Test Results of a Pilot Plant for KERI Microgrid

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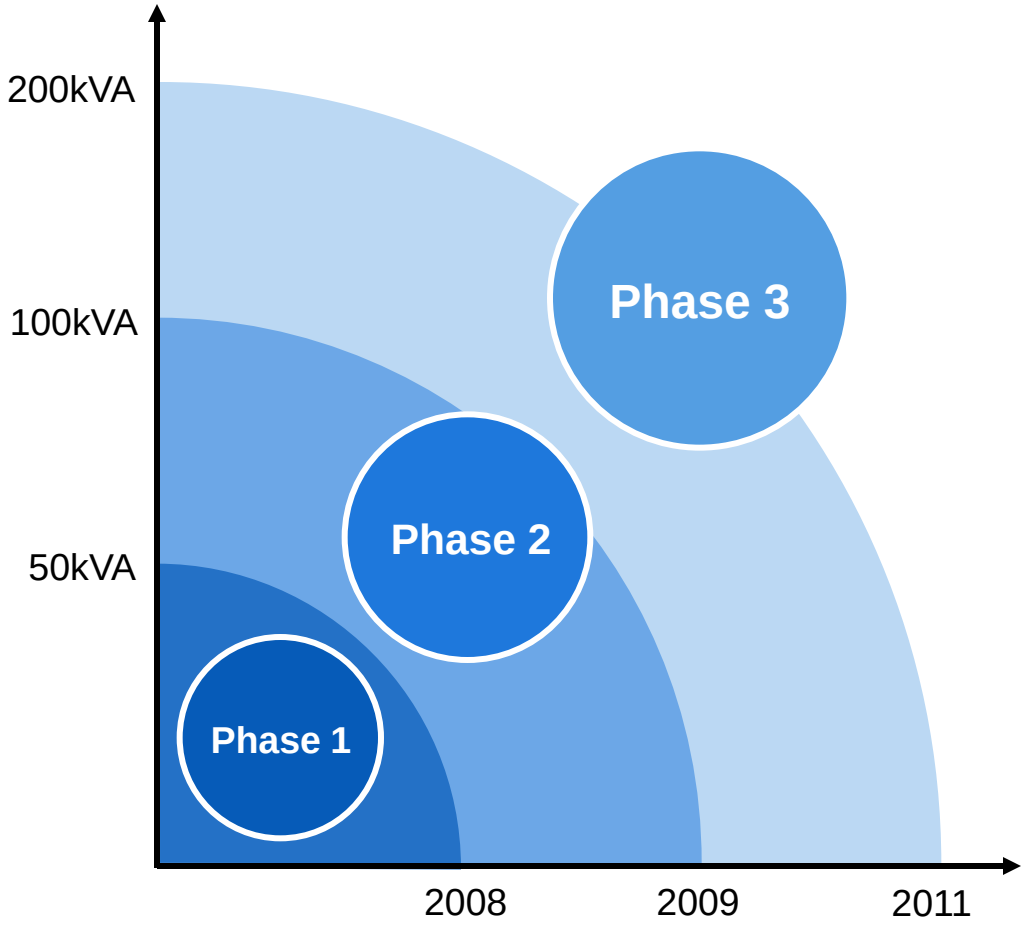
KERI Microgrid Pilot Plant



Phase 1

- 2007~2008
- System Size: 50kVA
- 3 Sources(1 Renewable, 1 DG, 1 Storage)
- PCC Power Flow Control, Islanding

Phase 2

- 2008~2009
- System Size: 100kVA
- 5 Sources(2 Renewables, 2 DGs, 1 Storage)
- PCC Flow Control, Islanding, Resynch.

Phase 3

- 2009~2011
- System Size: 200kVA
- 9 Sources(5 Renewables, 2 DGs, 2 Storages)
- PCC Flow Control, Islanding, Resynch., P.Q.

Pilot Plant Phase 1

Description

- Components

✓3 Sources, MMS, Loads
✓1 DG (20kVA D/E)
✓1 Renewable (20kVA PV/Wind Hybrid)
✓1 Storage (10kW BESS)

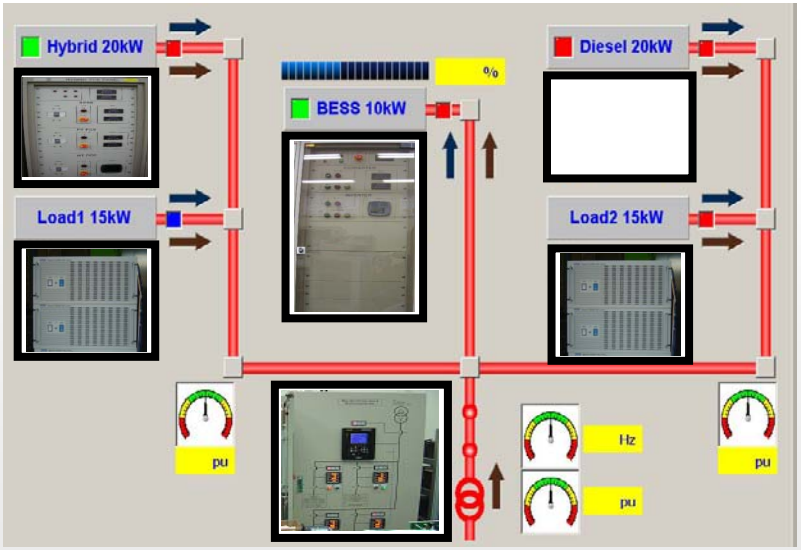
- Operations

✓ PCC Power Flow Control in Grid-Connected Mode
✓ Transition to Islanded Mode
✓ Frequency and Voltage Control in Island Mode

- Purposes

✓Construction of Pilot Plant
✓Basic Operation Test by Essential Elements
✓ Communication and Control Scheme Test

