



# Microgrid Demonstration based on the IEC61850 Communication Technology



2015-08-27 Aalborg Symposium on Microgrids  
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# IEC61850 summary

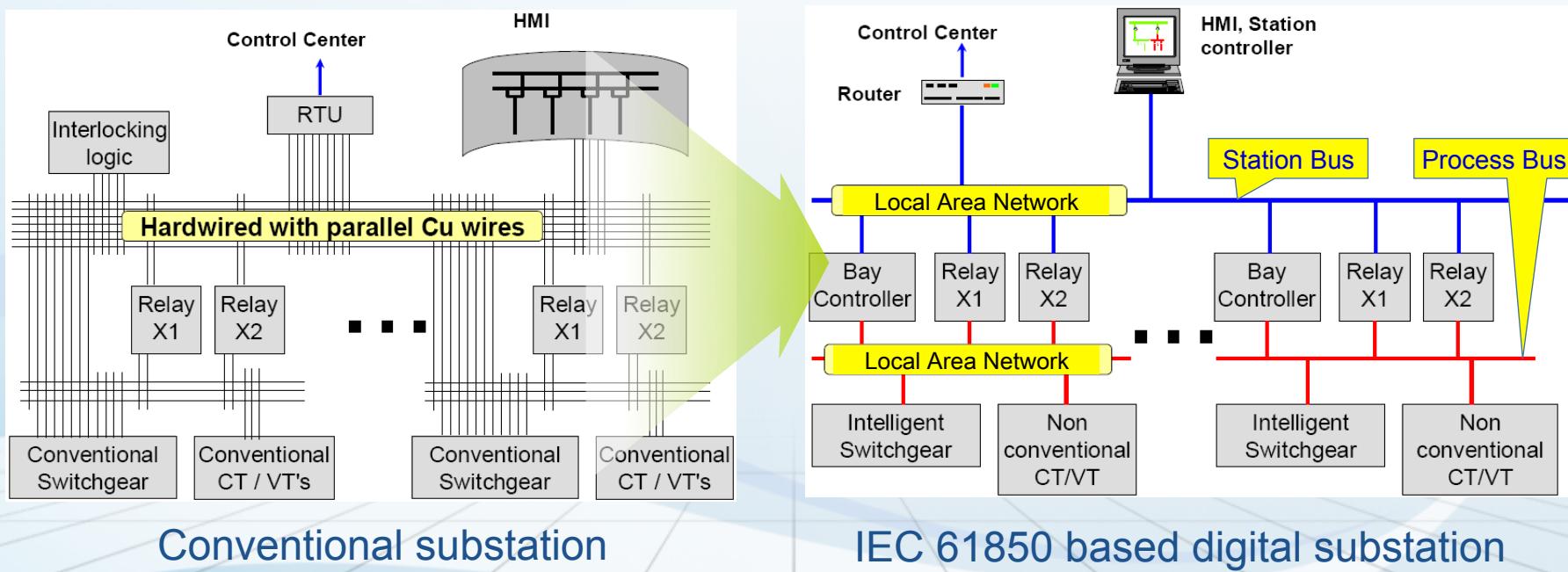
- ❖ Communication Networks and Systems in Substation (Ed.1 2003)



- ❖ IEC International Standard that was merged from IEC60870 and IEEE UCA 2.0
- ❖ IEC TC 57
  - Power systems management and associated information exchange
  - EMS, SCADA, Distribution automation, Tele-control, Tele-protection
  - WG10 --- Power system IED communication and associated data
- ❖ defines Data models(What to), Service(How to), Configuration language
- ❖ decoupled Data model (Slow changing) from communication stack (Fast changing)
- ❖ Client/Server (MMS message), Subscriber/Publisher (GOOSE, SV)
- ❖ XML based Self-descriptive SCL files (Engineering tool)

