Hyosung Corporation

ESS

for Future Energy Solution

Power Systems PU
2018

HYOSUNG

Contents

HYOSUNG
Global Top Energy Solution Provider

Ⅰ. About Hyosung

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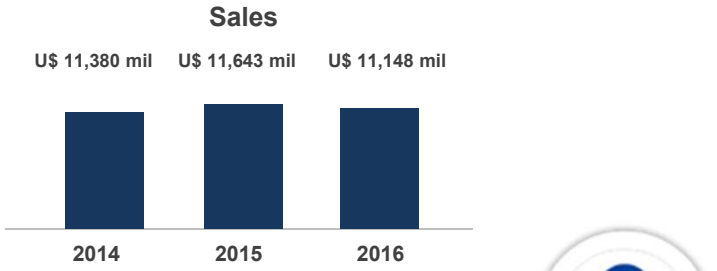
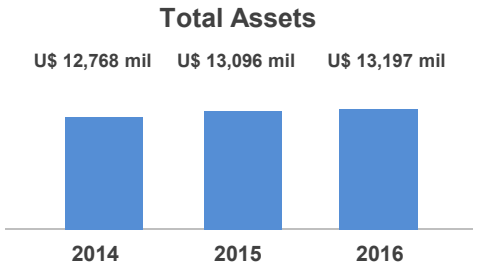
U$11B Revenue Company with 7 Performance Groups(PG*). Power and industrial systems performance group's major business area is T&D, motor and pump solutions.





* PG : Performance Group

Ⅱ. The concept of ESS

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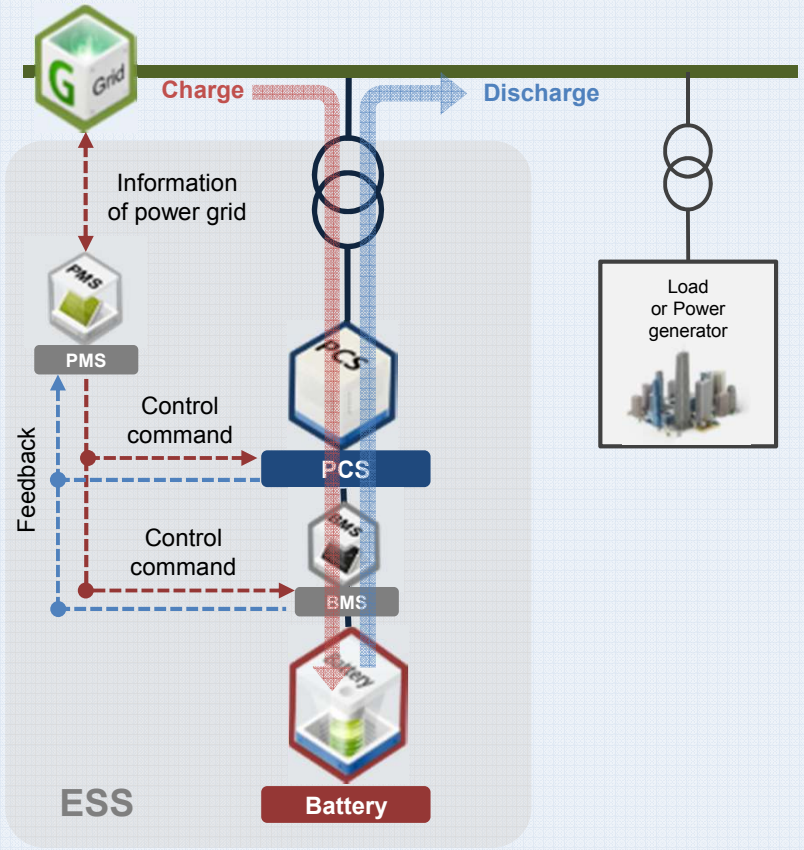
☑ BESS(Battery Energy Storage System), so-called ESS, is a system used for storing electrical energy to secondary battery for timely use.