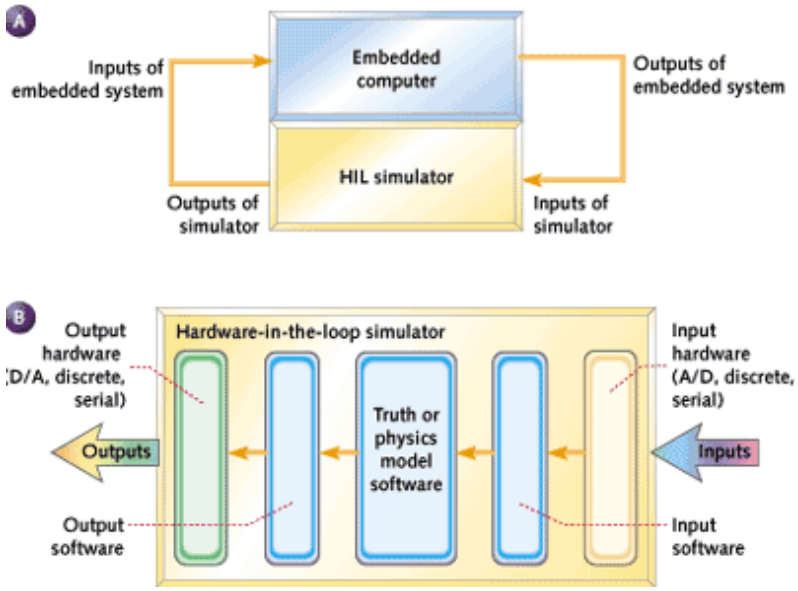
Phase 1 Pilot Plant Structure



3 Phase 380V, 50kVA Phase 1 System

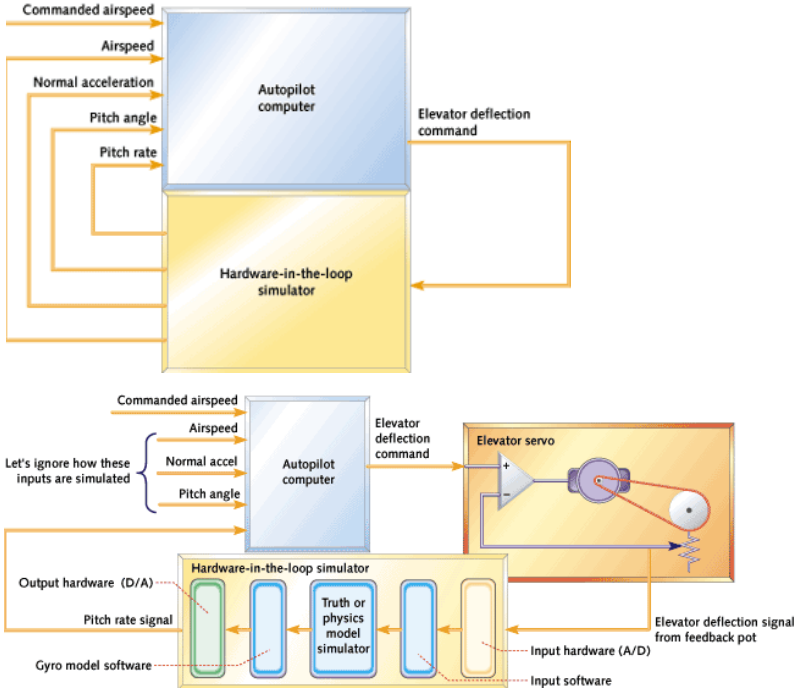
HILS (Hardware In-the-Loop Simulation)

“A technique used in developing and testing of complex real-time embedded systems”



A) Block diagram of embedded system connected to a hardware- in-the-loop simulator

B) Components of a simple hardware-in-the-loop simulator



Autopilot Example

www.embedded.com

Comparison of Different Approaches for MMS Performance Test

“How to test and debug the supervisory control algorithms of MMS”

	Off-Line Simulation	Real-Time HILS	Field Test
Reliability	Up to S/W Models	High	Very High
Necessary Equipment	S/W Tools, S/W Models (microgrid/MMS)	Real-Time Simulator, I/O interface, S/W models(microgrid), H/W component under test(MMS)	All relevant H/W components (microgrid, MMS, I/O interface, measuring devices)
Parameter Alterations	Fully Possible	Fully Possible	Limited
Repeatability Reproducibility	Fully Possible	Fully Possible	Limited
Relative Develop Time	Fast	Medium	Slow
Speed	Much Longer than Real-Time	Real-Time	Real-Time
Development Cost	Less than HILS	Less than Field Test	High

Requirements for MMS HILS Test

Needs for Microgrid Simulation

- Easy to Model Power System Components
- Easy to Use User Define Model for RES
- Easy to Simulate Power System
- Hard Real Time Simulator

RTDS Yes

Needs for MMS Interface

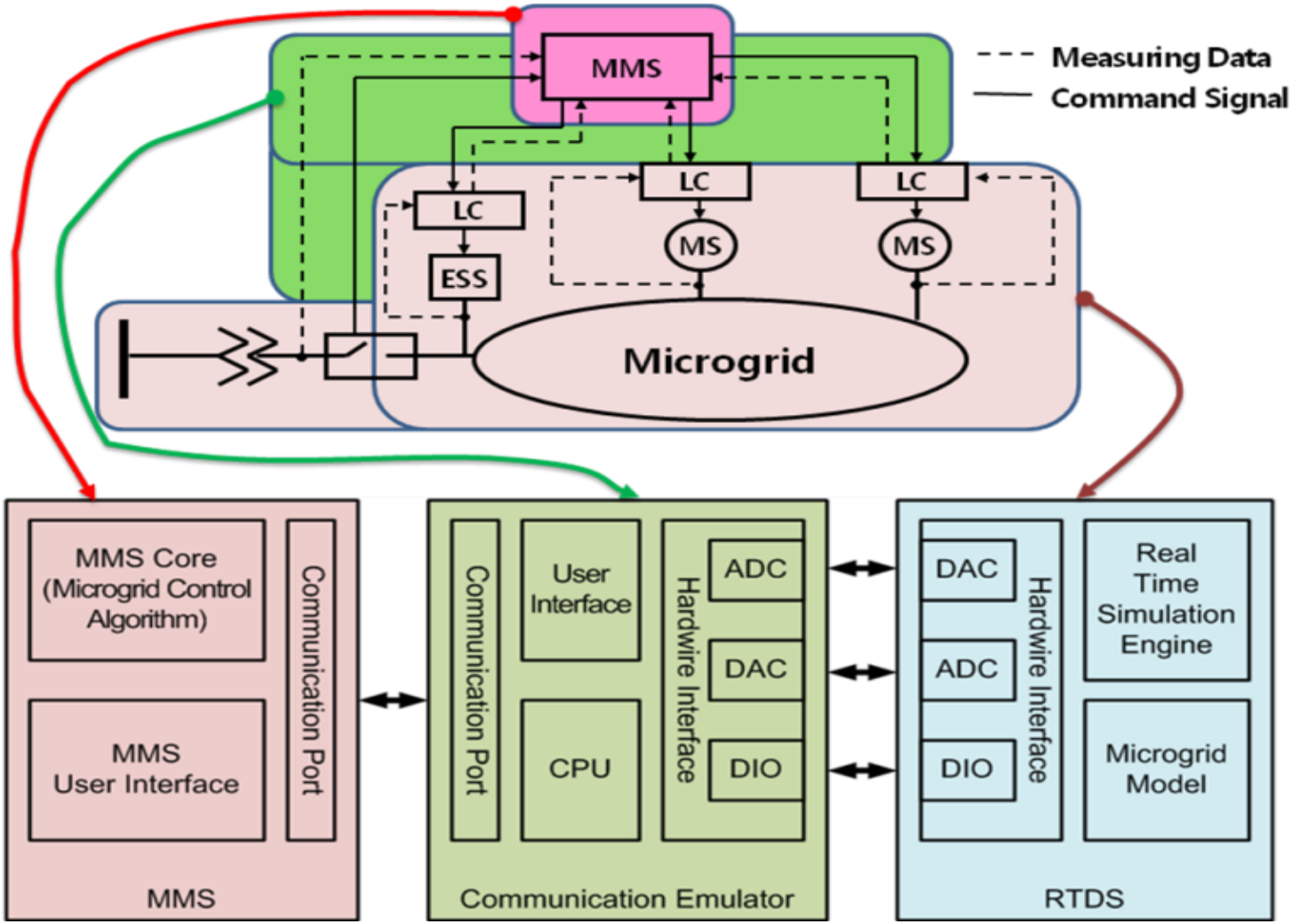
- RS232 or RS485 Interface
- Easy to Use User Define Protocols
- Easy to Use Modbus Protocols

