IT'S NECESSARY, NOT AN OPTION
POWERFUL & CREATIVE CHALLENGE FOR
THE GREEN FUTURE

A consideration of off-grid Micro-grids

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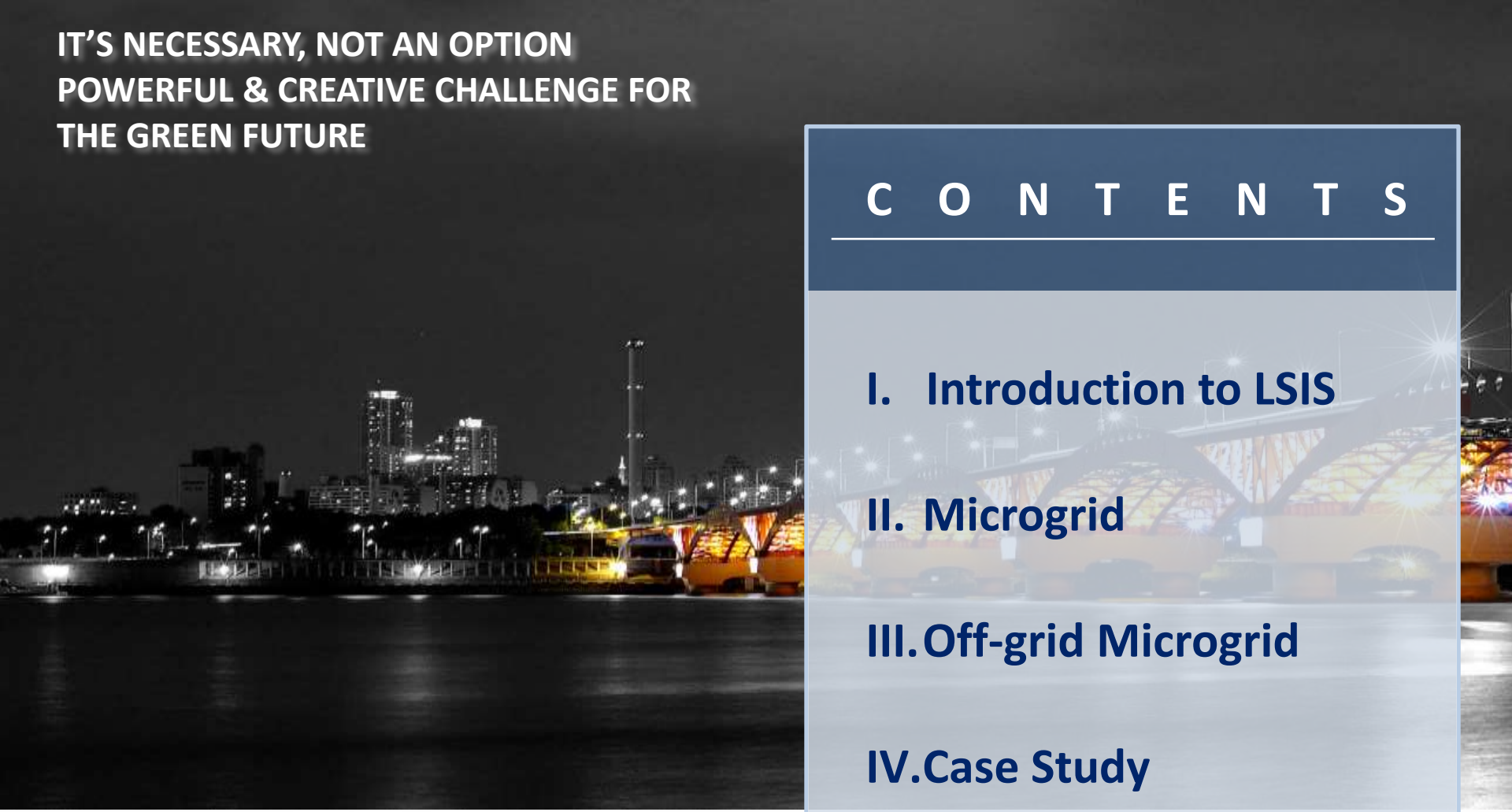
ADB

KSGA Korea Smart Grid Association

17 April 2017

LS IS



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C O N T E N T S

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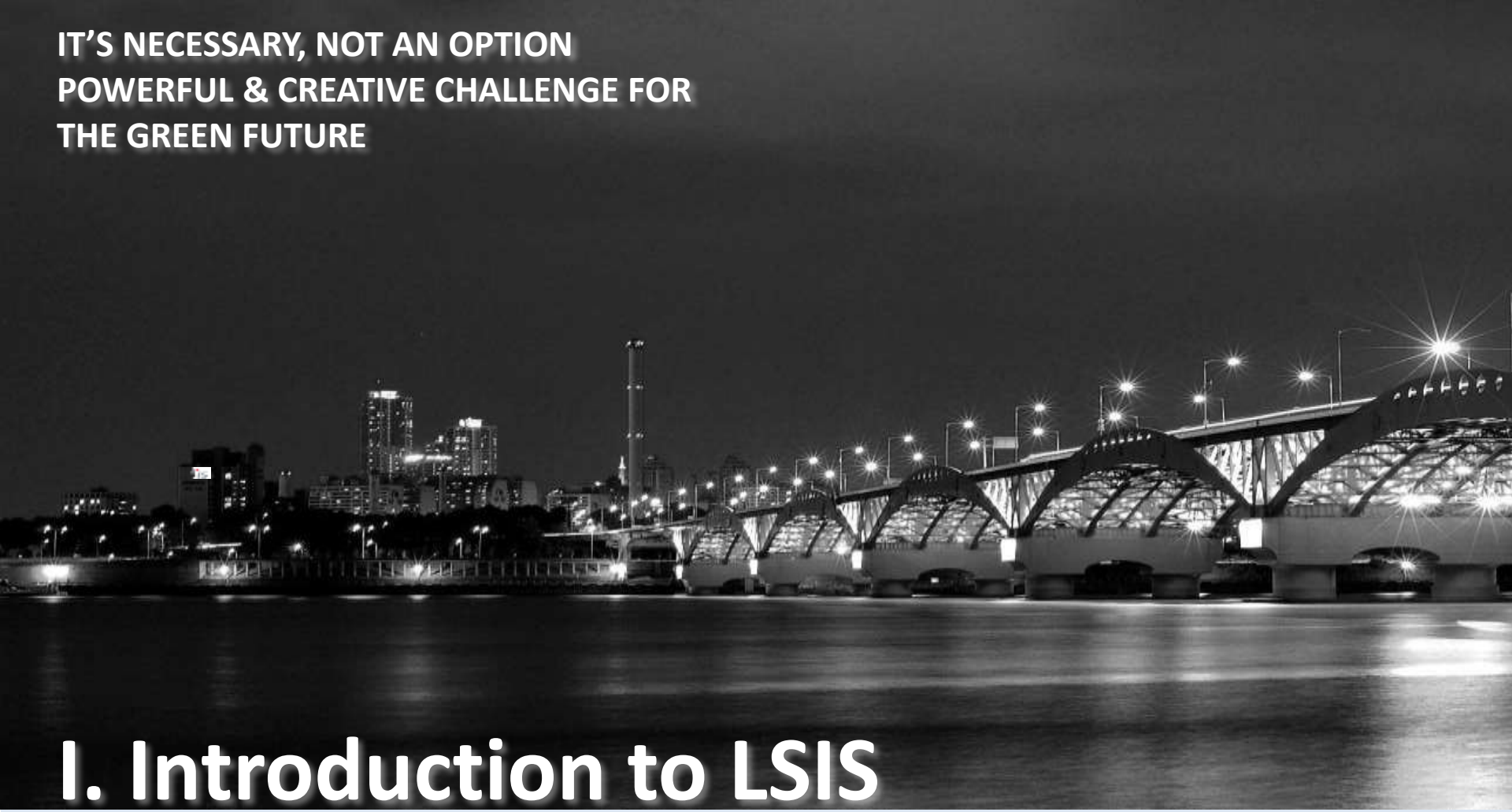
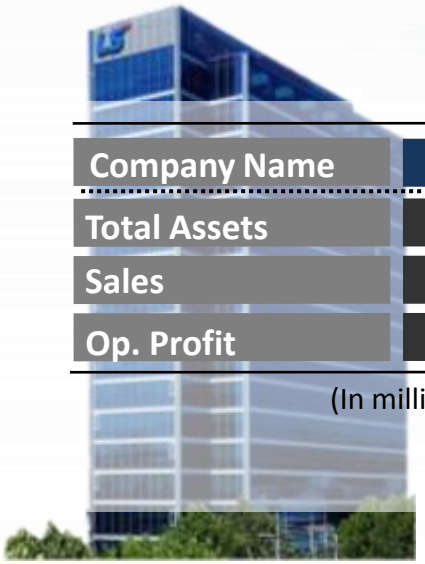


I. Introduction to LSIS

About LSIS

Leader in Power Solutions, Automation & Green Business

Company Overview



Company Name	LSIS CO., LTD
Total Assets	2,056
Sales	2,012
Op. Profit	113

(In millions of USD, As of 2016)

- **Headquarters** : LS Tower, Anyang-si, Gyeonggi-do, Korea
- **Plants** : Cheongju, Cheonan, Busan, Dalian, Wuxi, Hanoi
- **Overseas Subsidiary** : China, Vietnam, Japan, etc, 7 manufacturing / reselling subsidiaries in total
- **Overseas Branch** : USA, Europe, India, Vietnam, etc. 12 branches in total

LSIS Global Manufacturing Footprint

Main Business Areas

Electric Power Solution/ Automation Solution/Drive Solution / Transportation System SOC /Green Business (Smart Grid, PV, etc.)