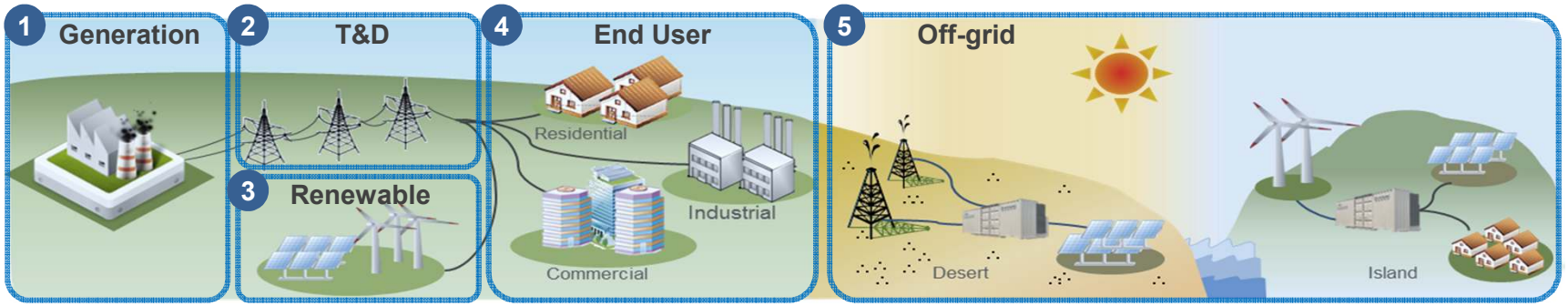
Concept



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

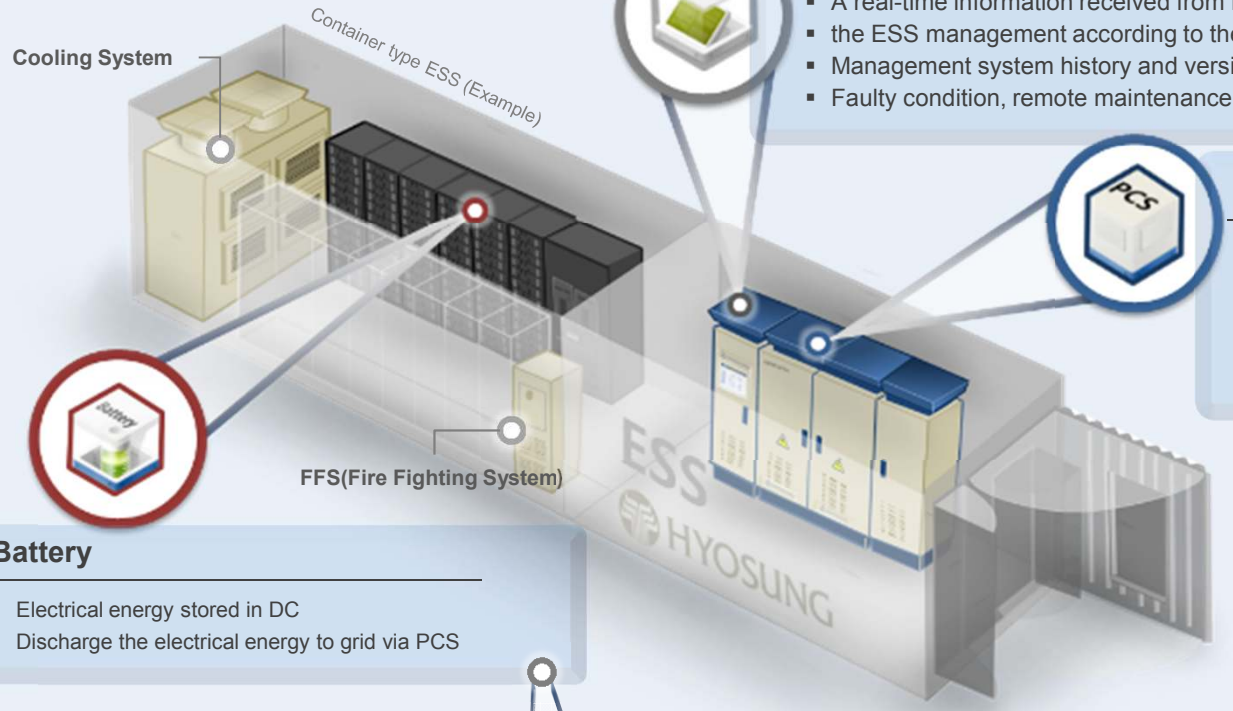
- **Supporting Effective Power usage**
  - Charge at off-peak, discharge at on-peak
  - Prevent blackout & voltage drop
  - Power usage management and UPS

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

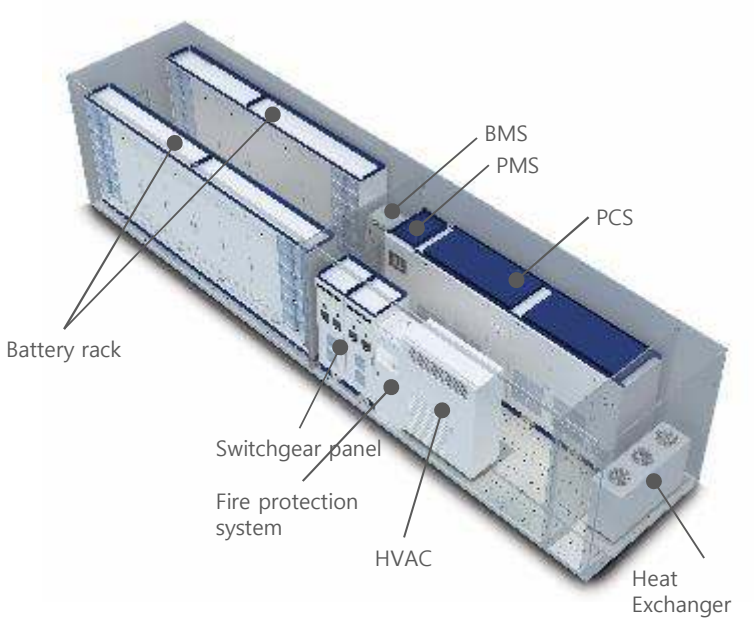
- Electrical energy stored in DC
- Discharge the electrical energy to grid via PCS

BMS(Battery Management System)

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

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

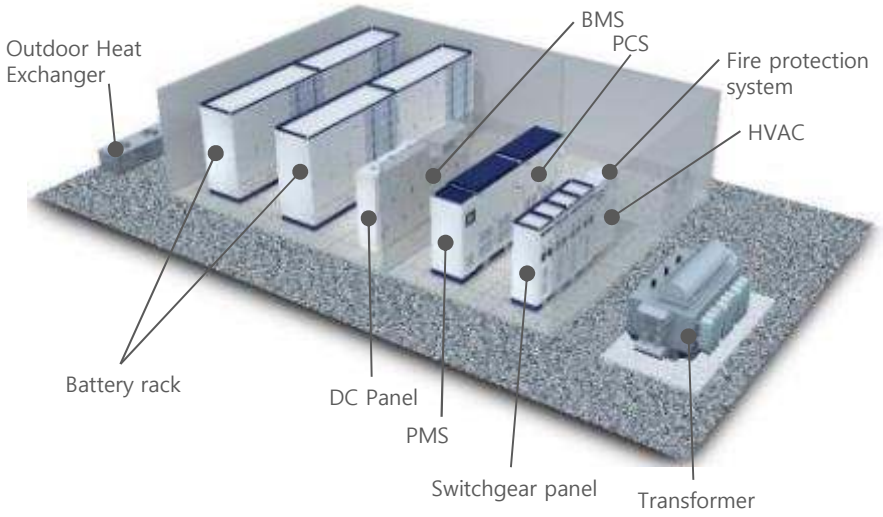
Container Type ESS



※ 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. Hyosung ESS Competitiveness