# IEC61850 benefits

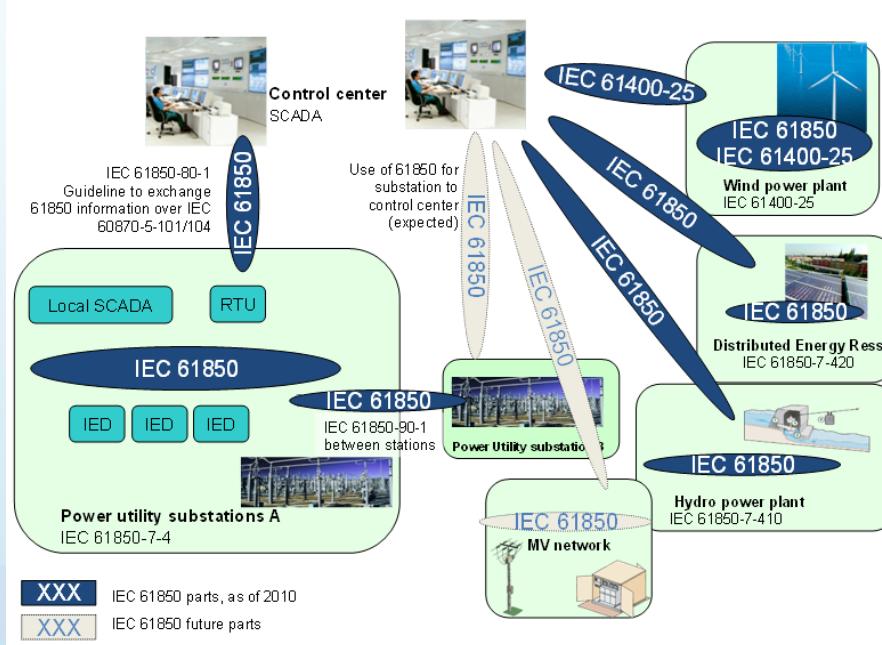
- ❖ Interoperability – manufacturer and customer
- ❖ Free configuration – provides flexibility in system design
- ❖ Long term stability – reduces Maintenance costs
- ❖ Reduced wiring – Installation/Commissioning costs



Conventional substation

IEC 61850 based digital substation

# IEC61850 standards expansion



Part	Title	Status	Ed.
IEC61850-1	Introduction and overview	OK	2.0(13.03)
IEC61850-2	Glossary	OK	1.0(3.08)
IEC61850-3	General requirements	OK	2.0(13.12)
IEC61850-4	System and project management	OK	2.0(11.04)
IEC61850-5	Communication requirements for functions and device models	OK	2.0(13.01)
Part	Title	Status	Ed.
IEC61850-7-1	Guideline to exchanging info. from a CDC-based data model using IEC 60870-5-101/104	OK	1.0(08.12)
IEC61850-7-2	mapping to web protocols - requirement analysis and technology assessment	New item	Telecontrol
IEC61850-7-3	Mapping between the DLMS/COSEM (IEC 62056) and the IEC 61850 data models	Process	AMI
IEC61850-7-4	Guideline for mapping information between IEC 61850 and IEC 61158-6 (Modbus)	Process	
IEC61850-7-410	Use of IEC 61850 for the communication between substations	OK	1.0(10.03)
IEC61850-7-420	Using IEC 61850 for the communication between substations and control centres	Process	
IEC61850-7-5	Using IEC 61850 for condition monitoring	New item	
IEC61850-7-500	Network engineering guidelines	OK	1.0(13.08)
IEC61850-7-510	Use of IEC 61850 to transmit synchronphasor information according to IEEE C37.118	OK	1.0(12.05)
IEC61850-7-520	Use of IEC 61850 for distribution automation systems	New item	
IEC61850-8-1	Object models for power converters in distributed energy resources (DER) systems	OK	1.0(13.02)
IEC61850-8-2	IEC 61850 object models for electrical mobility (EV)	New item	
IEC61850-9-1	Use of IEC 61850 for electrical storage systems	New item	
IEC61850-9-2	IEC 61850 object models for scheduling	New item	
IEC61850-10	Methodologies for modeling of logics for IEC 61850 based applications	New item	
IEC61850-10-2	Wide area network engineering guidelines	New item	
IEC61850-10-210	Extension of IEC 61850 info. Models(logical nodes & data models) for steam & gas turbines	Process	
IEC61850-90-13	FACTS data modeling	New item	
IEC61850-90-14	Hierarchical architecture of a DER system	New item	
IEC61850-90-15	System management	New item	
IEC61850-90-16	Using IEC 61850 to transmit power quality data	New item	
IEC61850-100-1	Commissioning testing of IEC 61850 based systems	New item	

