $0 | $134 | $104 | $238 | ($122) | $117 |
| 2020 | $0 | $115 | $97 | $212 | ($114) | $98 |
| Total | $11,521 | $1,302 | $992 | $13,815 | ($1,161) | $12,654 |

Option 1 New 2x5 MW GT

| | Capital Cost | OMA | Fuel | Sub-Total | Elect Value | Total |
|---|---|---|---|---|---|---|
| 2011 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2012 | $12,438 | $14 | $0 | $12,452 | $0 | $12,452 |
| 2013 | $0 | $187 | $136 | $322 | ($181) | $142 |
| 2014 | $0 | $174 | $127 | $301 | ($169) | $132 |
| 2015 | $0 | $162 | $119 | $281 | ($158) | $123 |
| 2016 | $0 | $151 | $111 | $262 | ($148) | $114 |
| 2017 | $0 | $141 | $104 | $245 | ($139) | $106 |
| 2018 | $0 | $131 | $98 | $229 | ($130) | $99 |
| 2019 | $0 | $122 | $91 | $214 | ($122) | $92 |
| 2020 | ($3,707) | $103 | $86 | ($3,519) | ($114) | ($3,633) |
| Total | $8,731 | $1,185 | $871 | $10,787 | ($1,161) | $9,626 |

Option 1A Used 2x5 MW GT

| | Capital Cost | OMA | Fuel | Sub-Total | Elect Value | Total |
|---|---|---|---|---|---|---|
| 2011 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2012 | $10,737 | $14 | $0 | $10,750 | $0 | $10,750 |
| 2013 | $0 | $187 | $136 | $322 | ($181) | $142 |
| 2014 | $0 | $174 | $127 | $301 | ($169) | $132 |
| 2015 | $0 | $162 | $119 | $281 | ($158) | $123 |
| 2016 | $0 | $151 | $111 | $262 | ($148) | $114 |
| 2017 | $0 | $141 | $104 | $245 | ($139) | $106 |
| 2018 | $0 | $131 | $98 | $229 | ($130) | $99 |
| 2019 | $0 | $122 | $91 | $214 | ($122) | $92 |
| 2020 | ($2,119) | $103 | $86 | ($1,930) | ($114) | ($2,044) |
| Total | $8,618 | $1,185 | $871 | $10,674 | ($1,161) | $9,513 |

Option 2 New 5 x 2 MW Diesel

| | Capital Cost | OMA | Fuel | Sub-Total | Elect Value | Total |
|---|---|---|---|---|---|---|
| 2011 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2012 | $10,070 | $0 | $0 | $10,070 | $0 | $10,070 |
| 2013 | $0 | $35 | $136 | $171 | ($181) | ($10) |
| 2014 | $0 | $33 | $127 | $160 | ($169) | ($10) |
| 2015 | $0 | $30 | $119 | $149 | ($158) | ($9) |
| 2016 | $2,810 | $28 | $111 | $2,950 | ($148) | $2,801 |
| 2017 | $0 | $26 | $104 | $131 | ($139) | ($8) |
| 2018 | $0 | $25 | $98 | $122 | ($130) | ($8) |
| 2019 | $0 | $23 | $91 | $114 | ($122) | ($7) |
| 2020 | ($2,648) | $21 | $86 | ($2,541) | ($114) | ($2,655) |
| Total | $10,232 | $222 | $871 | $11,325 | ($1,161) | $10,164 |

Option 2A used 5 x 2 MW Diesel

| | Capital Cost | OMA | Fuel | Sub-Total | Elect Value | Total |
|---|---|---|---|---|---|---|
| 2011 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2012 | $8,922 | $0 | $0 | $8,922 | $0 | $8,922 |
| 2013 | $0 | $35 | $136 | $171 | ($181) | ($10) |
| 2014 | $0 | $33 | $127 | $160 | ($169) | ($10) |
| 2015 | $0 | $30 | $119 | $149 | ($158) | ($9) |
| 2016 | $2,810 | $28 | $111 | $2,950 | ($148) | $2,801 |
| 2017 | $0 | $26 | $104 | $131 | ($139) | ($8) |
| 2018 | $0 | $25 | $98 | $122 | ($130) | ($8) |
| 2019 | $0 | $23 | $91 | $114 | ($122) | ($7) |
| 2020 | ($1,589) | $21 | $86 | ($1,482) | ($114) | ($1,596) |
| Total | $10,143 | $222 | $871 | $11,236 | ($1,161) | $10,075 |

# 5 CONCLUSIONS

## 5.1 Existing Gas Turbine Generator Unit

1. The existing GT generator should not be operated (started, operated, shutdown) except in an emergency situation, and in such an emergency its operation should be observe remotely to ensure personnel safety.
    - i) Fire from lube oil system gearbox seals remains a possible safety issue.
    - ii) Catastrophic failure of the power turbine disk is a possibility due to corrosion and high stress that may be present at blade roots and attachments
2. The existing GT generator requires extensive overhaul and repair work:
    - x) Power turbine disk may require replacement (9 month manufacturing lead time)
    - xi) One or more power turbine blades may require replacement or significant repair
    - xii) Gas generator blading requires cleaning and recoating
    - xiii) Inlet filter media requires replacement and inlet duct requires refurbishment (including cooling air duct to power turbine disk)
    - xiv) Exhaust stack requires replacement or extensive repairs
    - xv) Gearbox lube oil system requires modification and refurbishment
        - e. Seals require replacement/modification
        - f. Venting system modifications required to reduce lube oil pressure buildup
        - g. Lube oil pump system requires upgrade for start-ups.
        - h. Lube oil cooling fan is experiencing some leaks and snow and ice and water build-ups in its containment can cause start-issues
    - xvi) Gearbox bearings likely worn and need refurbishment or replacement and/or unit re-alignment
    - xvii) Unit generator requires significant testing and possibly rewind
    - xviii) Unit generator exciter needs refurbishment and likely replacement
3. GT electrical and controls system has elements that are not in compliance with current standards and/or are obsolete and hence necessitates replacement:
    - iii) Unit AVR
    - iv) Unit MCC's
4. The GT and generator enclosure rooms require modification to their fire detection and suppression systems to provide better coverage, as evidenced by the failure of the system to initially detect or suppress the gearbox lube oil fire in 2010.
5. GT fuel oil receiving, forwarding, and delivery system are in operable condition, but climatic conditions (icing, snow-buildup, water build-ups from rain, rusting from salty ambient air) result in significant periods where starts may fail or be significantly delayed. The GT generator building is in generally good condition, except for:
    - iv) Major leaks in and around the GT exhaust stack which are impacting the gas turbine power turbine volute and back end blades;
    - v) Minor leaks at generator ventilation stack; and
    - vi) Minor air leaks as a result of minor siding holes (corrosion) which require repair/ refurbishment
6. The electrical services room require expansion to allow for new electrical systems and current systems to be in compliance with current standards (i.e. space, separation distance for arc flash).