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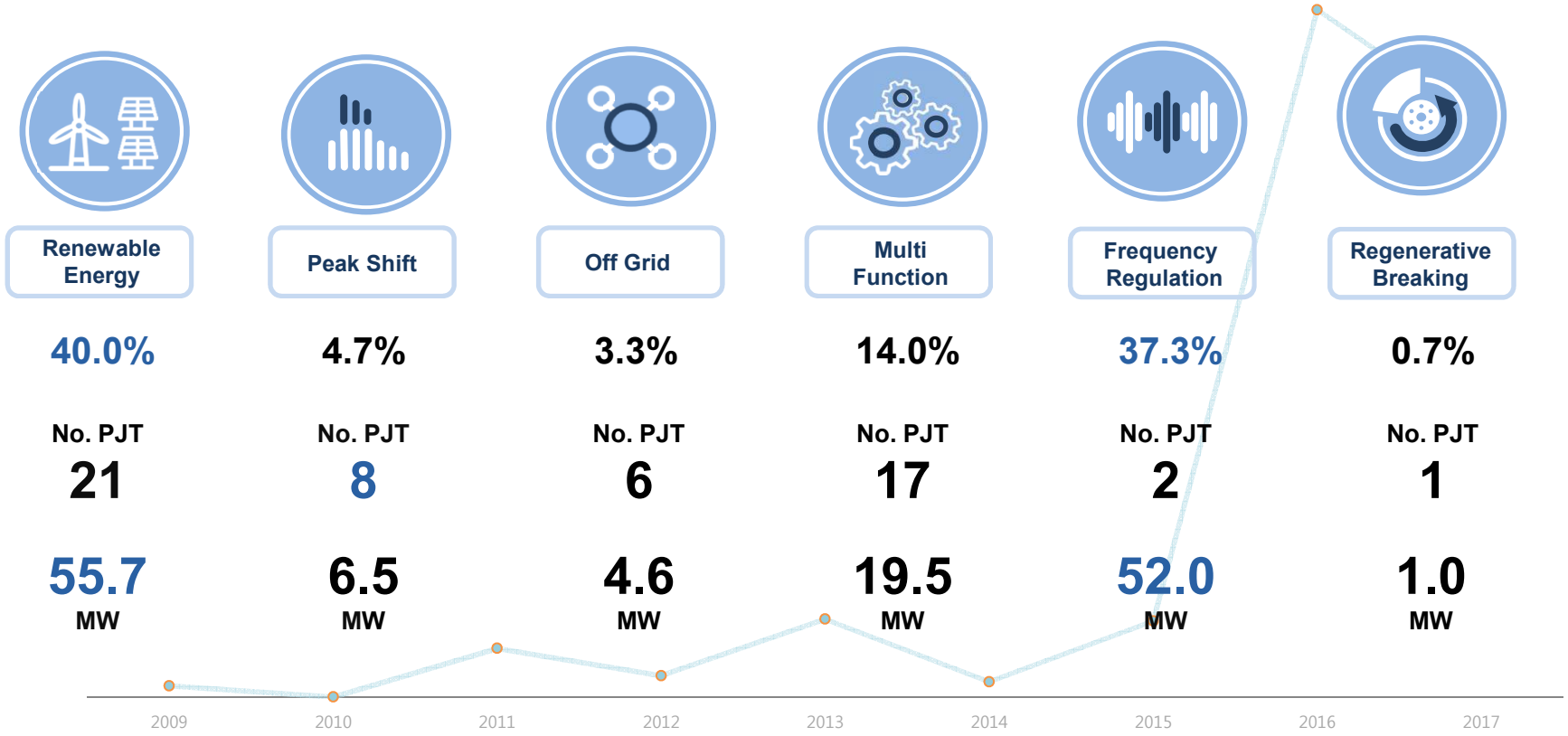
Hyosung Product Family for ESS & PV PCS

- We have various PCS product portfolio from 100kW, 125kW Modular Type to 2MW-class PCS and PMS system with built-in multi-function, and so can provide optimal proposal according to customer's needs.
- 1000kW PCS for PV is an UL-certificated product and other products are in compliance with IEC 62477.
- The configuration of PMS varies depending on the project size, and includes various functions such as renewable integration, frequency regulation, peak shaving and off-grid(microgrid).

Capacity	100/125kW	250kW	500kW	1000kW	2000kW
PV					
ESS PCS					
ESS PMS	       				

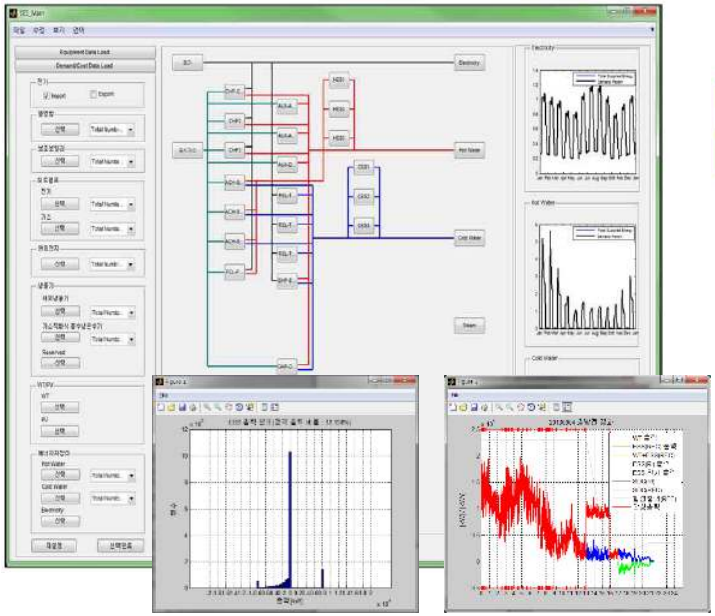
Technical Data		HS-E110G	HS-E250G	HS-E500GL	HS-E1000GL	HS-E2000GL
Input Side(DC)	Voltage Range	550~850V	550~850V	550~850V	750~1,050V	750~1,050V
	Max. Input Current	218A	500A	1,000A	1,333A	2,667A
Output Side(AC)	Rated Power	110kW	250kW	500kW	1,000kW	2,000kW
	Output Voltage	3Ø, 380V	3Ø, 380V	3Ø, 340V	3Ø, 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℃	-20~50℃	-20~50℃	-20~40℃	-20~40℃
	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						