Green Business | Electric Power Solutions | Automation Solutions | Drive Solutions | Transportation System SOC

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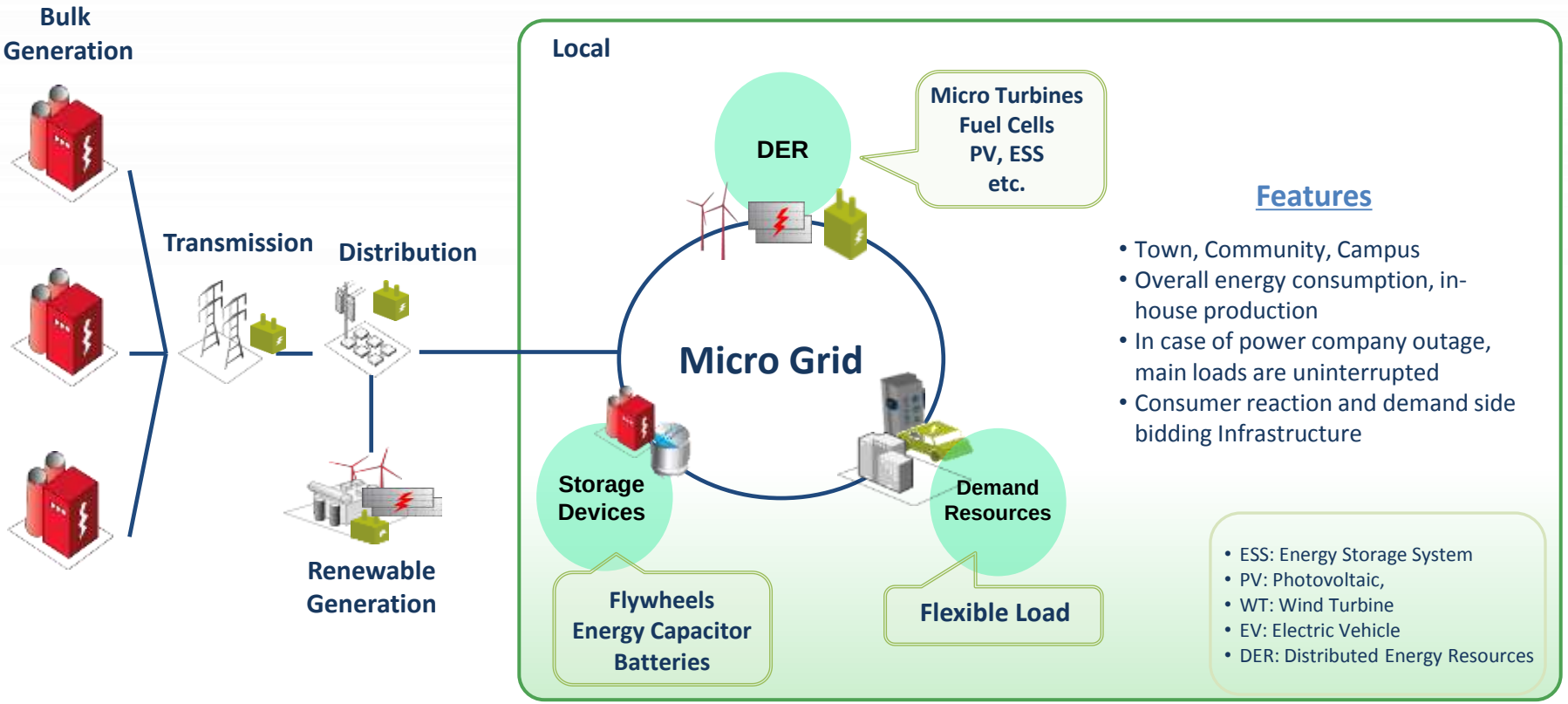
II. Microgrid(MG)

MG Definition

MG comprises LV(Low Voltage) distribution system with Distributed Energy Resources(DER) together with storage devices and flexible loads. It is an integration platform for supply-side(microgeneration), storage units and demand resources(controllable loads) located in a local distribution grid.

Smart Grid & MG

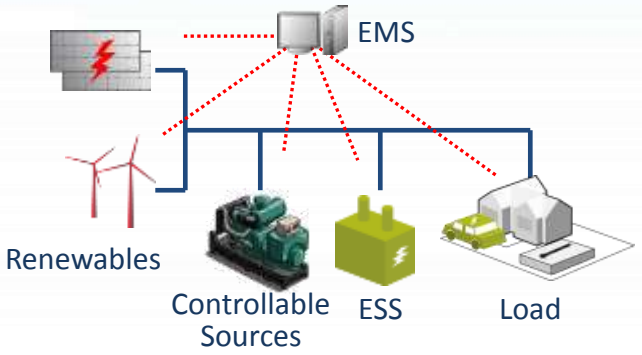


Types of MG

- **There are two types in MG, Off-Grid(Stand-Alone) and On-Grid(Grid-Connected).**
- **Off-Grid type lays focus on the reducing generation cost and stable operation, on the other hand, On-Grid type focuses on the avoiding of installation cost of power system.**

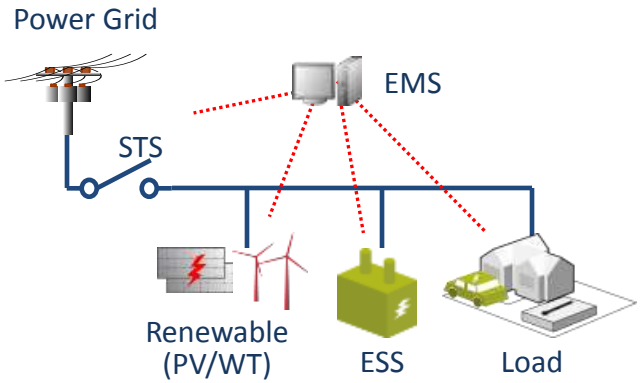
Off-Grid(Stand-Alone)

	Description
EMS Goal	Stable operation of power system(frequency control)
Site	Island or rural/mountainous area
Benefit	- Reducing generation cost - Enhancement of reliability for electricity supply



On-Grid(Grid–Tied)

	Description
EMS Goal	- Power flow control on tie line or optimization of distributed generation - Stable operation of power system in case of disconnection from main power grid
Site	Large scale customer
Benefit	- Avoiding of installation cost of power system - Increase of reliability in distribution network operation

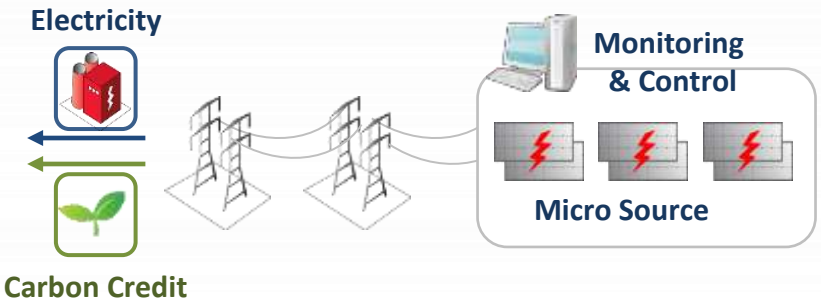


• EMS: Energy Management System • STS : Static Transfer Switch

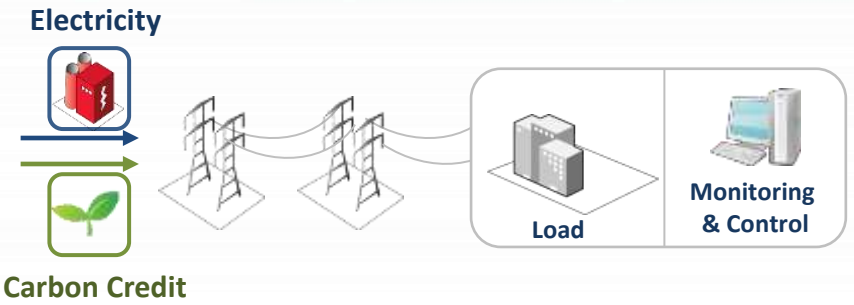
What is Not a MG?

The MG concept is further clarified by examples that highlight three essential MG features: local load, local Microsources and intelligent control. In many countries environmental protection is promoted by the provision of carbon credits by the use of renewable energy system and combined heat and power technologies.

