# Operation of Grid-connected Microgrid on KEPCO Test-bed

**Research Institute of KEPCO**

**September 4, 2012**

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# Overview

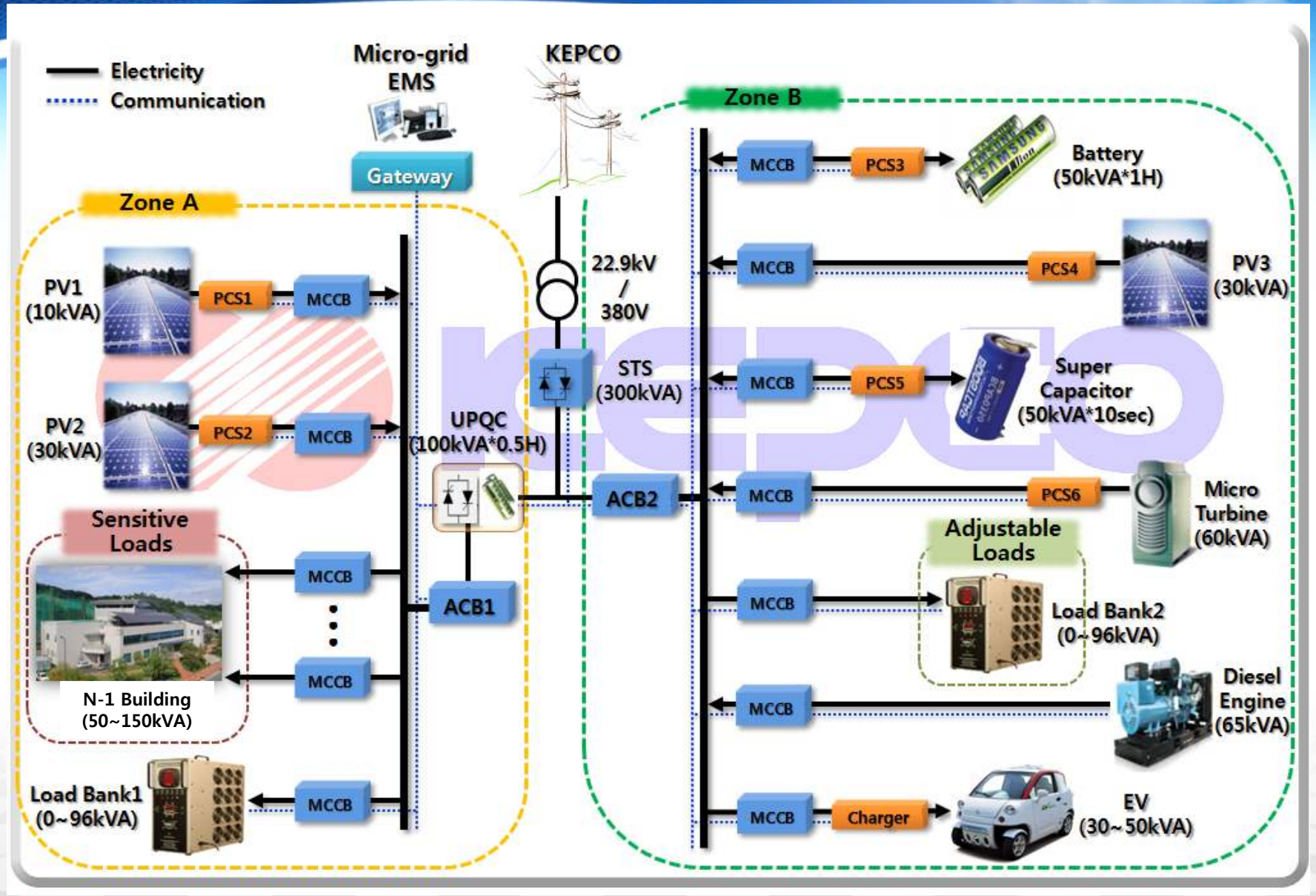
## Overview

| | |
|---|---|
| Goal | : To demonstrate Microgrid & its optimal operation tech. |
| Period/Budget | : 2010. 2 ~ 2013.1 (36 months) / $ 4.2 million |
| Participants | : KEPCO, LS Industial, Sanion, Inha University |

## Goals and Schedule

- Development of the core devices for Microgrid(MG)
  - Development the Microgrid EMS
  - Network Gateway, PCS for PV/BESS
  - UPQC for MG power quality, STS(Static Transfer Switch)
- Build & Actual Load Test in KEPCO 200kW MG site
- Development of the engineering technology for MG
- Develop the optimal operation strategies of MG
- Schedule
  - ~2012. 1 : Build of 200kW Microgrid Site at KEPCO RI
  - ~2013. 1 : Actual Load Test & Optimal Operation

# System Architecture



# Test Site




[Picture of the test site at Dae-jeon, Korea]

KEPCO

# Core Devices and Its Functions

| Core Device | Main Function |
|---|---|
| EMS | • Load/Generation(PV, WT) forecasting, AGC/ED<br>• Device Management : BESS, Load, Distributed Generation<br>• Power Exchange & Metering, Interconnection with DMS/DAS |
| STS/IED | • MG Protection from upper power system<br>• Fast open at upper system fault and resynchronization<br>• Power quality and power flow monitoring at PCC |
| PCS(BESS) | • Power converting of DC power of BESS into AC power<br>• Droop operation : Active power & Reactive power<br>• P & Q control by EMS command |
| PCS(PV) | • Power converting of DC power of PV into AC power<br>• Power limit & Power factor control by EMS command |
| Gateway | • Protocol conversion : Serial/Field Bus/Ethernet -> IEC61850 |
| UPQC | • Power quality Compensation : Sag, Swell, Harmonics, Flicker…<br>• Uninterruptable power supply for sensitive loads |
| Super Cap. | • Improvement of MG's transient stability due to fast response |