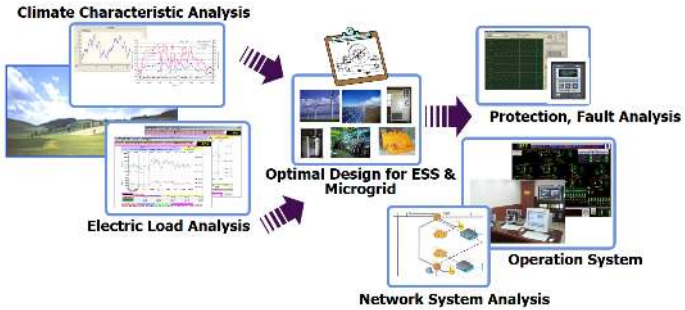
- Hyosung has experience in implementing **PCS 139MW and batteries 240MWh on about 55 sites.**
- In these projects, We operate stably with batteries from major companies such as Samsung SDI, LG Chemicals, KOKAM and SK innovation.
- Our systems cover various applications like renewable Integration, frequency 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.

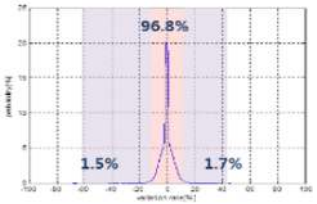


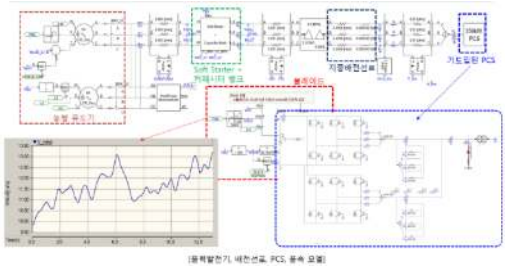
Engineering for ESS & Microgrid

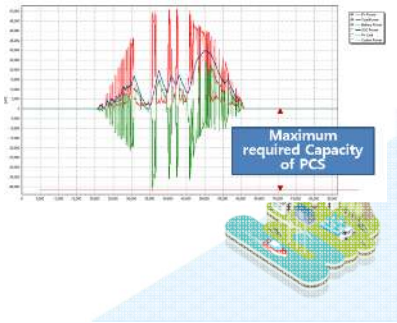
- Engineering capabilities to satisfy the diverse needs of customer
- Calculating optimal ESS capacity with load analysis and generation prediction of renewable energies
  - Optimal Design for ESS considering renewable energies
  - Design approach to “ESS” & “microgrid” considering economic feasibility
  - Power network analysis











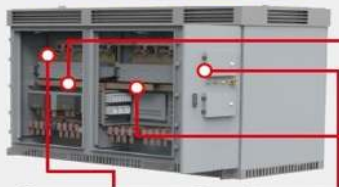
High Reliability and Availability

Implementation of Reliability-Centered Management for ensuring 20 year-performance of the ESS

- Consideration of system life and availability has been taken into account from product design