RTDS No

- RTDS Interface
  - ✓ Analog and Digital Interface by I/O Card
  - ✓ IEC61850 Protocol by GTNET Card

Need Something for Communication Interface → **Communication Emulator**

Proposed HILS System

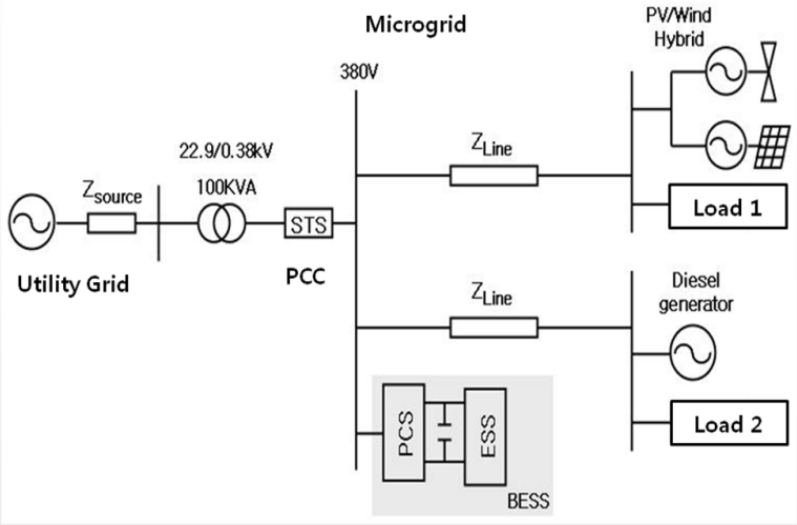


Real Time Simulation Model

Major Parameters for Simulation Model

Item	Specification
Test System Configuration	•No. of Sources: 3 (Hybrid, Diesel generator, BESS) •No. of Loads: 2 •No. of STS: 1(Static Switch)
Generation Capacity of Micro-sources	•Hybrid 20kW(PV 10kW, Wind 10kW) •Diesel generator 20kW •BESS system 10kW
Load1, Load2	•15kW+j9kVar •Constant impedance model (R/X)
Transformer	•3phase 22.9/0.38kV 100kVA •Leakage impedance %Z = 6%
Line impedance	•R= 0.1878Ω/km, X=0.0968Ω/km

Schematic Diagram of Simulation Model



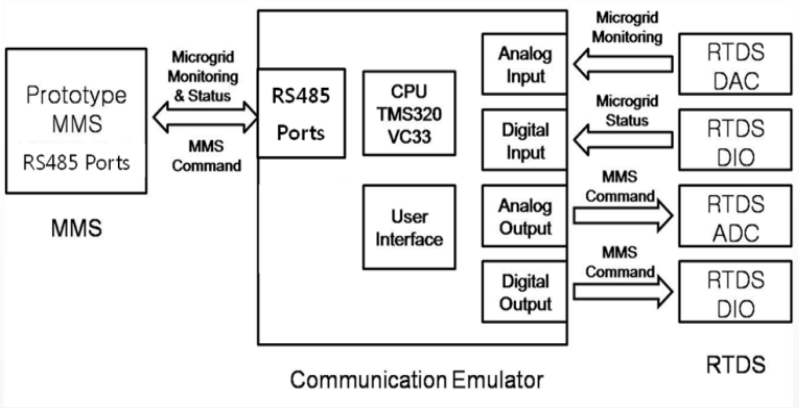
3 Phase 380V, 50kVA Phase 1 System

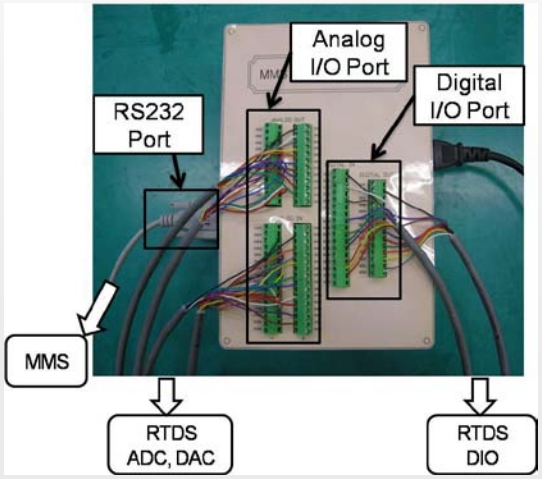
Communication Emulator

Specification

Item	Specification
CPU	TMS320VC33-150
Analog Input	16 Channel, ±10V, 12bit Resolution 500kS/s, 1kHz-40dB bandwidth
Digital Input	16 Channel, TTL
Analog Output	12 Channel, ±10V, 12bit Resolution 1kHz-40dB bandwidth
Digital Output	12 Channel, TTL
Communication	RS-485 3Ports
User Interface	Status LED 8EA, Character LCD
Size	300mm x 210mm x 80mm

