

Operation of ESS Interconnected to the Distribution Feeder by Distribution Management System

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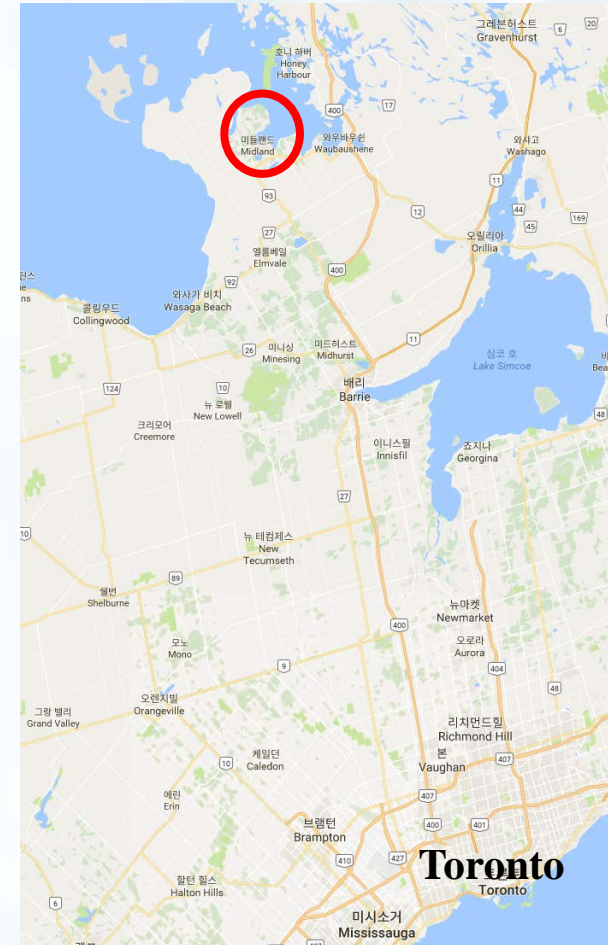
Project Overview

❖ Penetanguishene Distribution Microgrid (MG) Project

- Duration : 2015. 3. 1 ~ 2017. 2. 28 (24 Month)
- Cost : \$4.5 Million
 - KEPCO : \$2.7 Million, PowerStream : \$1.8 Million
- Final Goal
 - Distribution MG demonstration
 - Field test of MG operation system developed by KEPCO



MG Test Bed



Penetanguishene, Ontario

Project Overview

❖ Distribution Feeder MG Test Bed with Control Center

500kWh Battery Container

Control Room

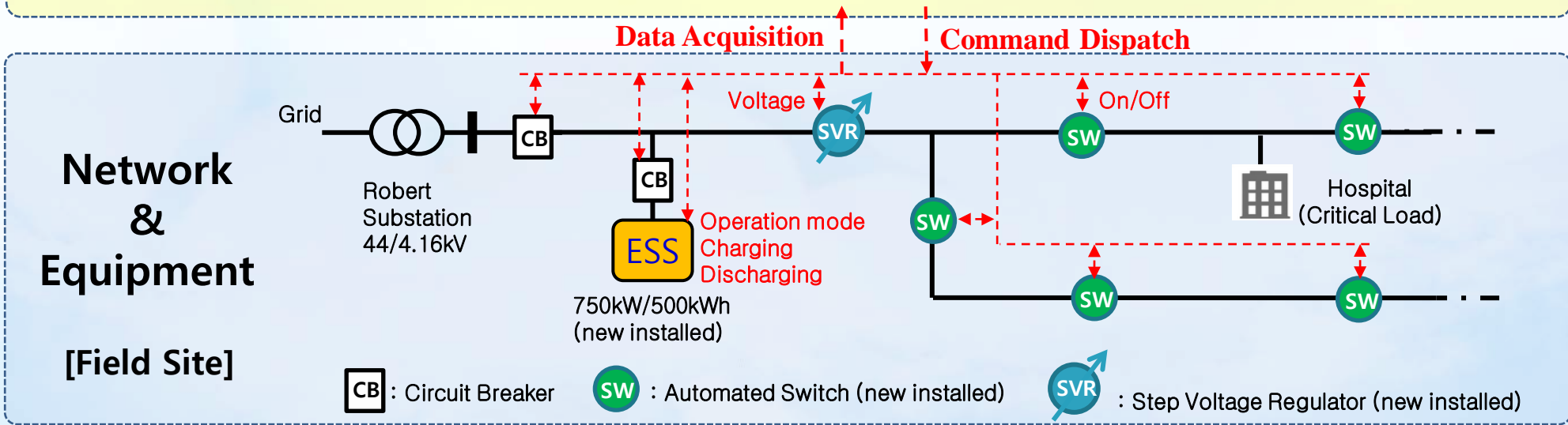
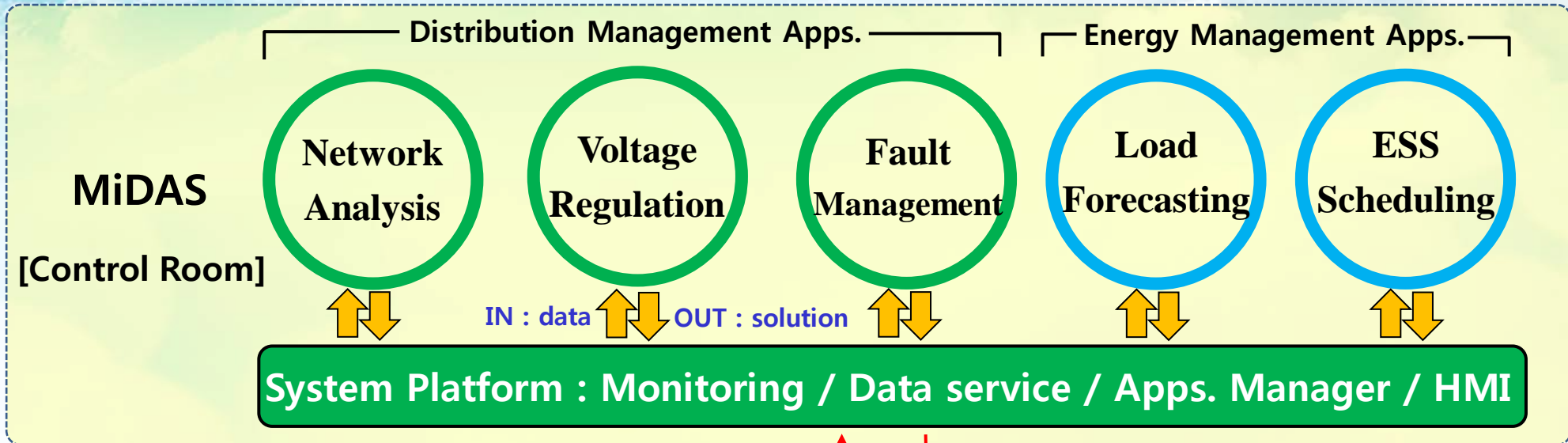