# EMS – Function

## MG Control



### EMS Function

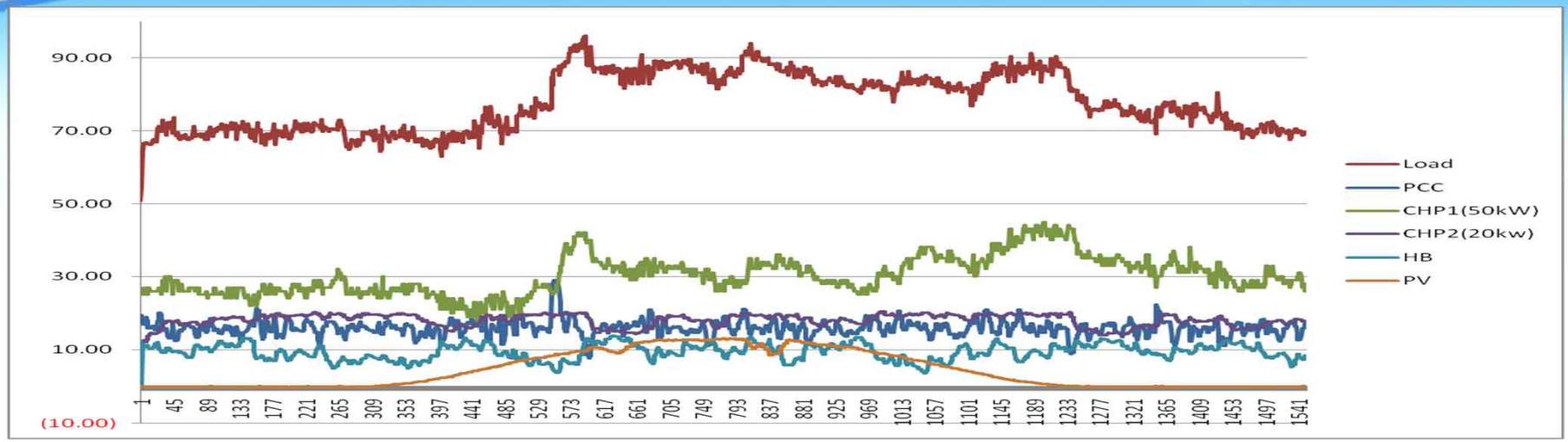
- Export & Import Power Control at PCC (Completed)
- Supervisory Control of BESS (Completed)
- Forecasting : Load (Power & Heat) & Renewable Energy Generation
- Generation Scheduling : Unit Commitment (including CHP)
- Economic Dispatch

| Generation Schedule & Dispatch | Supervisory Control |
|---|---|
| • Make the balance between demand & supply<br>• Optimize the objective related to Microgrid<br>• For the generation schedule & dispatch :<br>Forecast (Load & Renew. Gen.), UC and ED | • Tie-line control (power & voltage control at PCC)<br>• Power system fault detection and disconnection<br>• Reconnection to power system<br>• Secondary regulation regarding energy storage |

# EMS - AGC

- **AGC (Automatic Generation Control)**
  - AGC consists of ACE(Area Control Error) and ED (Economic Dispatch)
  - ACE of an interconnected group of systems is the resultant error in area interchange compared to the desired or scheduled interchange, including time error
    - ❖ **AGC = BP+RPF*TLE+TEDME*EPF**
      - BP(Base Point)
      - RPF(Regulation Participation Factor)
      - EPF(Economic Participation Factor)

