Q. Please provide *Volume III: Long-Term Resource Plan, Attachment 7: Battery Storage Alternative, Appendix E: NL Hydro Summary Table*.

A. The "Reliability and Resource Adequacy Study," Vol. III, Att. 7 encountered an error during document assembly that prevented the inclusion of pages 42 to 54 in the attachment. Please refer to PUB-NLH-004, Attachment 1 for a complete copy of the "NL Hydro Battery Storage Alternative Project Development Estimate" which includes Appendix E: NL Hydro Summary Table.

NEW COLLIERS LTD.

NL Hydro Battery Storage Alternative

Project Development Estimate

November 2, 2018

Revision 0 – For Client Use

To: Alex Guilbeault, Newfoundland & Labrador Hydro
From: Laurie Murphy, New Colliers Ltd.

1 Scope

1.1 What is being considered

New Colliers Ltd. (New Colliers) has been engaged by Newfoundland and Labrador Hydro (NL Hydro) to provide support in the feasibility assessment and preliminary cost estimation for the development of battery storage projects on the island of Newfoundland.

This document describes the basis for a preliminary cost estimate for a 100MW/200MWh lithium ion battery storage solution located on the Avalon Peninsula.

With the decommissioning of the Holyrood generating facility planned for 2021, the Avalon Peninsula will be without its largest generating station. New Colliers understand that the Avalon Peninsula will be connected to the rest of the island via two 230kV AC transmission lines and one HVDC line. The 613MW Bay D'Espoir hydro generating station will be the closest large-scale generating station to the Avalon Peninsula with an estimated 250km of 230kV line between the Bay D'Espoir generating station and the Solider's Pond station.

The DC link from Labrador to the island will frequently be delivering a high proportion of the total power to the island and a disturbance and/or temporary outage on this, or another major line may have the potential to disrupt portions of the island system, especially loads on the Avalon Peninsula. New Colliers has considered these factors in the development of this report and estimate. New Colliers understands from NL Hydro that the system is likely to have an abundance of energy over the long term and this feasibility level assessment is intended to explore how a battery storage system might support any short-term power shortfall in contingency situations.

Evaluation of a battery storage system is sensible in that pricing for battery systems is rapidly declining and legacy performance issues are being addressed and remedied. A battery system can be deployed at most accessible sites and can be situated at optimal grid interconnection points, without the same considerations of required topography for uses like hydro and wind facilities. Also, quite importantly, battery storage solutions provide a faster response to grid contingency events than their combustion turbine counterparts. There may be other suitable solutions for energy storage technologies, but an estimate of development costs for those options is not undertaken here. Other alternatives are presented in Section 3.3.2 for reference.

Based on New Colliers' preliminary examination of average and seasonal peak loads (available from an August 2014 Nalcor information share related to Muskrat Falls), New Colliers believes that a review and estimate of large-scale battery capacity is appropriate for preliminary evaluation of a battery storage solution. Based on the size of the largest existing battery storage installations, New Colliers has chosen a 100MW/200MWh battery storage project for estimate and evaluation. If higher capacities are required, NL Hydro can study multiple deployments of the 100MW/200MWh solution at select areas of the island. Also, shorter duration reserves may be studied (e.g. one-hour reserve instead of two-hour) to improve economics.

1.2 Notable Omissions

The estimates attached as Appendix A include detailed breakdowns for the CapEx costs (also generally referred to as “construction costs” by NL Hydro). The estimate generally encompasses development, procurement, construction and commissioning costs.

No legal fees or costs associated with financing have been allowed for. No contingency has been included in these estimates.

2 Basis of Estimate

This is a preliminary, Class 5 cost estimate. The intent of this estimate is to assess the feasibility and high-level cost of battery storage projects in Newfoundland based on 2018 conditions.

The preliminary cost estimate is primarily based on budgetary pricing from HICO and considers inputs from the document "US Battery Storage Market Trends – U.S. Energy Information Administration (EIA)" from May 2018 as well as insights gained from broader industry research.

Project Sizing

Based on 2014 information made available by Nalcor as part of the public consultation process for the Muskrat Falls project, the average winter load on the Avalon Peninsula is 557MW. Thus, it is expected that significant capacity may be required on the Avalon Peninsula during major contingency situations, such as the loss of the Labrador Island Link. New Colliers is not aware of any system studies that have defined the MW or MWh contingency needs of NL Hydro at this time, so we have used best judgment to define a suitable study case.

New Colliers chose a 100MW/200MWh project size as this is as large as the current largest installed global project. Tesla has installed a 100MW/129MWh battery storage project at the Hornsdale wind project near Adelaide, Australia. However, some larger projects are in the planning and permitting stages, particularly in California. Pacific Gas & Electric Co., for example, is seeking approval for 300MW and 182.5MW projects, among others, in California.

This 100MW/200MWh project can also be deployed at multiple locations or in conjunction with other storage technologies to give higher levels of reserve capacity and energy should more detailed studies prove those scenarios to be required or most feasible. New Colliers expects that dividing this 100MW/200MWh project into blocks to be concurrently deployed on the Avalon Peninsula would have similar costs per MW and per MWh. However, the cost of deploying smaller, one-off installations should be revisited if that deployment philosophy is pursued.

A more detailed discussion of deployment options is discussed in Section 3.

Development

The following development costs have been allowed for in the project estimate:

- Development of a needs identification study
- A limited geotechnical investigation to sufficiently characterize the geotechnical conditions at site to allow for most competitive bidding by contractors and suppliers. The costs for a more detailed geotechnical investigation, to be undertaken by the Contractor, have been allowed for in the construction phase
- A limited site survey of key features, as required
- An allowance for land acquisition costs to the extent required for site investigative purposes
- Interconnection System Impact Study (SIS), Facility Study and applicable interconnection fee required to mobilize utility crews for required system upgrades
- An environmental impact assessment
- The internal costs associated with undertaking competitive bid processes for battery system supply, construction contracting and competitive Power Purchase Agreement (PPA) pricing
- Internal engineering and management costs
- Owner's construction site representation
- Land rental costs during construction
- Development permits

Battery System Supply and Delivery

Battery system containers will be supplied and delivered to the project laydown area. Foundations are assumed to have been constructed in advance, to minimize laydown area requirements. Costs for delivery are included.

Project Construction

Each project estimate includes the following scope:

- Each 2MW battery container is estimated to be approximately 14m x 2.5m. Each 4MW battery power conditioning container is estimated to be approximately 14m x 2.5m.
- Installation of fenced battery array pad;
- Installation of reinforced concrete pads for container mounting
- A low voltage collection system is expected to be run underground with penetrations through pads to allow terminations at containers and AC equipment

- Battery storage system is assumed to be interconnected to the 66kV or 69kV bus of an existing NL Hydro substation. Costs to expand the existing substation have been allowed for.
- Testing of collection system and substation interconnection
- Primarily summer and fall construction are envisioned
- Pre-commissioning and commissioning of battery storage systems
- Competitively sourced labour
- Infrastructure for any future expansion is not included
- The estimate is based on August 2018 dollars (CAD$)
- No allowance for excess material to be hauled off-site has been included
- No rock hammering or blasting has been allowed for. It is assumed an excavator will be able to rip any rock during excavation, if required
- No utility or water crossings have been allowed for
- Taxes and duties are not included
- Costs of copper, steel, aluminum, concrete and labour may fluctuate and affect the accuracy of this estimate
- It is assumed that the developer will enter into a single design-build contract for all the balance-of-plant (BOP) facilities (i.e. the balance of all infrastructure outside of the battery system components)
- High level estimates of Owner development costs are included
- Contingency is not included and should be applied at the discretion of NL Hydro

Relevant Notes on Estimates

The battery storage industry is relatively young and is still seeing dramatically reduced battery prices year over year, with major cost reductions still projected in the coming years. There are several battery chemistries and technologies to choose from, but lithium ion technologies are the most widely deployed. According to the EIA study cited previously, "over 80% of U.S. large-scale battery storage power capacity is currently provided by batteries based on lithium-ion chemistries. "

As such, New Colliers has chosen to base the estimate on a lithium ion technology as supplied by HICO. Other chemistries may provide competitive benefits and those benefits can be explored during a subsequent investigation phase. For the purposes of this feasibility estimate, it is believed that a lithium ion solution provides a sound basis to evaluate preliminary project economics and performance.

3 Technical

3.1 Location

NL Hydro has not nominated any specific sites for consideration. However, interconnection at an existing major substation is a sensible basis on which to proceed. The Holyrood Generating Station, Western Avalon or Oxen Pond substations all appear to have 66kV/69kV buses to which a new battery storage project may be feasibly interconnected. This assumption should be verified in a subsequent phase of study. Alternatively, interconnection to the 25kV or 35kV bus of an existing or new wind project may provide for the most economical interconnection.

It may be that the solution that meets the capacity requirements of NL Hydro involves either a larger battery system than the 100MW/200MWh estimated here or multiple 100MW/200MWh installations at different substations across the Avalon Peninsula. The estimate presented here can be scaled according to the capacity required for preliminary feasibility purposes. However, both the single larger installation and, to a lesser degree, multiple 100MW/200MWh installations, would benefit from economies of scale.

3.2 Size of Units

HICO has provided a sample layout derived from a 10MW/20MWh project that provides some of the basis of the estimate herein. It is estimated that a 100MW/200MWh project can be supplied through 45-foot containerized modules with individual capacities of 2MW/4MWh. The Battery Management System (BMS), Power Management System (PMS) and Power Conditioning System (PCS) are expected to be supplied in separate 45-foot containers that have the capacity to support two 2MW/4MWh battery container modules. A sample layout for the conceptual 10MW/20MWh portion is provided as Appendix B to this report.

3.3 Characteristics

3.3.1 Efficiency

The HICO product literature states that the round-trip efficiency of their ESS offering is more than 85%. 85% is in-line with industry expectations for lithium ion roundtrip efficiencies although efficiencies up to 90% are reported with some technologies. Degradation of efficiency has not been specifically modeled by New Colliers. However, an annual "augmentation" cost has been allowed for to replace those units whose performance degrades below acceptable thresholds.

3.3.2 Performance Benefits and Comparisons

As discussed, battery storage can provide capacity in contingency situations. Battery storage can also provide many other services and benefits to the grid. Subject to a more in-depth system implementation study, those potential benefits could include:

- Resource adequacy during non-contingency peak times
- Frequency regulation
- Voltage support
- Black start support
- Congestion relief
- Deferral of transmission and/or distribution upgrades
- Firming of variable generations such as wind and solar

While battery storage can provide emergency capacity reserve and other ancillary services, providing frequency regulation and voltage support in non-contingency situations, for example, may reduce the reserve capacity of the battery system should a contingency situation arise. For this reason, the fine balance of providing ancillary services and reserve capacity must be carefully planned and controlled. With that said, the lifetime of lithium ion batteries may also be reduced if the batteries are kept at 100% charge for extended periods of time. A detailed study should be undertaken to characterize this control balance in a subsequent phase of feasibility analysis.

While lithium ion technologies are the most broadly deployed battery type in North America, there are other potentially viable options on the market, both battery-based and using other technologies. While lead-acid batteries are commonly deployed for smaller scale applications, New Colliers believes flow batteries are the most likely alternative to lithium ion at the grid scale.