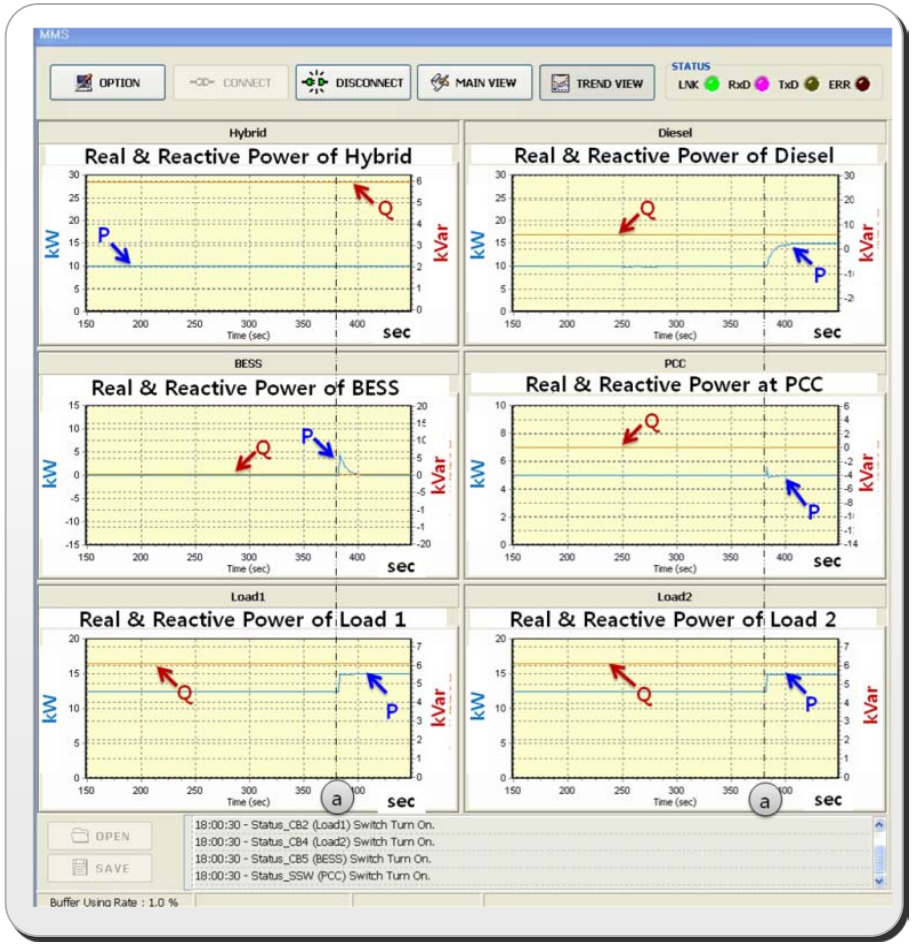
Schematic Diagram and Prototype



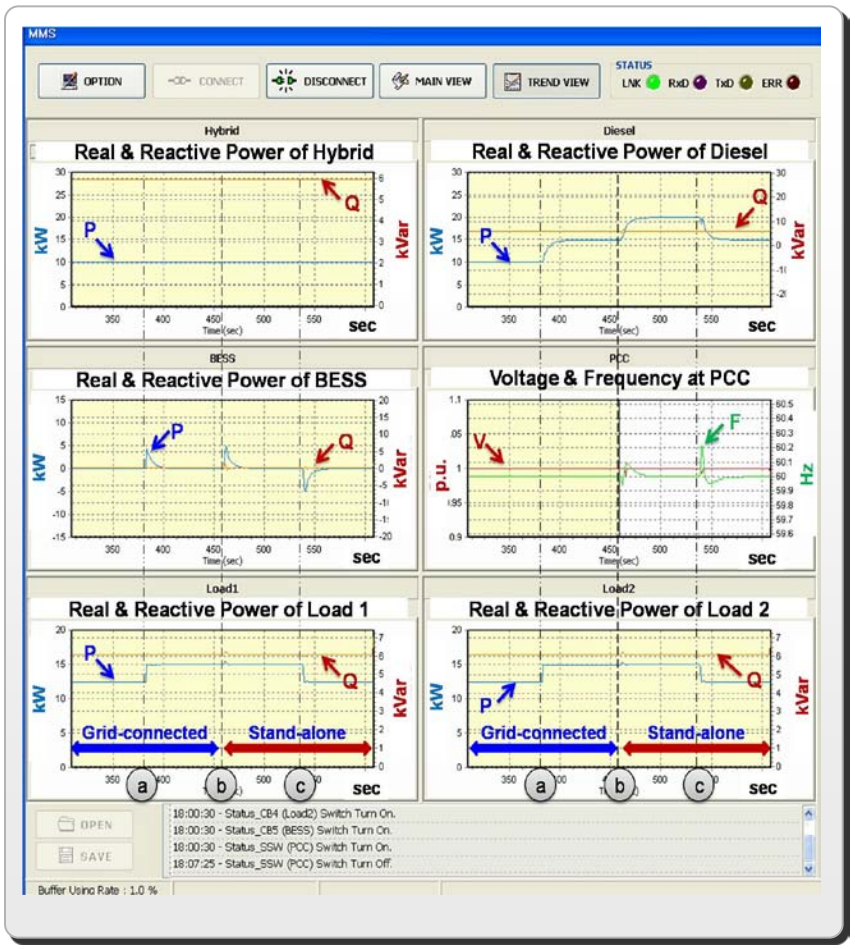


HILS Test Results for Phase 1 System

Grid-Connected Mode

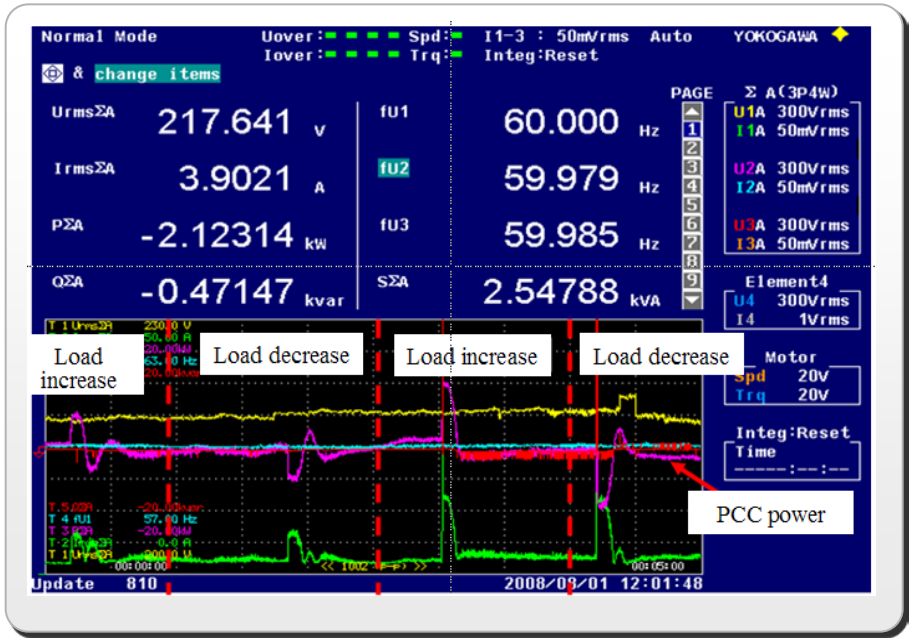


Island Mode

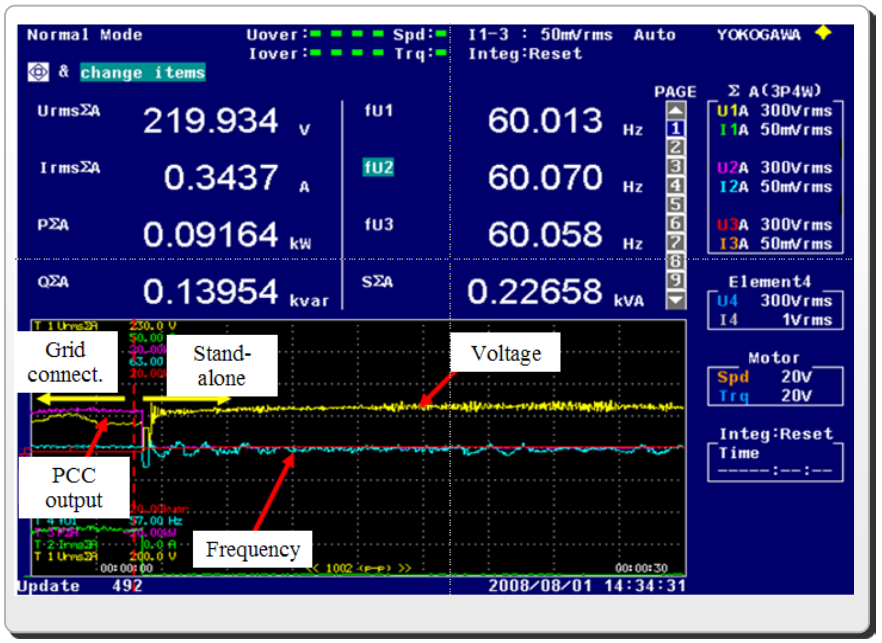


Test Results of Phase 1 System

Grid-Connected Mode



Island Mode



Pilot Plant Phase 2

Description

- Components

✓5 Sources, MMS, IED/STS, Loads

✓2 DGs (20kVA D/E, 50kVA D/E)

✓2 Renewables (20kVA PV/Wind Hybrid, 10kW PV)

✓1 Storage (20kW BESS)

- Operations

✓ PCC Power Flow Control in Grid-Connected Mode

✓ Transition to Islanded Mode/Resynch.