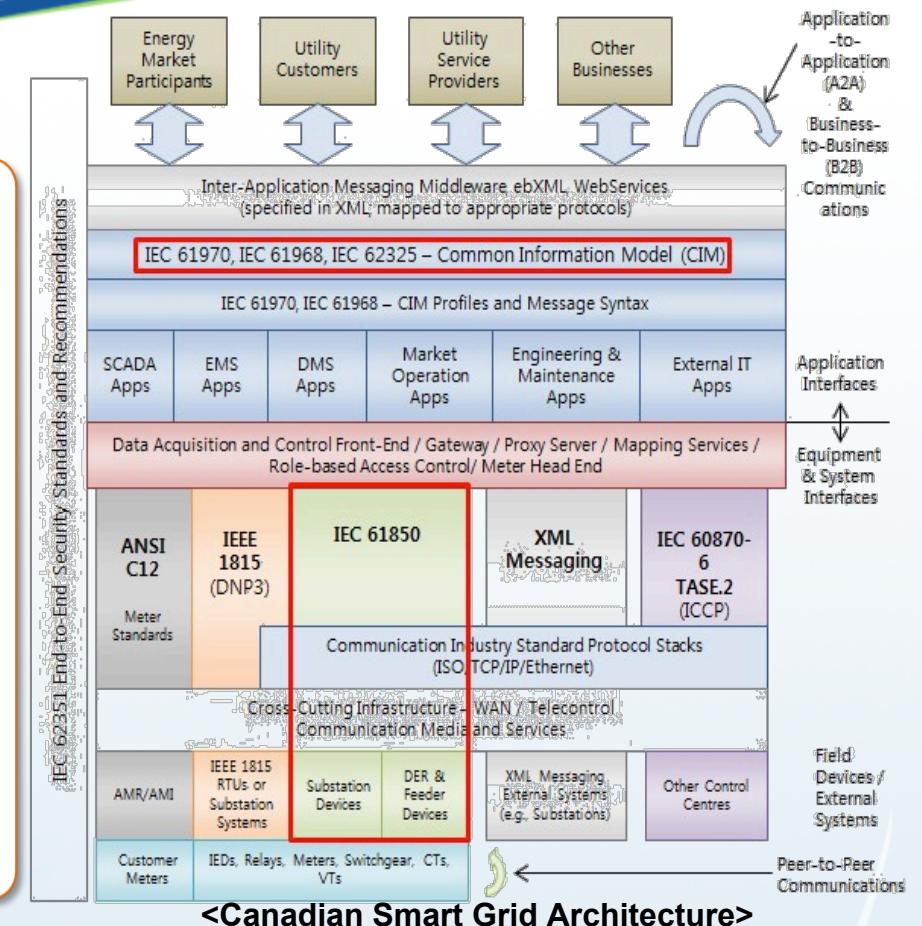
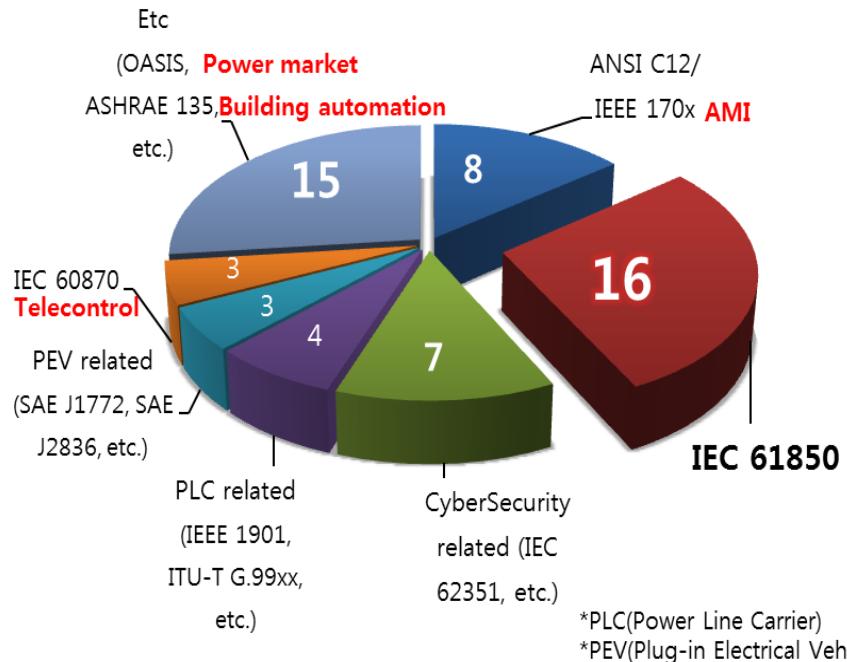
- IEC 61850 Ed1→Ed2 : "Communication Networks and Systems ~~in Substation~~ for Power Utility Automation"

- Standards expansion

Telecontrol, AMI, Condition monitoring, PMU, Distribution automation, DER, EV, ESS, FACTS, Power quality