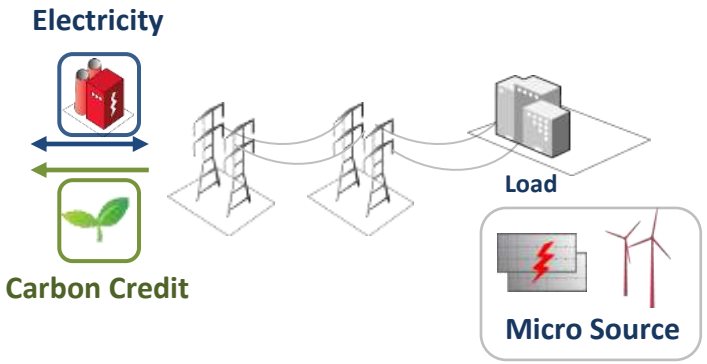
Absence of Load



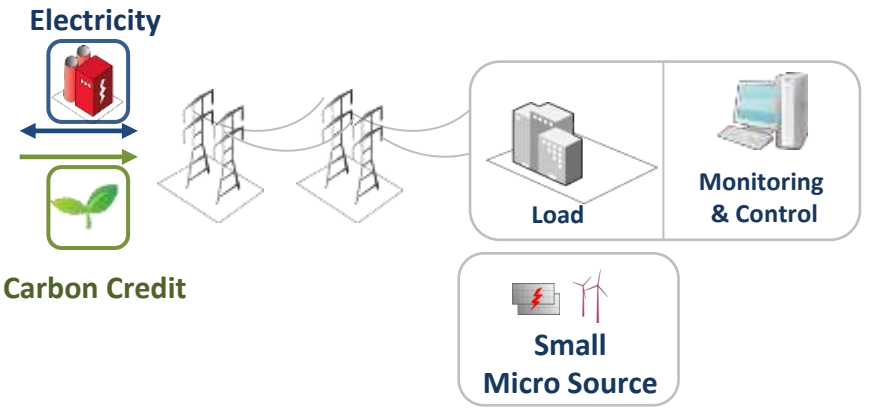
Absence of Microsources



Absence of Monitoring and Control



Insufficient Carbon Credit



Why, MG?

MG can give the various values such as power system reliability, energy efficiency, energy security and economic profits, in accordance with advanced technologies in renewables, ESS, power IT.

Cate.	Values
Economic Profit	Demand response in accordance with peak demand, i.e., peak shaving and load shifting for cost saving in customer side, peak shaving in utility side
	Avoidance of installation cost of power system from utility to local site
Power System Reliability	Enhancement of power system reliability
	Enhancement of power quality
Energy Efficiency	Reduction of the transmission losses by energy generation and consumption in local site
	Reduction of pollution using clean energy such as renewables, fuel cell and etc.
Energy Security or Islanding	Guarantee of uninterruptable power supply such as military, hospital and any other customers without interruption of power supply
	Independent power system for power supply into islands, mountainous to have constraints of connection from inland to its site

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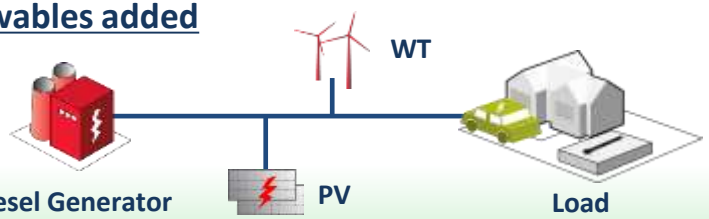
III. Off-grid Microgrid(MG)

Off-grid MG can reduce generation cost and increase reliability for electricity supply

Conventional small-sized power system (Islands or rural/mountainous area)

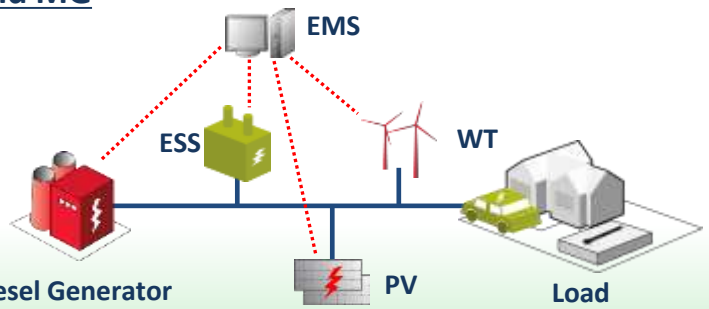
Generation costs of diesel are more expensive than those of generators in main grid

Renewables added



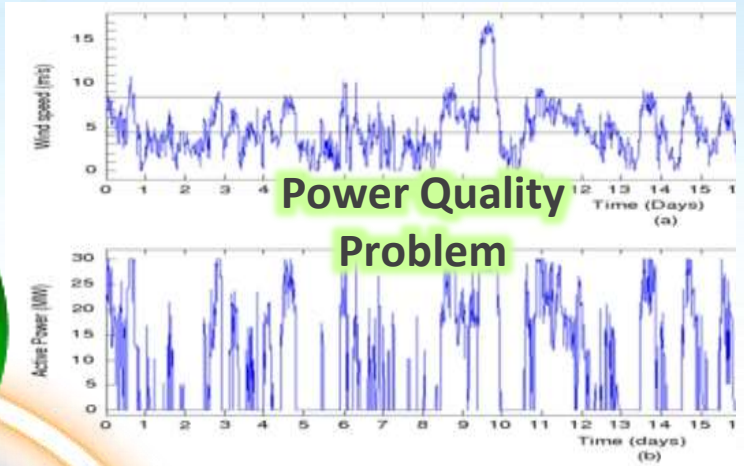
- ✓ Generation cost is reduced due to renewables
- ✓ Power quality decreases and stability problem increases caused by uncontrollable renewables

Off-grid MG



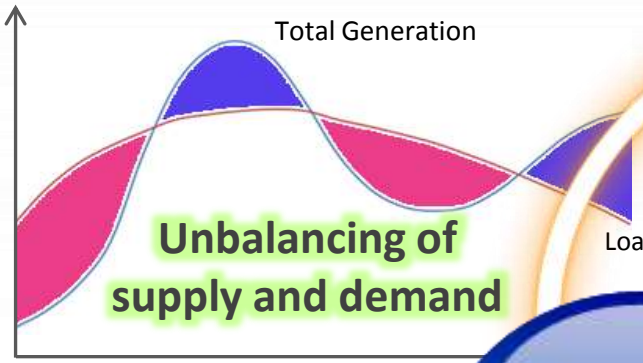
Enhancement of reliability for electricity supply by control of ESS

Characteristics of Renewables



Power Quality Problem

Fluctuation



Unbalancing of supply and demand

Uncontrollable

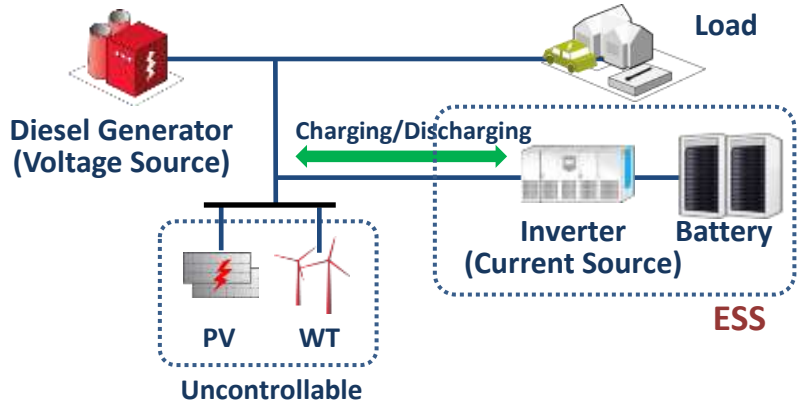
Distributed

A Number of Management

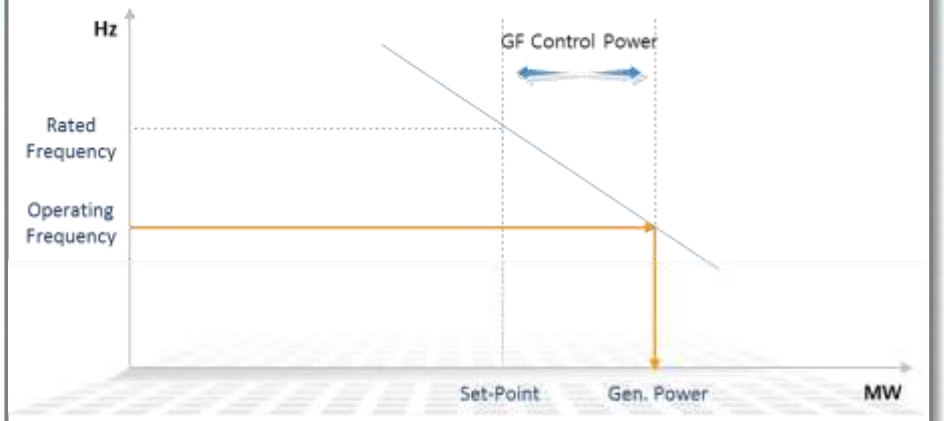
ESS with Current Source Inverter

ESS with current source inverter has three functions : frequency regulation, peak shift, and renewable integration