750kW PCS Container

Robert Substation (44 kV/4.16kV)

Introduction of MiDAS

❖ MiDAS is the Distribution Management and Energy Management System



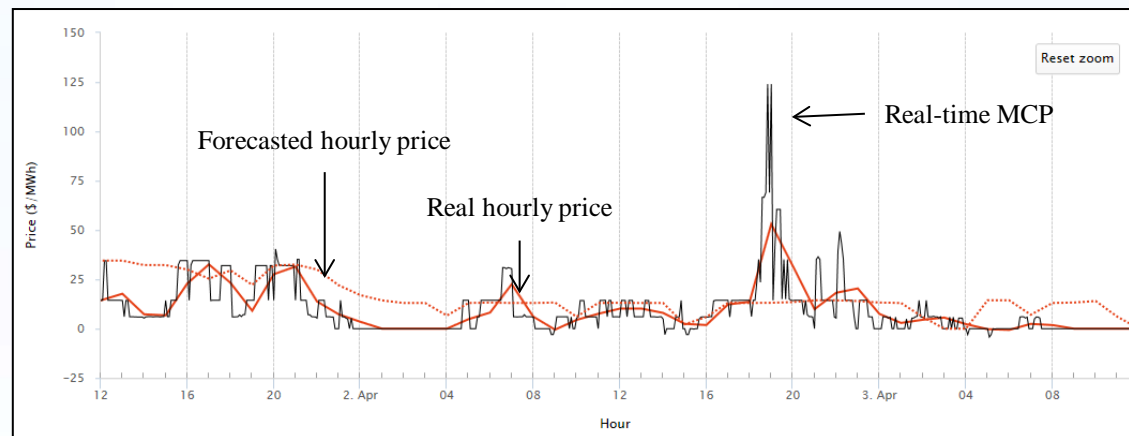
ESS Operation in Normal Condition

❖ Objective : Reduction of the electricity purchasing cost

- Every two minutes, an application determines the operation schedule for the ESS
- Every one minute, SCADA controls the ESS based on the schedule

❖ Ontario electricity market

- Independent Electricity System Operator (IESO) operates the market
- IESO calculates the market clearing price (MCP) every five minutes
- Based on the MCP, electricity price for an hour is determined by IESO
- Large customers pay electricity cost determined from hourly price, their peak demands, etc.