# IEC61850 in Smart Grid

## NIST Smart Grid Roadmap 3.0 - Catalog of Standards>



<Canadian Smart Grid Architecture>

### Cyber Security <IEC 62351>

- IEC 62351-1 : Communication network and system security - Introduction to security issues
- IEC 62351-2 : Glossary of terms
- IEC 62351-3 : Communication network and system security - Profiles including TCP/IP
- IEC 62351-4 : Profiles including MMS
- IEC 62351-5 : Security for IEC 60870-5 and derivatives
- IEC 62351-6 : Security for IEC 61850
- IEC 62351-7 : Network and system management (NSM) data object models

**16 IEC 61850 related Stds. from 56 Total (29.1%)**

### Canadian Smart Grid Architecture

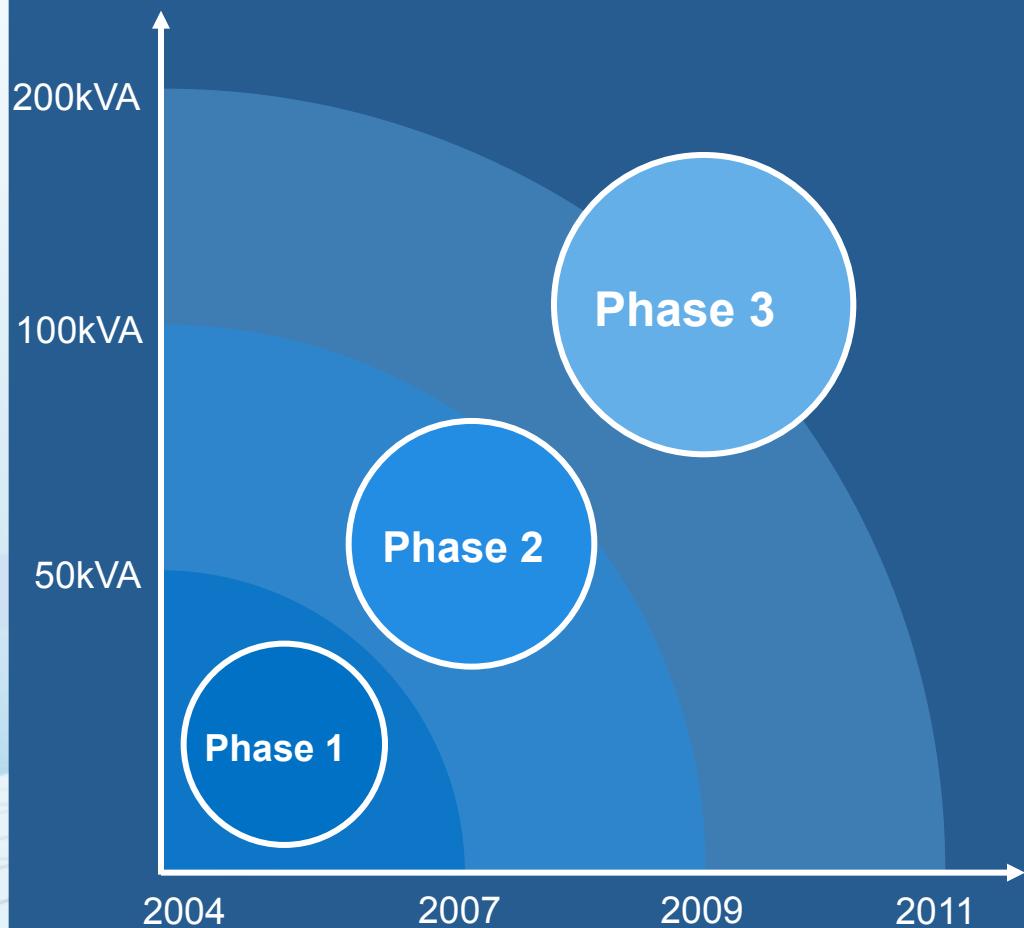
- IEC 62357-1(Service Oriented Architecture) based structure
- consists of 5 major layers
- defines the relationship between business layer, application layer, service layer, field device protocols

# KERI Microgrid

**K**orean  
**E**nvironmental  
**R**eliable  
**I**ntelligent  
**MICROGRID**



# KERI Microgrid Project History



## Phase 1

- 2004~2006
- System Size: 50kVA
- 3 Sources(1 Renewable, 1 DG, 1 Storage)
- Basic functions of DGs(MPPT,Anti-Islanding)