Lithium ion battery systems are desirable because of their high efficiency ratings and fast response times. They also have a relatively high energy density (i.e. take up less space) than some other battery chemistries.

Flow batteries are also a focus as an emerging technology. They are constructed with battery chemicals in a storage tank. While they have a lower energy density than lithium ion batteries (i.e. they take up more space), in projects where space is not a restriction, the tank size can be adjusted to provide additional energy capability, as required. In this respect, they may have some economies-of-scale advantages that can be leveraged to provide a lower cost per MWh in larger installations. The battery fluids for flow batteries can be corrosive or toxic. But on a positive note, fluids in the tank can be replaced to reinvigorate the battery over the project life.

Flow batteries have potential for lower capital costs in some use cases but they also have lower efficiencies as compared to lithium ion. Lithium ion batteries are also expected to provide faster response for power applications but have, historically, been capable of fewer charge-discharge cycles resulting in a shorter useful life. This requires the allowance for additional capital cost or additional sustaining capital expenditures to maintain the performance over a 20-year project life for the lithium ion option.

The technologies around these battery chemistries continue to rapidly evolve and actual competitive offerings of competing battery chemistries should be analyzed to assess the relative performance capability closer to the time of any planned deployment.

4 Cost and Schedule

4.1 Capital Cost

Detailed project cost estimates can be found in Appendix A. The following cost summaries are reflective of a 3-year development and construction schedule.

Cost Centre	Year 1	Year 2	Year 3	Year 4	Cost Centre Subtotals
Owner/Development Activities	$239,750	$645,250	$585,000	$0	$1,470,000
Battery Supply		$33,720,000	$134,880,000		$168,600,000
BOP Construction and Commissioning			$5,880,280	$0	$5,880,280
Annual Subtotals	*$239,750*	*$34,365,250*	*$141,345,280*	*$0*	

Project Cost	**$175,950,280**
Project Cost per MW	**$1,759,503**

Table 1 - Cost Summary for 100MW/200MWh Battery Storage Project

4.2 Construction Schedule

Independent of battery technology chosen, there is likely a two-year window required to complete key development activities. Developers will engage with stakeholders and conduct an environmental assessment based on a preliminary battery system layout. Developers and the interconnecting utility will conduct a system impact study in year 1 and facility study in year 2 to assess the impact, cost and system modifications associated with interconnecting the new battery storage generating facility.

Preliminary geotechnical work and preliminary project designs will be completed to sufficiently inform a design-build bid package that will serve as the basis for a competitive and thorough contract procurement process. Also, in year two, battery system down-payments will be made to initiate the battery system supply process.

In year 3, construction activities will commence. All project construction activities can likely be completed in one year with the Commercial Operation Date (COD) in December of year 3.

4.3 O&M costs

It is expected that the project Owner will self-perform battery system maintenance work. Basic maintenance will most typically include site access maintenance and snow clearing, collection system maintenance, project operational optimization and troubleshooting. It is expected that the developer will manage any third-party maintenance service contracts.

Operators will need to replace any battery units whose efficiency degrades beyond acceptable levels. This cost item is captured as augmentation cost in Table 2. Only a nominal augmentation cost of 0.5% of capital cost is allowed for in this estimate. New Colliers believes this is reasonable as we do not expect this plant to be used like a peaking power plant where it is frequently cycled with a significant depth of discharge. Further, it is expected that much of the system frequency regulation will be handled by NL Hydro’s existing converter stations and hydro generation facilities in regular operating conditions. Based on the expected low cycling duty on the batteries, these costs could be even lower. These costs are difficult to estimate at this preliminary stage of study, especially without a system study defining the need and use cases. A detailed system study must be completed to give confidence to these numbers.

In addition to pure operations and/or maintenance costs, owners will also have ongoing land lease and insurance costs to operate the project.

New Colliers estimates the following annual operational costs in 2018 dollars:

Operations Cost Item		Cost
Staff		$150,000
Maintenance & equipment use		$250,000
Land lease		$20,000
Insurance		$75,000
Battery system augmentation		$843,000
Total		**$1,338,000**

Table 2 - Battery Storage System Estimated Annual Operations Costs

With limited industry history from which to draw, operational costs for battery storage likely present the highest degree of uncertainty in the cost estimate.

4.4 Environmental

Battery storage technologies provide the means to increase the proportion of renewable energy on the grid. In addition, they are expected to have a relatively low impact on their surroundings during the construction and operational phases of the project.

A battery field the size of the one proposed here (approximately 1 hectare) is a significant industrial installation. However, required civil work is expected to be minimal, the installation has very low relative height and the project can be located adjacent to an existing substation. Thus, a battery project such as the one proposed is expected to enjoy good levels of public acceptance and have relatively few environmental impacts and risks. Environmental assessment processes are likely to address the following key considerations:

- Containment and recycling of heavy metals and electrolyte materials
- Disturbance of wetlands or other key habitats during construction and operation

Potential environmental impacts of a lithium ion battery storage solution are expected to be very manageable.

5 Feasibility

Large-scale battery storage projects are relatively new in North America. The EIS market trends report estimates that, as of 2017, the total installed capacity of large-scale battery storage is 708MW/867MWh. In Canada, New Colliers is only aware of the Basin 1 and Basin 2 projects which were due to come online in the spring of 2018. They are designed for a total capacity of 4MW/12MWh. Clearly, the industry is quite young in North America, but the potential performance and economics are quite appealing.

Key development risks in Newfoundland are likely to include:

- Due to limited industry history, a relatively higher level of uncertainty in battery life and associated uncertainty in lifetime maintenance and augmentation costs
- Currently a lack of accurate projections for system need and battery system response with Holyrood being decommissioned and new Muskrat Falls coming online. This refined characterization would eventually form the basis of any storage system design
- Potential lack of access to cost-effective injection points on the grid that can accommodate new storage capacity with modest system upgrades

It is understood that NL Hydro is exploring the addition of new capacity to mitigate any potential negative system stability effects associated with the decommissioning of the Holyrood Generating Station. New combustion turbines, new renewable generation, new storage capacity or some combination of these technologies are most likely the strongest candidates to make up any future shortfall in capacity in contingency situations. While the implementation a newer technology such as battery storage will come with its challenges, implementation of a battery storage system makes sense for NL Hydro for several reasons:

1) It is expected that NL Hydro will have access to surplus energy in the near future given the strong hydro generation portfolio to soon be supplemented by the commissioning of Muskrat Falls. The access to market priced energy to charge the batteries is likely to compare favourably with the uncertainty in fuel pricing for a new combustion turbine generating station that might be an alternative for new capacity
2) In general, battery systems can respond faster and more accurately than thermal generation plants. This would be especially important in grid contingency situations like a disruption to one of the DC connections to the island or any of the DC or AC connections to the Avalon Peninsula

3) Battery systems (as well as other storage systems) can provide full negative and positive capacity for regulation (i.e. through charging and discharging) in contrast to traditional combustion turbines
4) Newfoundland has a very strong wind resource and new wind projects paired with storage would help to firm capacity from wind generation and allow NL Hydro to draw upon the grid supporting capability of both the battery system as well as modern full-converter type wind turbines. Combining new wind and storage may also provide for better economics for the interconnection portion of the new projects. The storage can be interconnected at 35kV instead of 66/69kV. Supplementary interconnection facilities at the point of interconnection (such as a three-breaker ring bus) may be avoided or the costs shared across a larger project.

For next steps, New Colliers recommends that NL Hydro:

1) Quantifies the need for capacity so that a storage solution may be refined in terms of size and intended use. Criteria such as the total storage time required (e.g. 10 minutes to 4 hours) and the degree to which NL Hydro would like the storage system to provide grid support functions such as frequency and voltage regulation (in addition to reserve capacity) will help refine the characteristics and cost of the storage system
2) Develop a more refined model that more accurately defines expected frequency of battery cycling, depth of discharge, etc. Operational costs can be refined on this basis
3) Engage suppliers in a more focused pricing exercise based on the outcome of the activities above
4) Attempt to identify lower costs points of interconnection on the grid than the 66/69kV points assumed herein

Laurie Murphy
LM:lm

Appendix A: 100MW/200MWh Estimate
Appendix B: Sample HICO Arrangement for 10MW/20MWh Project
Appendix C: Interconnection SLD
Appendix D: HICO ESS Product Literature
Appendix E: NL Hydro Summary Table

Appendix A

100MW/200MWh Estimate

Total Costs

	Year 1	Year 2	Year 3	Year 4	Cost
Development Activities	$239,750	$645,250	$585,000	$0	$1,470,000
Battery System Supply		$33,720,000	$134,880,000		$168,600,000
BOP Construction and Commissioning			$0	$0	$5,880,280
Annual Subtotals	*$239,750*	*$34,365,250*	*$135,465,000*	*$0*	
				Project Cost	**$175,950,280**
				Project Cost per MW	**$1,759,503**

Development Activities

	Year 1	Year 2	Year 3	Year 4	Cost
System needs forecasting	$40,000.0	$10,000			$50,000
Site surveying, preliminary geotechnical investigation	$2,250.00	$12,750			$15,000
Stakeholder consultation/engagement	$30,000.0	$30,000			$60,000
Land acquisition	$0.0	$25,000			$25,000
Interconnection studies, application and agreement	$30,000.00	$170,000			$200,000
Interconnection fee			$150,000		$150,000
Environmental Impact Assessment	$37,500.0	$87,500			$125,000
Project contract procurement and capacity pricing	$70,000.0	$280,000			$350,000
Inhouse engineering, project management and oversight	$30,000	$30,000	$120,000		$180,000
Construction management	$0	$0	$165,000		$165,000
Land rental during construction	$0	$0	$25,000		$25,000
Permits and licenses	$0	$0	$125,000		$125,000
Annual Subtotals	*$239,750*	*$645,250*	*$585,000*		
				Development Cost	**$1,470,000**
				Development Cost per MW	**$14,700**

Battery System Supply and Delivery

	Year 2	Year 3	Cost
HICO ESS Battery System	$33,720,000	$134,880,000	$168,600,000
		Battery System Cost	**$168,600,000**
		Battery System Cost per MW	**$1,686,000**