7. The earliest in-service dates for refurbishing the existing unit and returning it to service:
    a. Without back-up during the existing unit outage, but restricting the outage to lower risk, late spring to early fall periods is October 2013, with a roughly six month outage.
    b. With a nearly new 2 x 5 MW GT leased unit required during an existing unit outage is July 2013 with the existing unit on outage about five months.
    c. With shorter duration engineering and procurement times for BOP, fuel system and electrical systems, the in-service can theoretically be advance two to three months, but outage scheduling would likely mitigate this.

    Note: Using leased parts during outage, or procuring used parts and refurbishing them, has no significant positive impact.
8. The capital cost for refurbishing the existing unit is between $4.5 and $5 million, depending on the amount of additional work found during refurbishment. If leasing a replacement 2 x 5 MW unit is required to avoid any outage, then the total capital cost would be between $9.5 and $10.0 million, depending on the market price and availability of portable/mobile equipment. There is some opportunity to slightly reduce costs if used parts for the unit, and in particular the power turbine disk, are available.

## 5.2 New and Nearly-New 2 x 5 MW Portable/Transportable Gas Turbine Generator Units

1. The two 5 MW transportable gas turbine units option is consistent with the requirements for black start power, the need to start a 3 MW power block (one boiler feed pump motor), and simplicity of managing the number of black start units in parallel.
2. The space requirements for the two 5 MW transportable gas turbine units (2 trailers each plus a common electrical building) cannot be accommodated in the existing GT area.
3. Space and civil requirements support the use of the existing well graded area behind the old security building as the best location.
4. Two new 5 MW transportable gas turbine units could be readily purchased, with a manufacturing time of about 12 months.
5. Two nearly new, used 5 MW transportable GT units may be possible to acquire to a shorter time. Their availability and cost are functions of the market place. The units may also have to be adapted to suit Holyrood conditions (motor and start voltages, applicable codes, design fuel combustors, NOx levels).
6. Emissions, particularly NOx emissions, will have to be addressed:
    iv) NOx emissions are dependent on the nitrogen content of the diesel fuel oil used.
    v) NOx emissions will be lower than those of the current GTG units, but being oil fuelled units will be challenged to meet Canadian Council of Ministers of the Environment (CCME gas turbine NOx emission guidelines
    vi) Newfoundland & Labrador environmental regulations require Best Available Control Technology (BACT), although the regulations have provisions relaxing BACT requirements for both economic impacts as well as flexibility of approval by the Minister considering roles.
        c. The current designs do not have special technology (i.e. Selective Catalytic Reduction (SCR)). Their costs, the impacts of the technology on black start readiness and reliability, and the costs and impacts of ammonia use and storage for SCR use, make their consideration unreasonable for the roles contemplated.

d. A project going forth will have to seek approval for an exemption from the BACT requirement, and will likely have restrictions placed on the unit such as a limit on the number of operating hours per year.

7. Five MW units are likely the upper limit of useful unit size for redeployment in support of transmission and distribution line maintenance support either post 2020 or periods up to 2020.
8. The earliest in-service date for procuring and installing 2 x 5 MW new gas turbine generators is May 2013. The earliest in-service date for procuring and installing 2 x 5 MW nearly new/used gas turbine generators is March 2013.
9. The capital cost for procuring and installing 2 x 5 MW new gas turbine generators is $13.3 million. The capital cost for procuring and installing 2 x 5 MW nearly new/used gas turbine generators is $11.5 million.

## 5.3 New and Nearly-New 5 x 2 MW Portable/Transportable Diesel Engine Generator Units

1. The five 2 MW transportable diesel engine generator units option is potentially consistent with the requirements for black start power, but:
   i) The units may have significant difficulty responding to a block load start of 3 MW power block (one boiler feed pump motor), and
   ii) Islanded synchronous operation during start-up of five units may be difficult to maintain and affect overall system capacity available and overall system start-up reliability. It will also likely require a more complex control system.
2. The space requirements for the five 2 MW transportable diesel engine generator units (5 trailers plus two electrical trailers plus a common electrical building) cannot be accommodated in the existing GT area.
   i) Space and civil requirements suggested that use of the existing well graded area behind the old security building was the best location.
   ii) Spacing requirements are increased by separation requirements between units
3. Five new 2 MW transportable diesel engine generator units could be readily purchased, with a manufacturing time of about 12 months.
4. Five nearly new, used 2 MW transportable diesel engine generator units may be possible to acquire to a shorter time. Their availability and cost are functions of the marketplace and the units may have to be adapted to suit Holyrood conditions (motor and start voltages, applicable codes, design fuel combustors, NOx levels).
5. Emissions, particularly NOx emissions, will have to be addressed:
   i) NOx emissions are dependent on the nitrogen content of the diesel fuel oil used.
   ii) NOx emissions, particularly for some used engines, may not be lower than those of the existing GT unit. They will have higher emission levels than the GT options.
   iii) Applicable diesel engine generator emission regulations in the US and Canada are in flux, with significantly more stringent requirements likely for units coming into service in the 2012 through 2015 period. Emergency power non-mobile (i.e. not on road or off-road units) will face significant but less stringent levels, but will have their operation limited to emergency use only (in effect similar to the restriction imposed on the existing GT).
   iv) Newfoundland & Labrador environmental regulations require BACT, although the regulations have provisions relaxing BACT requirements for both economic impacts as well as flexibility of approval by the Minister considering roles.

a. The current designs do not have special technology (i.e. Selective Catalytic Reduction (SCR)). Their costs, the impacts of the technology on black start readiness and reliability, and the costs and impacts of ammonia use and storage for SCR use, make their consideration unreasonable for the roles contemplated.
b. A project going forth will have to seek approval for an exemption from the BACT requirement, and will likely have restrictions placed on its role and likely a limit on the number of operating hours per year.