## Phase 2

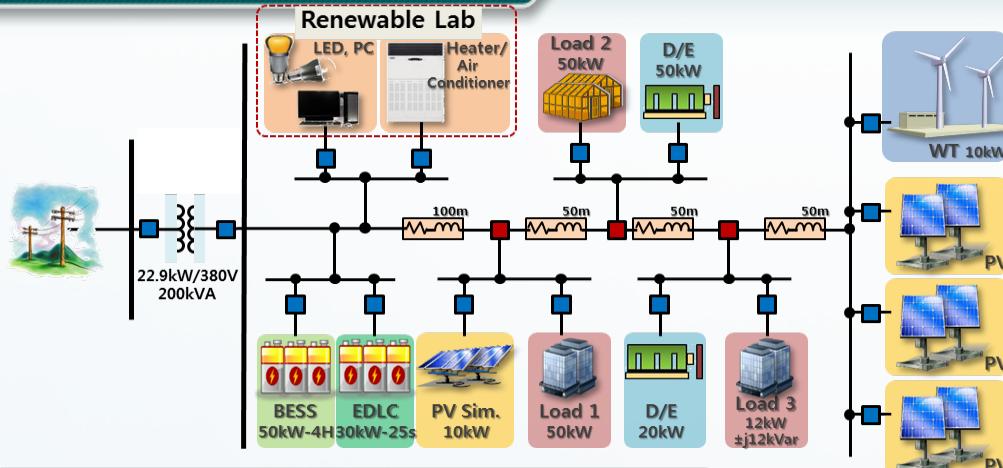
- 2007~2009
- System Size: 100kVA
- 5 Sources(2 Renewables, 2 DGs, 1 Storage)
- PCC Flow Control, Islanding, Resynch.

## Phase 3

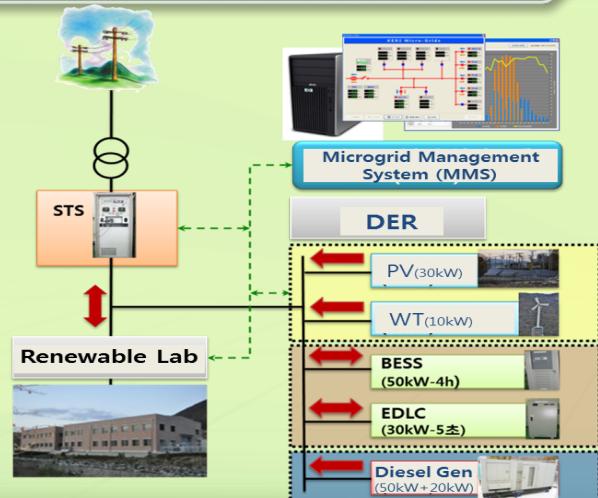
- 2009~2011
- System Size: 200kVA
- 9 Sources(5 Renewables, 2 DGs, 2 Storages)
- Real Load, Energy Optimization, Power Quality