✓ Frequency and Voltage Control in Island Mode

✓ Economically Optimized Dispatch

✓ Black Start

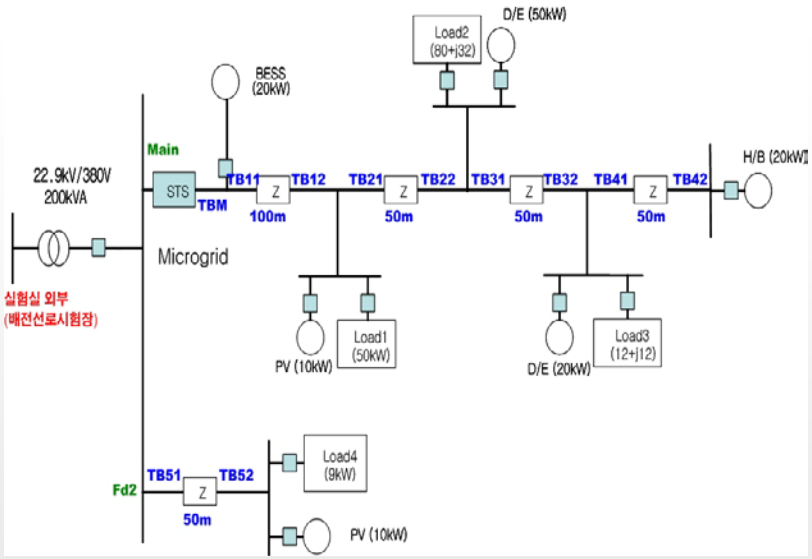
- Purposes

✓ More Operation Test with More Components

✓ CHP Test with Simulated Thermal Load

✓ Performance Test of Microgrid Components

Phase 2 Pilot Plant Structure



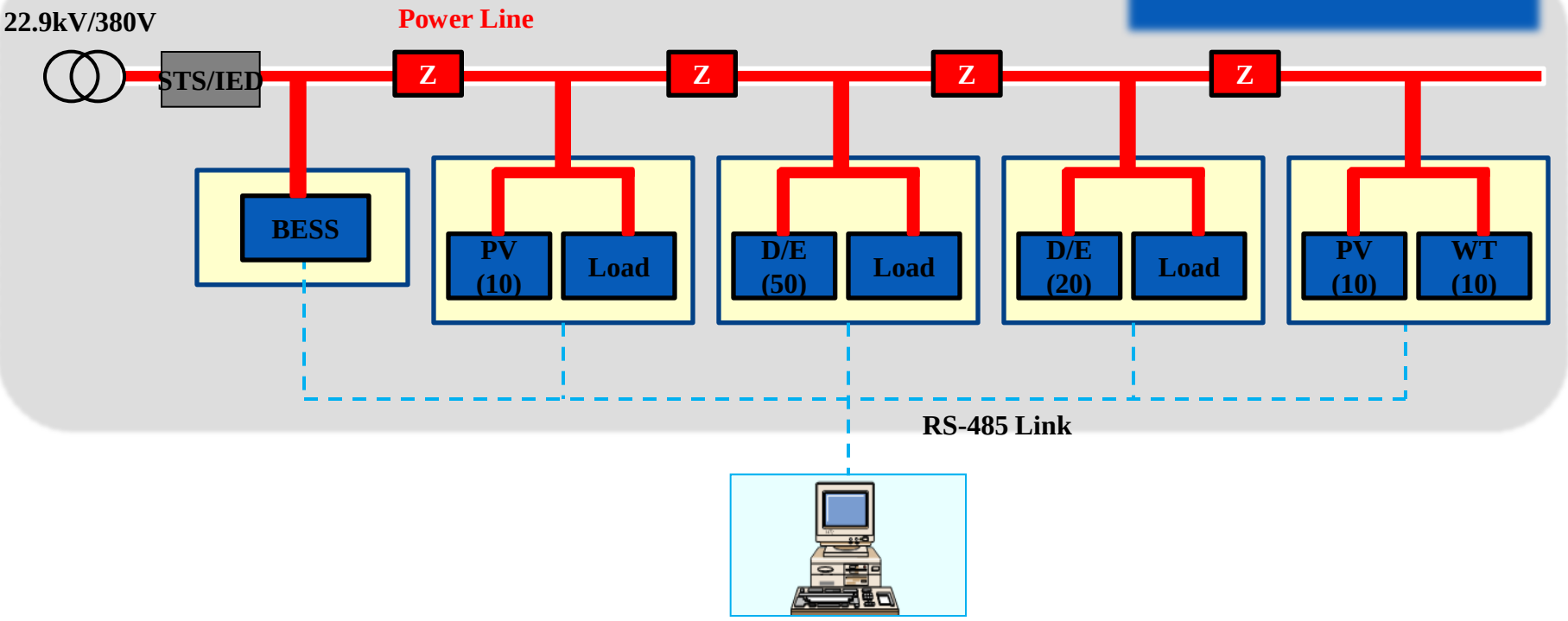
3 Phase 380V, 100kVA Phase 2 System

Configuration of Phase 2 System

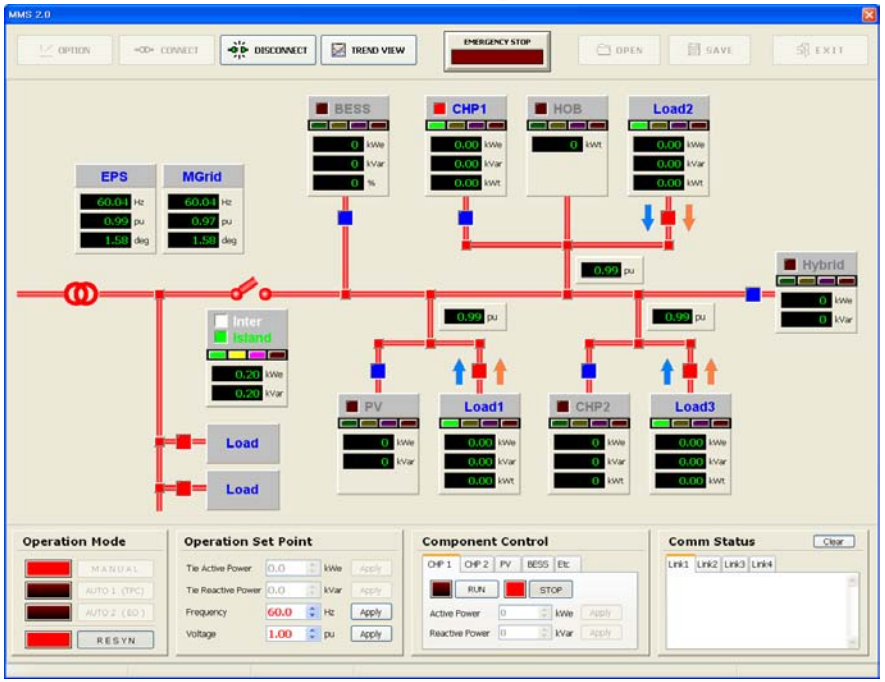