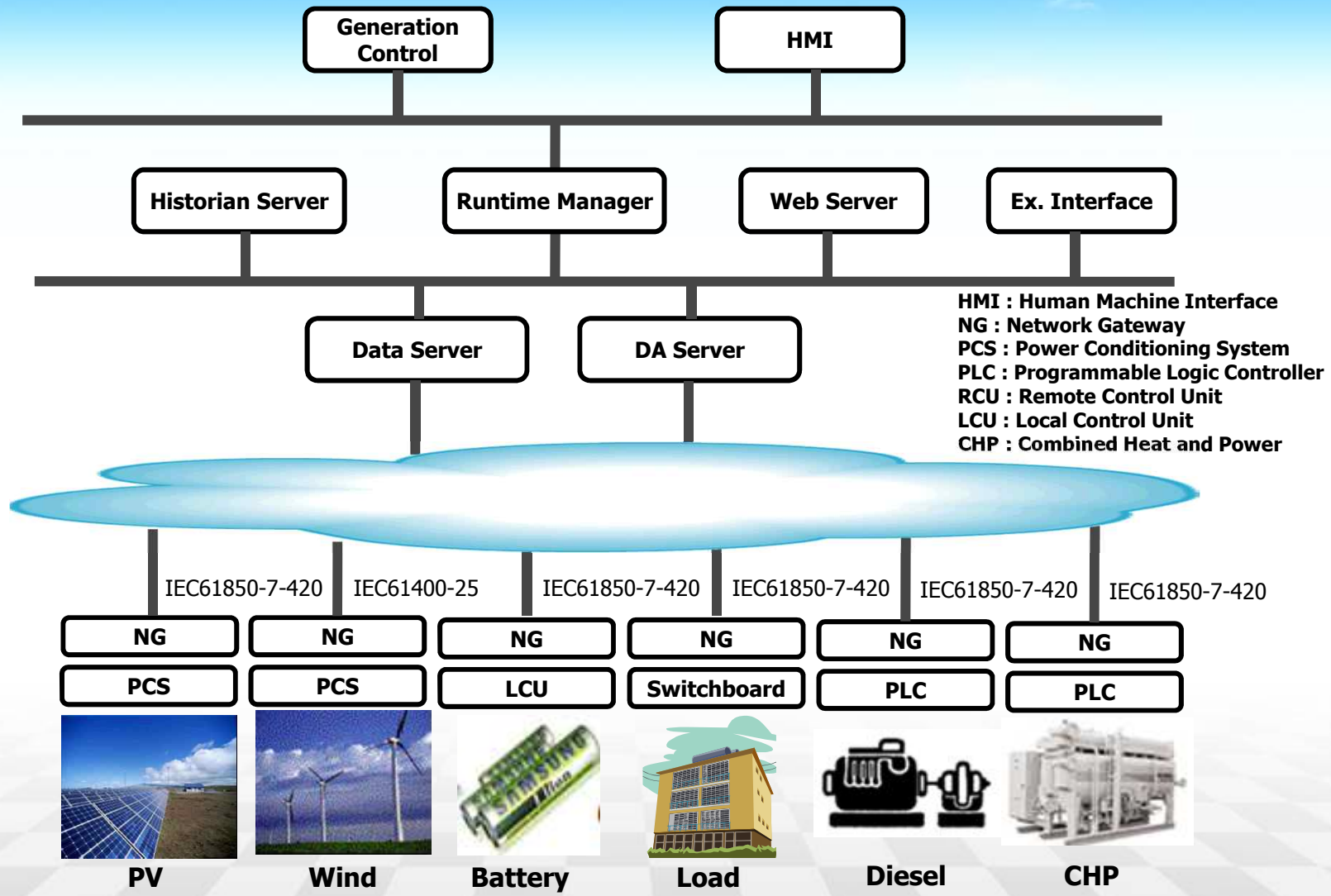
# EMS - Example




**AGC without ED**


**AGC with ED**

# EMS - Structure

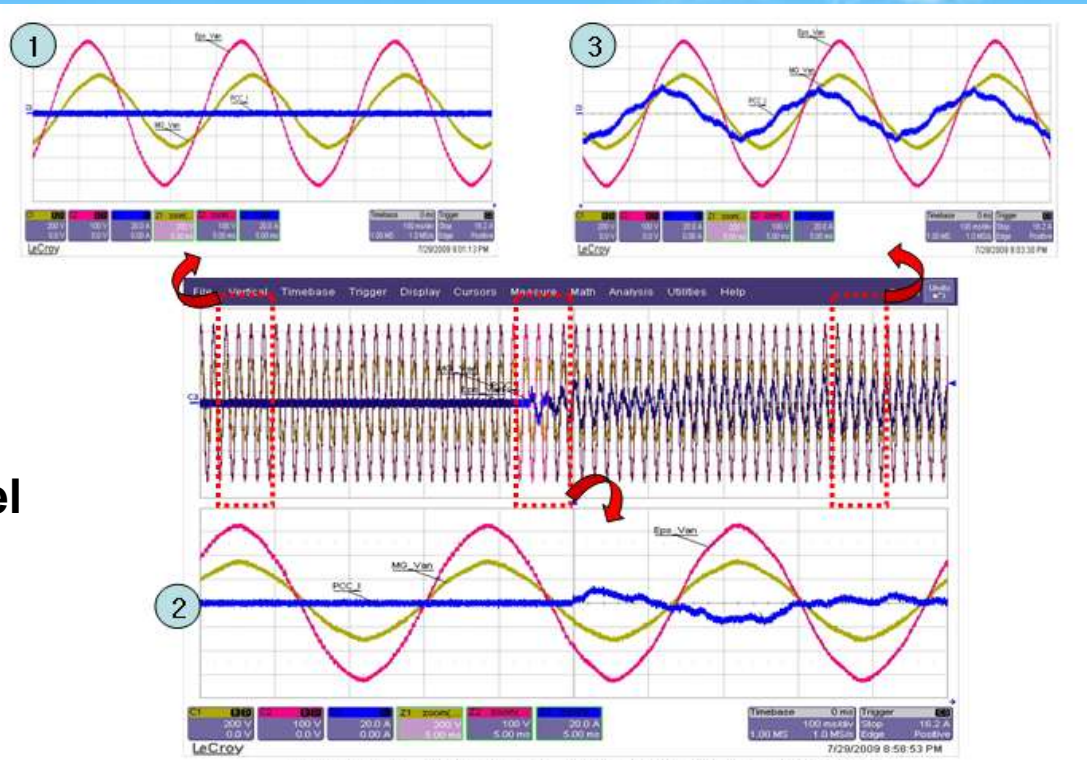


# STS(Static Transfer Switch)

## Re-sync Test

IED

Control Panel




시간 축으로 계측한 동기 투입에 따른 전압/전류 변동

- Open : Auto or By EMS
- Re-sync by EMS order
  - i ) Re-sync order by EMS
  - ii) Detecting sync by STS
  - iii) Closing at acceptable error range