Component-based Design Quality Management

Guaranteed life: 20 years



DC CB — MTBF 27.4 yr

AC CB — MTBF 23.3

DC Capacitor — MTBF 19.4 yr

AC Capacitor — MTBF 19.4 yr

Component-based Design Quality Management

Warehousing

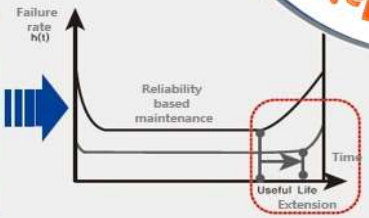
Process

QC Automation

Maintenance Quality Management

Performance Guarantee: 20 years

Parts	MTBF[yr]	Maintenance time
IGBT	70.1	5
PFan	6.5	1
Filter Capacitor	45.6	2



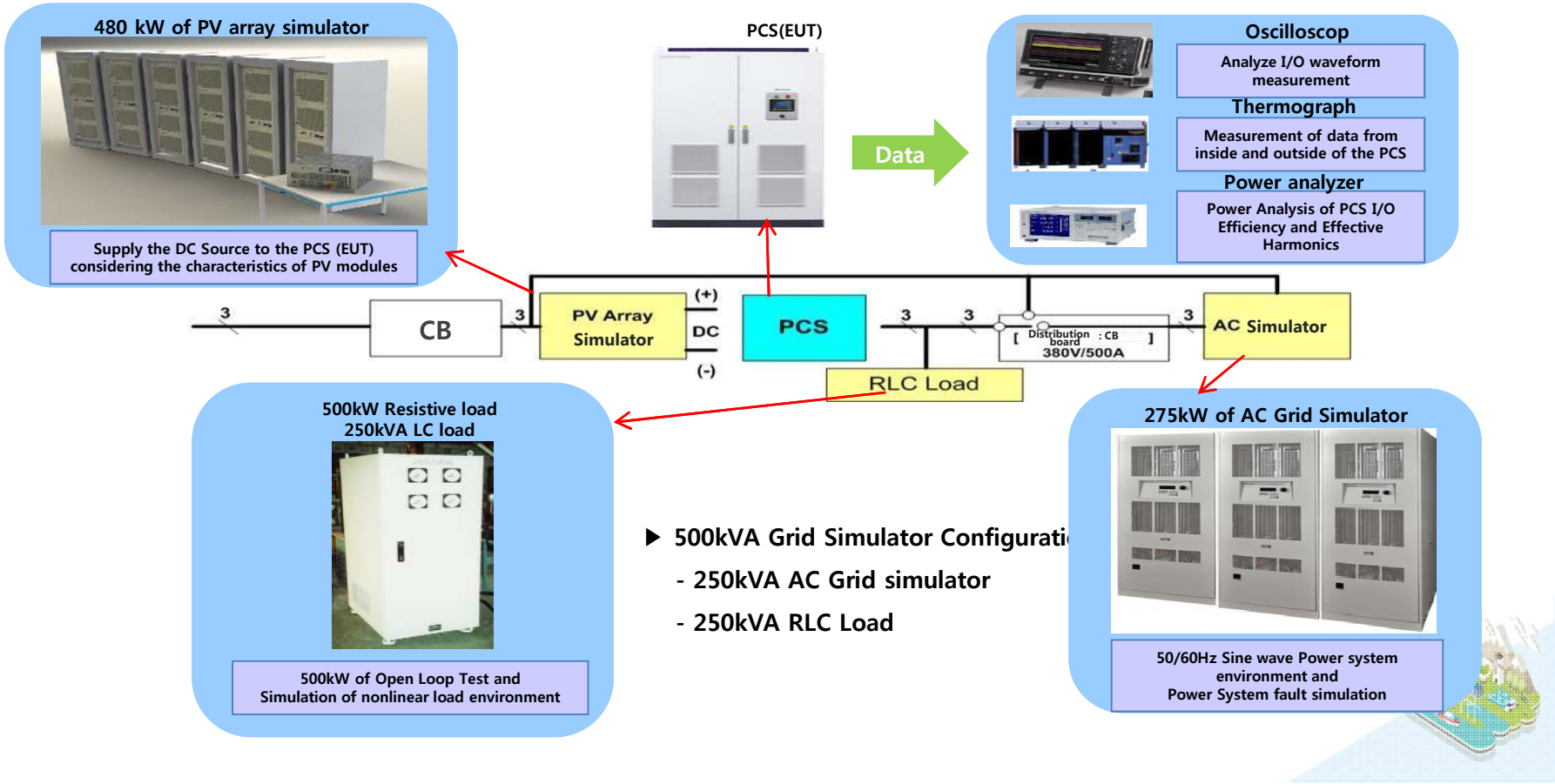
Reliability Test Center

Production & Test Facility for 100% Quality Assurance

Hyosung has own production line and test facilities to deliver RELIABLE system ON TIME.

Test Facilities for Inspection, QA and FAT of ESS system

We operate testing facilities to verify the performance and functions of PCS and ESS as well as type-testing for certification and performing FAT for customer in our own factory.



Ⅳ. Applications of ESS

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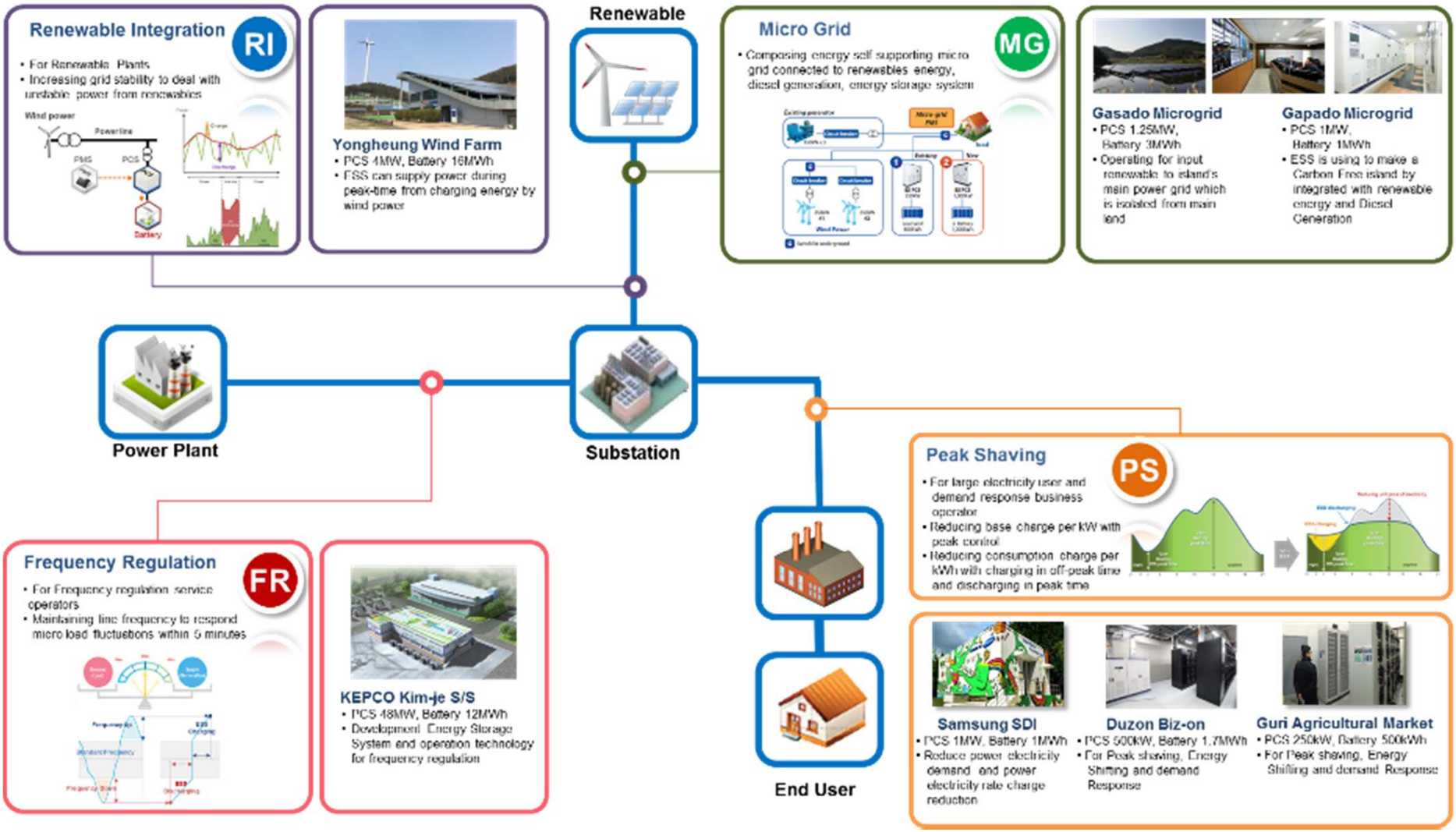
Major applications are Peak Shaving(PS), Frequency Regulation(FR), Renewable Integration(RI) and Micro-grid(MG) as shown the figure.