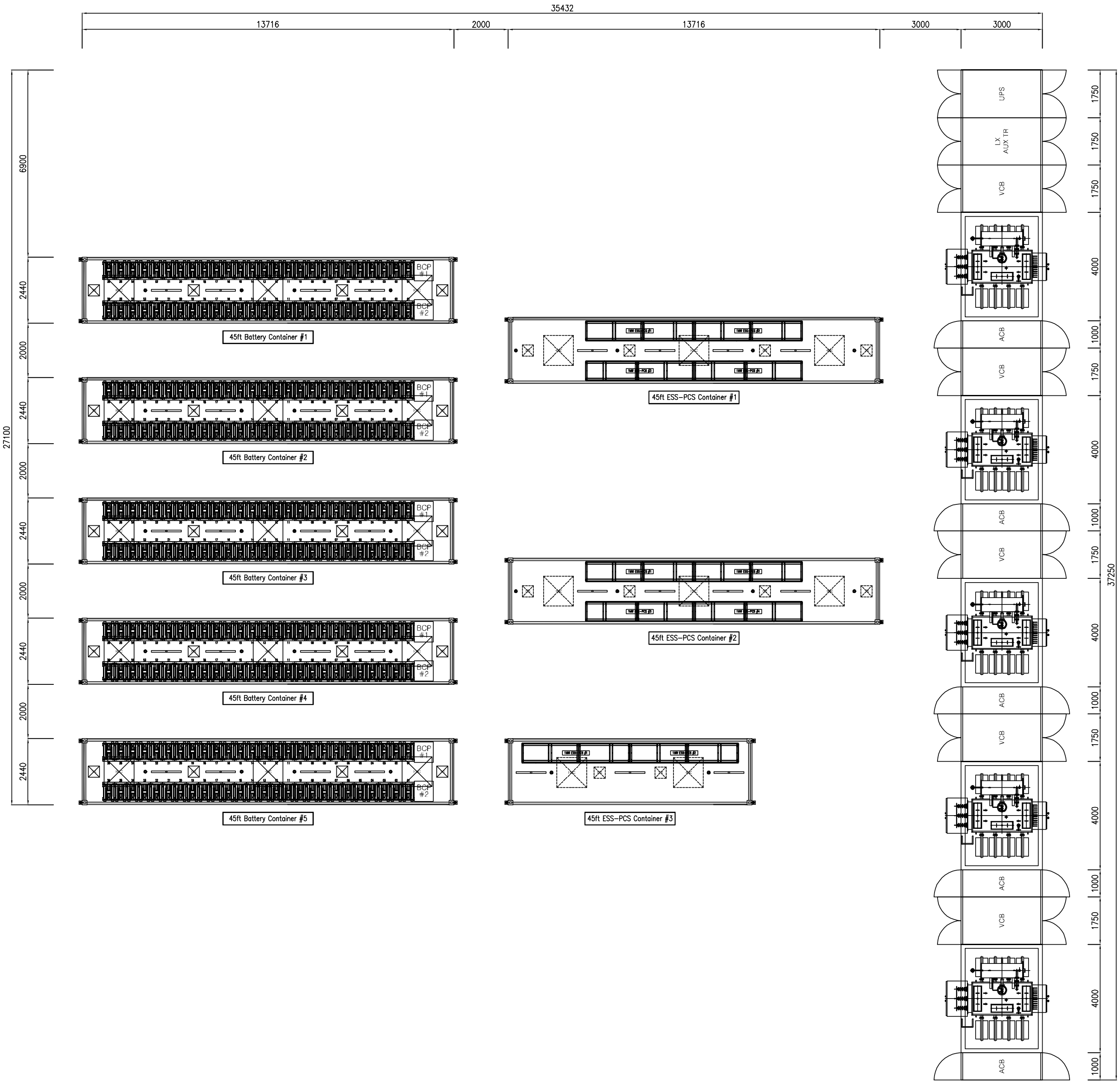
Balance-of-Plant (BOP) Construction Estimate

Construct Laydown and Trailer Area				
	Quantity	**Unit**	**Unit Rate**	**Cost**
Excavate and Backfill Trailer Area	1	each	$ 50,000.00	$ 50,000.00
Reclamation of Temporary Area	1	LS	$ 50,000.00	$ 50,000.00
			Subtotal	$ 100,000.00
Improve Existing Roads				
	Quantity	**Unit**	**Unit Rate**	**Cost**
Improve Existing Roads	0	m	$ 100.00	$ -
Allowance for improved major approaches	1	each	$ 20,000.00	$ 20,000.00
			Subtotal	$ 20,000.00
Construct New Roads and Drainage				
	Quantity	**Unit**	**Unit Rate**	**Cost**
Wood Cutting and Grubbing	0.1	Ha	$ 9,000.00	$ 900.00
Construct new roads	100	m	$ 120.00	$ 12,000.00
Roads maintenance and reclamation	100	m	$ 40.00	$ 4,000.00
			Subtotal	$ 16,900.00
Battery Container Array Site Preparation				
	Quantity	**Unit**	**Unit Rate**	**Cost**
Wood Cutting and Grubbing	0.99	Ha	$ 9,000.00	$ 8,930.25
Surface excavation, backfill and pad prep	0.95	Ha	$ 10,000.00	$ 9,450.00
Reclamation allowance	1	Unit	$ 10,000.00	$ 10,000.00
			Subtotal	$ 28,380.25
Container Foundations				
	Quantity	**Unit**	**Unit Rate**	**Cost**
Container Foundations	85	each	$ 7,500.00	$ 637,500.00
			Subtotal	$ 637,500.00
DC Equipment Installation				
	Quantity	**Unit**	**Unit Rate**	**Cost**
Container mounting and grounding	85	each	$ 7,500.00	$ 637,500.00
DC external wiring	85	each	$ 4,000.00	$ 340,000.00
			Subtotal	$ 977,500.00
AC Equipment Supply and Installation				
	Quantity	**Unit**	**Unit Rate**	**Cost**
20 MW transformer supply and installation	5	each	$ 250,000.00	$ 1,250,000.00
Low voltage breakers	5	each	$ 50,000.00	$ 250,000.00
69kV feeder breakers	5	each	$ 150,000.00	$ 750,000.00
Main 69kV breaker	1	each	$ 175,000.00	$ 175,000.00
Auxiliary power, UPS and other controls	5	each	$ 50,000.00	$ 250,000.00
			Subtotal	$ 2,675,000.00
69kV Substation Bus Interconnection				
	Quantity	**Unit**	**Unit Rate**	**Cost**
Substation yard and fence additions	1	each	$ 100,000.00	$ 100,000.00
Bus extension	1	each	$ 100,000.00	$ 100,000.00
Protection settings adjustment	1	each	$ 50,000.00	$ 50,000.00
Foundation and grounding Works	1	each	$ 30,000.00	$ 30,000.00
			Subtotal	$ 280,000.00
Miscellaneous Site Costs				
	Quantity	**Unit**	**Unit Rate**	**Cost**
Surveying	1	LS	$ 10,000.00	$ 10,000.00
Commissioning	1	LS	$ 250,000.00	$ 250,000.00
Testing for Pads and Foundations	1	LS	$ 25,000.00	$ 25,000.00
Fencing	300	lm	$ 100.00	$ 30,000.00
			Subtotal	$ 315,000.00

Balance-of-Plant (BOP) Construction Estimate (Continued)					
Contractor Engineering					
	Quantity	**Unit**	**Unit Rate**	**Cost**	
Civil Engineering including Foundation	1	LS	$ 50,000.00	$ 50,000.00	
DC Collection System and LV Engineering	1	LS	$ 50,000.00	$ 50,000.00	
AC Collection and Interconnection Engineering	1	LS	$ 250,000.00	$ 250,000.00	
Geotech Study	1	LS	$ 20,000.00	$ 20,000.00	
			Subtotal	$ 370,000.00	
Contractor Construction Management					
	Quantity	**Unit**	**Unit Rate**	**Cost**	
Staff and Management	8	Months	$ 25,000.00	$ 200,000.00	
Temporary Installation Including Power and Comms	8	Months	$ 25,000.00	$ 200,000.00	
Health and Safety	8	Months	$ 7,500.00	$ 60,000.00	
			Subtotal	$ 460,000.00	
			Total	$ 5,880,280.25	
			BOP Cost Per MW	$ 58,802.80	
			BOP Cost Per MWh	$ 29,401.40	

Appendix B

Sample HICO Arrangement for 10MW/20MWh Project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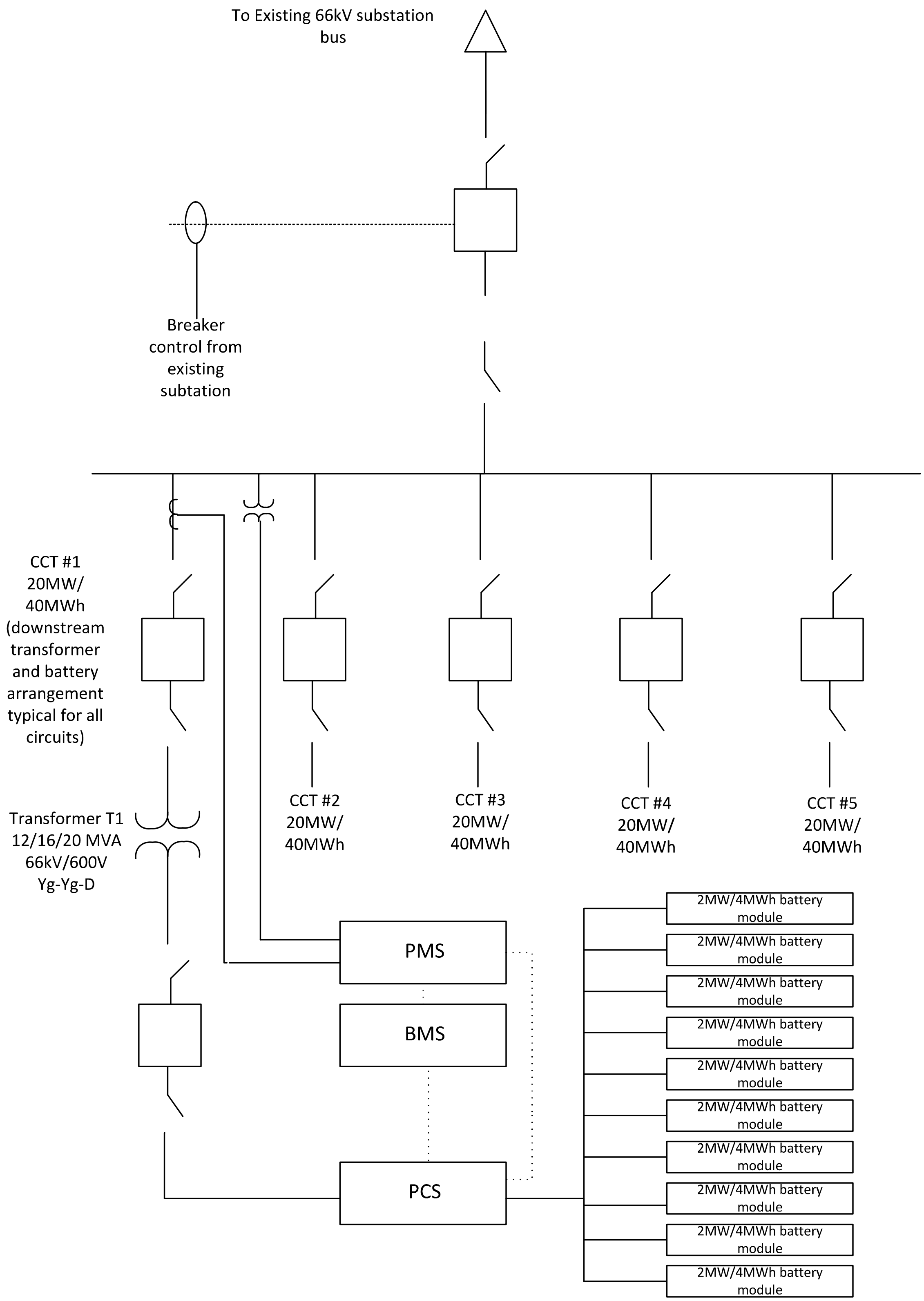
ACB
BCP #1
BCP #2
45ft Battery Container #1
45ft Battery Container #2
45ft Battery Container #3
45ft Battery Container #4
45ft Battery Container #5
45ft ESS-PCS Container #1
45ft ESS-PCS Container #2
45ft ESS-PCS Container #3

Appendix C

Interconnection SLD

NEW COLLIERS LTD.