Total Load : 100kW+j44kVar

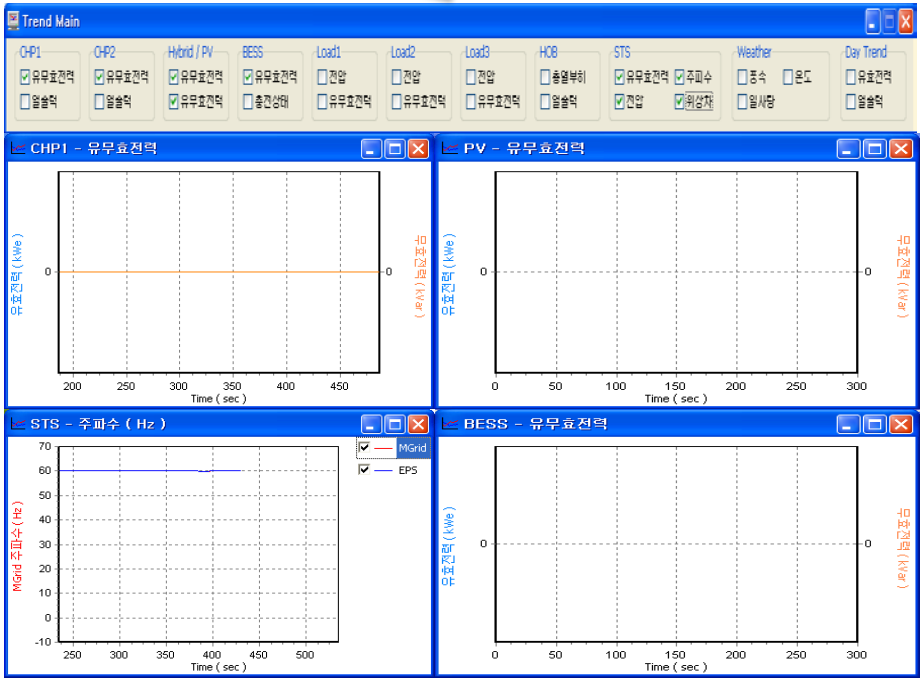
Total Gen : 120kW

- D/E : 70kW (50kW+20kW)
- RES : 30kW
- BESS : 20kW



MMS for Phase 2 System



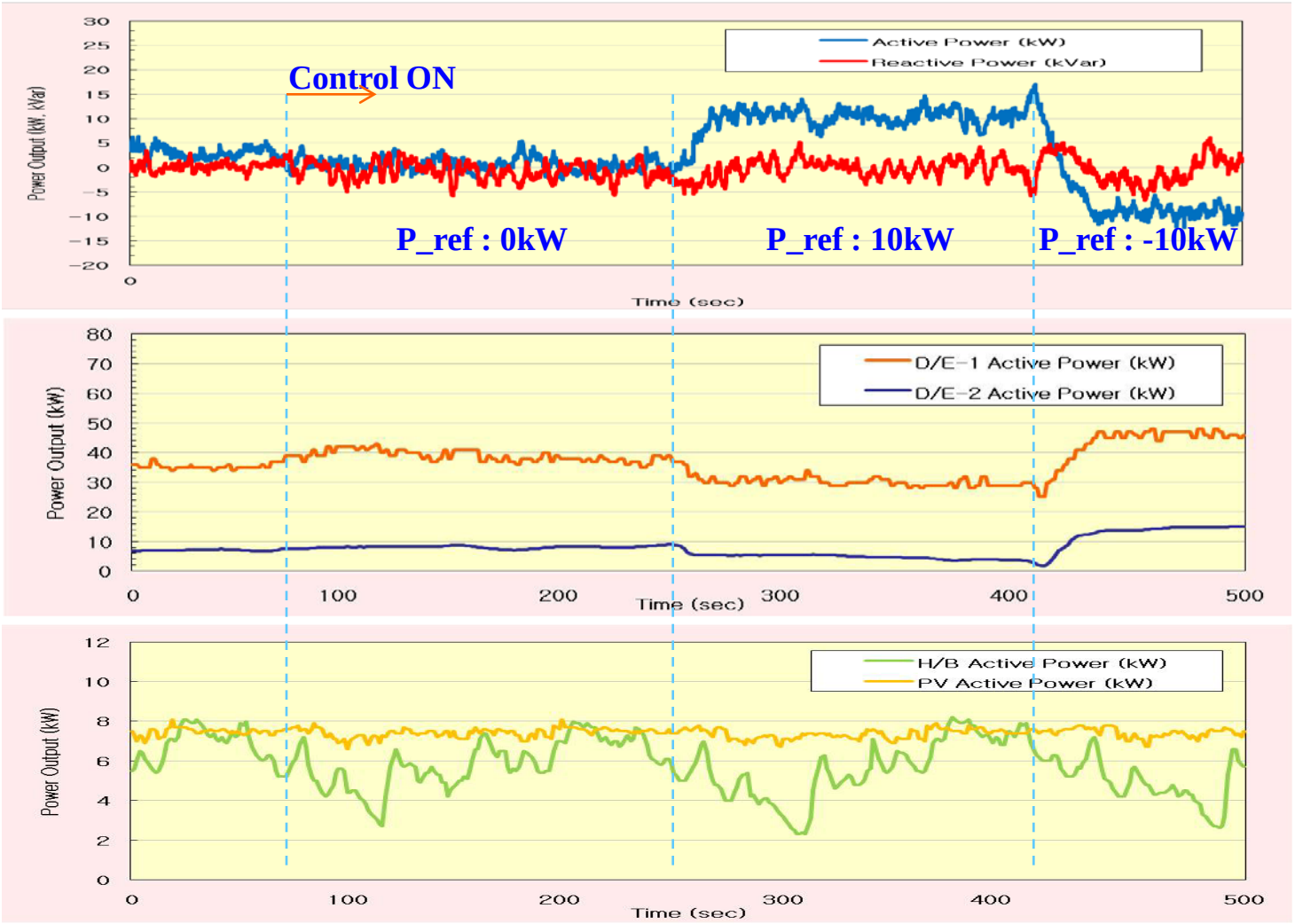


Test Cases for Phase 2 System

Case	Operation Mode	Control Mode	Control Function
Case-1-1	Inter Mode	μ-source -> P,Q cont. BESS-> P,Q cont.	Active Power Control of PCC
Case-1-2			
Case-2-1	Inter -> Islanded	μ-source -> P,Q cont. BESS-> F/V cont.	F/V Control of Microgrid