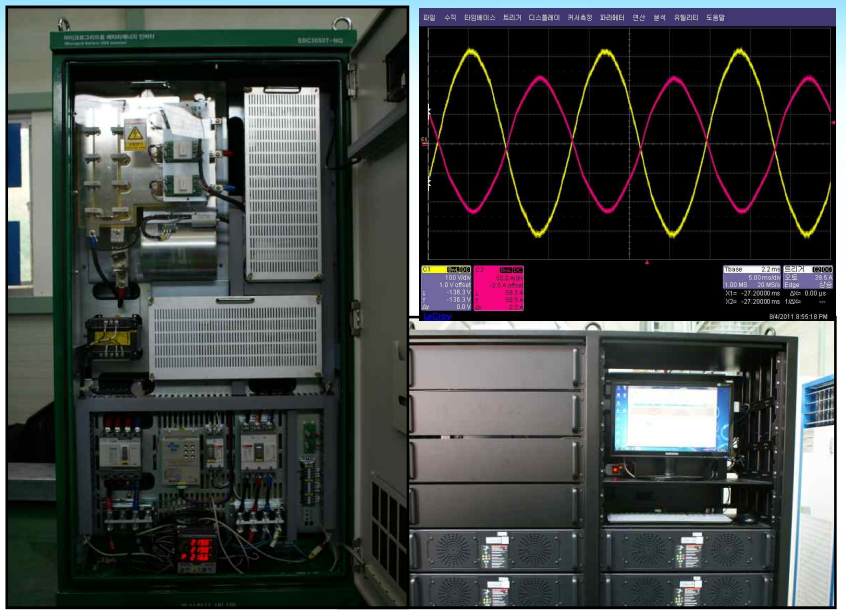
*1Cycle : 1/60 sec = X : 335.1us*

*X = 0.3351 ms / 16.667ms = 0.02 Cycle*

*1Cycle : 360˚ = 0.02 Cycle : Y,  Y = 7.2˚*

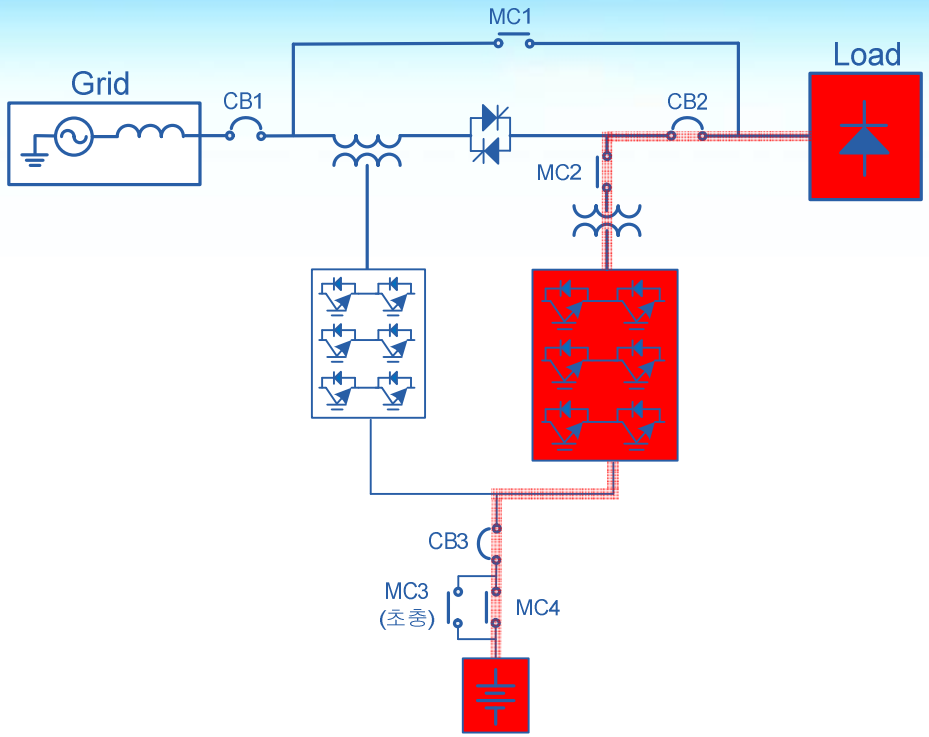
**Re-sync closing at 7.2˚**

# PCS for PV / BESS

| - PCS & Photovoltaic Generator | - PCS & Li-Polymer Battery |
|---|---|
| - 30kVA | - 50kVA / 50kW * 1H |
| - Power can be limited by EMS if there is no chargeable battery.<br>- Power factor controllable from EMS | - P/Q/PF controllable from EMS<br>- Droop function added<br>- P/Q/PF controllable during droop<br>- Black start capability added |