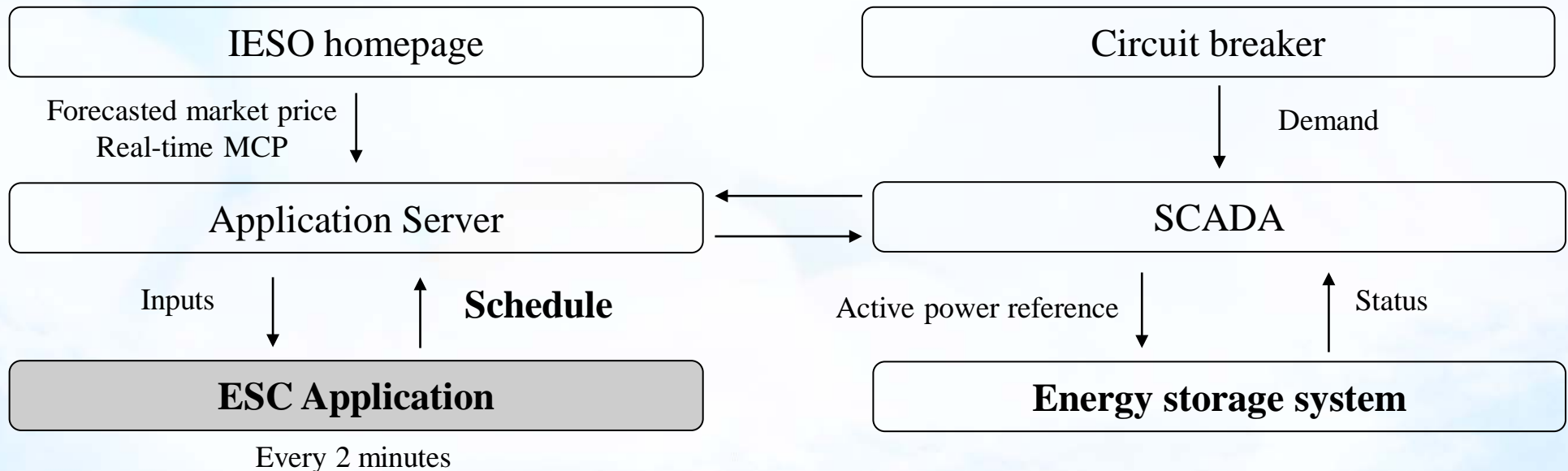


Electricity price in Ontario market

ESS Charging & Discharging Scheduling

❖ ESS schedule-based control (ESC) application

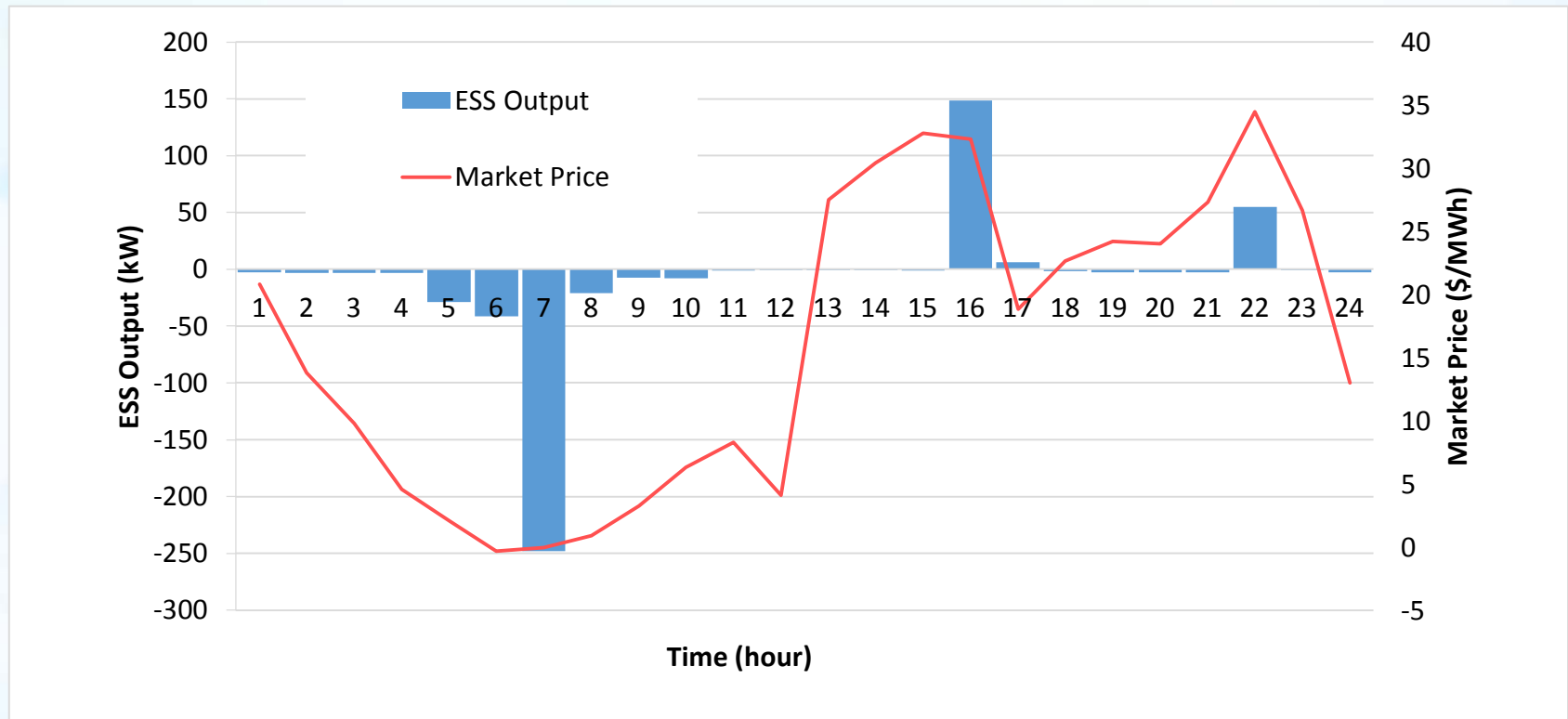
- ESC makes an optimal operation schedule for a day
 - Objective : Minimizing electricity cost
(energy cost determined by hourly price + peak demand cost)
 - Inputs : forecasted market price and demand, real-time MCP and demand, ESS status, etc.
- Deterministic optimization method was adopted to improve the calculation speed



Field Test Results of ESC Application(1)

❖ ESS output was responded to market price!!