6. Two MW units are good candidates for redeployment in support of transmission and distribution line maintenance support either post 2020 or in possible periods up to 2020. They are typical of larger unit sizes deployed for that purpose now.
7. The earliest in-service date for procuring and installing 5 x 2 MW new diesel gensets is May 2013. The earliest in-service date for procuring and installing 5 x 2 MW nearly new/used diesel gensets is March 2013.
8. The capital cost for procuring and installing 5 x 2 MW new diesel gensets is $10.8 million. The capital cost for procuring and installing 5 x 2 MW nearly new/used diesel gensets is $9.6 million.

## 5.4 Overall Economics

Using the Assessment Basis,

1. The base capital cost comparison of the options is as follows:

**BASE CAPITAL COST COMPARISON OF OPTIONS**

**Capital Cost Comparison**
Capital cost estimate $1.000 Can 2011

| Option Number | 0 | 1 | 1A | 2 | 2A |
|---|---|---|---|---|---|
| Option | Existing GT Refurb | New 2 x 5 MW GT | Used 2 x 5 MW GT | New 5 x 2 MW Diesel | Used 5 x 2 MW Diesel |
| GT/Diesel Cost | $2.950 | $10.865 | $9.234 | $8.553 | $7.453 |
| Civil Works | $224 | $131 | $131 | $131 | $131 |
| Electrical Works | $541 | $759 | $759 | $801 | $801 |
| BOP Systems | $330 | $129 | $129 | $129 | $129 |
| Existing Unit Demolition & Removal | $0 | $7 | $7 | $7 | $7 |
| **Sub-Total - Directs and Indirects** | $4.046 | $11.891 | $10.260 | $9.620 | $8.520 |
| Project Engineering | $324 | $625 | $544 | $513 | $458 |
| Project Management | $283 | $832 | $718 | $673 | $596 |
| Total | $4.652 | $13.348 | $11.522 | $10.807 | $9.575 |

| | |
|---|---|
| + Standby = Total | $4.825 |
| | |
| + New Rental Stdby = Total | $9.421 |

2. The life cycle cost comparison of the options in:
   - un-escalated non-discounted (not present worthed),
   - un-escalated discounted (present worthed),
   - escalated non-discounted (not present worthed), and
   - escalated discounted (present worthed) costs is as follows.

The existing unit refurbishment option costs include the lower cost standby option assuming that a replacement gas generator and power turbine are leased and installed while the existing units are sent out for refurbishment. This adds only about $170,000 to the base cost. The existing unit refurbishment option costs assuming the standby option using a complete, installed 2 x 5 MW nearly new GT leased option would add an additional $4.7 M. The options include a cost for differences in the likelihood of a failure occurring once during the period – an additional $10 million in 2016 for the existing GT and $3 to 4 million in 2016 for the 5 x 2 MW diesel options.

| | | Refurbished Unit, Use of Spare Gas Generator & Power Turbine | | | | | |
|---|---|---|---|---|---|---|---|
| | | Capital Cost | OMA | Fuel | Sub-Total | Elect Value | Total |
| 1 | UNESCALATED | $14,825 | $1,885 | $1,408 | $18,118 | ($1,648) | $16,470 |
| 2 | UNESCALATED, DISCOUTED CASHFLOW | $11,454 | $1,291 | $959 | $13,704 | ($1,122) | $12,582 |
| 3 | ESCALATED CASHFLOW | $16,260 | $2,159 | $1,660 | $20,079 | ($1,943) | $18,136 |
| 4 | ESCALATED, DISCOUTED CASHFLOW | $11,521 | $1,302 | $992 | $13,815 | ($1,161) | $12,654 |

| | | Option 1 New 2x5 MW GT | | | | | |
|---|---|---|---|---|---|---|---|
| | | Capital Cost | OMA | Fuel | Sub-Total | Elect Value | Total |
| 1 | UNESCALATED | $6,348 | $1,714 | $1,237 | $9,300 | ($1,648) | $7,652 |
| 2 | UNESCALATED, DISCOUTED CASHFLOW | $8,766 | $1,175 | $842 | $10,783 | ($1,122) | $9,661 |
| 3 | ESCALATED CASHFLOW | $4,940 | $1,963 | $1,459 | $8,362 | ($1,943) | $6,419 |
| 4 | ESCALATED, DISCOUTED CASHFLOW | $8,731 | $1,185 | $871 | $10,787 | ($1,161) | $9,626 |

| | Option 1A Used 2x5 MW GT | | | | | |
|---|---|---|---|---|---|---|
| | Capital Cost | OMA | Fuel | Sub-Total | Elect Value | Total |
| 1 | $7,522 | $1,714 | $1,237 | $10,473 | ($1,648) | $8,826 |
| 2 | $8,632 | $1,175 | $842 | $10,649 | ($1,122) | $9,527 |
| 3 | $6,815 | $1,963 | $1,459 | $10,236 | ($1,943) | $8,294 |
| 4 | $8,618 | $1,185 | $871 | $10,674 | ($1,161) | $9,513 |

| | | Option 2 New 5x2MW Diesel | | | | | |
|---|---|---|---|---|---|---|---|
| | | Capital Cost | OMA | Fuel | Sub-Total | Elect Value | Total |
| 1 | UNESCALATED | $9,807 | $323 | $1,237 | $11,366 | ($1,648) | $9,719 |
| 2 | UNESCALATED, DISCOUTED CASHFLOW | $10,231 | $220 | $842 | $11,293 | ($1,122) | $10,171 |
| 3 | ESCALATED CASHFLOW | $9,358 | $370 | $1,459 | $11,187 | ($1,943) | $9,244 |
| 4 | ESCALATED, DISCOUTED CASHFLOW | $10,232 | $222 | $871 | $11,325 | ($1,161) | $10,164 |

| | Option 2A Used 5x2MW Diesel | | | | | |
|---|---|---|---|---|---|---|
| | Capital Cost | OMA | Fuel | Sub-Total | Elect Value | Total |
| 1 | $10,575 | $323 | $1,237 | $12,134 | ($1,648) | $10,487 |
| 2 | $10,128 | $220 | $842 | $11,190 | ($1,122) | $10,068 |
| 3 | $10,593 | $370 | $1,459 | $12,422 | ($1,943) | $10,479 |
| 4 | $10,143 | $222 | $871 | $11,236 | ($1,161) | $10,075 |