# UPQC(Unified Power Quality Compensator)

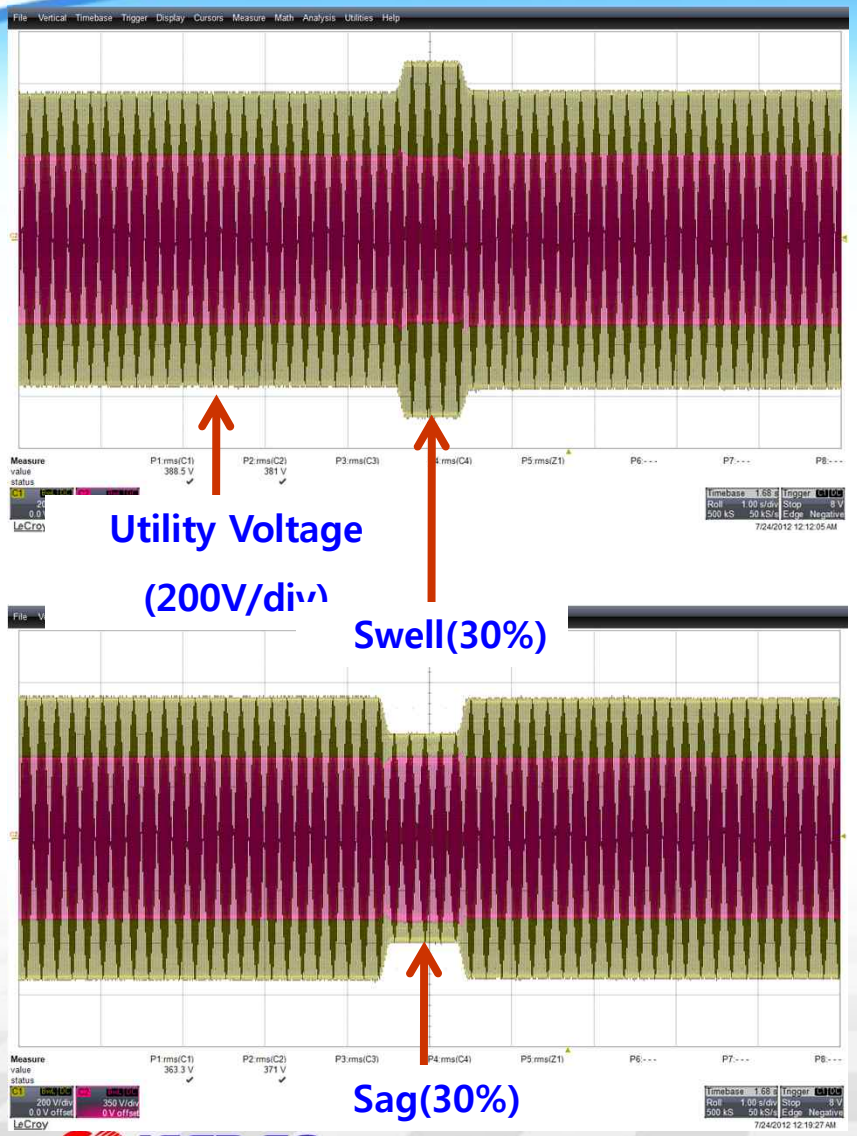



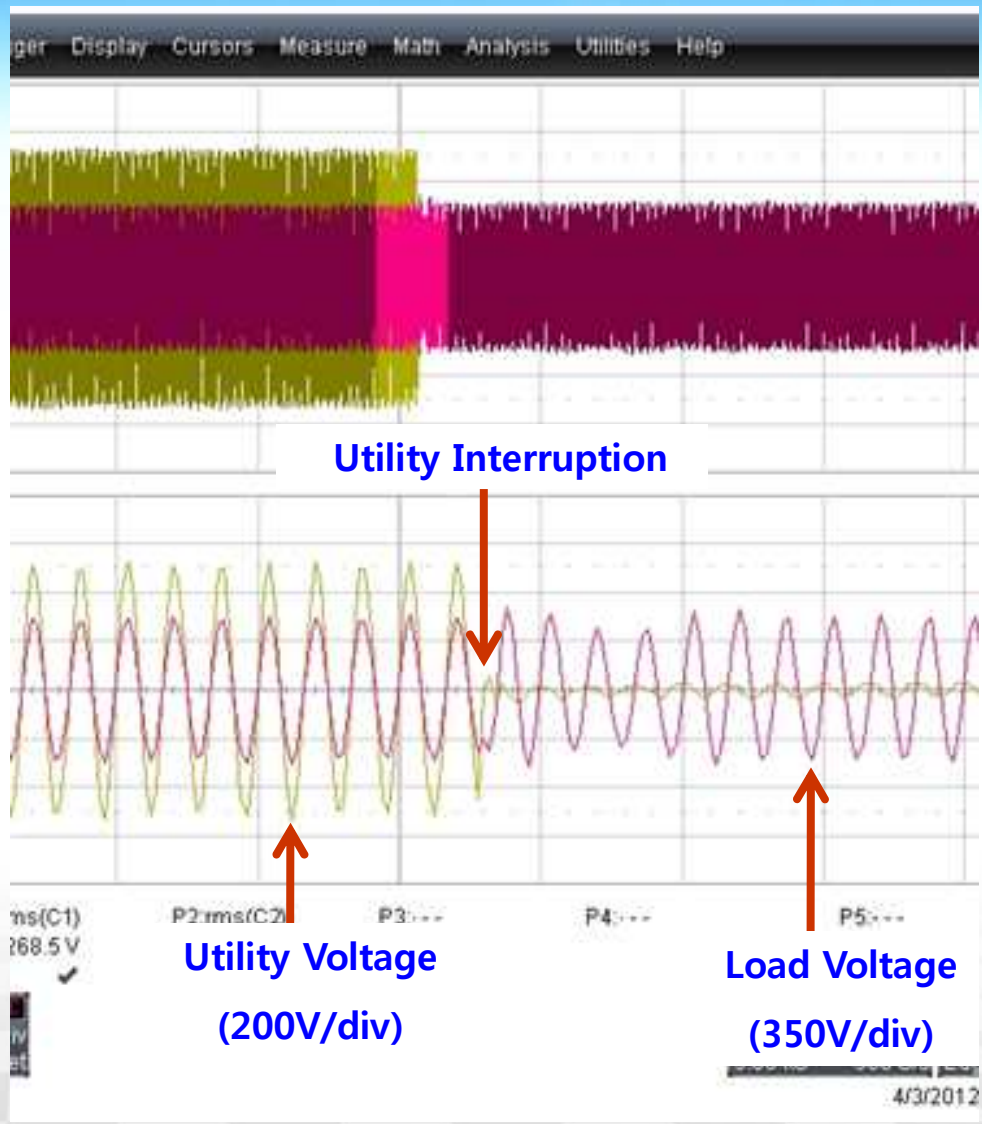

**- Unified Power Quality Compensator**

- 100kVA ± 30min

- Sag, Swell, Harmonics, Flicker, Power factor correction, Voltage support
- UPS at emergency

# UPQC : Test results



# Super Capacitor, Load Bank

|  |  |
|---|---|
| **- Super Capacitor & PCS** | **- Load Bank(R/L/C)** |
| - 50kVA ± 10sec | - 75kVA ± 50kVar |
| - Droop function added<br>- No control from EMS<br>- Act by frequency variation<br>- Rated output is limited due to MG's size. | - Controlled from EMS<br>- To test the core devices without the real loads<br>- To test the load shedding algorithms |

# Micro Gas Turbine, Diesel Generator

| | |
|---|---|
|  |  |
| - **Micro Gas Turbine** | - **Diesel Generator** |
| - 60kVA | - 82kVA |
| - P/Q controlled from EMS<br>- Co-generation Capability(scheduled) | - P/Q controlled from EMS<br>- Black Start Capability at Emergency<br>- Installed for Island Type Microgrid |