100MW/200MWh Battery Storage Project
66kV Interconnection to Existing Substation
Preliminary Single Line Diagram
Rev. A – August 31, 2018



Appendix D

HICO ESS Product Literature

Hyosung Corporation

ESS

for Future Energy Solution

Power Systems PU
2018

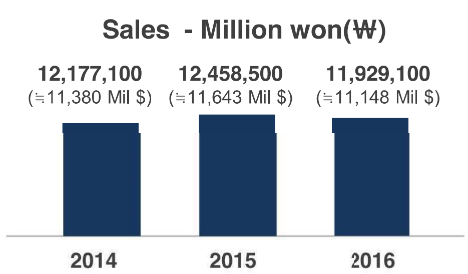
HYOSUNG

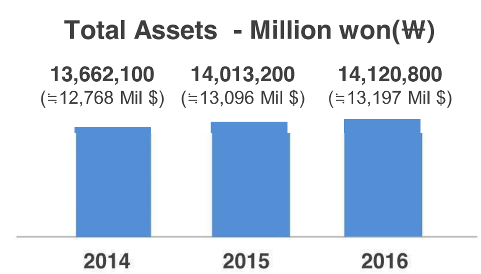
Contents

I. About Hyosung

HYOSUNG
Global Top Energy Solution Provider

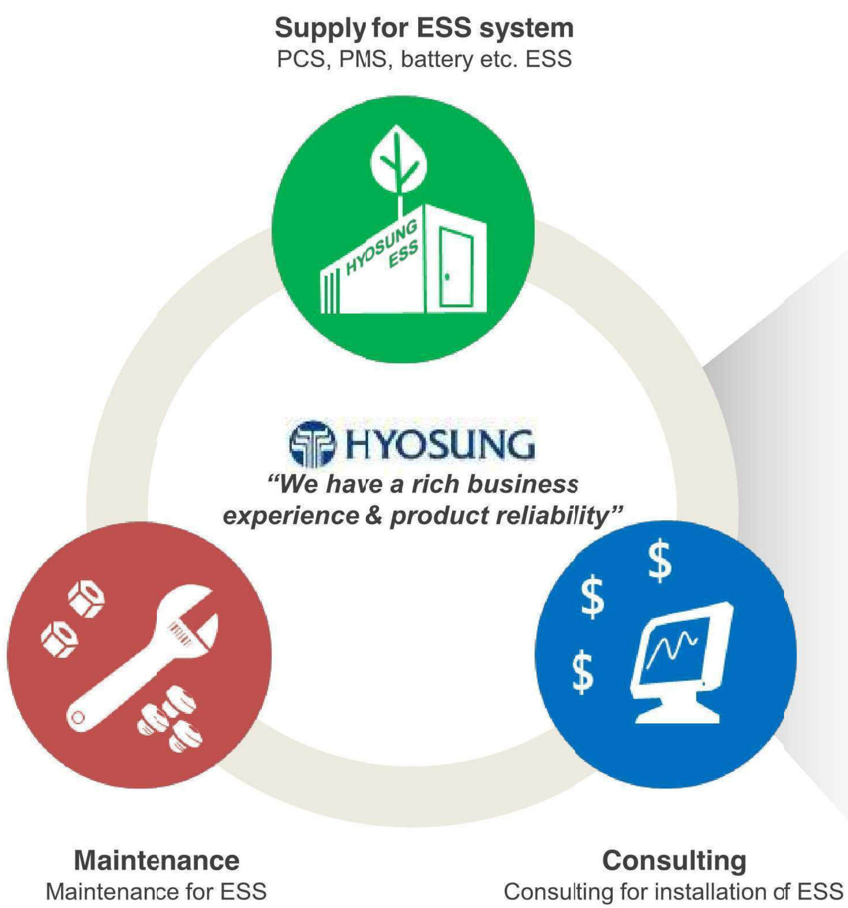
$11B Revenue Company with 7 Performance Groups(PG*). Power and industrial systems performance group's major business area is T&D, motor and pump solutions.





* PG : Performance Group

Hyosung can provide energy storage solution with grid base engineering know-hows to maximize customers economic benefits with reliable product lines.



Strengths of HYOSUNG for ESS

Reliable products

- Hyosung experienced lots of ESS national project.
- Hyosung has a lot of experiences to provide ESS to customers (KHNP, KEPCO etc.) that require high reliability.

ESS experts and Maintenance

- Hyosung has been a lot of projects and has strong project pipeline, so problems encountered during the project implementation could to minimize.
- When a problem occurs, Hyosung's ESS experts will respond quickly to problems.

ESS engineering & design capabilities

- Through Korea's no.1 power equipment manufacturer experience, Hyosung holds a high understanding for the grid.
- Hyosung can suggest ESS specifications and operational plans for the customers.

Ⅱ. The concept of ESS

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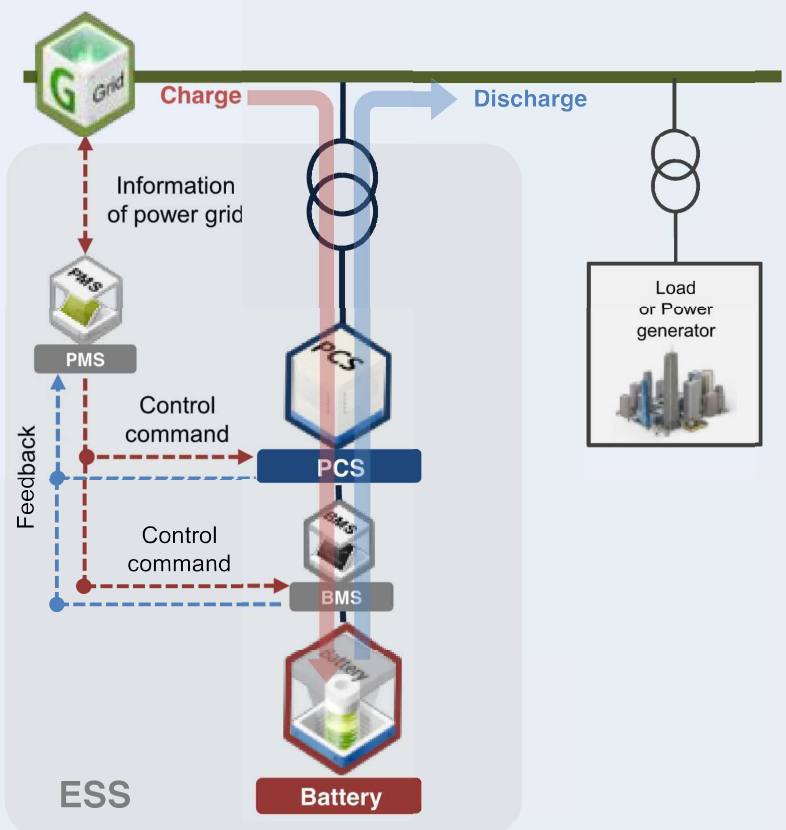
BESS(Battery Energy Storage System), so-called ESS, is a system used for storing electrical energy to secondary battery for timely use.

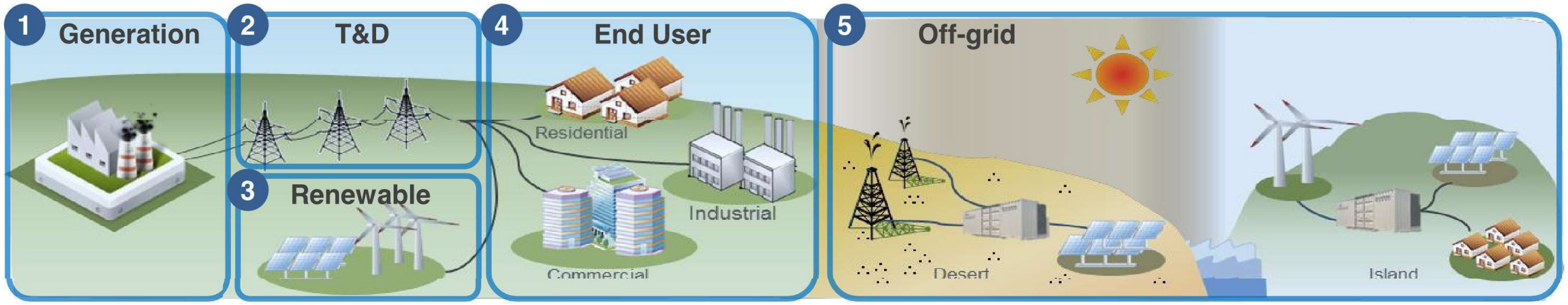
Concept



Summary

Principle	▪ Storing electrical energy to Secondary batteries (Li-ion, Lead-acid, NaS, etc)
Composition Role	▪ PMS: Control PCS, BMS ▪ PCS: Convert AC/DC, Power quality control ▪ BMS: Control and Monitoring batteries ▪ Battery: Store electrical energy
Life Expectancy	10~20 years
Efficiency	More than 85%
Benefits	▪ Reserving Power electricity ▪ Frequency Regulation ▪ Improving Power quality ▪ Supporting Renewables ▪ Supporting Users for efficient power usage ▪ Voltage control ▪ T&D investment Deferral
Construction Period	Less than 1 year

ESS is applicable to entire power system area from generation to end user. It has multiple benefits such as improving & stabilizing power quality, supporting renewables and off-grids.



1 Generation

- **Improving Generation efficiency**
  - Aiding generators by smoothing load fluctuation
  - Decentering peak load / Improving power quality
  - Supplying seconds-scale reserve
  - Providing spinning reserves

2 T&D

- **Ancillary services**
  - Defer additional investments by reduce load
  - Responding sharp drop of voltage in a grid
  - Stabilizing power grid with regulating frequency

3 Renewables

- **Controlling Renewable output**
  - Smoothing irregular output power
  - Profit obtained by the difference between REC's weighting*