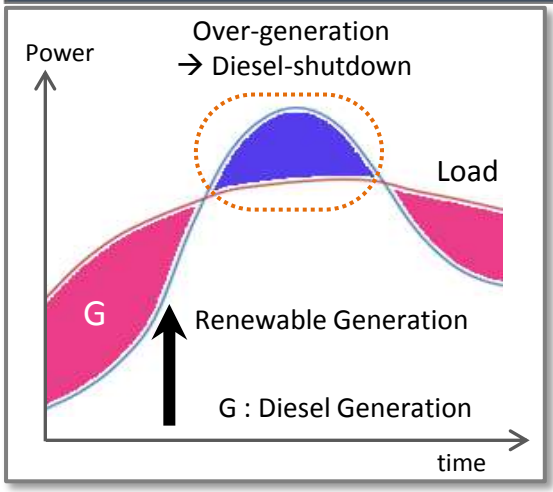
Diagram of off-grid MG

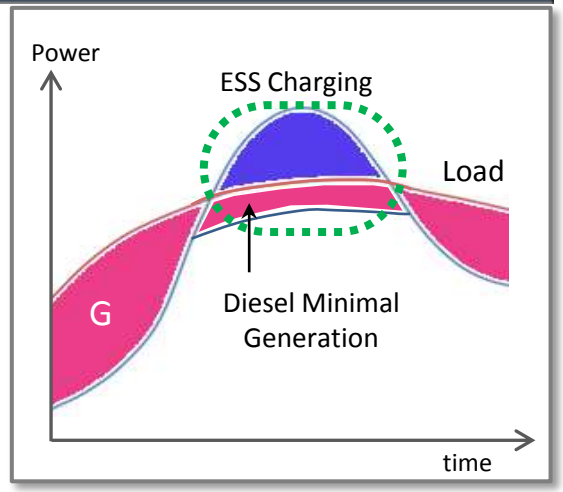


FR(Frequency Regulation) of ESS

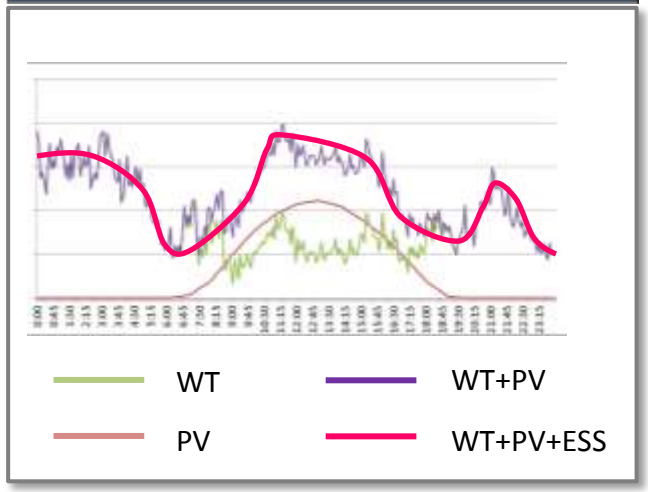


PS(Peak Shift) of ESS





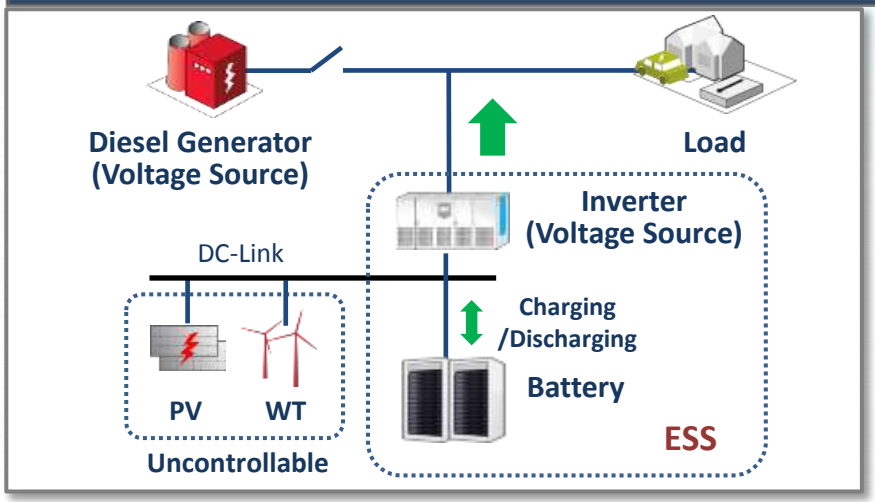
RI(Renewable Integration) of ESS

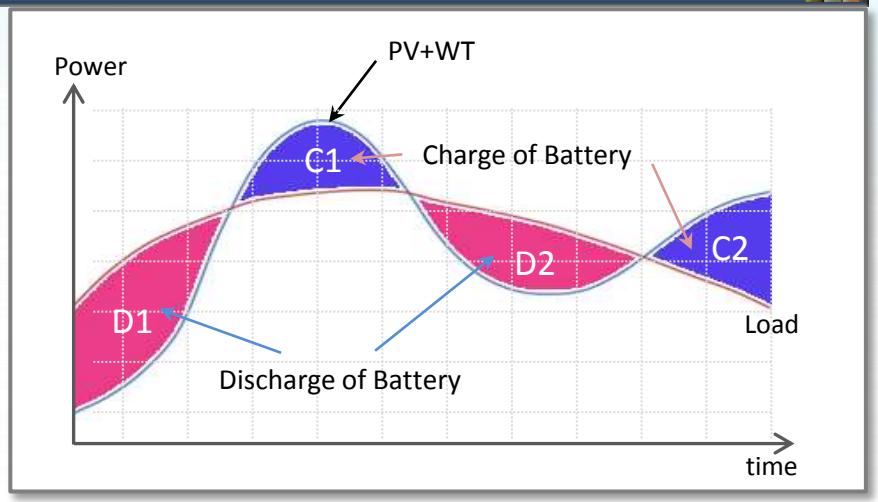


ESS with Voltage Source Inverter

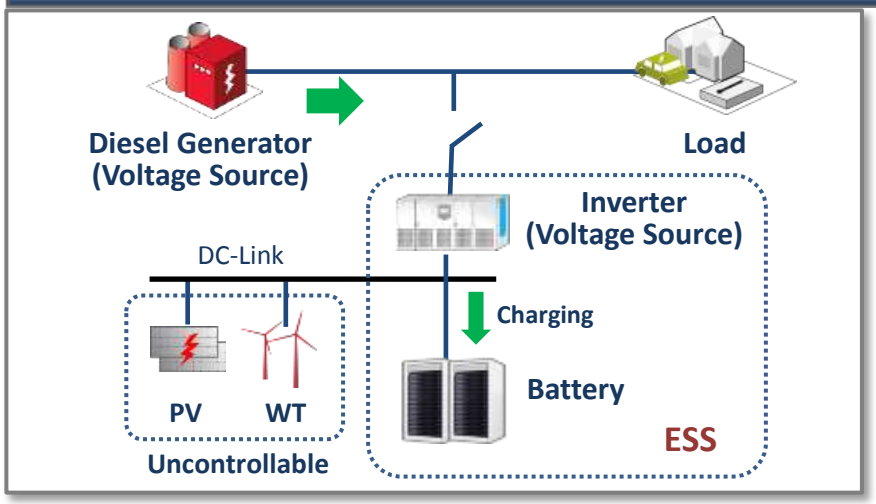
ESS with voltage source inverter supplies electric power to customer when output of renewable is larger than demand

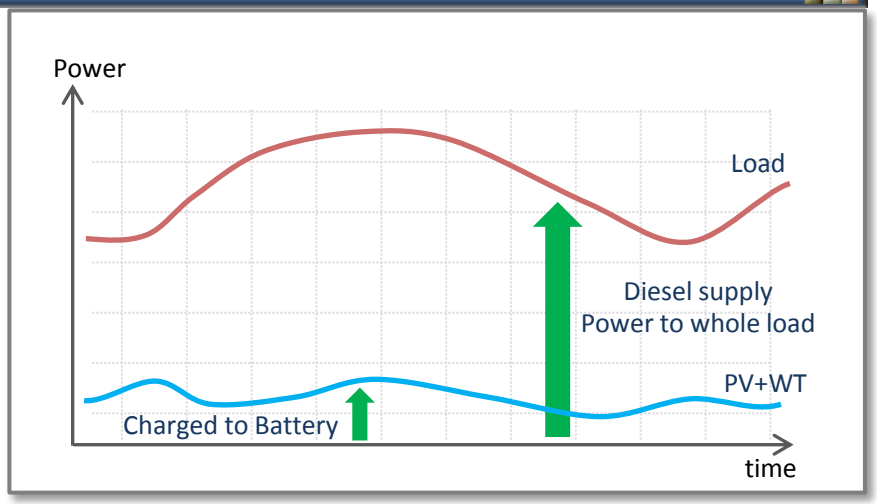
Operation of MG when renewable output is large or battery is sufficiently charged