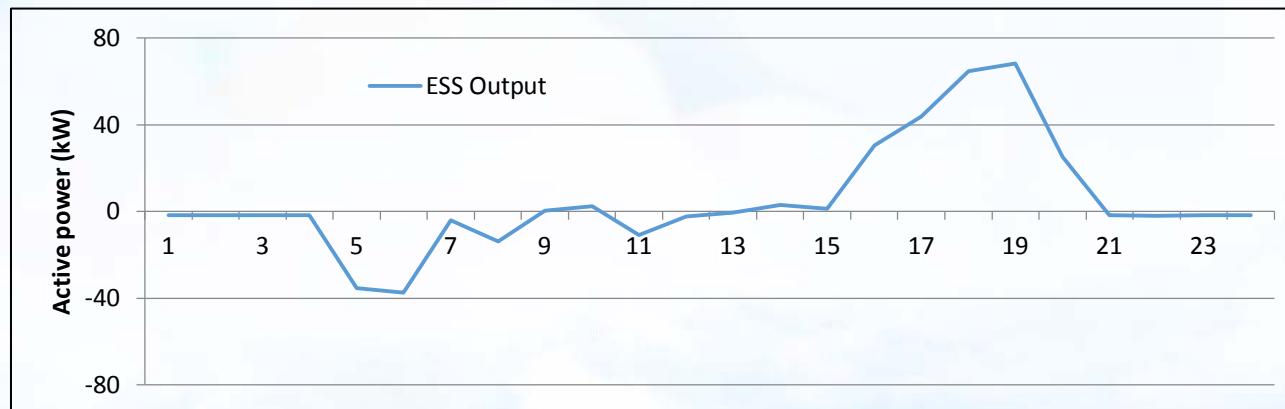
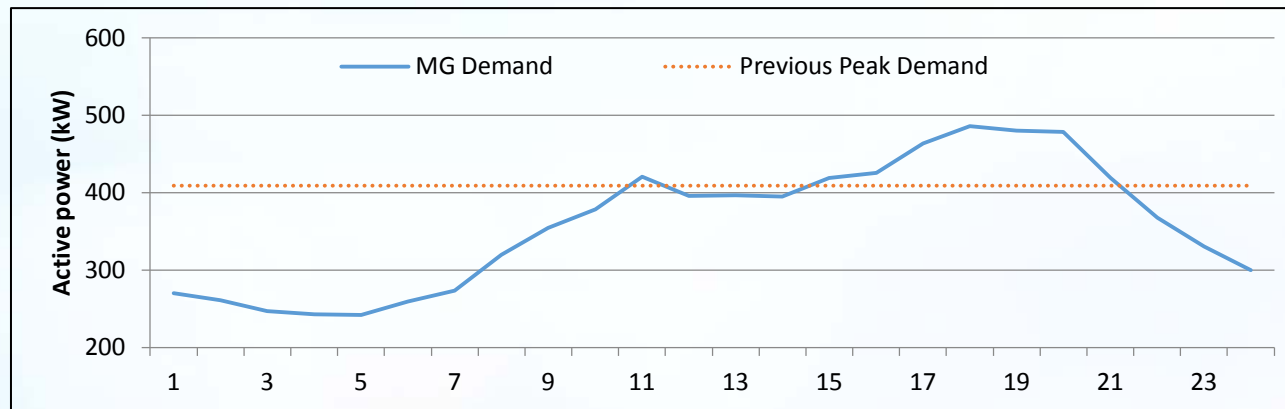
- ESS was charged when the market price was low
- ESS was discharged when the market price was high
- Consequently, the energy cost was reduced



Field Test Results of ESC Application(2)

❖ ESS reduced the peak demand of the MG!!

- Previous peak demand was about 410 kW
- ESS was discharged when the MG demand was higher than the previous demand peak
- Consequently, the peak demand cost of the MG was reduced



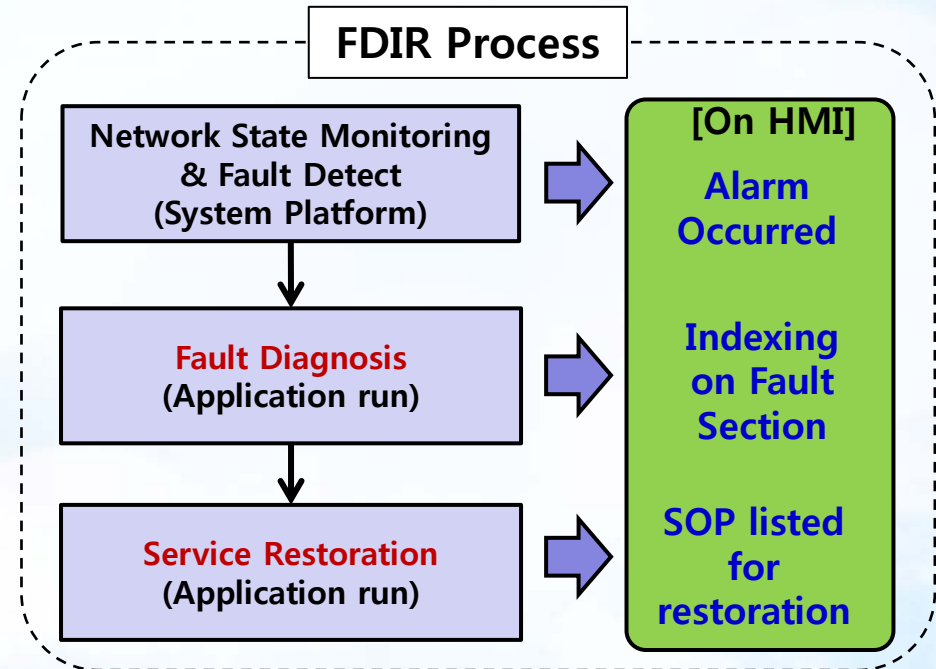
ESS Operation in Abnormal Condition

❖ Objective : Backup generator

- For a fault in the transmission system, the distribution system cannot be restored
- In this case, ESS is used as a backup generator and supplies power to the distribution system,
- If the transmission system is restored, the islanded system can be seamlessly reconnected

❖ FDIR applications in MiDAS

- FDIR determines fault location base on the measured current data from CB & Switches
- FDIR determines the sequence of switch operations to isolate the MG and to make the total load is less than the maximum output of the ESS
- Finally, FDIR recommends the start of the ESS to the operator

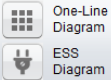


FDIR : Fault Alarm

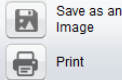
MIDAS(N) Grid Information - ON Mode(DMS_SERVER1) - 20160621_V1.0