# Expecting devices

**[Wind Turbine Simulator]**
-20kW will be interconnected


**[Fuel Cell]**
-5kW will be interconnected

**[Electric Vehicle & Charger]**
-Test of Charging at Microgrid
-Embody V2G

# Contents of Field Test

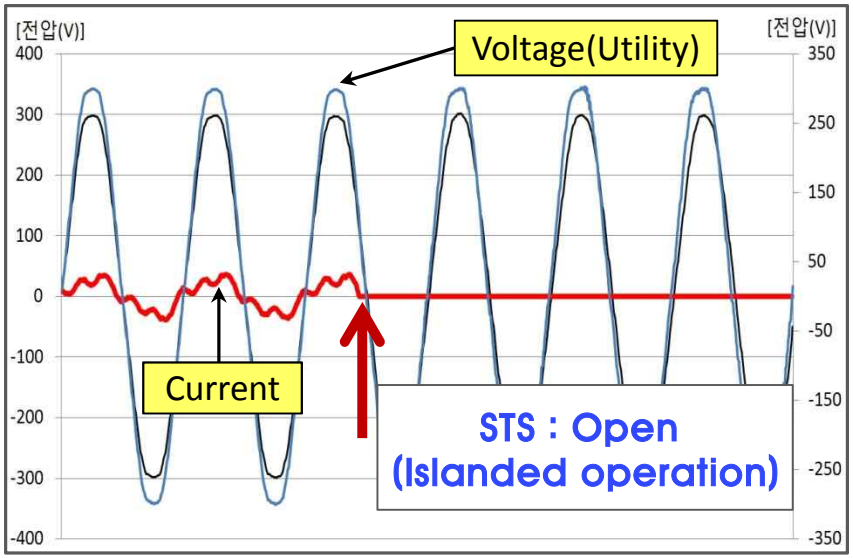
| Mode | Contents of Test | Purpose of Test |
|---|---|---|
| Interconne-cted mode | -Max operation capability<br>-Power flow control at PCC<br>-Thermal load following | -Verification of installed generator<br>-Peak shaving, Power sales..<br>-Optimal thermal supply |
| Standalone | -Voltage & Frequency control<br>-Keep supply and demand in balance | -Island operation at interruption<br>-Power supply for island, isolated area |
| Transition | -Transient stability by power flow quantity at PCC | -Cooperated control using BESS & Super Capacitor<br>-Stable transition at interruption |
| Re-sync | -Seamless re-sync by STS & EMS | -Stable coexistence with Distribution System & Utility<br>-Improvement of power quality |

# Test Results

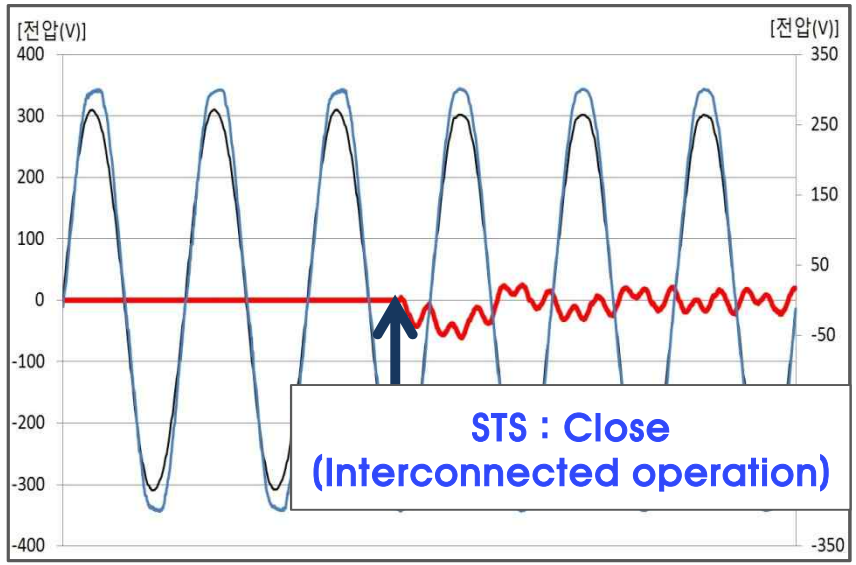
## Operation Mode Transfer

- Field test of seamless operation mode transfer

### ① Interconnected → Standalone




### ② Standalone → Interconnected

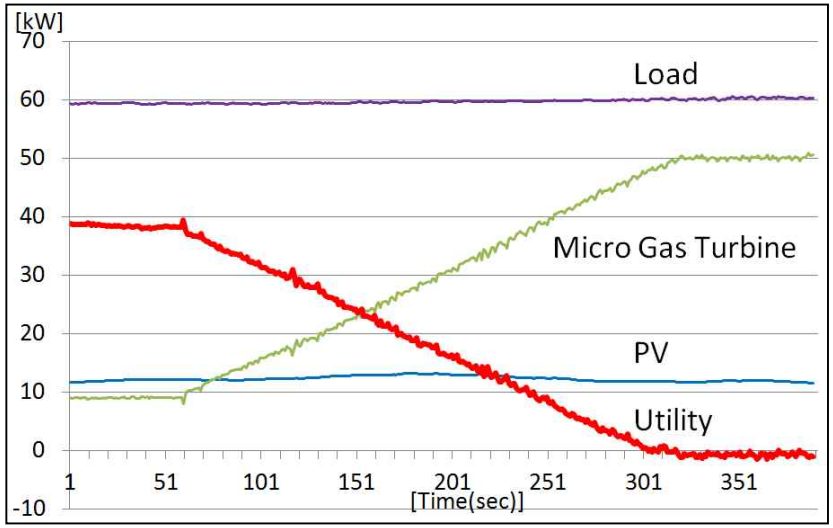



- Seamless operation mode transfer under 20% power flow
- Reliability of the delivery is raised(No momentary interruption)

# Test Results

## Feeder Flow Control

- Power Exchange
- Maximum Demand Control



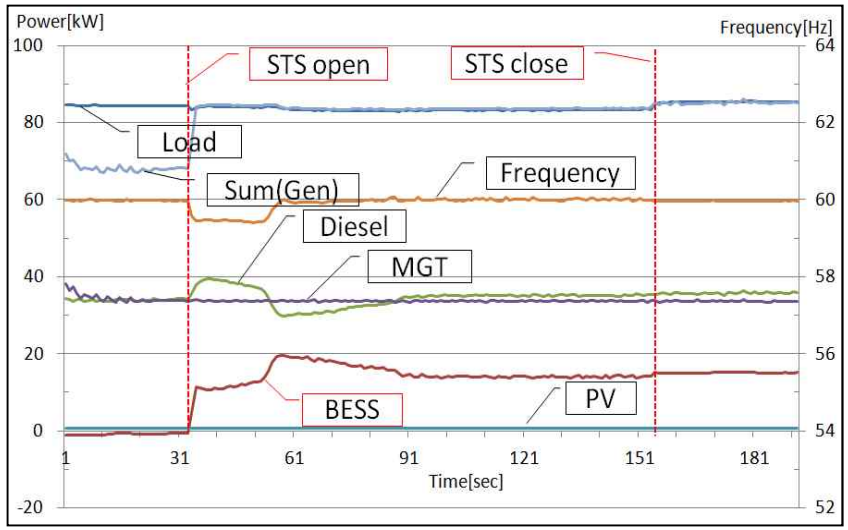

### Results

- Power flow at PCC can be controlled automatically by EMS.