# 6 RECOMMENDATIONS

1. The existing gas turbine generator should not be operated (started, operated, shut down), except in an emergency situation, and in such an emergency its operation should be observed remotely.
2. Using the Assessment Basis, the preferred option is Option 1, the 2 x 5 MW new GT installation.
3. Hydro should review the Assessment Basis and any impacts of changes in it as part of its internal decision-making process on the options.
4. Hydro should proceed with a preferred option as soon as practically possible, given that the likelihood of safely and successfully starting the existing GT unit in an emergency condition in its existing state is very poor and likely to decrease rapidly with time idle.
5. If Hydro internally chooses refurbishment of the existing GT generator as its preferred option, then the existing GT generator should undergo an extensive overhaul and repair program, including:

   i) Gas Turbine Unit

      a. Power turbine disk replacement (9 month manufacturing lead time);
      b. Power turbine damaged blades replacement (one or more) or significant repair;
      c. Gas generator blading cleaning and recoating;
      d. Inlet filter media replacement and inlet duct refurbishment (including cooling air duct to power turbine disk); and
      e. Exhaust stack replacement or extensive repairs

   ii) Gearbox lube oil system modification and refurbishment

      a. Seals replacement/modification;
      b. Venting system modifications to reduce lube oil pressure buildup;
      c. Lube oil pump system upgrade for start-ups; and
      d. Lube oil cooling fan replacement

   iii) Gearbox bearings refurbishment or replacement and/or unit re-alignment

   iv) GT Generator testing and refurbishment

      a. Unit generator electrical testing and possible rewind; and
      b. Unit generator exciter testing, and refurbishment/replacement as necessary

   v) GT electrical and controls system update to compliance with current standards and/or obsolescence replacement

      a. Unit AVR
      b. Unit MCC's

   vi) The GT and generator enclosure rooms' fire detection and suppression systems modifications to provide better coverage (as evidenced by the failure of the system to initially detect or suppress the gearbox lube oil fire in 2010).

   vii) GT fuel oil receiving, forwarding, and delivery system replacement in an enclosed shed.

   viii) GT generator building repairs:

      a. Major leaks in and around the gas turbine exhaust stack
      b. Minor leaks at generator ventilation stack
      c. Minor air leaks as a result of minor siding holes (corrosion)

   ix) Expansion of the electrical services room to allow for new electrical systems and current systems to be in compliance with current standards (i.e. space, separation distance for arc flash)

# APPENDIX 1
# GENERAL ARRANGEMENT DRAWING

# APPENDIX 2
# SEQUENCE OF EVENTS REPORT

# APPENDIX 3
# COST REPORT BY WORK ORDER/ASSET

# APPENDIX 4
# BUDGETARY INFORMATION - SOLAR TURBINES

# APPENDIX 5
# BUDGETARY INFORMATION - PETERSON POWER SYSTEMS

# APPENDIX 6
# BUDGETARY INFORMATION - ROLLS ROYCE

# APPENDIX 7
# EXISTING UNIT REFURBISHMENT CAPITAL COST DETAILS

# Appendix 7

# EXISTING UNIT REFURBISHMENT CAPITAL COST DETAILS

## Base Existing GT Unit Refurbishment

### Capital Cost
### Existing Gas Turbine Generator and Major Auxiliaries.

**Capital cost estimate $ ,000 Can 2011**

| Gas Turbine Generator & Auxiliaries | | Material | Labour | Total | Range |
|---|---|---|---|---|---|
| | **Gas Generator (Avon)** | **$500** | **$0** | **$500** | **$400-$700** |
| | **Power Turbine** | **$534** | **$402** | **$936** | **$900-$1,100** |
| | Disassemble/reassemble | $0 | $75 | $75 | |
| | New Disk | $331 | $0 | $331 | |
| | Moving blades | $93 | $0 | $93 | |
| | Rotor rehabilitation | $0 | $282 | $282 | |
| | Inlet structure repairs | $10 | $5 | $15 | |
| | Diaphragm section | $30 | $10 | $40 | |
| | Bearings | $50 | $20 | $70 | |
| | Exhaust volute | $20 | $10 | $30 | |
| | **Gearbox** | **$125** | **$39** | **$164** | **$125-$200** |
| | Bearings | $80 | $34 | $114 | |
| | Gearbox venting | $20 | $5 | $25 | |
| | Contingency; 2nd opinion | $25 | $0 | $25 | |
| | **Generator and aux** | **$950** | **$0** | **$950** | **$150-$1,200** |
| | Generator | $900 | $0 | $900 | |
| | Exciter | $50 | $0 | $50 | |
| | **Inlet filter** | **$120** | **$30** | **$150** | **$100-$1200** |
| | **Exhaust stack** | **$40** | **$10** | **$50** | **$30-$75** |
| | **Commission unit** | | **$50** | **$50** | **$30-$75** |
| | **Sub-Total** | **$2,269** | **$531** | **$2,800** | **$2,400-$3,500** |
| | **Contingency (excl Avon)** | **$125** | **$25** | **$150** | **$100-$250** |
| | **SUB-TOTAL -GTG & Auxiliaries** | **$2,394** | **$556** | **$2,950** | **$2,500 - $3,750** |

| Site Civil & Structural Works - Rental Unit | | Material | Labour | Total | Range |
|---|---|---|---|---|---|
| | Geotech Investigation - bearing capacity of soil | $0 | $4 | $4 | $3-$10 |
| | Pre-engineered shelter for elec. equipment | $40 | $5 | $45 | $37-$55 |
| | Concrete cable trench | $60 | $10 | $70 | $60-$85 |
| | Repair sections of roofing and siding that are corroded | $3 | $2 | $5 | $3-$8 |
| | Building extension shelter - for elec. equipment expansion | $30 | $10 | $40 | $30-$50 |
| | Building extension shelter - turbine fuel line mechanical equipment | $30 | $10 | $40 | $30-$50 |
| | **Sub-Total** | **$163** | **$41** | **$204** | **$175-$250** |
| 10% | **Contingency** | **$16** | **$4** | **$20** | **$20-$25** |
| | **TOTAL Civil Works** | **$179** | **$45** | **$224** | **$195-$275** |