*REC : Renewable Energy Certificate

4 End User

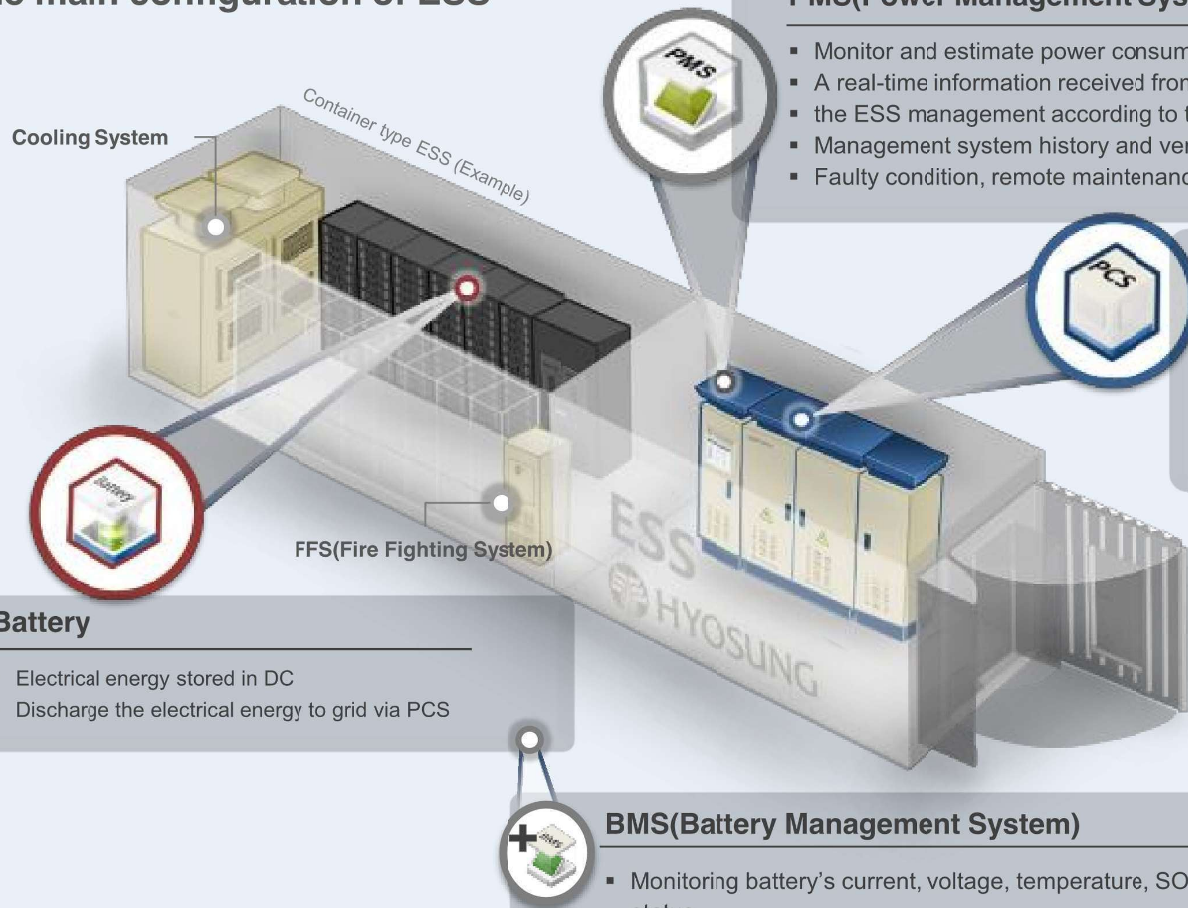
- **Supporting Effective Power usage**
  - Charge at off-peak, discharge at on-peak
  - Prevent blackout & voltage drop
  - Power usage management and UPS

5 Off-grid

- **Supply power to the grid insufficient area through renewable integration**
  - Store produced electricity through renewable energy in the areas of power does not reach such as island and desert

ESS is composed of PMS which control all the component of ESS, PCS which convert AC to DC and Batteries and BMS which control battery Modules and cells.

The main configuration of ESS



PMS(Power Management System)

- Monitor and estimate power consumption and active operation
- A real-time information received from PCS to monitor the ESS
- the ESS management according to the host controller command
- Management system history and version
- Faulty condition, remote maintenance for recovery available

PCS(Power Conditioning System)

- Invert DC power stored in batteries to AC power with voltage and frequency of commercial
- Convert AC power to DC and charged in batteries

Battery

- Electrical energy stored in DC
- Discharge the electrical energy to grid via PCS

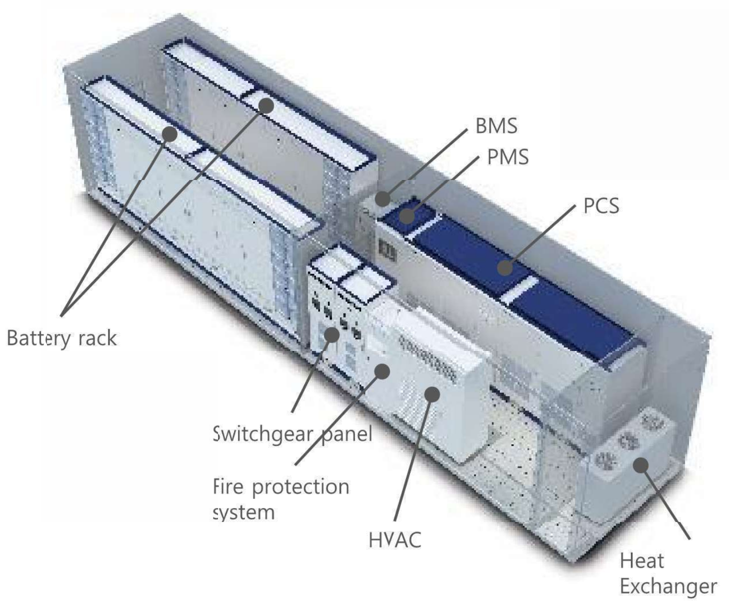
BMS(Battery Management System)

- Monitoring battery's current, voltage, temperature, SOC, devices status
- Exchange information and data to communicate with PCS

Composition of basic ESS installation

ESS could be installed with container type ESS or structure type ESS depends on capacity or customer's needs.

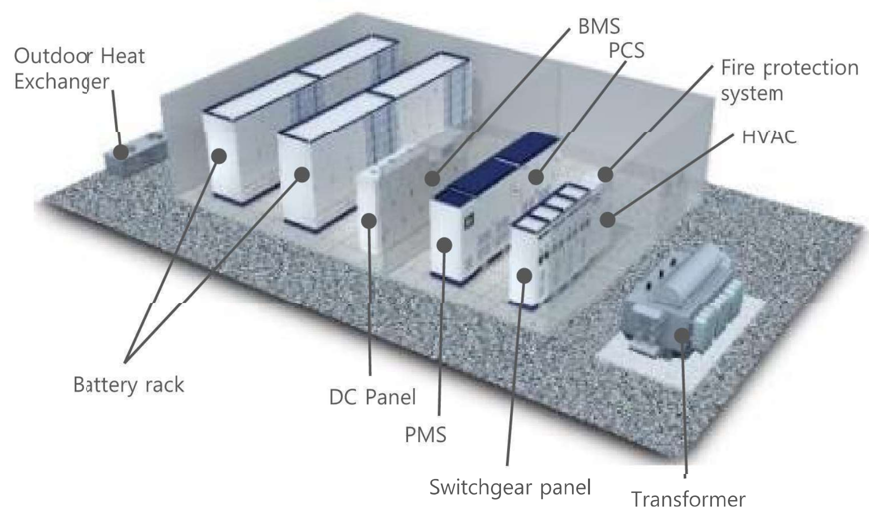
Container Type ESS



※ Up to 1MW/500kWh for standard 40ft. container

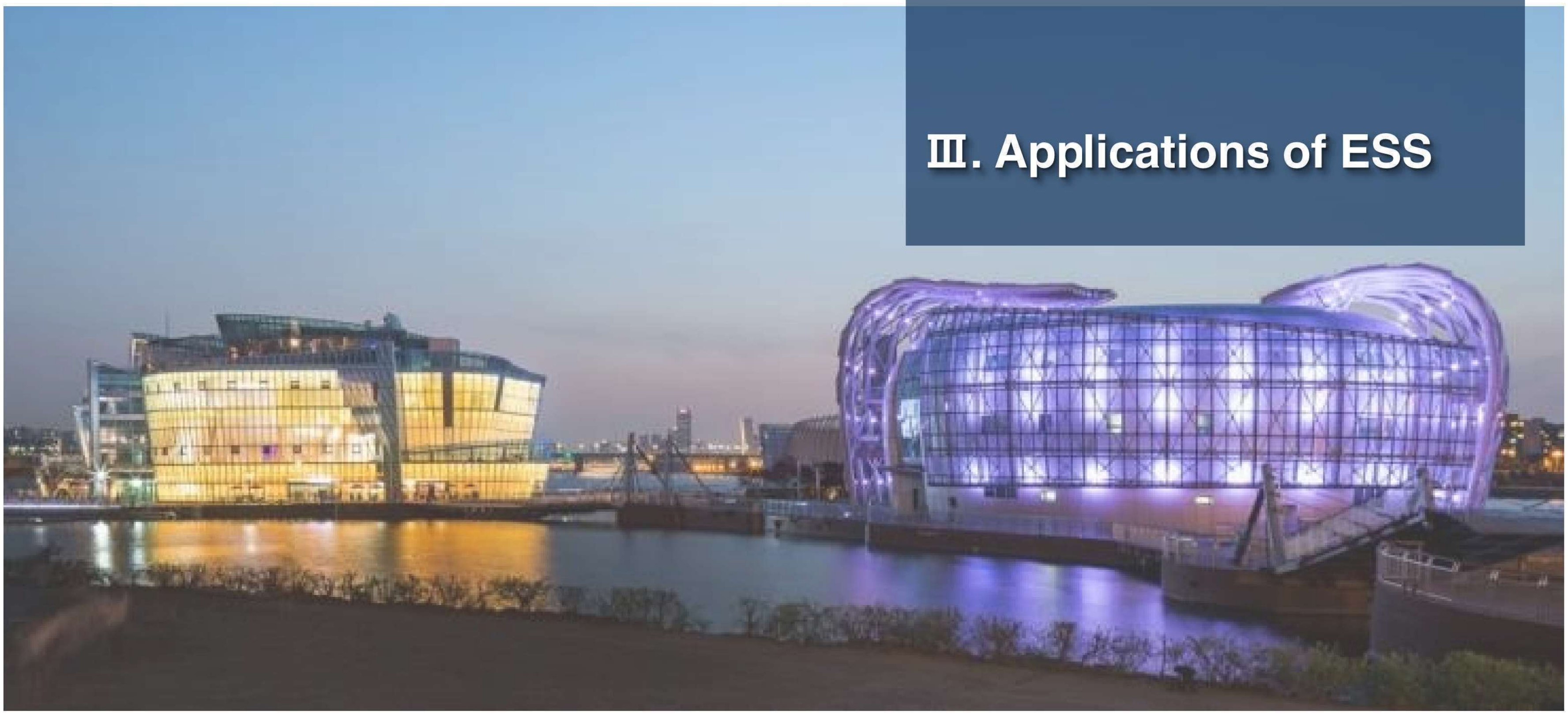
- Configured with PCS, Battery, HVAC, DC Link, monitoring module and fire protection system and may include transformer and switchgear panel if necessary
- Up to 1MW/500kWh (Standard 40ft. container)
- Transportable form production is also possible upon Customer's need
- Due to the nature of Battery, optimization design of air-cooling and fire safety equipment are critical design elements

Indoor Type ESS



- Most ESS more than 10MW of the U.S. is in the form of building structure include PCS, STATCOM and Battery
- Battery and PCS is required isolation or blocking for fire prevention
- STACOM can compensate active and reactive power with ESS