Peak and facility investment reduction

## Frequency Control

-Frequency control under islanded mode using BESS and diesel generator



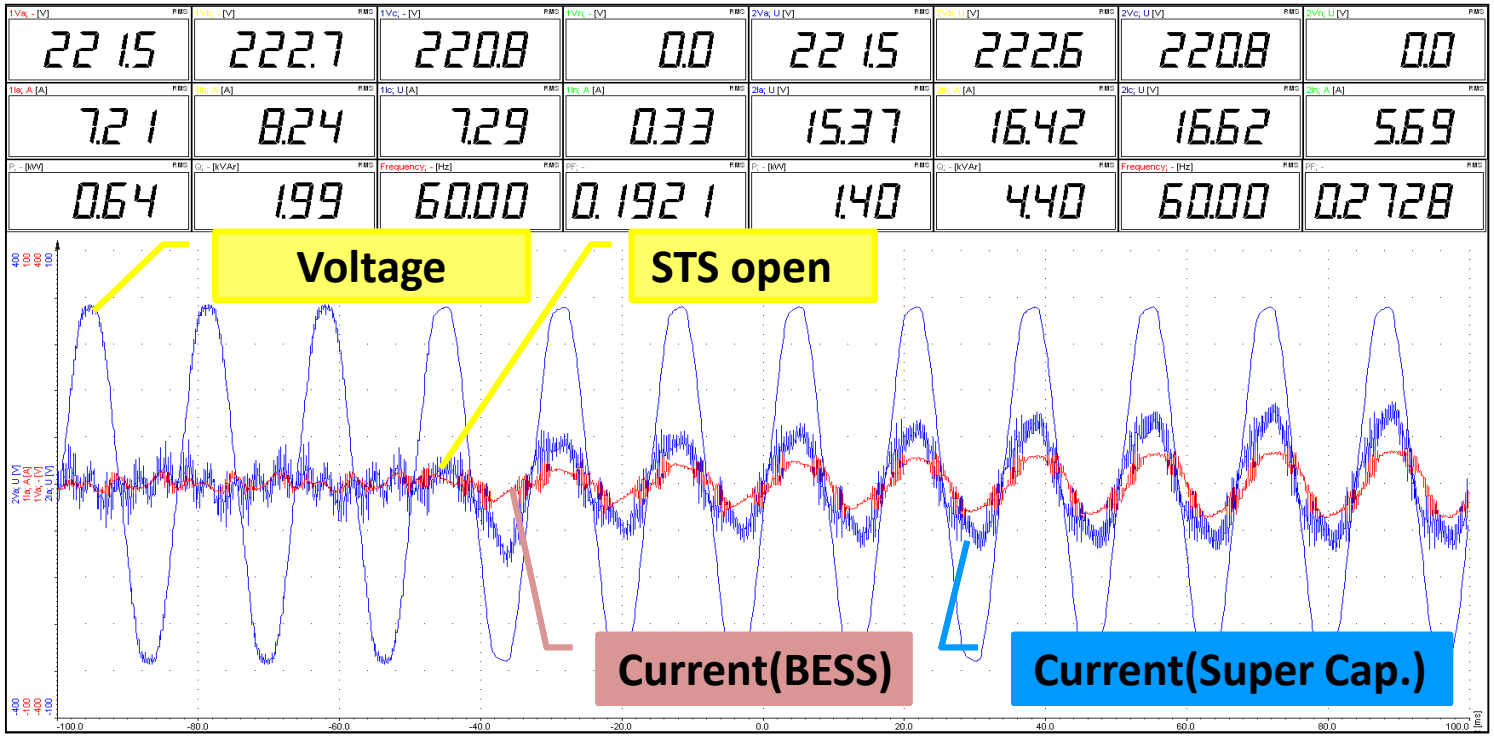

### Results

- Frequency can be controlled by BESS's droop function(Diesel : P/Q control mode)

Continuous power supply at emergency

# Test Results

## Cooperative operation between BESS and Super Capacitor




- Cooperative operation using Droop function under mode transfer
  - Super cap. discharge the power due to its fast response.
  - BESS discharge the power using droop function.
  - MG's Stability would be raised and BESS's life time would be prolonged.