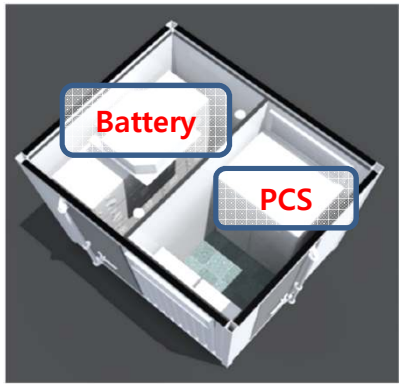


Major applications are Peak Shaving(PS), Frequency Regulation(FR), Renewable Integration(RI) and Micro-grid(MG) as shown the table.

	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)

Hyosung can provide the package energy storage(99kW/273kWh) solution with grid base to maximize installation and convenience in use for small solar power plant

Description of Products



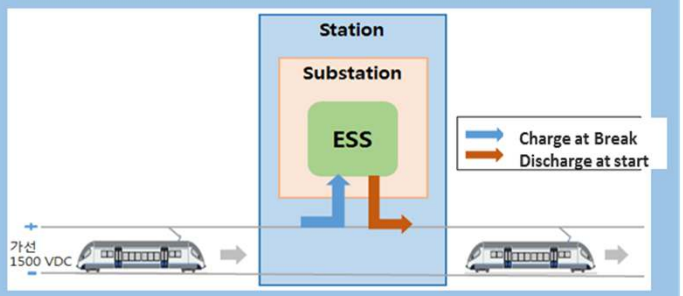
Classification	Description
PCS	99kW
Battery	273kWh
Panel board	Circuit breaker and Electricity Meter
Software	Monitoring and Automatic Charge & Discharge System
W X D X H	3,048 X 2,438 X 2,691 (mm)
Weight	6ton(Include Battery 2.2ton)

Specifications

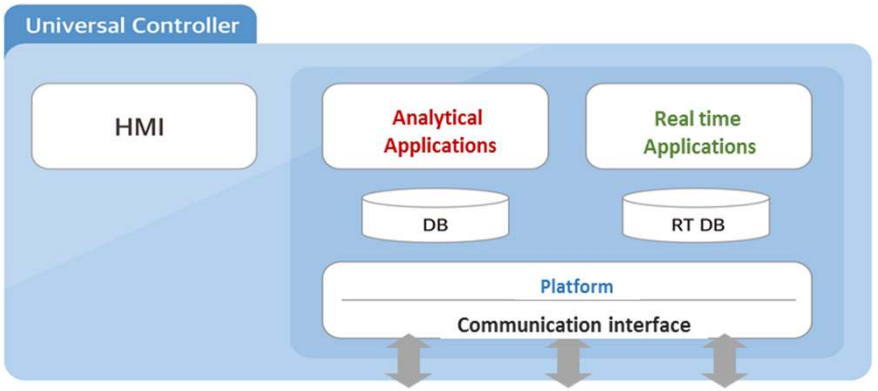
	Technical Data	
PCS	Voltage Range	550~850V DC
	Maximum Input Current	180A
	Rated output	99kW
	Output voltage	3ø, 380V AC
	Output current	150A
	Transmission frequency	50/60Hz
	THD	<5%
	Power factor	>0.99
	Max. Efficiency	>96%
	Grid Tied Transformer	○
	Cooling system	Forced Air
	Ambient temperature	-20~70℃
	Relative humidity	<95%RH
	Weight	870kg
Battery	Nominal energy	273kWh
	Nominal voltage	720V DC
	Operating voltage	630V~ 820V DC
	Operating temperature	23±5℃
	Weight	2,200 kg

Hyosung can provide the ESS for DC rail transportation and the multi-function operation solutions in the one platform for various application.

Diagram



Definition	When the train is braked, the regenerative power generated by switching the electric motor of the train to the generator is saved through ESS, When the train is restarted, the devices supply charged power to increase power efficiency and stabilize power plants.
Standard	<6cars, 1Train> - Available energy : more 14MJ, - Wire line supply voltage : 1500V, - Maximum load supply time : 20Sec.(Operation time)
Spec.	- Charging time : less 1Min. - PCS : 700kW, - Battery : 328kWh(more 2c-rate) - Controller(MMI) : Operation algorithm using voltage control
Feature	- Application of Li-ion Battery (Compared to existing Super Capacitor) - Multi-application applicable (ex voltage control and DR) - Many installation and operation experiences in various kinds of sites - Ensure the safety of reliable air-conditioning system and operation - Engineering progress through site operation analysis



Platform

- Plug and Play
- Web based Configuration tool
- Redundancy
- Data quality monitoring
- Self recovery
- Scalability through modularity
- Real time performance
- Large Data Distribution Processing

Analytical Applications

- Load prediction
- Renewable Power Forecast
- Power generated Plan
- Participation in the electricity market

Communication interface

- IEC 61850
- IEC 60870-5-101. 104
- Modbus TCP/Serial
- CAN
- DNP 3.0

Real time Applications

- Peak Shaving
  - Peak Control
  - Connection point voltage control
  - Power factor compensation
- Renewable Integration
  - Smoothing Control
  - rate of change Control
- Frequency Regulation
  - Governor Free Control
  - Automatic Gen. Control
- Off-Grid
  - Black start
  - Separated Operating
- Micro Grid
  - MG Status monitoring
  - Optimal operation in real time
  - System re-connection

Ⅴ. Experience records

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ESS projects – Experience records

	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
	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
2015	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
	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
2016	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
	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)
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.