Ⅲ. Applications of ESS



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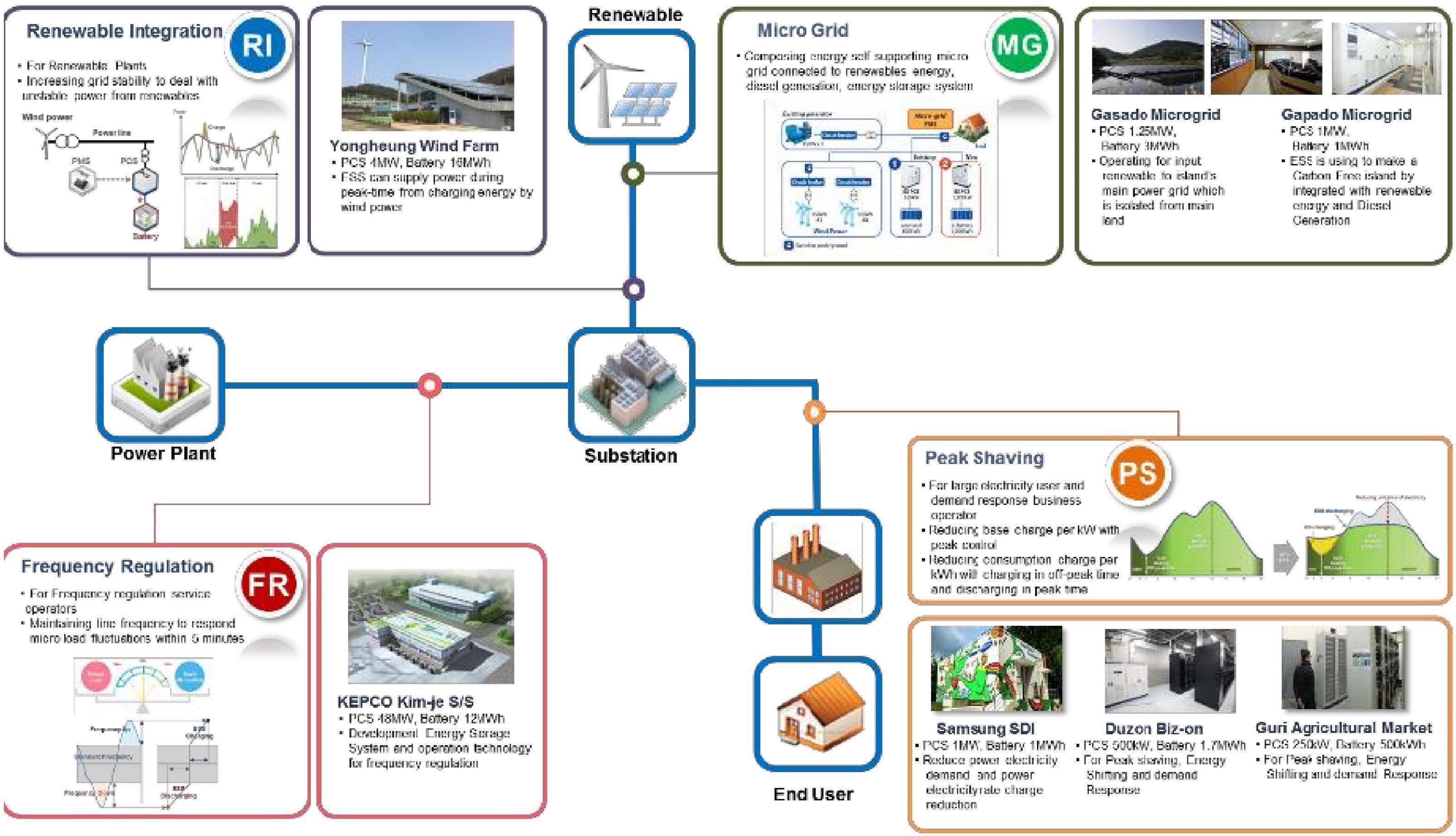
Major applications are Peak Shaving(PS), Frequency Regulation(FR), Renewable Integration(RI) and Micro-grid(MG) as shown the figure.



Major applications are Peak Shaving(PS), Frequency Regulation(FR), Renewable Integration(RI) and Micro-grid(MG) as shown the table.

	FR Frequency Regulation	PS Peak Shaving	RI Renewable Integration	MG Micro-grid
Purpose	▪ Providing spinning reserves ▪ Stabilizing power grid with regulating frequency ▪ Supplying reserve to grid	▪ Doing arbitrage with charging in off-peak and discharging in peak. ▪ Distracting load in peak time(Peak shifting)	▪ the difference between the REC ▪ Smoothing output of wind and photovoltaic generators ▪ Postponing investments to additional T&D infrastructure integrated renewables	▪ Smoothing output of wind and photovoltaic generators ▪ Postponing investments to additional T&D infrastructure integrated renewables ▪ Supply power to the grid insufficient area through renewables integration
Discharging Time	Less than 10~30 minutes	More than 2 hours	0.5~5 hours	0.5~5 hours
Benefits	▪ Saving fuel and overhaul cost of frequency regulation by conventional generation ▪ Stabilizing power grid with fast response performance ▪ Improving power quality	▪ Reducing risk of power shortage in peak time ▪ Postponing investments to additional power plant ▪ Doing arbitrage with electricity	▪ Maximizing revenue of selling power with timely discharging ▪ Stabilizing power grid ▪ Saving cost of grid operation with controlling renewables power output	▪ Maximizing revenue of selling power with timely discharging ▪ Stabilizing power grid ▪ Saving cost of grid operation with controlling renewables power output
Major user	Grid operator, Generation company	End-users	Renewables power plants	Renewables power plants
Case of installation	▪ 1MW ESS (PJM for ancillary service) ▪ 8MW ESS (NYISO for Frequency Regulation) ▪ 4MW ESS (KEPCO for supplying reserve and improving power quality in Chochun S/S)	▪ 1MW/1MWh Samsung SDI Ki-heung Plant, Gyeonggi Province ▪ 250kW/500kWh Guri Agricultural & Marine Products Wholesale Market, Gyeonggi Province	▪ KOSEP(Young-Heung WT) 4MW/16MWh ESS ▪ 800kW ESS (Haengwon, Jeju for integrating wind power plant)	▪ Jaeju Gapado island 1MW/1MWh ESS ▪ Gasado island 1.25MW/3MWh ESS ▪ Mozambique Off-grid(desert)

IV. Hyosung's ESS

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For convenience of customer value, Hyosung can provides all equipment and service for energy storage system.

Turn-key Solution

- Based on power electronics and energy management technology, Hyosung provides various equipment, system and service for energy storage system, including ES-PCS, power management system and turnkey solution.

PCS

- Hyosung manufactures and supplies 250kW, 500kW and 1MW PCS units for ESS.
- All of the PCS have isolated system operating functions. Based on high efficiency and high reliability, Hyosung's PCS can be applied various environment, including building, plants, substation and renewable energy.

PMS

- For maximize performance of energy storage system, Hyosung's power management system provides various operation algorithm and functions.
- By monitoring, controlling, and interoperating with other system. Power management system can improve power quality and cost-effectiveness of energy users.

Hyosung ES-PCS provides highly effective power conditioning system for all kinds of storage technology and we have PCS manufacturing & test facilities in Korea.

PCS(Power Conditioning System)

Hyosung PCS's main function

Bi-directional power control	▪ Controlling power inflow and outflow between battery and power grid
Power quality compensation	▪ Compensating voltage (reactive power) of power grid
Grid synchronization	▪ Providing phase angle by estimating system voltage phase
Protecting grid	▪ Protecting power grid based on IEEE Standard 1547
Communication interface	▪ Communicating with BMS and PMS for effective operation of ESS

PCS manufacturing and test facilities

- HYOSUNG perform the PCS production and inspection directly at Se-jong Plant(Korea).
- PCS factory and QC equipment factory

PCS manufacturing factory

PCS manufacturing line

QC equipment factory

Equipment of TEST

[AC Grid Simulator] [DC Supplier] [RLC Load simulator]

HYOSUNG's ES-PCS(2/2)

Technical Data		HS-E110G	HS-E250G	HS-E500GL	HS-E1000G	HS-E2000GL
Input Side(DC)	Voltage Range	550~850V	550~850V	550~850V	750~1,050V	750~1,050V
	Max. Input Current	218A	500A	1,000A	1,333A	2,667A
Output Side(AC)	Rated Power	110kW	250kW	500kW	1,000kW	2,000kW
	Output Voltage	3Ø, 380V	3Ø, 380V	3Ø, 340V	3Ø, 440V	3Ø, 440V
	Output Current	167A	380A	849A	1,312A	2,625A
	Grid Frequency	50/60Hz	50/60Hz	60Hz	60Hz	60Hz
	THD	<5%	<5%	<5%	<5%	<5%
	Power Factor	>0.99	>0.99	>0.99	>0.99	>0.99
Efficiency	Max. Efficiency	>97%	>97%	>97%	>97%	>97%
Environ-mental	Grid Tied Transformer	O	O	X	X	X
	Cooling	Forced Air	Forced Air	Forced Air	Forced Air	Forced Air
	Ambient Temperature	-20~50°C	-20~50°C	-20~50°C	-20~40°C	-20~40°C
	Relative humidity	<95%RH	<95%RH	<95%RH	<95%RH	<95%RH
Mechanical Spec.	Protection Class	IP20	IP20	IP20	IP20	IP20
	Dimensions (W/D/H)[mm]	1200*850*2120	2400*850*2120	2200*990*2200	4000*750*2220	5500*1100*2200
	Weight	1,070kg	2,400kg	1,930kg	2,930kg	5,000kg
Communication	Comm. Port	CAN2.0, RS422	CAN2.0, RS422	CAN2.0, RS422	CAN2.0, RS422	CAN2.0, RS422
Image						

through lots of ESS business experiences, Hyosung's PMS has operation functions of FR, DR, RI & off-grid.

PMS(Power Management System)

PMS can communicate with PCS in the real time, monitor the status of PCS, and control charging and discharging battery

PMS's main functions

- System monitoring
- Measure data
- Operation control
- Confirmation of alarm
- Alarm data storage
- Data storage/search
- Setting of Control condition
- Report