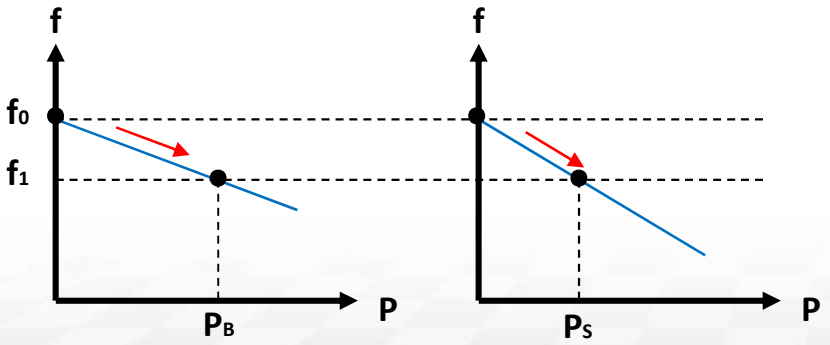
# Cooperative operation of BESS & SC

**[1] Droop of BESS & Super Capacitor(SC)**

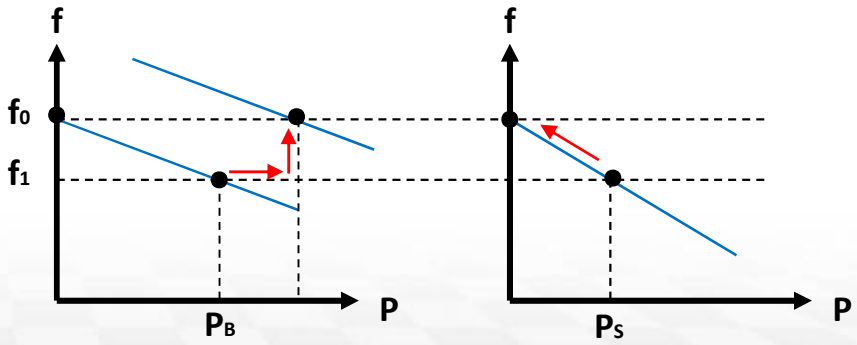
-> Cooperative operation of BESS & SC( Power variation = PB + PS )
-> Frequency variation : f0 -> f1
-> Without SC : Frequency will fluctuate more rapidly.
-> Battery's life span will lengthen due to SC

**[2] Frequency Restoration by BESS**

-> Frequency will be restored to 60[Hz] by BESS
-> SC's power will come back to zero due to frequency restoration.




[1] Frequency Variation by Droop(BESS & SC)



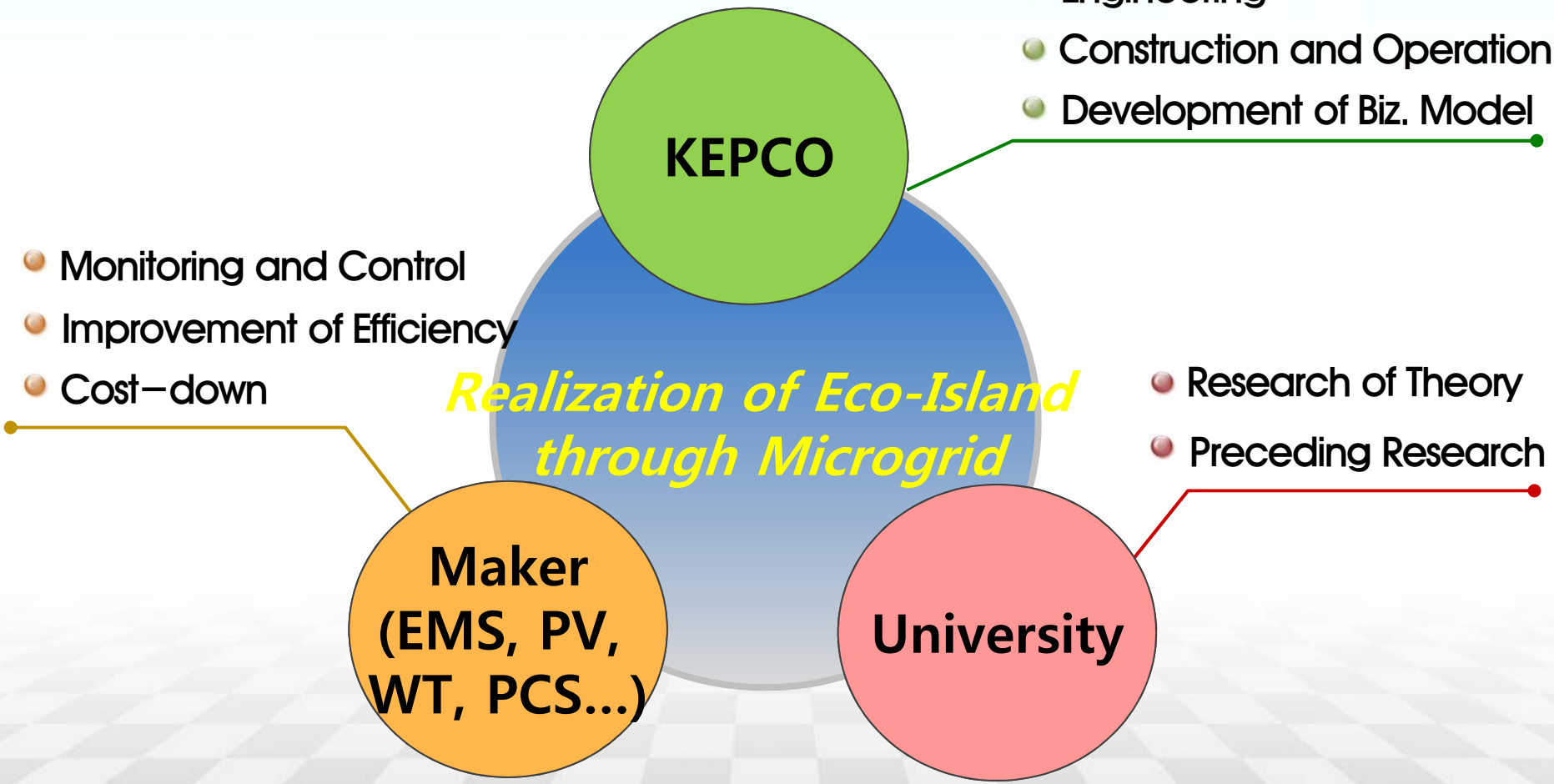

[2] Frequency Restoration by BESS

# Interesting Area in MicroGrid

- **Protection coordination**
  - ✓ Economical Feasibility, Bi-directional relay
- **Economic Feasibility**
  - ✓ Optimal sizing of renewables & battery
- **Utilization of surplus thermal energy**
  - ✓ Especially in Building type
- **V2G(Vehicle to Grid)**
  - ✓ V2G instead of Battery

# TeamWork in MicroGrid Business

- Development of Economic and Exportable Island Type Microgrid




Thank you
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