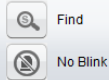
Grid Scope



File



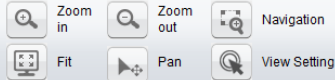
Edit



FDIR



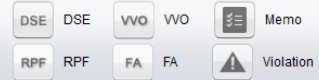
View



Display Devices



Analysis Results



- Waubashene T.
 - Robert MS (MS 422)
 - 422-F1_B7435_CB
 - 422-F2_B7380_CB

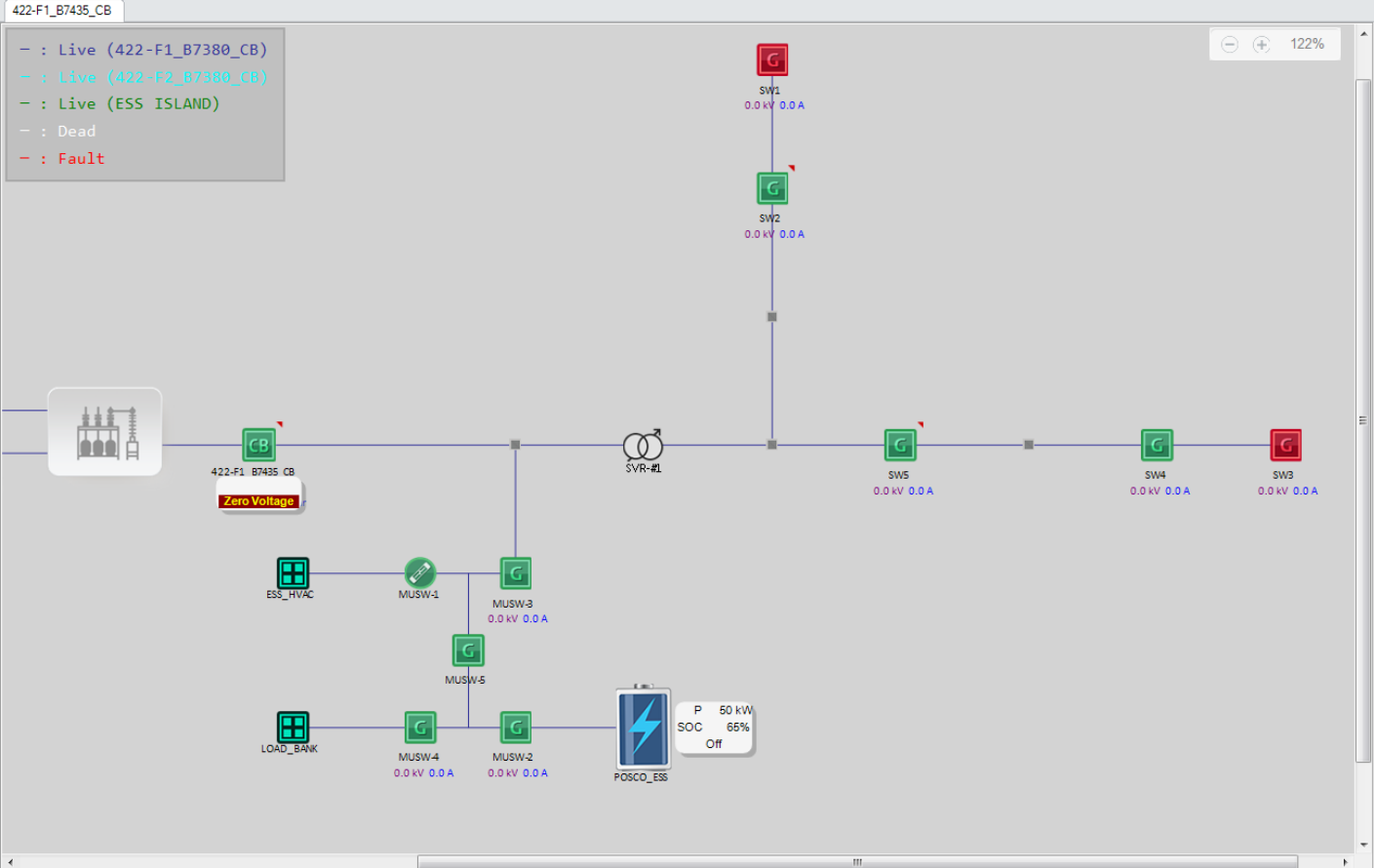
- 422-F1_B7435_CB
- : Live (422-F1_B7380_CB)
 - : Live (422-F2_B7380_CB)
 - : Live (ESS ISLAND)
 - : Dead
 - : Fault

Feeder Explorer

Link feeders Meter Reading & Analysis

422-F1_B7435_CB

	Measure	Analysis
Voltage [kV]		
Red	0.00	0.00
White	0.00	0.00
Blue	0.00	0.00
Current [A]		
Red	400.00	0.00
White	400.00	0.00
Blue	400.00	0.00
Active Power [MW]		
3 Phase	0.00	0.00
Red	-	-
White	-	-
Blue	-	-
Reactive Power [MVar]		
3 Phase	-	-
Red	-	-
White	-	-
Blue	-	-



FI List

Device Name	Detection
422-F1_B7435_CB	Zero Voltage

Fault Elapsed: 00:00:17 Isolation Stop FDIR Complete

Feeder Information

Fault Records Event List Log Direct Control

FDIR Control FI List



FDIR : Solution for Fault Isolation

MIDAS(N) Grid Information - ON Mode(DMS_SERVER1) - 20160621_V1.0

MIDAS^N
Microgrid and DER Interconnected Active Distribution System

Grid Scope
One-Line Diagram
ESS Diagram

File
Save as an Image
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No Blink

FDIR
DSR DSR
DFD Select
FI List
DFD Deselect

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Zoom out
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Navigation
View Setting

Display Devices
Remote Only On/Off

Analysis Results
DSE DSE
RPF RPF
VVO VVO
FA FA
Memo
Violation

Power Stream
KEPCO

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422-F1_B7435_CB
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422-F1_B7435_CB

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White	-	-
Blue	-	-
Reactive Power [MVar]		
3 Phase	-	-
Red	-	-
White	-	-
Blue	-	-

FDIR Control

DFD List DSR List

Batch Control

Device Name	Bef...	After
422-F1_B7435_CB	Close	Open

Control List

Device Name	Before	After
422-F1_B7435_CB	422-F1_B7435_CB	Close

1, Open
422-F1_B7435 CB
Zero Voltage

SW1 0.0 kV 0.0 A
SW2 0.0 kV 0.0 A
SW5 0.0 kV 0.0 A
SW4 0.0 kV 0.0 A
SW3 0.0 kV 0.0 A