Case-2-2			
Case-3	Resynch	μ-source -> P,Q cont. BESS-> F/V cont.	Resynchronization

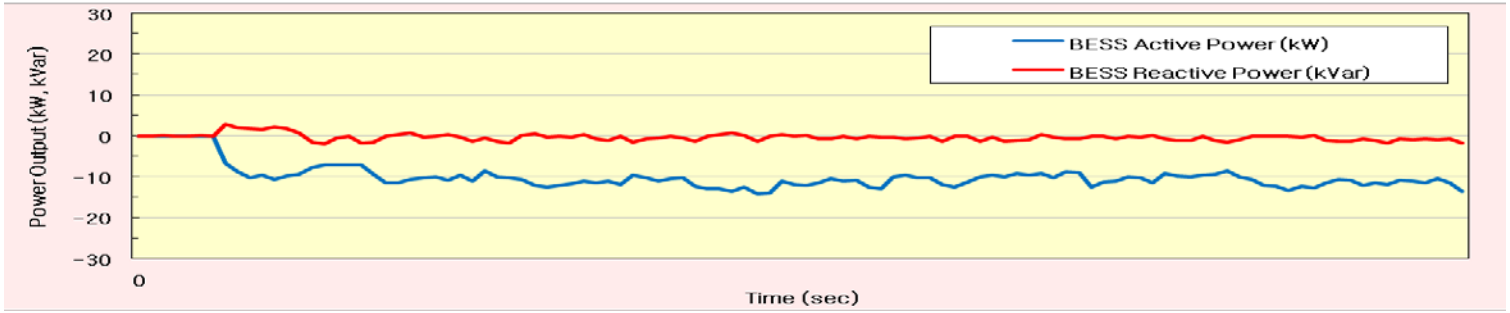
Test Results of Phase 2 System

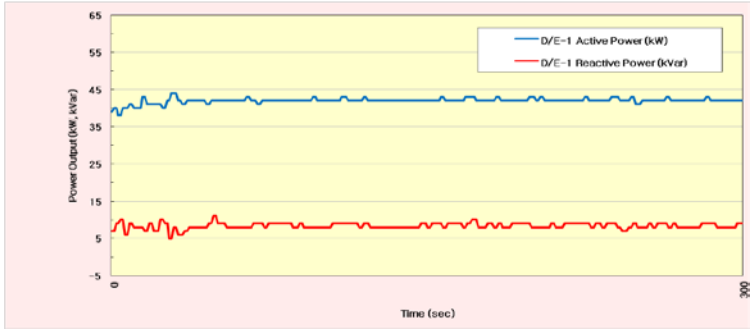
Case 1: Active Power Control of PCC in Inter. mode

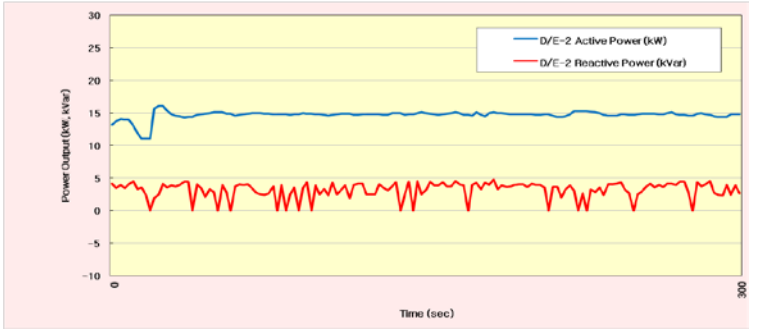


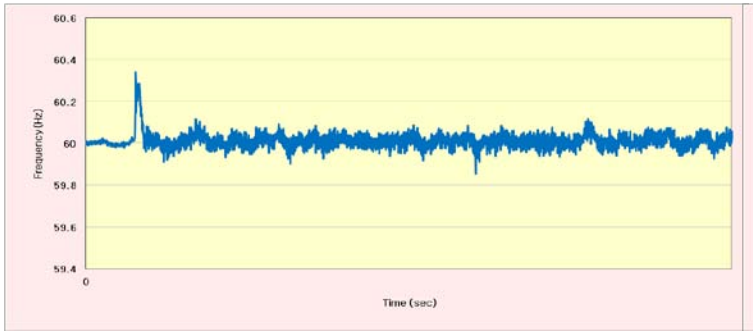
Test Results of Phase 2 System

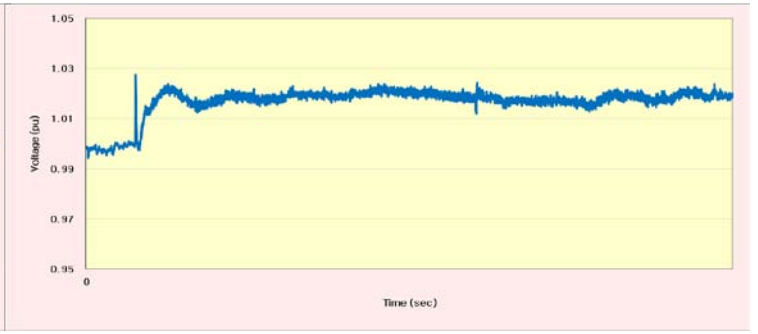
Case 2: Frequency/Voltage Control in Islanded mode