# KERI Microgrid

## Microgrid Pilot Plant



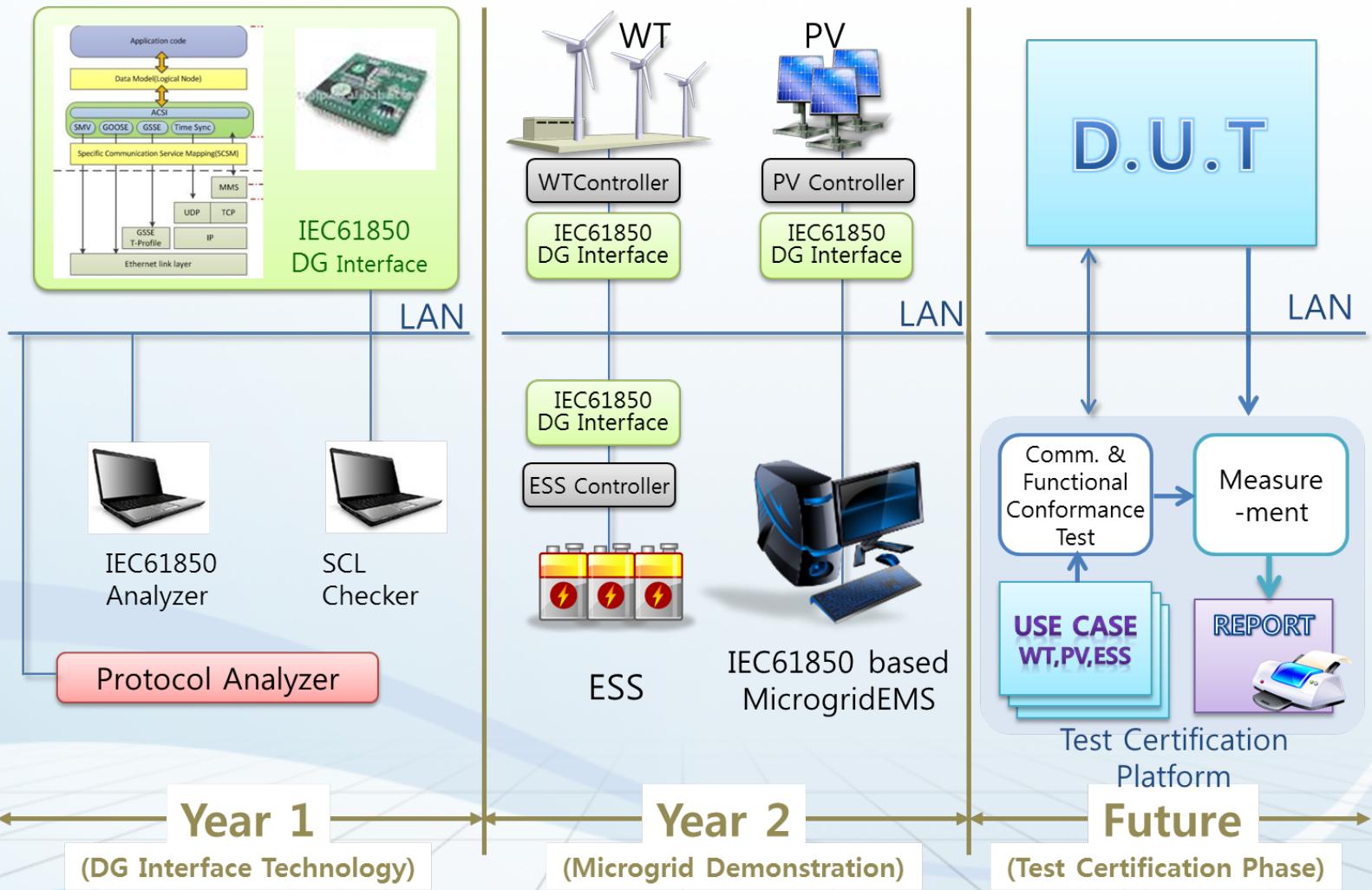
## Microgrid Demonstraion - Grid Connected



## Hybrid Coordinated Control - Islanded MG



# KERI IEC61850 Roadmap



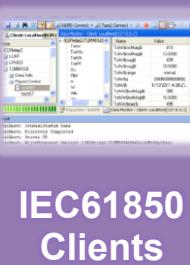
❖ **WT** : Wind Turbine   **PV** : Photovoltaic   **ESS** : Energy Storage System   **EMS** : Energy Management System

# IEC 61850 DG Interface

## IEC61850 System



Other  
IEC61850  
Servers



IEC61850  
Clients



KERI DGIF-61850-001

## Distributed Generation



### Features

Credit card sized 1GHz processor  
Embedded Linux OS  
DG <-> IEC 61850 Interface  
Data models for DG  
Serial communication with DG device



### Supported IEC 61850 Services

Server, Association, DataSet, GOOSE,  
Reporting, Control, File transfer, Time-sy-  
nc, etc.

#### S/W Compatibility

Angström Linux  
Android  
Ubuntu  
Cloud9IDE on node.js  
BoneScript Library  
more...