**Newfoundland and Labrador Hydro a NALCOR Energy Co.
Holyrood Thermal Generating Station
Gas Turbine Condition Assessment & Options Study**

## Base Existing GT Unit Refurbishment (Contd)

## Capital Cost
## Existing Gas Turbine Generator and Major Auxiliaries.

**Capital cost estimate $ ,000 Can 2011**

| Electrical Systems | | Material | Labour | Total | Range |
|---|---|---|---|---|---|
| | Installation new 800A, 13.8 kV, 3ph, 60Hz Generator Main Breaker | $126.86 | $12.80 | $139.66 | |
| | Removal of Existing Main Breaker | | $1.60 | $1.60 | |
| | Installation of Cable Tray | $3.50 | $1.25 | $4.75 | |
| | Installation of New Junction Box | $1.00 | $0.48 | $1.48 | |
| | Removal of Existing Power Cables from Existing Breaker to Generator and T9 Transformer | | $1.60 | $1.60 | |
| | Installation of New Power Cables from New Breaker to Generator (2 x 500kcmil) and T9 Transformer (2x500kcmil) | $50.00 | $10.00 | $60.00 | |
| | Connection of Existing and Used CT, PT and Control Cables in New JB, and run the new CT, PT and Control Cables from new JB to new 13.8 kV Main Breaker (4 x 4c10, 1 x 4c12, 1 x 12c12). | $0.60 | $1.60 | $2.20 | |
| | Installation of New 13.8kV Fusible Switch | | | $0.00 | |
| | Removal of Existing 13.8 kV Fusible Switch | | $1.60 | $1.60 | |
| | Install 3c2AWG, Teeck, 15kV, Cable from 112kVA Transformer to new 13.8kV Fusible Switch | $0.75 | $0.30 | $1.05 | |
| | Remove Existing MCC | | $8.00 | $8.00 | |
| | Install New MCC | $30.00 | $8.00 | $38.00 | |
| | Install Cable Tray | $1.60 | $0.90 | $2.50 | |
| | Install New Incoming and Feeder Cables for 600V Circuits | | | $0.00 | |
| | 3C12, Teck, 1000V, (Seven Circuits) | $1.26 | $0.53 | $1.79 | |
| | 3c10, Teck, 1000V, (One Circuit) | $0.24 | $0.12 | $0.36 | |
| | 3c6, Teck, 1000V, (Five Circuits) | $1.03 | $0.35 | $1.38 | |
| | 3c2, Teck, 1000V, (One Circuit) | $1.04 | $0.20 | $1.24 | |
| | Install New 230V, 3ph, Auxiliary Distribution Panel | $0.65 | $0.35 | $1.00 | |
| | Relocate 30kVA, 3ph, 550:230V Transformer and Connect to MCC and New 230V, 3ph, Auxiliary Distribution Panel | | $3.00 | $3.00 | |
| | 3c12, Teck, 1000V (One Circuit) | $0.18 | $0.08 | $0.26 | |
| | 3c10, Teck, 1000V, (Two Circuits) | $0.12 | $0.06 | $0.18 | |
| | Install new 110VDC,. NEMA 1 Breaker, new NEMA1 Splitter, new DC Starters, and Existing 100A DC Distribution Panel | $31.00 | $6.40 | $37.40 | |
| | **Install New Feeders from Splitter to DC Starters and DC Distribution Panel** | | | $0.00 | |
| | 3c12, Teck, 1000V (One Circuit) | $0.18 | $0.08 | $0.26 | |
| | 3c10, Teck, 1000V, (One Circuit) | $0.21 | $0.12 | $0.33 | |
| | 3c2, Teck 1000V (One Circuit) | $0.41 | $0.14 | $0.55 | |
| | Remove Existing AVR/Start Rectifier | | $1.60 | $1.60 | |
| | Install New AVR/Start Rectifier | $145.00 | $20.00 | $165.00 | |
| | Miscellaneous Hardware, Tray and 4/0 Grounding | $7.50 | $7.50 | $15.00 | |
| | **Sub-Total** | **$403** | **$89** | **$492** | **$450-$600** |
| 10% | **Contingency** | **$40** | **$9** | **$49** | **$45-$60** |
| | **TOTAL Electrical Works** | **$443** | **$98** | **$541** | **$500-$650** |

## Base Existing GT Unit Refurbishment (Contd)

### Capital Cost
### Existing Gas Turbine Generator and Major Auxiliaries.

**Capital cost estimate $ ,000 Can 2011**

| BOP Systems | | Material | Labour | Total | Range |
|---|---|---|---|---|---|
| | Fuel enclosure (See Civil/Structural) | | | | |
| | Fuel piping | $60 | $15 | $75 | $60-$90 |
| | Stack removal | $0 | $75 | $75 | $25-$35 |
| | Inergen system | $7 | $3 | $10 | $7-$15 |
| | Lube oil cooler | $130 | $10 | $140 | $75-$175 |
| | **Sub-Total** | **$197** | **$103** | **$300** | **$150-$320** |
| 10% | **Contingency** | **$20** | **$10** | **$30** | |
| | **TOTAL BOP** | **$217** | **$113** | **$330** | **$180-$350** |

| TOTAL DIRECTS | | Material | Labour | Total | Range |
|---|---|---|---|---|---|
| | **Sub-Total** | **$3,032** | **$764** | **$3,796** | **$3,200-$4670** |
| | **Contingency** | **$201** | **$48** | **$250** | |
| **TOTAL DIRECTS** | | **$3,234** | **$812** | **$4,046** | **$3,500-$5,000** |

| Project Engineering Costs Mechanical | | Material | Labour | Total | Range |
|---|---|---|---|---|---|
| | Project Engineering Costs | | $324 | $324 | |
| | Project Management Costs | | $283 | $283 | |
| | **TOTAL Project Engineering & Management** | **$0** | **$607** | **$607** | **$550-$700** |

| Total Without Transition Replacement | Material | Labour | Total | Range |
|---|---|---|---|---|
| | **$3,234** | **$1,419** | **$4,652** | **$4,000-$5,700** |