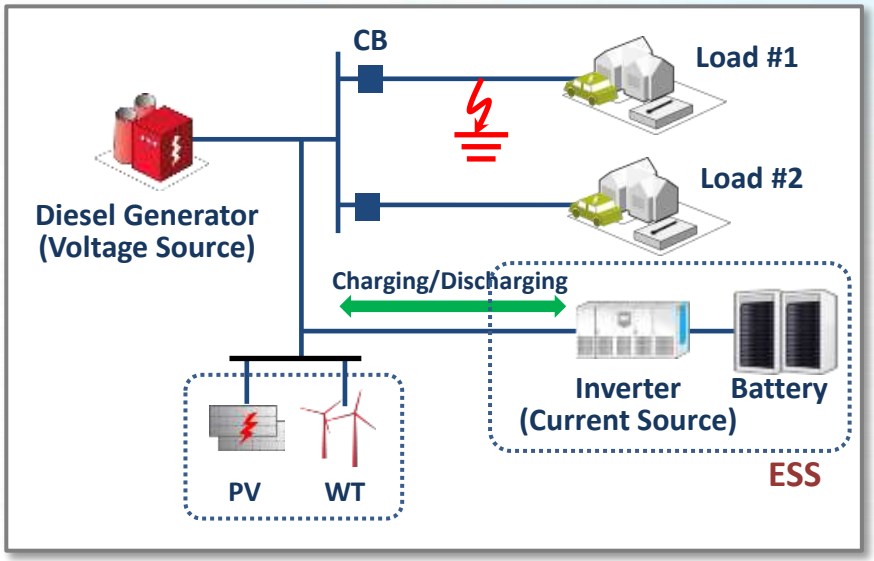
Operation of MG when renewable output is small and stored energy in battery is small





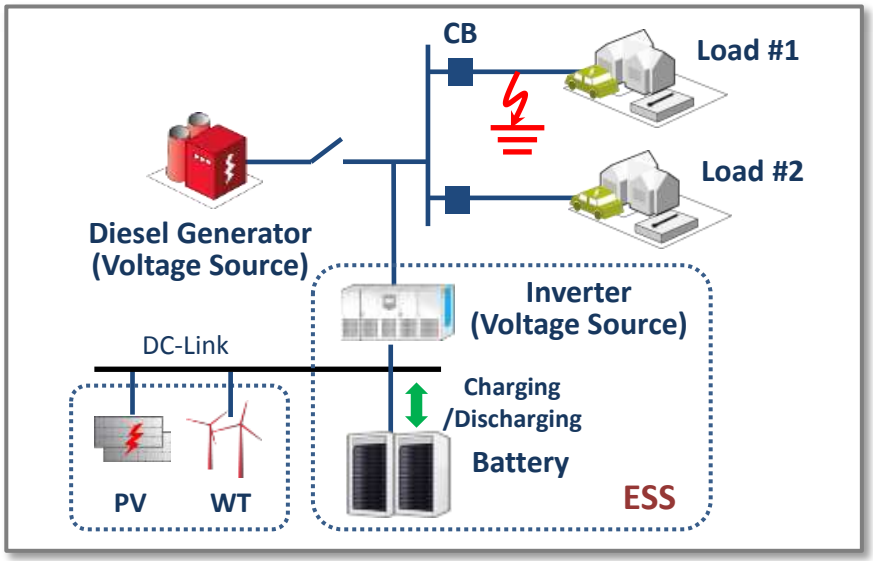
Pros and Cons – Robustness to fault

ESS with current source inverter is more robust to fault



ESS with current source inverter

① Line to ground fault (Instantaneous)
② CB(Circuit Breaker) status → 'open'
③ Outage in 'load #1'
④ Recloser is operated
⑤ CB status → 'close'
⑥ Restoration in 'load #1'



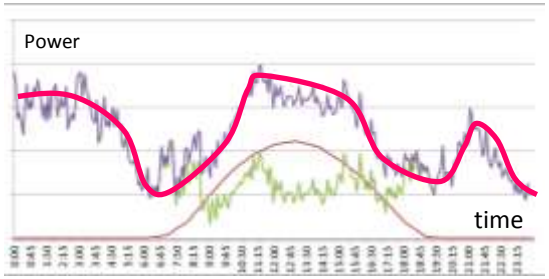
ESS with voltage source inverter

① Line to ground fault (Instantaneous)
② Inverter in ESS stop (CB not operated)
③ Outage in 'load #1' and 'load #2'
④ Restart of inverter in ESS
⑤ Restoration in 'load #1' and 'load #2'

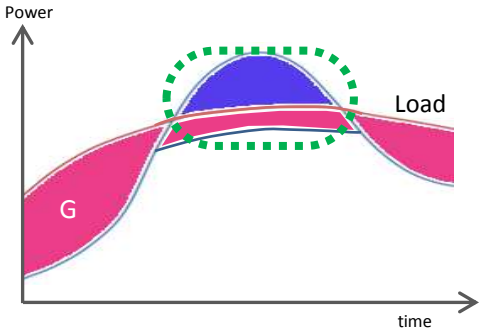
ESS with current source inverter has three functions(FR, PS, RI)

Functions of ESS with current source inverter

Frequency Regulation

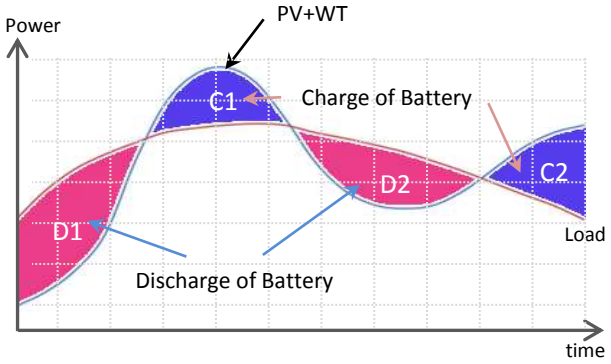


Renewable Integration



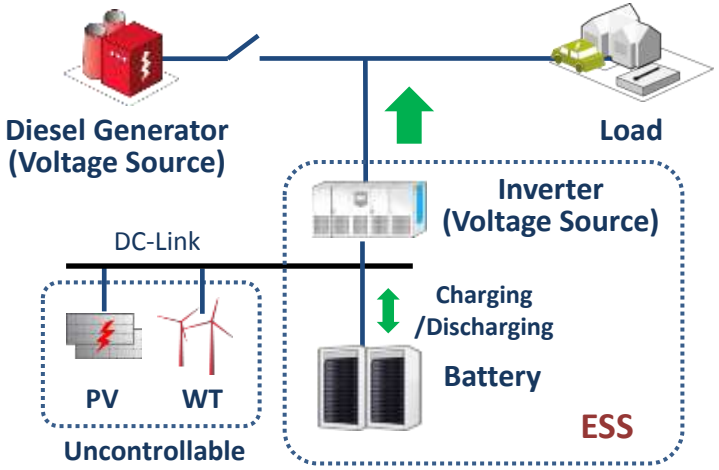
Peak Shift

A Function of ESS with voltage source inverter



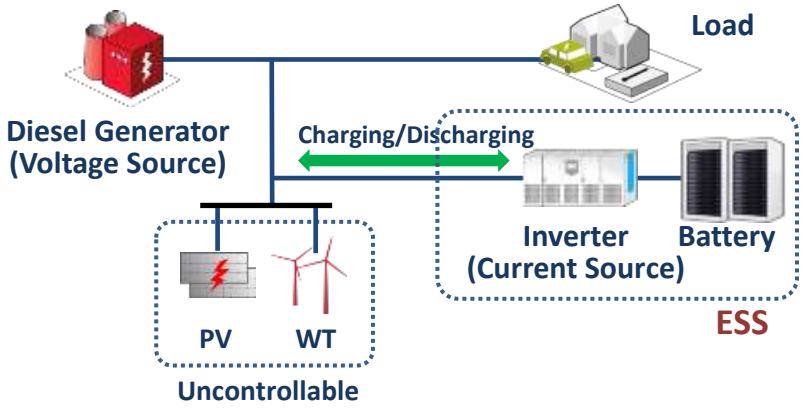
Pros and Cons – Capacity of inverter

ESS with voltage source inverter



- Inverter supplies electricity energy to whole load
- Capacity of inverter should be larger than peak load
- Reliability of inverter is lower than diesel generator → Redundancy of inverter needed
- ESS with voltage source inverter is suitable for small-sized off-grid MG

ESS with current source inverter



- Diesel generator, renewables and inverter supplies electricity energy to whole load
- Capacity of inverter could be smaller than peak load
- ESS with current source inverter is suitable for medium-sized off-grid MG