V. Experience records

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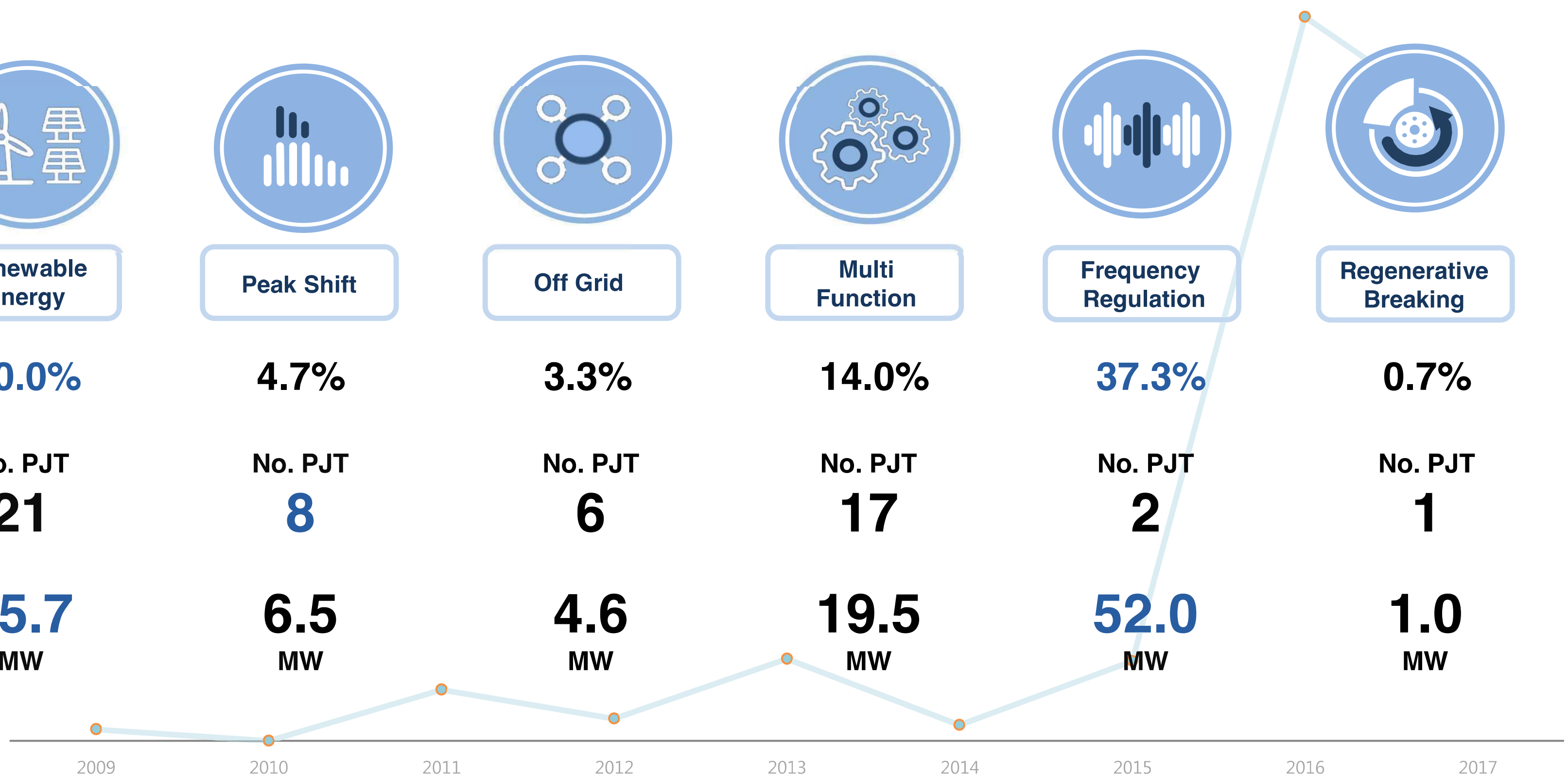
Global Top Energy Solution Provider

- Hyosung has experience in implementing **PCS for ESS 139MW and batteries 240MWh on about 55 sites.**
- In these projects, We operate stably with batteries from major companies such as Samsung SDI, LG Chemicals, KOKAM and SK innovation.
- Our systems cover various applications like renewable Integration, frequency regulation, energy shift and off-grid, and have recently conducted a regenerative braking system project.
- Hyosung has the competitiveness for consulting and engineering to satisfy customer needs.

Renewable Energy	Peak Shift	Off Grid	Multi Function	Frequency Regulation	Regenerative Breaking
40.0%	4.7%	3.3%	14.0%	37.3%	0.7%
No. PJT 21	No. PJT 8	No. PJT 6	No. PJT 17	No. PJT 2	No. PJT 1
55.7 MW	6.5 MW	4.6 MW	19.5 MW	52.0 MW	1.0 MW



ESS projects – Experience records

Year	Project	End User	Installation site	PMS	PCS	Battery	Applications	Installation period
2009	JEJU Smart Renewable	KEPCO	Haeng won wind farm (Jeju Island)	Dynamic Power Control	800kW [800kW X 1]	Li-ion 200kWh Samsung SDI / 20min	RI	'09. 12 - '11. 05
	JEJU Smart Place	Korea Telecom	Sehwa middle school (Jeju Island)	Building Energy Management	120kW [20kW X 6]	Li-ion 180kWh Samsung SDI / 1.5hour	PS	'09.12 – '11. 05
2011	Jo-cheon Substation Project	KEPCO	Jo-cheon Substation (Jeju Island)	Dynamic Power Control	4MW [1MW X 4]	Li-ion 8MWh Samsung SDI / 2hour	PS RI FR	'11. 07 – '14. 06
2012	Samsung SDI Project	Samsung SDI	Samsung SDI Gi-heung Plant	Building Energy Management	1MW [1MW X 1]	Li-ion 1MWh Samsung SDI / 1hour	PS	'12. 03 – '12. 10
	Smart grid Project for Peak shifting	Korea Telecom	Guri Agricultural Market	Community Energy Management	250kW [250kW X 1]	Li-ion 500kWh LG chemical / 2hour	PS	'12. 08 – '12. 12
	Hong Kong CLP Project	CLP	Hong kong Kowloon	Dynamic Power Control	500kW [250kW X 2]	Li-ion 300kWh Samsung SDI / 1hour	PS RI	'12. 11 – '13. 08
2013	Mozambique Off-grid PV generator	FUNAE	Mavago, Mecula, Muembe	Off-grid PV Control	900kW [5kW X 180]	Lead Acid 20MWh Sae-bang / 20hour	MG	'13. 01 – '13. 12
	Frequency Regulation ESS	Korea Power Exchange	Korea East West Power Company (EWP)	Frequency Regulation	4MW [1MW X 4]	Li-ion 2MWh SK innovation/30min	FR	'13. 06 – '16. 06
	Smart grid Project for Peak shifting	Duzon Biz-on	Duzon Biz-on Data Center	Building Energy Management	500kW [250kW X 2]	Li-ion 1.6MWh Samsung SDI / 3hour	PS	'13. 08 – '13. 12
	Renewable & Off-grid Integration	Jeju Provincial Government	Gapado Island	Micro-grid	1MW [1MW X 1]	Li-ion 1MWh Samsung SDI / 1hour	MG	'13. 08 – '14. 06
2014	Renewable & Off-grid Integration	KEPCO	Gasado Island	Micro-grid	1.25MW [250kW X 1/500kW X 2]	Li-ion 3MWh KOKAM / 3hour	MG	'14.03 – '14. 09
2015	KOSEP Wind Farm ESS Project	Korea South Eastern Power	Young-Heung Wind Farm	Renewable Integration	4MW [1MW X 4]	Li-ion 16MWh LG chemical / 4hour	RI	'15. 06 – '15. 10
	KHNP Demand Response ESS Project	Korea Hydro & Nuclear Power	KHNP HQ	Building Energy Management	1MW [1MW X 1]	Li-ion 2MWh LG chemical / 2hour	PS	'15. 09 – '15. 12
	Renewable & Micro-grid Integration	Jeju Provincial Government	Gapado Island (※ additional installation)	Micro-grid	1.25MW [1MW X 1/250kW X 1]	Li-ion 2MWh Samsung SDI / 2hour	MG	'15. 12 – '16. 04
2016	DC Grid ESS	KEPCO	Go-chang Test center	DC Grid ESS	500kW [250kW X 2]	Li-ion 2MWh Samsung SDI / 4hour	MG	'16. 05 – '17. 05
	KEPCO 154kV Gim-Je S/S FR ESS	KEPCO	Gim-Je Substation	Frequency Regulation	48MW [2MW X 24]	Li-ion 12MWh LG화학 / 15min	FR	'16. 05 – '17. 06
	Pyeong-Chang Wind Farm ESS	EMAX	Pyeong-Chang Wind Farm	Renewable Integration	6MW [2MW X 3]	Li-ion 18MWh 삼성SDI / 3hour	RI	' '16. 09 – '16. 12
2017	KOSEP Solar Farm ESS Project	Korea South Eastern Power	Young-Heung Solar Farm	Renewable Integration	7MW [2MW X 2, 1MW X 3]	Li-ion 18MWh 삼성SDI / 3hour	RI	In progress (2017)
	Hae-Nam Solar Farm ESS	Top Solar	Hae-Nam Solar Farm	Renewable Integration	8MW [2MW X 4]	Li-ion 33MWh Samsung SDI / 4hour	RI	In progress (2017)
	University Project for Peak shifting	DAEHO	Chosun University	Building Energy Management	2MW [1MW X 2]	Li-ion 7MWh 삼성SDI / 3hour	PS	In progress (2017)
	Best Solar Farm ESS	Best Solar	Best Solar Farm	Renewable Integration	8MW [2MW X 4]	Li-ion 34MWh 삼성SDI / 4hour	RI	In progress (2017)
	Gang-Dong Wind Farm ESS	Gang-Dong Wind	Gang-Dong Wind Farm	Renewable Integration	2MW [2MW X 1]	Li-ion 6MWh 삼성SDI / 3hour	RI	In progress (2017)
	Sam Chon Po Solar Farm ESS	Korea South Eastern Power	Sam Chon Po Solar Farm	Renewable Integration	12.5MW	Li-ion 32MWh 삼성SDI / 3hour	RI	In progress (2017)

For the purpose of demonstration of Demand Response, Renewable Integration, Voltage support application, grid-tied ESS has been deployed at Jocheon S/S of Kepco, Kowloon S/S of CLP, Hongkong.

PS RI FR Multifunctional ESS for substation

Jocheon S/S, Jeju(KEPCO, 4MW/8MWh)

- Renewable integration(output smoothing), Voltage support (VAR compensation), Black start etc.
- Integrator : KEPCO
- PCS : HYOSUNG 1MW X 4Unit
- Battery : Samsung SDI 8MWh

Kowloon S/S, Hongkong(CLP, 400kW/350kWh)

- Load leveling, Peak Shaving, Renewable integration(output smoothing)
- Integrator : HYOSUNG
- PCS : HYOSUNG 250kW X 2Unit
- Battery : Samsung SDI 350kWh

Hyosung has supplied ESS in compliance with customer requirement with customized by reviewing historical data.

PS Peak Shaving ESS

Guri Agricultural and Fishery Center(KT, 250kW/500kWh)

- Savings : Demand charge : $20,000, Energy charge : $10,000
- Installed Indoor, 22.9kW feeder connected
- Integrator : HYOSUNG
- PCS : HYOSUNG 250kW X 1Unit
- Battery : LG Chem. 500kWh

Deozon Biz-on Chucheon Campus(500kW/1.6MWh)

- Savings : Demand charge $32,000
- Integrator : HYOSUNG
- PCS : HYOSUNG 250kW X 2 Unit
- Battery : Samsung SDI 1.6MWh

Samsung SDI Kiheung Campus(SDI, 1MW/1MWh)

- Savings : Demand Charge $80,000 Energy Charge : $20,000
- Installed indoor 22.9kW feeder connected
- Integrator : HYOSUNG
- PCS : HYOSUNG 1MW X 1Unit
- Battery : Samsung SDI 1MWh