ESS_HVAC
MUSW-1
MUSW-3 0.0 kV 0.0 A
MUSW-5
MUSW-4 0.0 kV 0.0 A
MUSW-2 0.0 kV 0.0 A
LOAD_BANK
POSCO_ESS
P 50 kW
SOC 65%
Off

Fault Elapsed: 00:01:17

Outage Recovery Stop FDIR Complete

Feeder Information
Fault Records Event List Log Direct Control

FDIR Control FI List

FDIR : Solution for Restoration

MIDAS(N) Grid Information - ON Mode(DMS_SERVER1) - 20160621_V1.0

MIDAS^N
Microgrid and DER Interconnected
Active Distribution System

Grid Scope
One-Line Diagram
ESS Diagram

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FDIR
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DFD Select
FI List
DFD Deselect

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422-F1_B7435_CB
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422-F1_B7435_CB

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Feeder Explorer
Link feeders Meter Reading & Analysis

422-F1_B7435_CB

	Measure	Analysis
Voltage [kV]		
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Blue	400.00	0.00
Active Power [MW]		
3 Phase	0.00	0.00
Red	-	-
White	-	-
Blue	-	-
Reactive Power [MVar]		
3 Phase	-	-
Red	-	-
White	-	-
Blue	-	-

Diagram showing a power distribution network with components: 422-F1_B7435_CB, SVR-#1, SW1 (232 kW Load, 1200 kW Margin), SW2 (0.0 kV, 0.0 A), SW5 (0.0 kV, 0.0 A), SW4 (0.0 kV, 0.0 A), SW3 (0.0 kV, 0.0 A), ESS_HVAC, MUSW-1, MUSW-3 (0.0 kV, 0.0 A), MUSW-5, LOAD_BANK, MUSW-4 (0.0 kV, 0.0 A), MUSW-2 (0.0 kV, 0.0 A), POSCO_ESS (P: 50 kW, SOC: 65%, Off, Load: 578kW, Available Time: 23.33778min).

FDIR Control
DFD List | DSR List
Batch Control

Device Na...	Ref...	After
SW5	Close	Open
SW2	Close	Open
POSCO_ESS		
SW1	Open	Close

Fault Elapsed: 00:01:34

Outage Recovery Stop FDIR Complete

Feeder Information
Fault Records Event List Log Direct Control

FDIR Control FI List

FDIR : Restoration with ESS

MIDAS(N) Grid Information - ON Mode(DMS_SERVER1) - 20160621_V1.0

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Active Distribution System

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DSE DSE VVO WO
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KEPCO

Waubashene T.

- Robert MS (MS 422)
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Feeder Explorer

Link feeders Meter Reading & Analysis

POSCO_ESS

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Blue	-	-
Active Power [MW]		
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Blue	-	-
Reactive Power [MVar]		
3 Phase	-	-
Red	-	-
White	-	-
Blue	-	-

422-F1_B7435_CB

- : Live (422-F1_B7380_CB)
- : Live (422-F2_B7380_CB)
- : Live (ESS ISLAND)
- : Dead
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FDIR Control

DFD List DSR List

Batch Control

Device No...	Bef...	After
SW5	Close	Open
SW2	Close	Open
POSCO_ESS		
SW1	Open	Close

Fault

Elapsed: 00:03:26

Outage Recovery

Stop

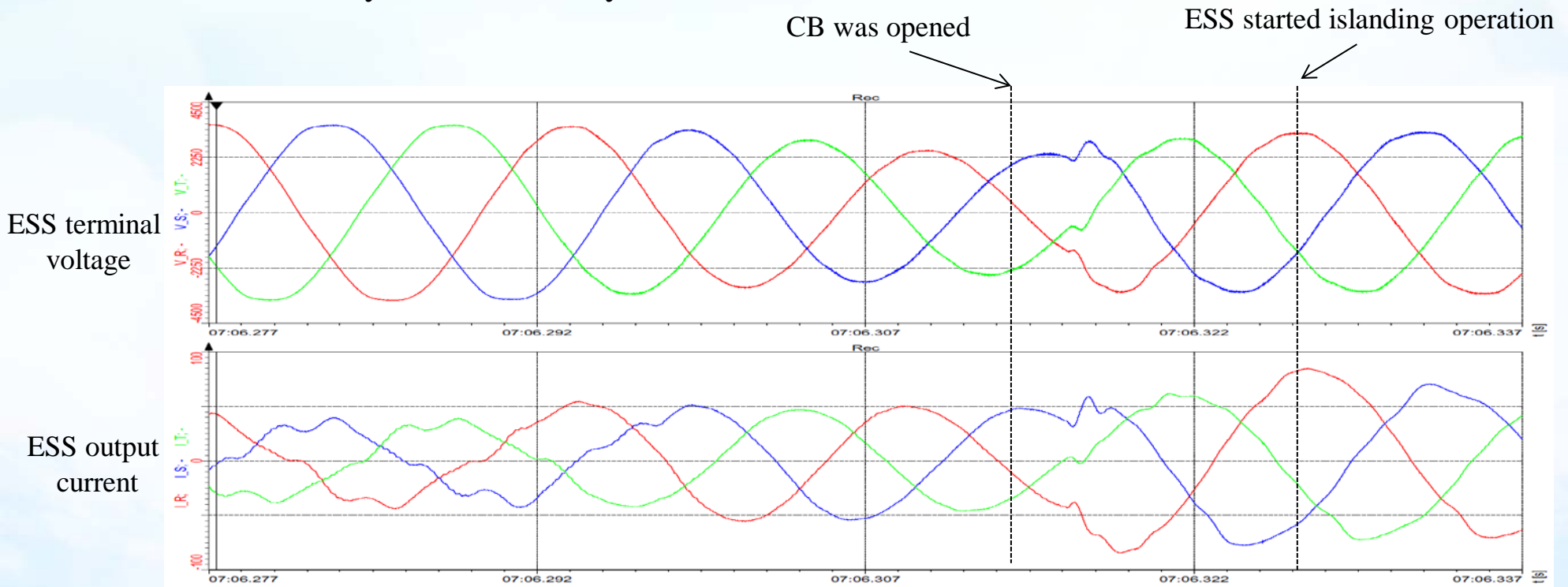
FDIR Complete

Feeder Information Fault Records Event List Log Direct Control FDIR Control FI List