#### Performance

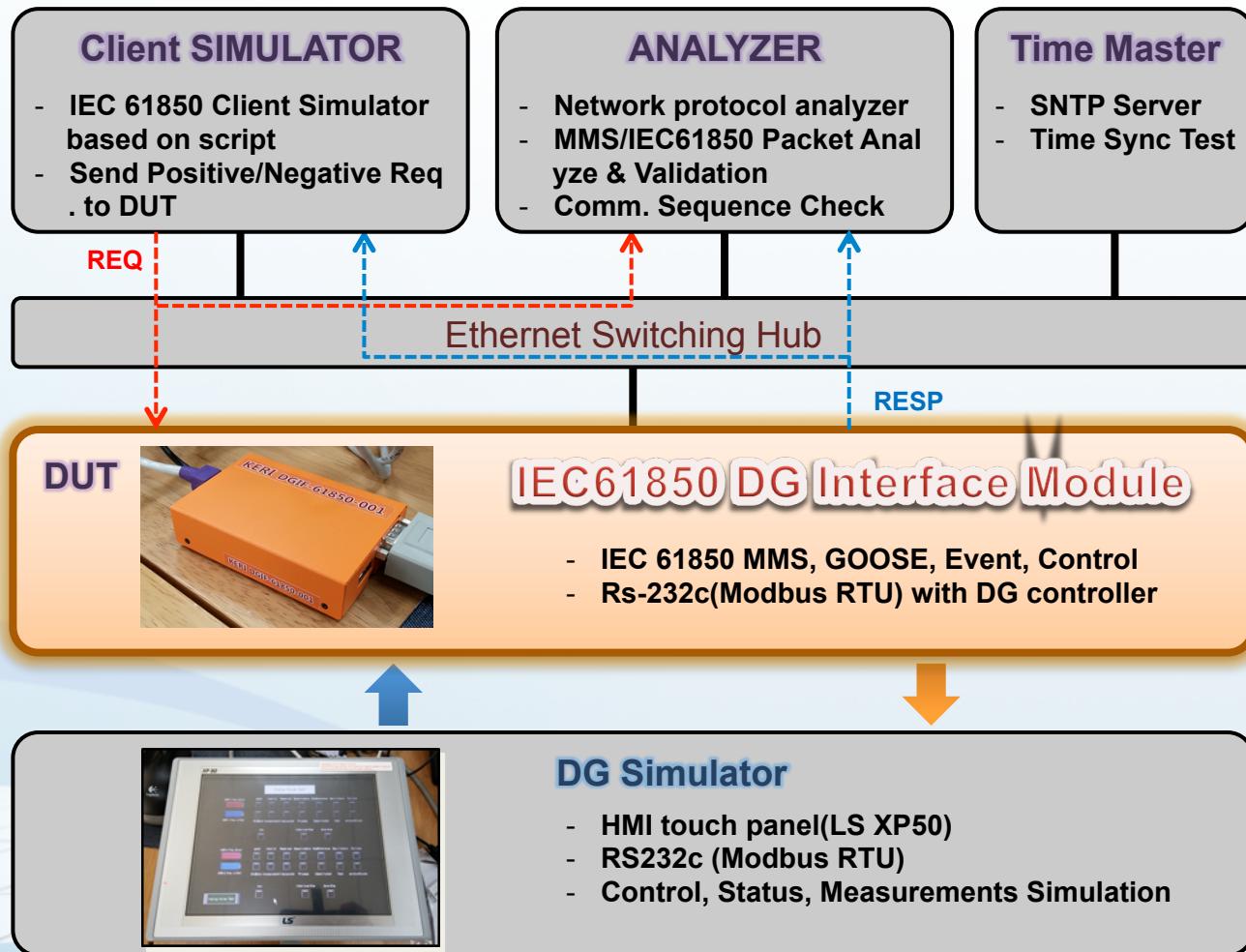
AM335x 1GHz ARM Cortex-A8  
3D graphics accelerator  
NEON floating-point accelerator  
2x PRU 32-bit microcontrollers