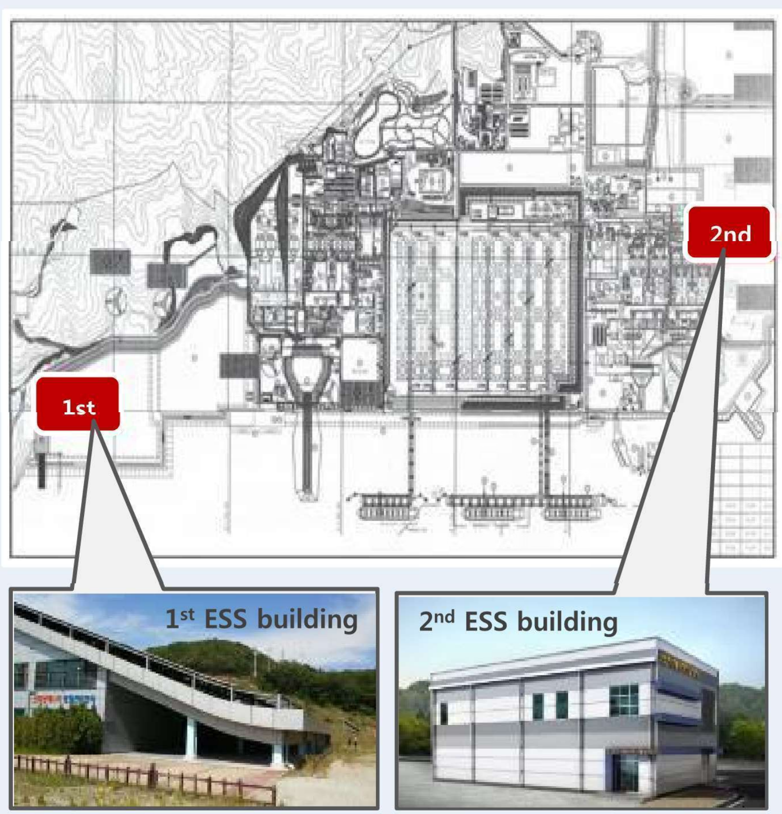
Korea Hydro and Nuclear Power(1MW/2MWh)

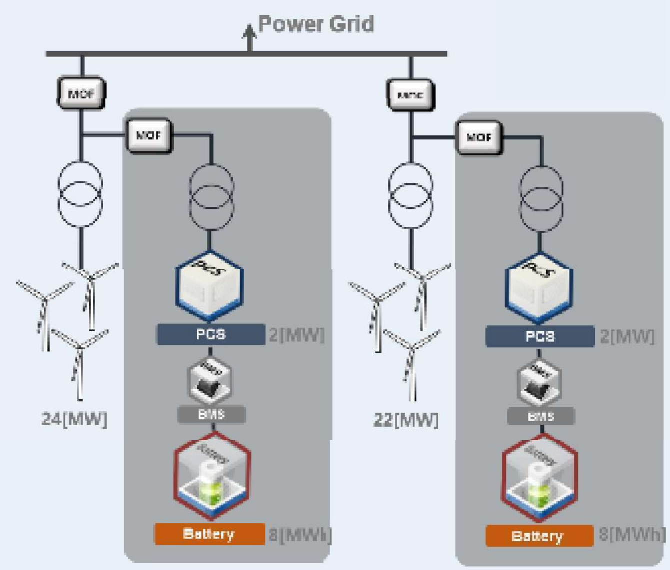
- Peak shaving and back up power supply
- Integrator : HYOSUNG
- PCS : HYOSUNG 1MW X 1Unit
- Battery : LG Chem 2MWh

Hyosung has delivered ESS in Youngheung power plant belongs to South-East Power aims to improve profitability through the acquisition of REC .

RI Renewable Integration ESS – Wind linked ESS

Youngheung ESS(South East Power, 4MW/16MWh)





- By integrating of ESS aims output smoothing and ensures additional subsidies
- Total 4MW/16MWh(2MW/8MWh X 2set)
- Integrator : HYOSUNG
- PCS : HYOSUNG 4MW(1MW X 2Unit, 2set)
- Battery : LG Chem. 16MWh

Hyosung has built the world's largest stand-alone solar power plant in Mozambique and the country's first Carbon Free Island in Jeju Gapado successfully.

MG Micro-grid Solution

Mozambique Solar integrated ESS(900kW/20MWh)

- Mavago(550kW), Mecula(400kW), Muembe(350kW) Solar power plant forms stand alone micro grid
- Integrator : HYOSUNG
- PCS : SMA Single phase 5kW 180Unit, 900kW
- Battery : Lead Acid 2V, 2000Ah, 5105Unit, Total 20MWh

Gapado Stand alone ESS(1MW/1MWh, Y2013)

- Using 2unit of Wind turbine and ESS provide to 200 residential with electric power
- Integrator : HYOSUNG
- PCS : HYOSUNG 1MW X 1Unit
- Battery : Samsung SDI 1MWh

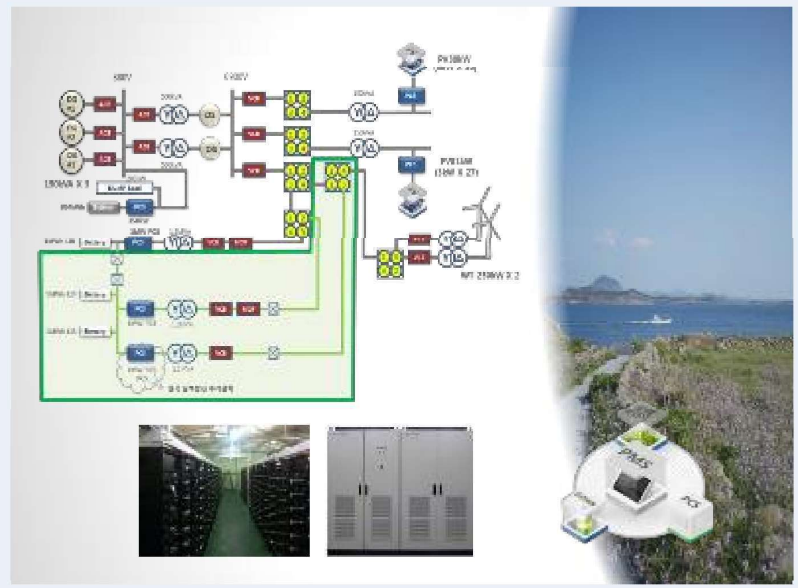
Using accumulated technology and know how, Hyosung expands to development of stand alone Micro-grid.

MG Micro-grid Solution

Gasado Micro-grid ESS(1.25MW/3MWh)

- Integrating Solar, Wind with ESS provide electricity to population in Island, conventional generator used as back up
- Integrator : HYOSUNG
- PCS : HYOSUNG 250kW X 1Unit, 500kW X 2Unit
- Battery : Kokam 3MWh

Gapado ESS 2nd stage ESS (1.25MW/2MWh)

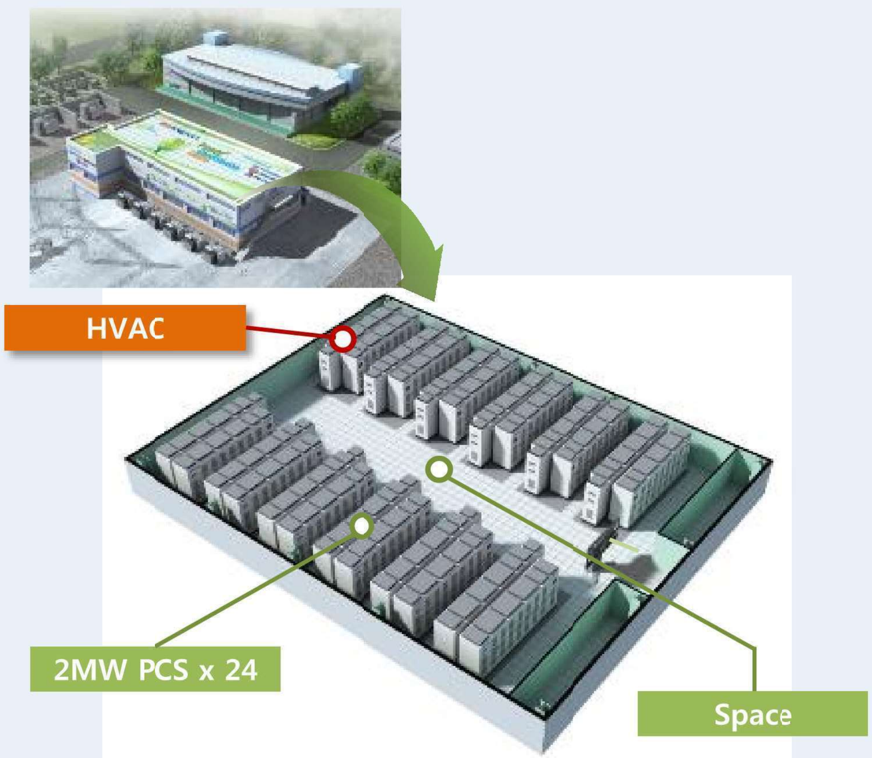


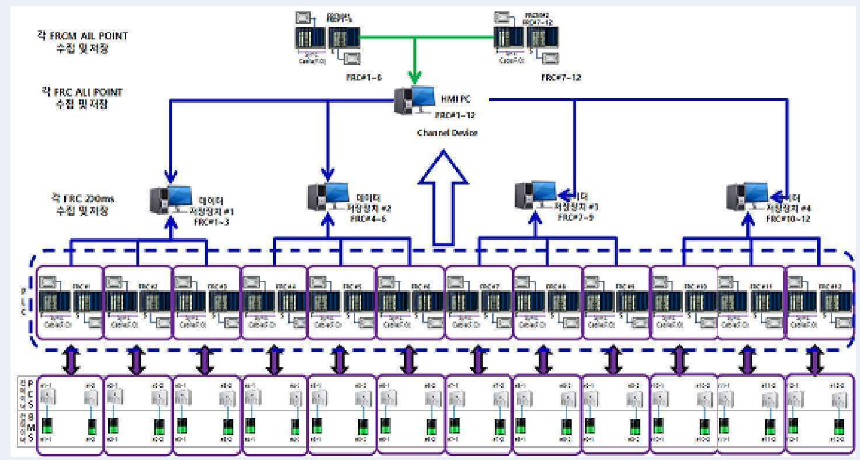
- To enlarge capacity of ESS on 1st stage ESS
- Integrator : HYOSUNG
- PCS : HYOSUNG 1MW X 1Unit, 250kW X 1Unit
- Battery : Samsung SDI 2MWh

Hyosung will provide ESS 48MW for Frequency Regulation at Kim-Je substation. This ESS is the largest capacity since FR ESS has been started.

FR Frequency Regulation ESS

Kim-Je S/S ESS (KEPCO, 48MW/12MWh)





- Integrator : HYOSUNG
- PCS : HYOSUNG 48MW(2MW X 24)
- Battery : LG Chemical 12MWh

Thank you

Global Top
Energy, Machinery & Plant
Solution Provider

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Appendix E

NL Hydro Summary Table

NEW COLLIERS LTD.

Preliminary Project Development and Construction Estimate - NL Hydro Table Format
Oct 15, 2018

System Adequacy Study Data Request - Battery Storage Development

Instructions: In support of our system adequacy study, please fill out the following table as an input to the Plexos model
All costs should be in 2018 dollars, the model will escalate the costs automatically

Input		Unit	Notes
Plant Maximum Capacity	100	MW	200MWh
Unit Capacity	2	MW	4MWh
Number of Units	50	Units	
Average Annual Energy	18.25	GWh	High level estimate, to be refined by NL Hydro
Construction Length	3	year	
Construction Cost	$175,950,280	$	Class 5 estimate
% Cost (Year 1)	0.1%	%	Class 5 estimate
% Cost (Year 2)	19.5%	%	Class 5 estimate
% Cost (Year 3)	80.3%	%	Class 5 estimate
% Cost (Year 4)	0.0	%	Class 5 estimate
Variable O&M	$46.19	$/MWh	Class 5 estimate
Fixed O&M	$495,000	$/year	Class 5 estimate
Maintenance Rate	1	days/year	Equivalent of 2 half-day plant-wide planned outages
Forced Outage Rate	0.5	%	1.5 days related to grid or complete plant outages