PSRIFR 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

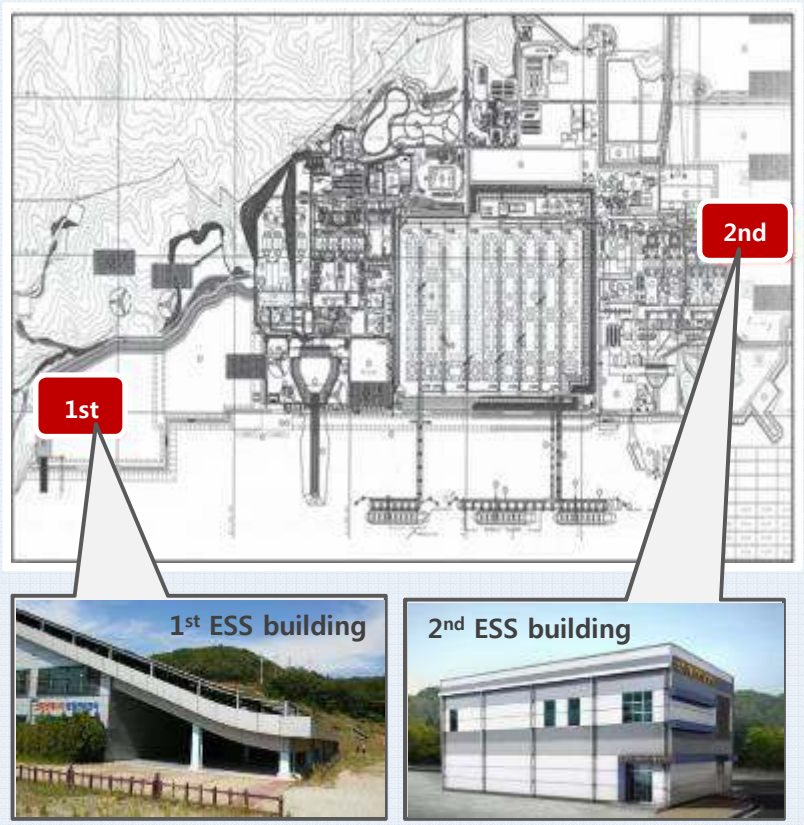
Korea Hydro and Nuclear Power(1MW/2MWh)

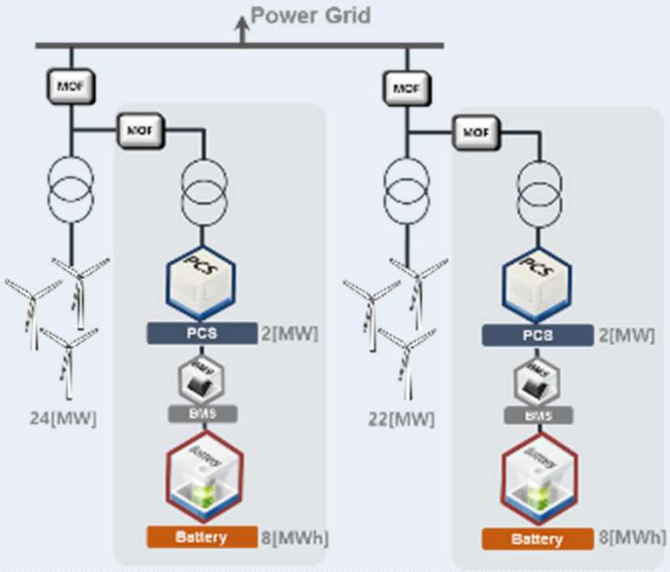
- Peak shaving and back up power supply
- Integrator : HYOSUNG
- PCS : HYOSUNG 1MW X 1Unit
- Battery : LG Chem 2MWh

☑ 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

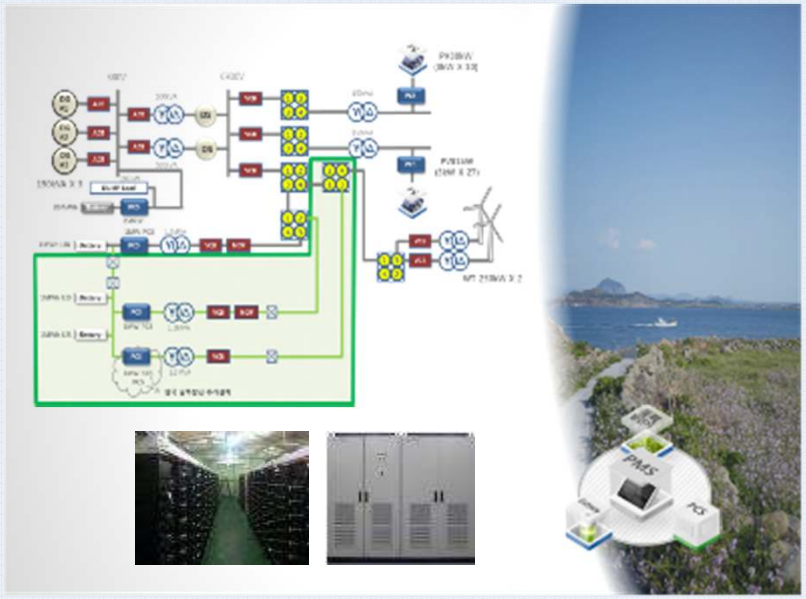
☑ Using accumulated technology and know how, Hyosung expands to development of stand alone Micro-grid.

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)

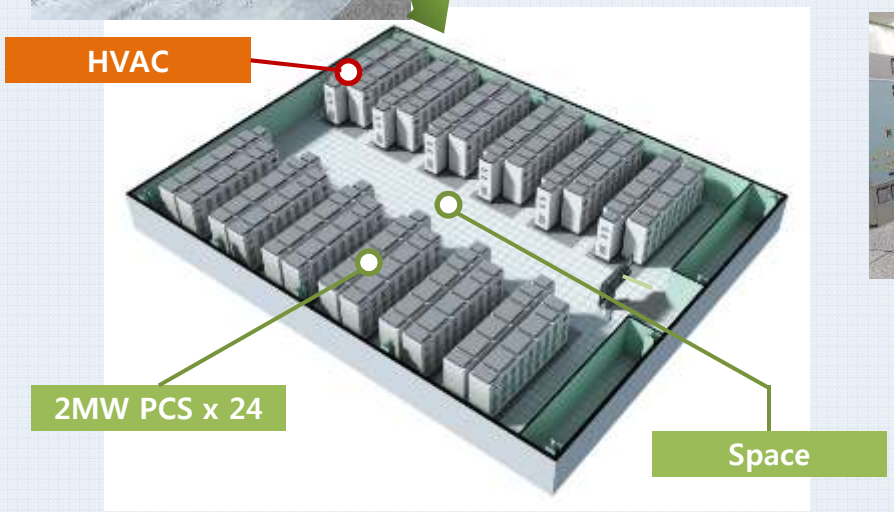


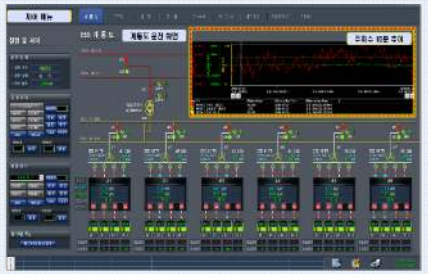
- To enlarge capacity of ESS on 1st stage ESS
- Integrator : HYOSUNG
- PCS : HYOSUNG 1MW X 1Unit, 250kW X 1Unit
- Battery : Samsung SDI 2MWh