## Standby Option – Installing Leased Gas generator and Power Turbine Parts To Reduce Unit Outage

### Capital Cost
### Existing Gas Turbine Generator and Major Auxiliaries.

**Capital cost estimate $ ,000 Can 2011**

| Total Without Transition Replacement | Material | Labour | Total | Range |
|---|---|---|---|---|
| | **$3,234** | **$1,419** | **$4,652** | **$4,000-$5,700** |

| Standby Unit Costs - Leased Parts | | Material | Labour | Total | Range |
|---|---|---|---|---|---|
| (Substituting Gas Generator & PT During Refurb) | | | | | |
| | **Gas Generator Rental and Use** | $42 | $10 | $52 | |
| | **Power Turbine Rental & Use** | $42 | $11 | $53 | |
| | **Gas Generator Delivery** | $10 | $10 | $20 | |
| | **Power Turbine Delivery** | $10 | $10 | $20 | |
| | **Sub-Total** | **$103** | **$41** | **$144** | **$125-$200** |
| 20% | **Contingency** | **$21** | **$8** | **$29** | |
| | **TOTAL GTG Lease Parts** | **$124** | **$49** | **$173** | **$150-$225** |

| Total Including Lease Parts | Material | Labour | Total | Range |
|---|---|---|---|---|
| | **$3,357** | **$1,468** | **$4,825** | **$4,150-$5,900** |

## Standby Option – Installing Leased Gas generator and Power Turbine Parts To Reduce Unit Outage

## Standby Option –Leased Nearly new 2 x 5 MW GT To Reduce Unit Outage

### Capital Cost
### Existing Gas Turbine Generator and Major Auxiliaries.

**Capital cost estimate $ ,000 Can 2011**

| Total Without Transition Replacement | | Material | Labour | Total | Range |
|---|---|---|---|---|---|
| | | **$3,234** | **$1,419** | **$4,652** | **$4,000-$5,700** |

| New GT Replacement During Outage | | Material | Labour | Total | Range |
|---|---|---|---|---|---|
| | GT Lease - 2 x 5 MW | | | | |
| | Rental ($/mo/GT=$105k for 2 GT and 10 months) | $2,100 | $0 | $2,100 | |
| | Hourly operation charge (Assume $41/hr/GT x 1/mo x 2 Hrs) | $2 | $0 | $2 | |
| | Delivery to Site (k$/GT) | $70 | | $70 | |
| | Removal from site (k$/GT) | $70 | | $70 | |
| | Mobilization (k$/GT) | $30 | | $30 | |
| | Setup/Commissioning (k$/GT) | | $220 | $220 | |
| | Breakdown/Demob (k$/GT) | $100 | | $100 | |
| | **Sub-Total** | **$2,372** | **$220** | **$2,592** | |
| | Tax 10-15% | $237 | $22 | $259 | |
| | **Sub-Total** | **$2,609** | **$242** | **$2,851** | **$2,500-$3,300** |
| 10% | Contingency | $261 | $24 | $285 | $250-$350 |
| | **TOTAL GT Lease** | **$2,870** | **$266** | **$3,136** | **$2,750-$3,650** |

| Site Civil & Structural Works - Rental Unit | | Material | Labour | Total | Range |
|---|---|---|---|---|---|
| | Geotech Investigation - bearing capacity of soil | $0 | $4 | $4 | $3-$10 |
| | Pre-engineered shelter for elec. equipment | $40 | $5 | $45 | $37-$55 |
| | Concrete cable trench | $60 | $10 | $70 | $60-$85 |
| | **Sub-Total** | **$100** | **$19** | **$119** | **$100-$150** |
| 10% | **Contingency** | **$10** | **$2** | **$12** | **$10-$15** |
| | **TOTAL Civil Works - rental Unit** | **$110** | **$21** | **$131** | **$110-$165** |

| Electrical Systems - Rental Unit | | Material | Labour | Total | Range |
|---|---|---|---|---|---|
| | 3c500 kemil, Teck 15kV cable | $112.8 | $10.0 | $123 | |
| | 13.8kV isolating switchgear (3+1 fused switch) | $95.0 | $10.0 | $105 | |
| | P&C/DCS interface | $55.0 | $10.0 | $65 | |
| | 10 x 3c12AWG, Teck, 1000V cable | $1.0 | $2.3 | $3 | |
| | 2 x 25c16AWG, Teck, 1000V cable | $8.5 | $3.2 | $12 | |
| | 4 x 4c12AWG, Teck, 1000V cable | $3.3 | $6.3 | $10 | |
| | 1 x 12C12AWG, Teck, 1000V cable | $2.2 | $1.6 | $4 | |
| | 3c2AWG, Teck, 15kV cable | $0.9 | $0.3 | $1 | |
| | 2 x 3c1/0, Teck, 1000V cable | $4.5 | $1.1 | $6 | |
| | 112kVA, 13.8kV:575V, 3ph, 60Hz transformer | $30.0 | $3.0 | $33 | |
| | 200A, 600V, 3ph, 60Hz automatic transfer switch | $5.3 | $1.5 | $7 | |
| | 200A, 600V, 3ph, 60Hz manual transfer switch | $2.0 | $1.0 | $3 | |
| | MCC, 600A, 600V, 3ph, 3W | $30.0 | $5.0 | $35 | |
| | 30kVA, 575:120/280V, 3ph, 60Hz transformer | $1.0 | $0.5 | $2 | |
| | 129VDC distribution panel, motor starters and disconnects | $35.0 | $6.5 | $42 | |
| | 100A, 120/208V, 3ph, 60Hz distribution panel c/w breakers | $1.4 | $0.4 | $2 | |
| | 600V, battery charger, 129VDC output | $16.0 | $3.2 | $19 | |
| | 129VDC battery bank | $39.0 | $7.5 | $47 | |
| | All interconnecting cabling | $16.0 | $12.0 | $28 | |
| | Miscellaneous 4/0 ground wire, conducts trays and hardware | $16.0 | $9.0 | $25 | |
| | Reconfiguration of DCS screens, conducts and existing system | $0.0 | $25.0 | $25 | |
| | 25kVA, 13.8kV, 3ph, 60Hz, zig-zag grounding transformer | $31.0 | $2.0 | $33 | |
| | Commissioning | **$0.0** | **$63.0** | $63 | |
| | **Sub-Total** | **$506** | **$184** | **$690** | **$650-$800** |
| 10% | Contingency | $51 | $18 | $69 | $65-$80 |
| | **TOTAL Electrical Works - Rental Unit** | **$557** | **$203** | **$759** | **$725-$880** |