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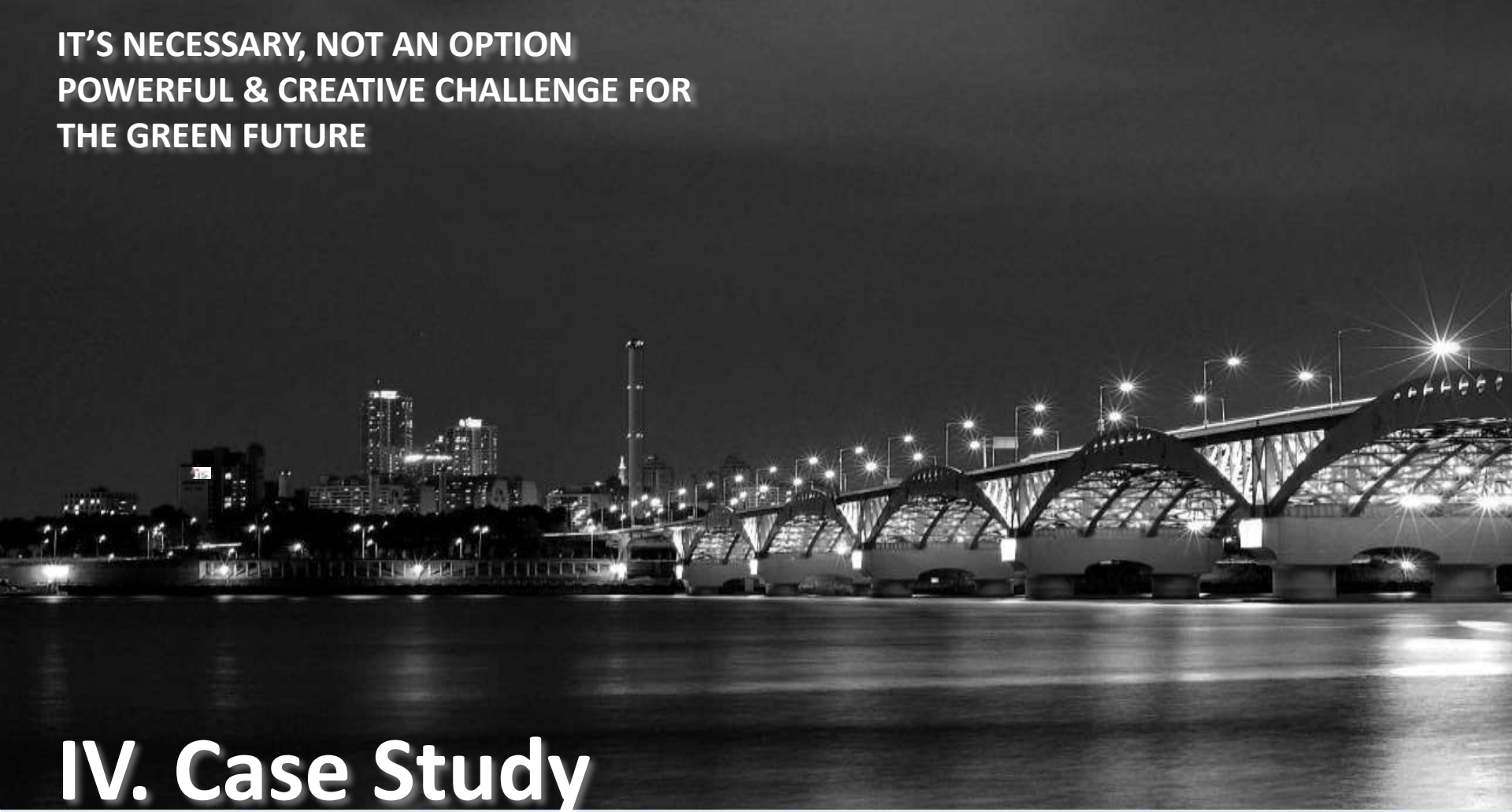
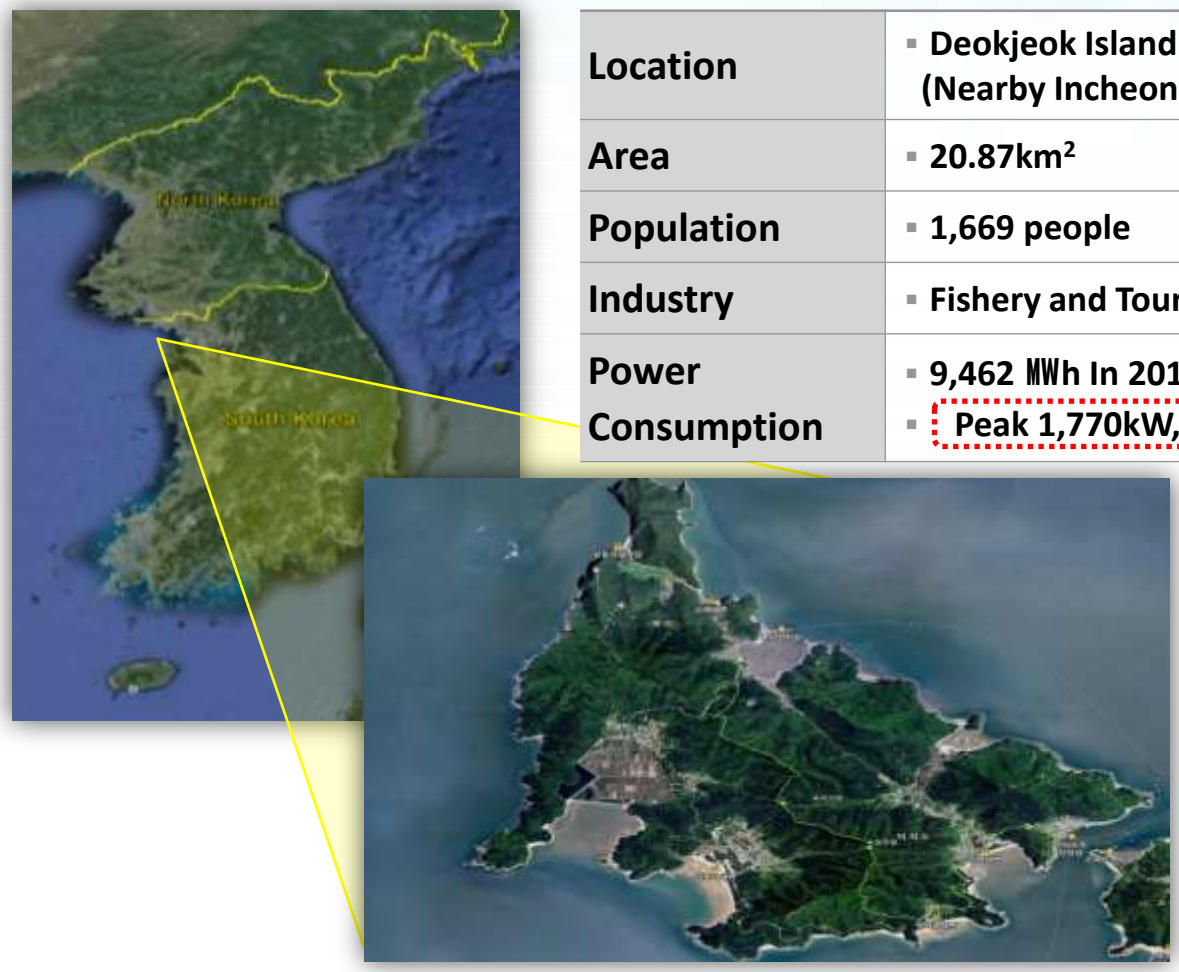


IV. Case Study

Low-Carbon Island in Korea – 1/2

LSIS performed the analysis considering MG in Deokjeok island. Its power system has been operated by KEPCO since 1989.

General Information



Location	▪ **Deokjeok Island (Nearby Incheon International Airport)**
Area	▪ **20.87km²**
Population	▪ **1,669 people**
Industry	▪ **Fishery and Tourism**
Power Consumption	▪ **9,462 MWh In 2014** ▪ **Peak 1,770kW, Average 1,080kW**

ESS with voltage source inverter
→ **Inverter : 2MW X 2 set**
ESS with current source inverter is suitable for this sites

Power System

Voltage level	6.6kV 3Phase 3Wire
Total Power	2,900kW
Generator	Diesel 300kW x 3EA Diesel 500kW x 4EA

Low-Carbon Island in Korea – 2/2

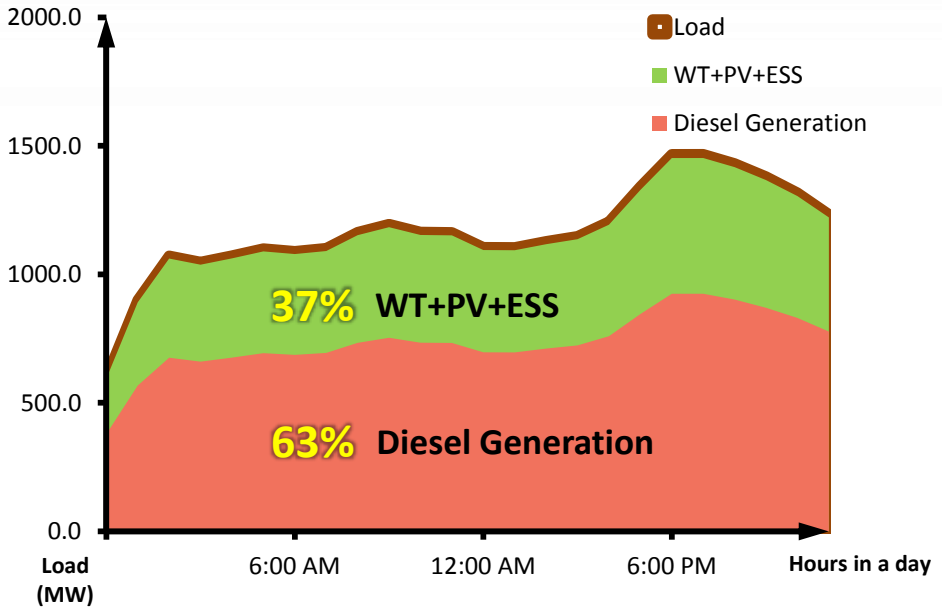
MG in the island will be operated by applying renewable energy sources such as PV, Wind Turbine and ESS technology. Rate of diesel power is at a level of 63% of the total electricity generation, and remaining demand is also driving with a combined generation of renewable energy and ESS.