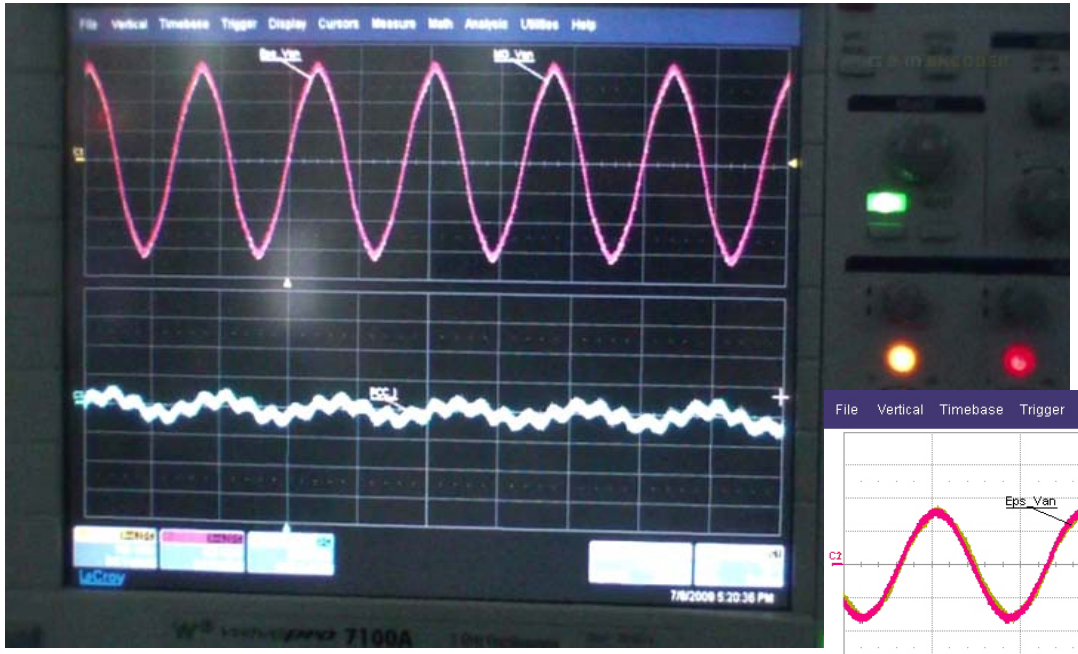


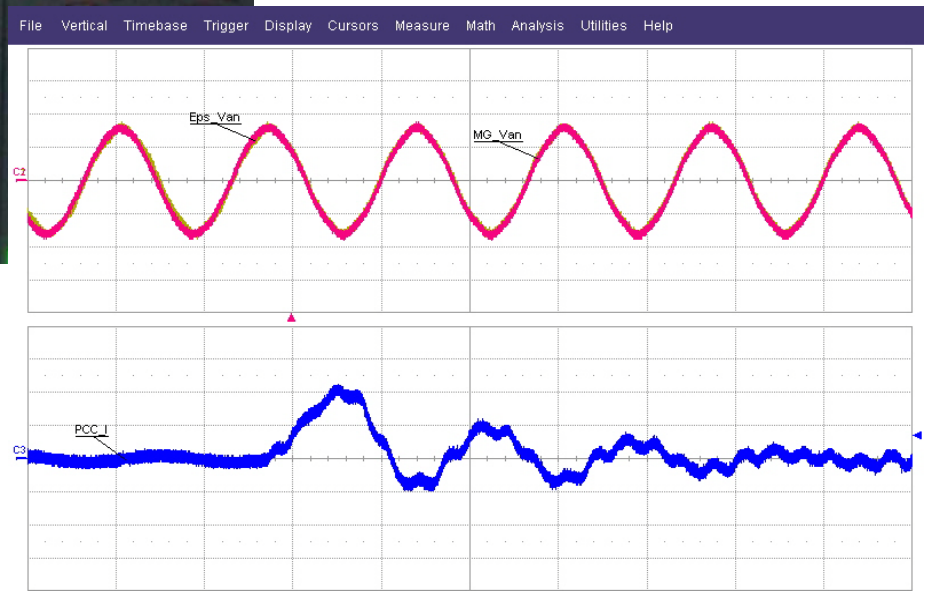
Test Results of Phase 2 System

Case 2: Frequency/Voltage Control in Islanded mode

Test Results of Phase 2 System

Case 3: Reconnection with Utility Grid





Pilot Plant Phase 3

Description

- Components

✓9 Sources, MMS, IED/STS, Loads

✓2 DGs (20kVA D/E, 50kVA D/E)

✓5 Renewables (20kVA PV/Wind Hybrid, 30kW PV, 10kW Wind, 10kW Thermo-Electric, 1kW Fuel Cell)

✓2 Storage (50kW BESS, 30kW EDLC)

- Operations

✓ PCC Power Flow Control in Grid-Connected Mode

✓ Transition to Islanded Mode/Resynch.

✓ Frequency and Voltage Control in Island Mode

✓ Economically Optimized Dispatch

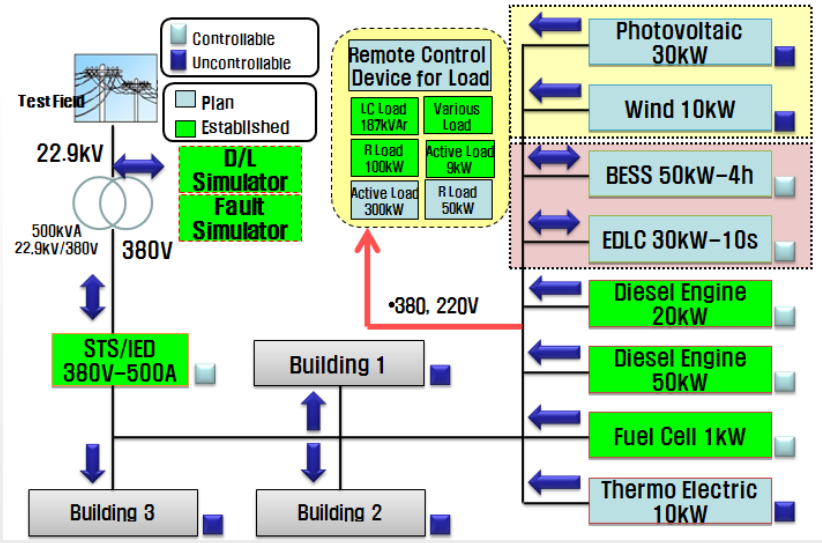
✓ Black Start, Power Quality Compensation

- Purposes

✓ Operation Test with Real-Site Load

✓ Demonstrate a Low Voltage Commercial Power Supply System

Phase 3 Pilot Plant Structure



3 Phase 380V, 200kVA Phase 3 System

Thank You!

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