## Standby Option –Leased Nearly new 2 x 5 MW GT To Reduce Unit Outage (Contd)

### Capital Cost

### Existing Gas Turbine Generator and Major Auxiliaries.

**Capital cost estimate $ ,000 Can 2011**

| BOP Systems - Rental Units | | Material | Labour | Total | Range |
|---|---|---|---|---|---|
| | 3" supply and return fuel line | $55 | $22 | $110 | |
| | **Sub-Total** | **$55** | **$22** | **$110** | **$100-$125** |
| 10% | Contingency | $6 | $2 | $11 | $10-$13 |
| | **TOTAL BOP Rental Units - Rental Unit** | **$61** | **$24** | **$121** | **$110-$138** |

| TOTAL DIRECTS - Rental Units | | Material | Labour | Total | Range |
|---|---|---|---|---|---|
| | **Sub-Total** | **$3,270** | **$467** | **$3,770** | **$3,500-$4,000** |
| | Contingency | $327 | $47 | $377 | $250-$500 |
| **TOTAL DIRECTS - Rental Units** | | **$3,597** | **$514** | **$4,147** | **$3,750-$4,500** |

| Project Engineering & Management Costs - Rental Units | | Material | Labour | Total | Range |
|---|---|---|---|---|---|
| | Project Engineering Costs | | $332 | $332 | |
| | Project Management Costs | | $290 | $290 | |
| | **TOTAL Project Engineering & Management - Rental** | **$0** | **$622** | **$622** | **$500-$750** |

| | Material | Labour | Total | Range |
|---|---|---|---|---|
| **Sub-Total Rental Units** | **$3,597** | **$1,136** | **$4,769** | **$4,250-$5,550** |

| | Material | Labour | Total | Range |
|---|---|---|---|---|
| **Total Including Rental Unit** | **$6,830** | **$2,555** | **$9,421** | **$8,400-$11,500** |

# APPENDIX 8
# DRAWINGS FROM HYDRO

The following drawings will be provided to CONSULTANT for information during the PROJECT:

Holyrood Generating Station - Stage 1 238 - 13 - 3000 – 003 Gas Turbine Unit Relaying and Metering 3 Line A.C. Schematic
Holyrood Generating Station 238 - 13 - 3000 – 007 Gas Turbine Unit - Cabinet No. 4 Control & Protection, Turbine &Generator Wiring Diagram (5 of 5)
Holyrood Generating Station 238 - 13 - 3000 – 007 Gas Turbine - Cabinet No. 3 Termination Assembly Layout and Wiring Diagram (Sheet 4A of 5)
Holyrood Generating Station 238 - 13 - 3000 – 007 Gas Turbine Unit - Cabinet No. 3 Control & Protection, Turbine &Generator (4 of 5)
Holyrood Generating Station 238 - 13 - 3000 – 007 Gas Turbine - Cabinet No. 2 Termination Assembly Layout and Wiring Diagram (Sheet 3A of 5)
Holyrood Generating Station 238 - 13 - 3000 – 007 Gas Turbine Unit - Cabinet No. 2 Control & Protection, Turbine & Generator Wiring Diagram (3 of 5)
Holyrood Generating Station 238 - 13 - 3000 – 007 Gas Turbine - Cabinet No. 1 Termination Assembly Layout and Wiring Diagram (Sheet 2A of 5)
Holyrood Generating Station 238 - 13 3000 – 007 Panel, Control & Protection, Turbine and Generator Cabinet No. 1 Wiring Diagram (Sheet 2 of 5)
Holyrood Generating Station 238 - 13 - 3000 – 007 Gas Turbine - Cabinet No. 5 DCS Layout and Wiring Diagram (Sheet 7)
Holyrood Generating Station 238 - 13 - 3000 – 008 Gas Turbine Unit Interconnections, Site Wiring Diagram (Sheet 1 of 3)
Holyrood Generating Station 238- 13 - 3000 – 010 Gas Turbine Unit Control & Protection Schematic Diagram (Sheet 1 of 6)
Holyrood Generating Station 238- 13- 3000-010 Gas Turbine Unit Control & Protection Schematic Diagram (Sheet 2 of 6)
Holyrood Generating Station 238 - 13 - 3000 – 010 Gas Turbine Unit Control & Protection Schematic Diagram (Sheet 3 of 6)
Holyrood Generating Station 238- 13- 3000-010 Gas Turbine Unit Control & Protection Schematic Diagram (Sheet 4 of 6)
Holyrood Generating Station 238 - 13- 3000-010 Gas Turbine Unit Control & Protection Schematic Diagram (Sheet 5 of 6)
Holyrood Generating Station 238 - 13 - 3000 – 010 Gas Turbine Unit Control & Protection Schematic Diagram (Sheet 6 of 6)
Holyrood Gas Turbine 238- 13- 2000- 016 Phasing Diagram
Holyrood Generating Station 238 - 13 - 2000 – 015 Gas Turbine Station Services Panel No. 2 Wiring Diagram
Holyrood Gas Turbine 238 - 13 - 2000 – 014 Exciter & A.V.R. Control Schematic Diagram
Holyrood Gas Turbine 238- 13-2000-013 Avon Start System Connection Diagram
Holyrood Generating Station - Gas Turbine 238 - 13- 2000- 012 575 Volt Motor Control
3 Phase AC. Schematic
Holyrood Generating Station - Gas Turbine 238 - 13- 2000-011 230 V, *30,* AC & 1 1OV DC Auxiliaries Control Schematic
Holyrood Generating Station - Gas Turbine 238 - 13 - 2000 – 010 575 V, *30,* Station Service Supplies and Auto Transfer Switch Control Schematic
NL and Labrador HYDRO 238 - 13- 2000- 017 Wiring Schedule (Sheets 1-28)
Holyrood Generating Station 238 - 13- 0310 -204 Station Service Units 1 & 2, Gas Turbine 4160V Breakers Auxiliary Relay Schematic (Control)
Holyrood Generating Station 238 - 08 - 2000 – 006 Gas Turbine Building Mechanical Equipment
Holyrood Thermal Plant 238 - 08 - 2000 – 007 Gas Turbine Building Modifications to Generator Cooling Air Exhaust Dampers
Holyrood Generating Station 238 - 08 - 2000 – 008 Gas Turbine Avon Vent Ducting