☑ **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)



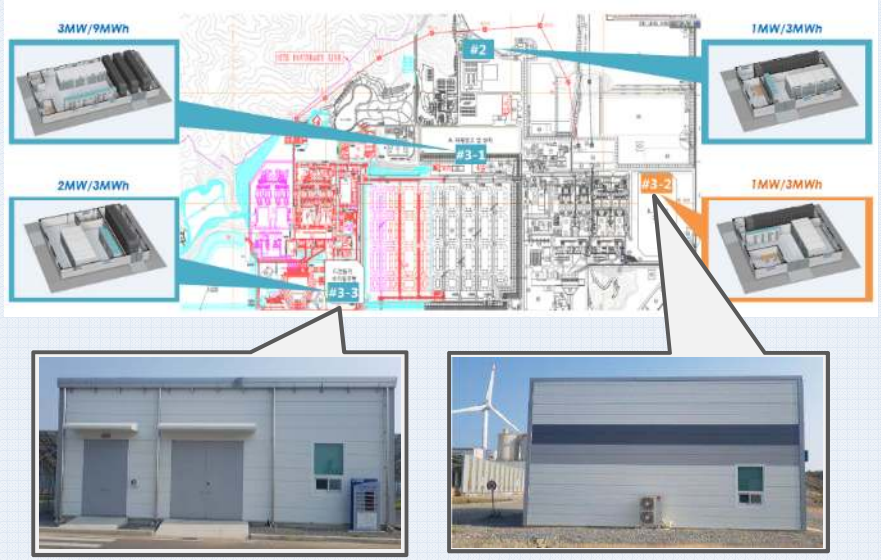


- Integrator : HYOSUNG
- PCS : HYOSUNG 48MW(2MW X 24)
- Battery : LG Chemical 12MWh

Hyosung installed 7MW/18MWh ESS system connected to a solar power plant in South East Power Co., the biggest government-owned power plant company in Korea.

RI Renewable Integration ESS – for Solar Power Farm

("South East Power" ESS , 7MW/18MWh)

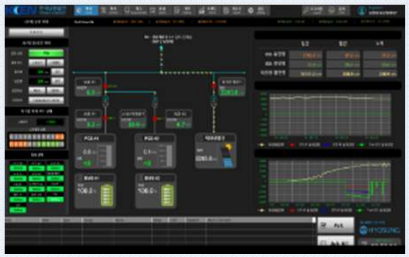



PV

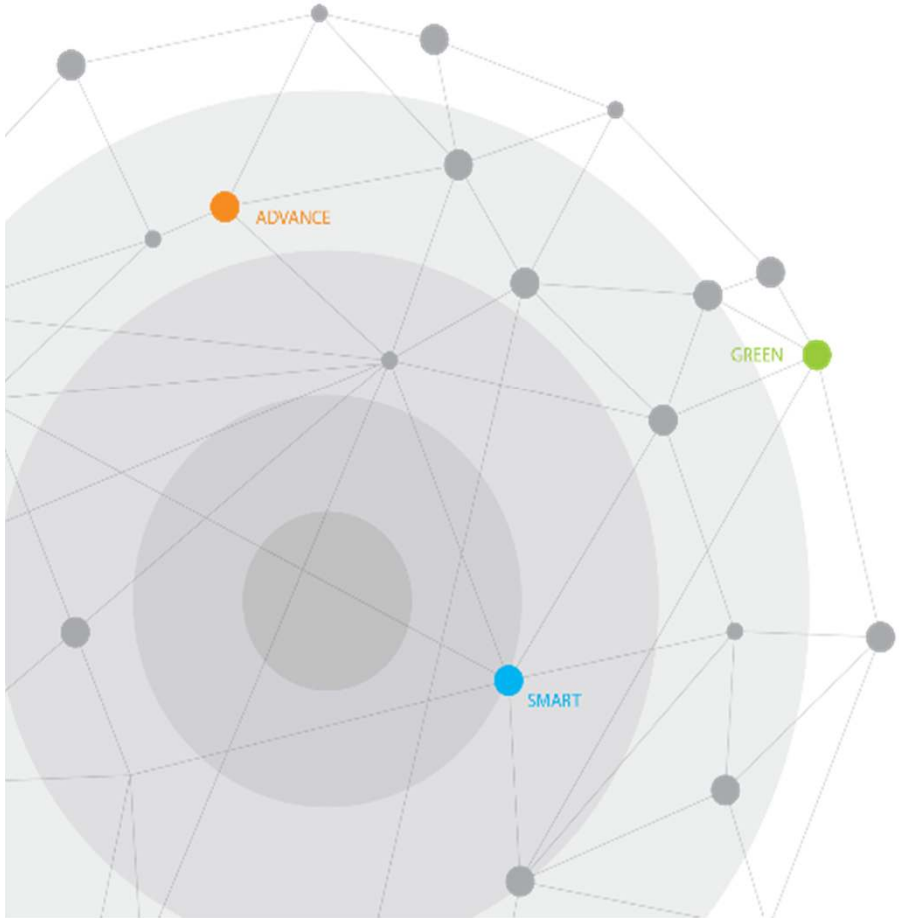

PCS & Incoming panel


PMS


Bettery


PMS HMI


PMS HMI



Thank you

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