MG Architecture

- **Renewables : PV 0.5MW, WT 1.5MW**
- **ESS with current source inverter is applied**
- **Diesel Generators, renewables and ESS produce electricity energy**
- **ESS capacity : 2MW/6MWh(Inverter/Battery)**

Control

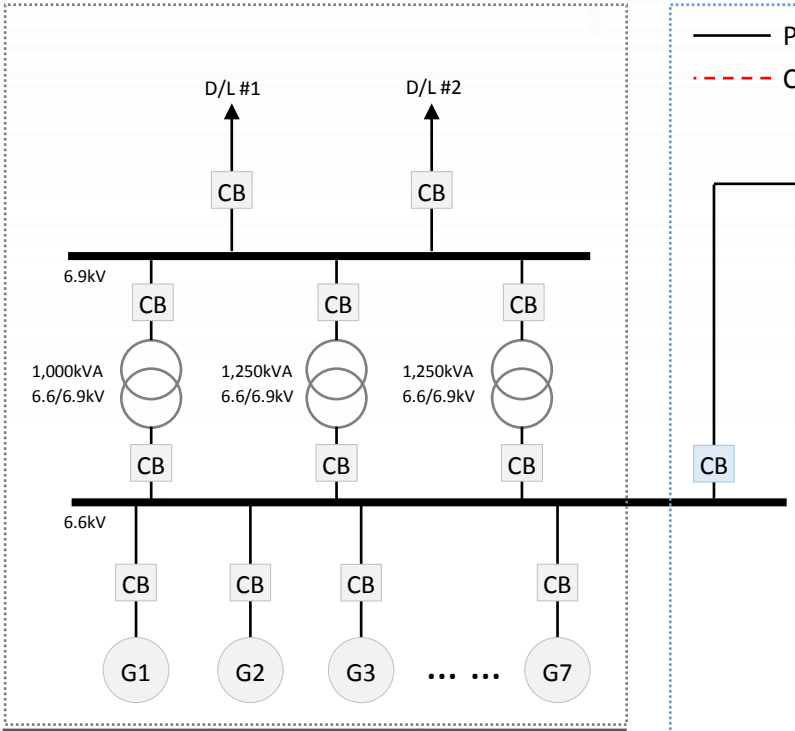
- **The amount of DG energy: 63%**
- **The amount of Renewable energy + ESS: 37%**
- **Diesel reduction: 933,494 [L] / year**
- **CO_2 reduction: 2,408 [tCO_2] / year**



Design of Off-grid MG

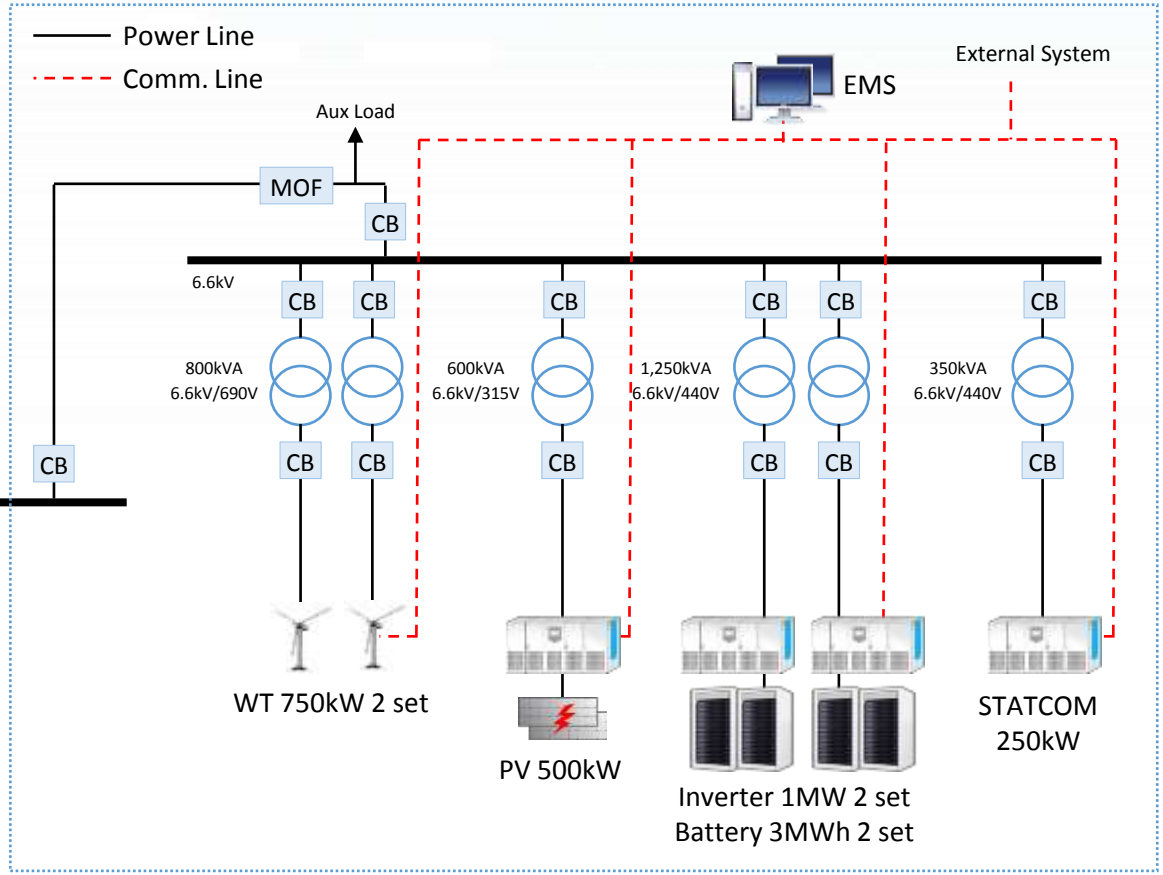
Renewables and ESS are connected to existing generation bus. The capacities of inverters and batteries are calculated by simulation of renewables and ESS functions(FR/PS/RI).

Existing Diesel Generation



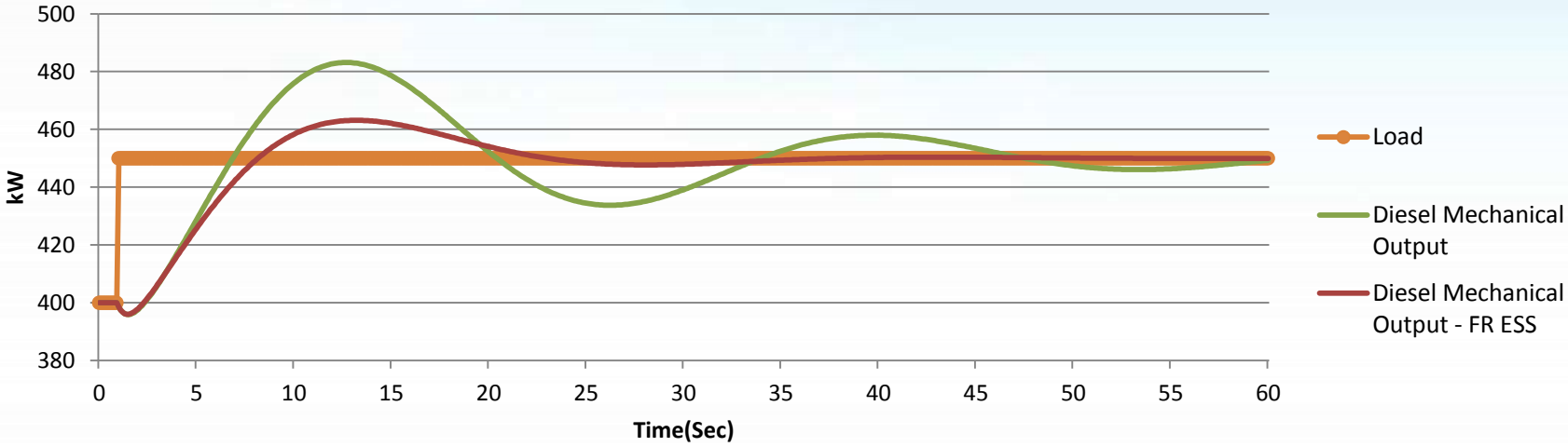
Diesel	G1/2/3	G4/5/6/7
Capacity(kW)	300	500