Field Test Results of Islanding (1)

❖ Seamless transition from grid-connected operation to islanded operation

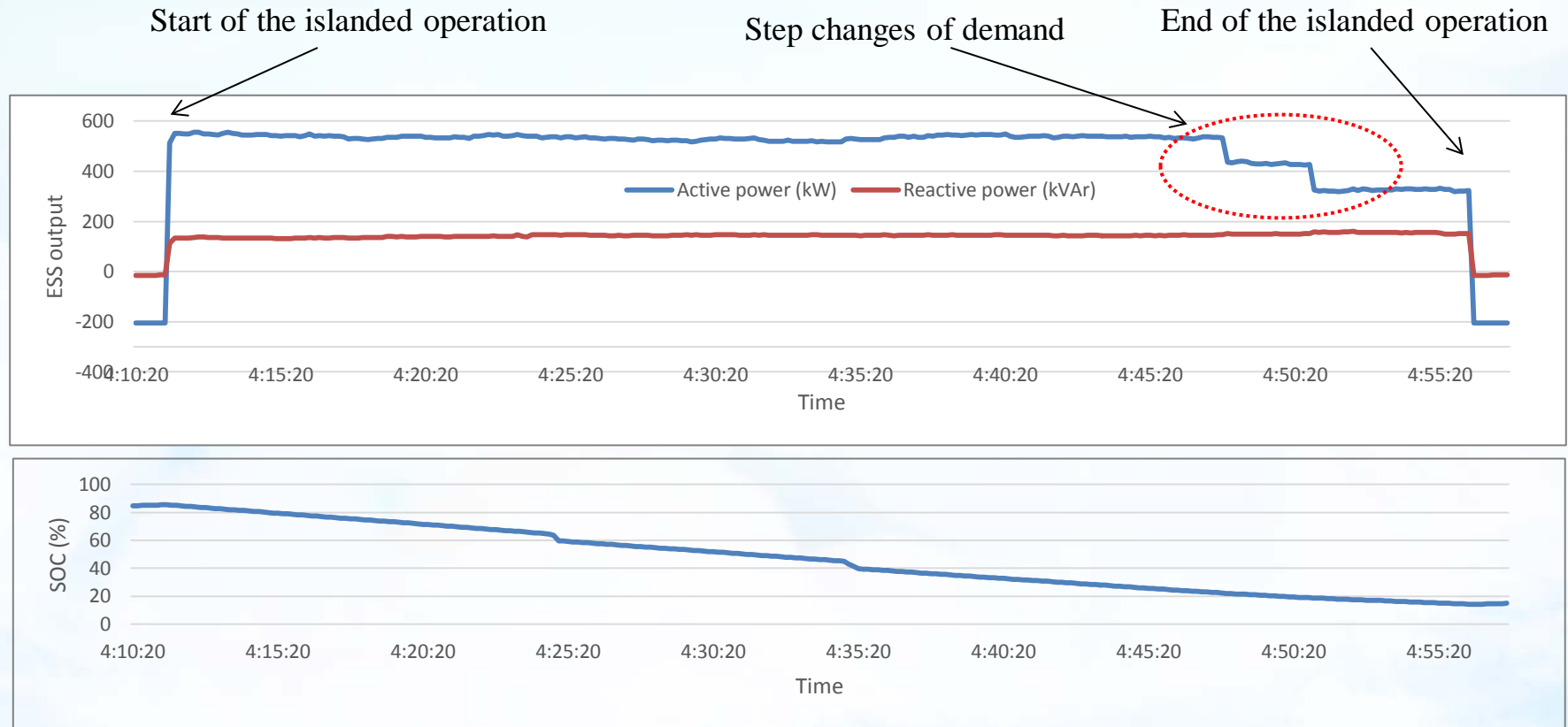
- By opening the CB, the MG was disconnected from the main grid
- ESS automatically detected the isolation and started the islanding operation
- It takes only one and half cycles



Field Test Results of Islanding (2)

❖ Islanded operation maintained about 40 minutes

- ESS supplied load without any problem even though there were step changes in the demand