Holyrood Gas Turbine 238 - 08 - 2000 – 009 Compressed Air System Single Line Diagram
Holyrood Generating Station 238 - 13 - 3000 – 009 Gas Turbine Unit Junction Box, Assembly Arrangement of Air Piping 238 - 13- 6010- 015 For A.P.I. Gas Turbine (Sheet 1 of 3)
Holyrood Generating Station 238 - 13 - 3000 – 002 Gas Turbine Unit Panel, Control and Protection, Turbine & Generator
Holyrood Generating Station 238 - 13 3000 – 004 Gas Turbine Unit Junction Box, Pressure Switch, Assembly
Holyrood Generating Station 238 - 13 - 3000 – 005 Gas Turbine Unit Junction Box, Assembly
Holyrood Generating Station 238 - 13 - 3000 – 006 Gas Turbine Unit Junction Box, Assembly
Gas Turbine Generator Transformer Outline 238 - 13 - 6030 - 007R2 Halon 1301 Fire Extinguishing System Layout, 238 - 13- 3003- 001 Turbine & Generator Rooms
Holyrood Generating Station Fire Alarm/Halon Release 238 - 13 - 3003 – 002 Electrical Layout
Holyrood Generating Station Fire Alarm/Halon Release 238 - 13 - 3003 – 003 Control Panel Wiring Diagram
Holyrood Generating Station Holyrood Generating Station 238 - 13- 3000- 001 Gas Turbine Unit Interconnections, Site, Control System
Holyrood Thermal Plant 238 - 08 - 2000 – 001 Gas Turbine Building Outline of Exhaust Gas Stack
Holyrood Thermal Plant 238 - 08 - 2000 – 003 Gas Turbine Stack Support Steel (Original)
Holyrood Thermal Plant 238 - 08 - 2000 – 004 Gas Turbine Building Mechanical Equipment Mounting Details
Holyrood Generating Plant 238 - 04 - 2000 – 001 Proposed Building - Gas Turbine Floor Plan - (Electrical Equipment)
Holyrood Thermal Plant 238 - 08 - 2000 – 002 Gas Turbine Building Volute Exhaust Flange
Holyrood Generating Plant 238 - 04 - 2000 – 002 Proposed Building - Gas Turbine Elevations
Holyrood Thermal Plant 238 - 04 - 2000 – 003 Gas Turbine Building Roof Plan and Elevations
Holyrood Thermal Plant 238 - 04 - 2000 – 005 Gas Turbine Building Structural Steel Framing Plan
Holyrood Thermal Plant 238 - 04 - 2000 – 004 Gas Turbine Building Foundation Plan & Details
Holyrood Thermal Plant 238 - 04 - 2000 – 007 Gas Turbine Building Floor Plan and Section
Holyrood Thermal Plant 238 - 04 - 2000 – 008 Gas Turbine Building Miscellaneous Details
Holyrood Generating Station 238- 13- 0310-019 Gas Turbine Fuel Totalizer
Stack Cap (Snow Doors) 238 - 08 - 3001 – 001 Expansion Joint Fabric (Type C) Rectangular 238 - 08 - 3001 - 002
Holyrood Gas Turbine 238 - 13 - 2000 – 003 Single Line Diagram
Holyrood Thermal Plant 238 - 13 - 2000 – 004 Gas Turbine Building Grounding Layout
Holyrood Thermal Plant 238 - 13- 2000 – 005 Gas Turbine Building Conduit Layout & Details
Holyrood Gas Turbine 238 - 13 - 2000 – 001 Metering and Protection Single Line Diagram
Holyrood Gas Turbine 238 - 13 - 2000 – 006 Rehabilitation Project Schedule
Holyrood Thermal Plant 238 - 13 - 2000 – 007 Gas Turbine Building Lighting and Heating Layout
Holyrood Generating Station 238 - 13 - 2000 – 008 575 V, *30,* 230,1 iSV, 10 & 110 V D.C. Dist. PNL.'s 575V, 3 Phase Light Oil Transfer Pump
Holyrood Generating Station - Gas Turbine 238 - 13 - 2000 – 009 A.C. and D.C. Station Service Supplies Single Line
Holyrood Gas Turbine 238 - 13 - 6010 – 047 A.P.I. Governing & Control System Arrangement of Air Piping for A.P.I. Gas Turbine 238- 13- 6010-015 (Sheet 2 of 3)
Arrangement of Air Piping for A.P.I. Gas Turbine 238- 13-6010-015 (Sheet 3 of 3)

# APPENDIX 9
# BRADEN MANUFACTURING SITE SERVICE REPORT

# APPENDIX 10
# GREENRAY TURBINE SERVICE REPORT

# APPENDIX 11
# SIEMENS HRD CONDITION ASSESSMENT AND BUDGET PRICING

# APPENDIX 12
# ROLLS WOOD GROUP FIELD SERVICE REPORT