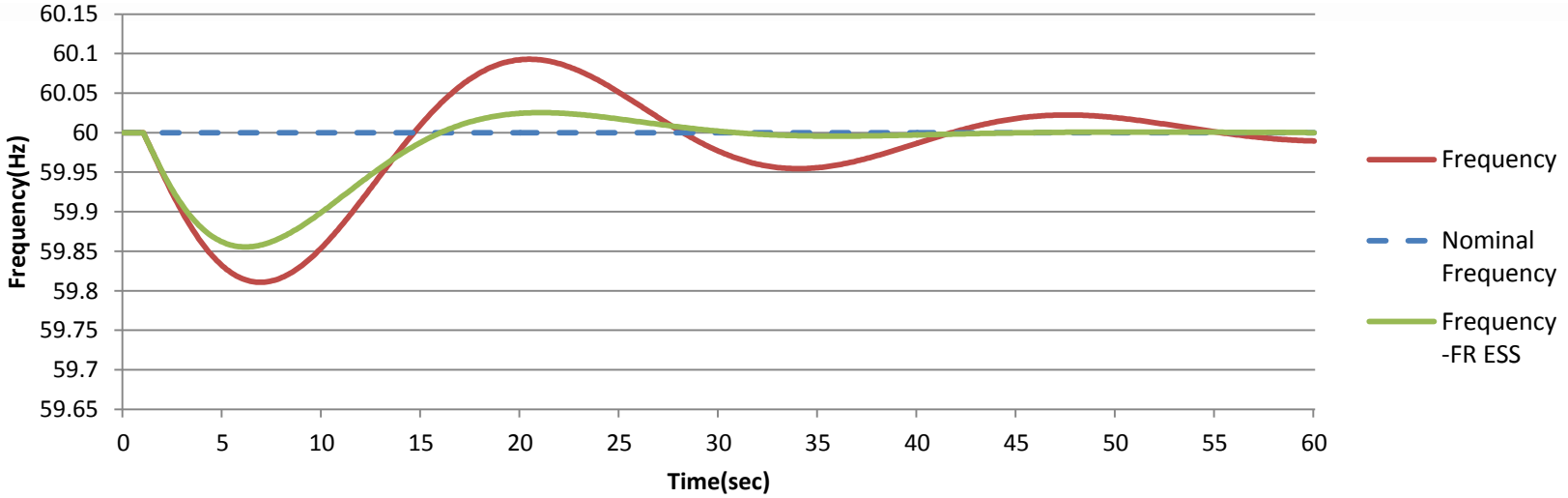
Renewables / ESS / EMS



Simulation Results – Frequency Regulation

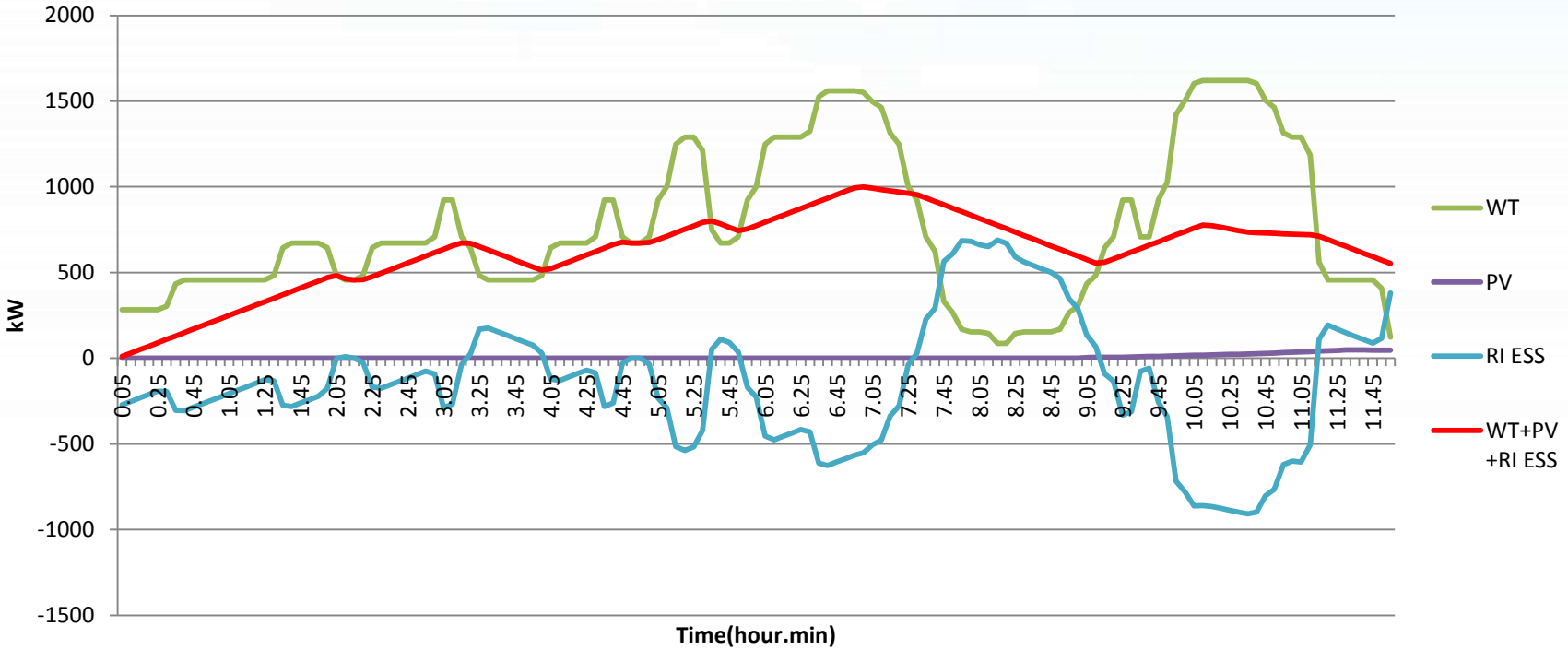
The performance of frequency regulation is improved when ESS for FR is installed in MG





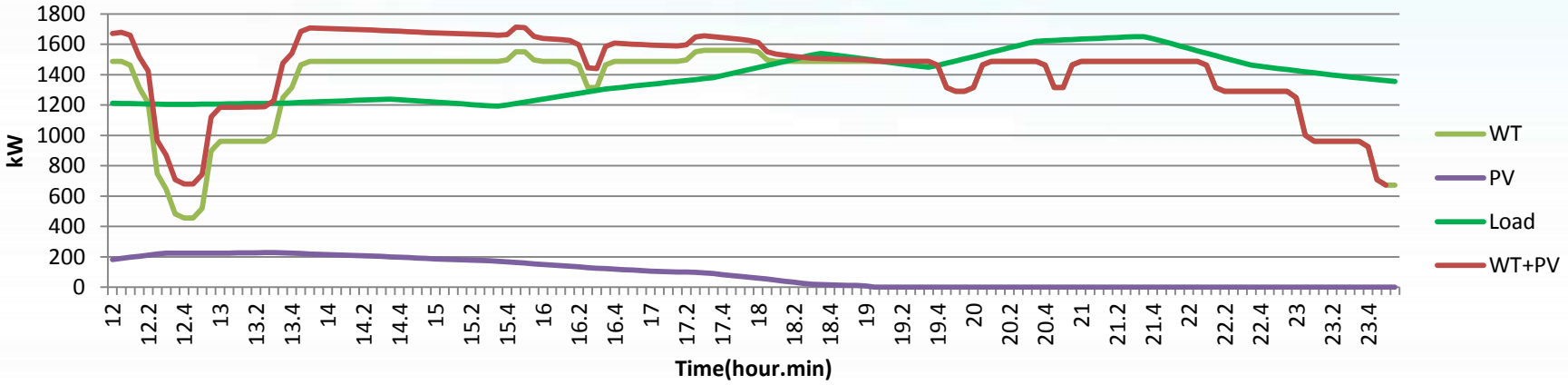
Simulation Results – Renewable Integration

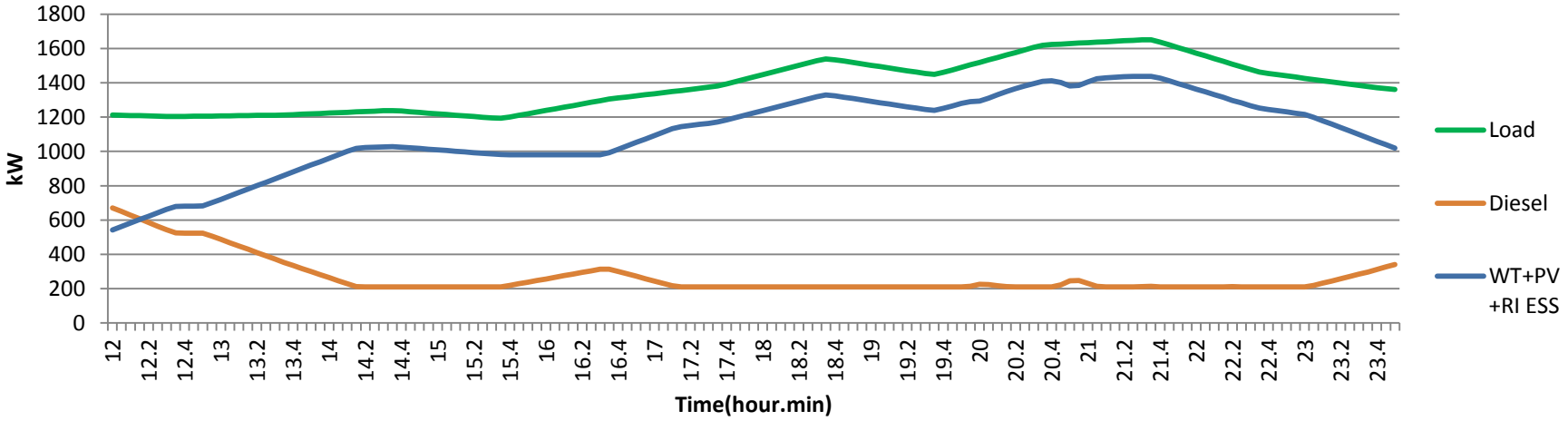
Fluctuation of renewable outputs decrease with ESS for RI to improve power quality



Simulation Results – Peak Shift

ESS for PS prevent diesel generation shut-down by energy absorption when output of renewable is higher than load





Thank you

For more information… please contact

e-mail : jhleea@lsis.com