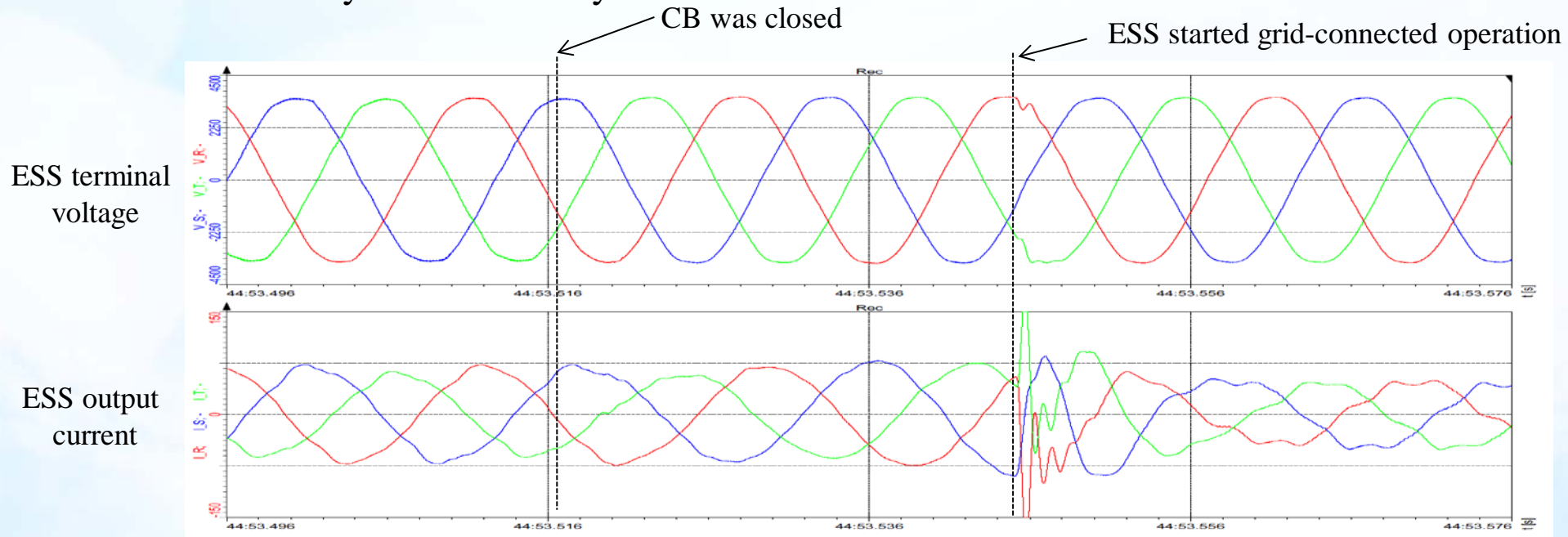


Islanded operation

Field Test Results of Islanding (3)

❖ Seamless transition from islanded operation to grid-connected operation

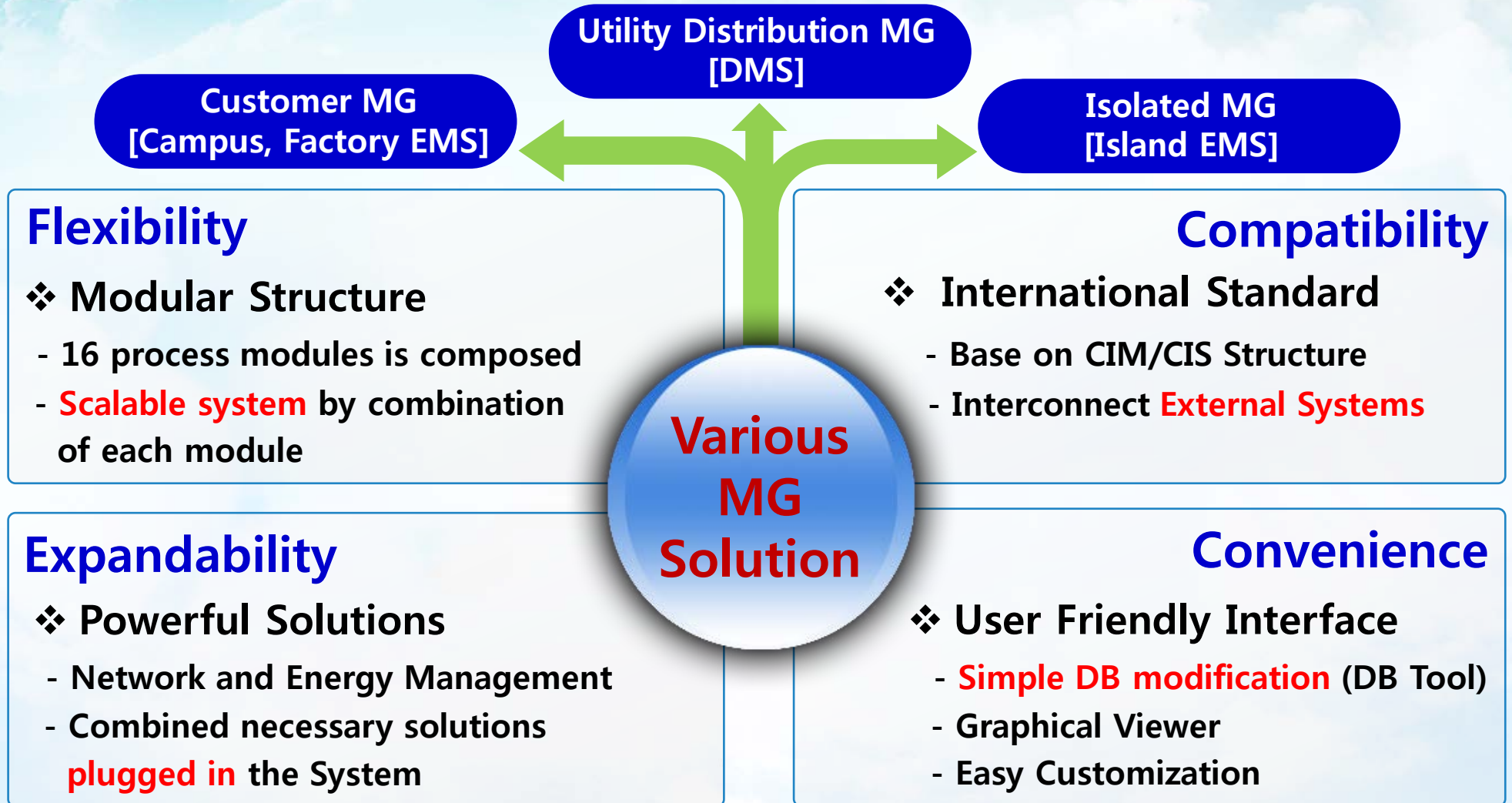
- ESS automatically synchronized its output voltage to that of the main grid when the main grid was energized
- Islanded MG was reconnected to the main grid by closing the CB without any problem
- ESS changed its operation mode to grid-connected mode automatically
- It takes only one and half cycles



Islanded operation → Grid-connected operation

MiDAS Feature & Commercialization

“MiDAS can be applied to Various MG Business Model”



Thank you

18th May, 2017 | KEPCO Research Institute (wonwook.jung@kepco.co.kr)