#### Connectivity

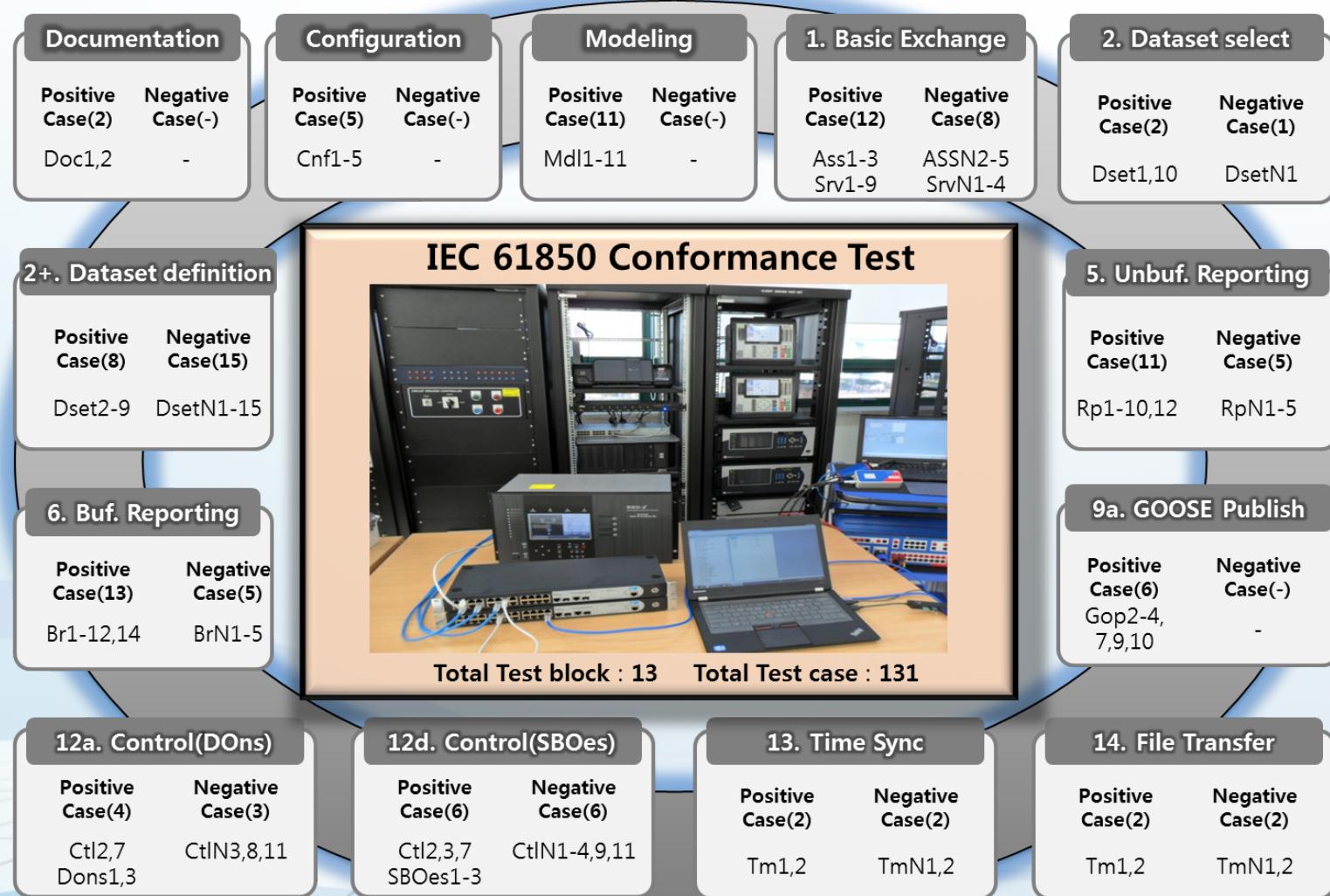
USB client for power/debug  
USB host Ethernet HDMI  
2x 46 headers uSDHC  
SPI, I2C, GPIO(69), LCD, 7AIN,  
4Timers, 4Serial, CAN0, etc...  
5V DC power



# IEC61850 conformance test



# IEC61850 conformance test



<IEC61850 Conformance Test Block & Cases>

# IEC61850 conformance test

1st Test 14.04.16~14.04.17

61/131 Cases passed  
Progress : 45%  
Basic functional Test

2nd Test 14.05.29~14.05.30

80/131 cases passed  
Progress : 61%  
Additional functions and  
Exception handling Test

3rd Test 14.06.19~14.06.20

131/131 cases passed  
Progress : 100%  
Documentation check  
and Final Test

#	Test Procedure / Description	Problem	DER interface	IED Discovered	S-Suite	SP
1	All quality values have the normal values. FCN<="1" is required if the function is not implemented. The name space field is required, when LN or CDD or DB is differently defined from the standard.					
2	Srv6  Except GoEna, all components in GoCBs are not allowed to write for changing. If GoEna is changeable, GOOSE message should follow GoEna.		DER interface	16-Apr-14 OPEN	ISSUE	
3	GopN1  ED<="1" is required if the function is not implemented. In association, "ServiceSupporteded" field should reflect only for which service DUT can provide.		DER interface	16-Apr-14 OPEN	ISSUE	
4	Ass1  DUT didn't transmit any packet for KEEP ALIVE checking.		DER interface	16-Apr-14 OPEN	ISSUE	
5	AssN4  The initial value of SUlt was "0", but there is no definition of "0" in ENUM. DUT could make more datasets than PIXIT described		DER interface	16-Apr-14 OPEN	ISSUE	
6	SrvN2  Error code should be changed from "definition invalid address".		DER interface	16-Apr-14 OPEN	ISSUE	
7	DsetN5  DUT could make more datasets than PIXIT described		DER interface	16-Apr-14 OPEN	ISSUE	
8	DsetN7, 11  Correct error code should be mapped instead of "service other".		DER interface	16-Apr-14 OPEN	ISSUE	
9	DsetN10, 11  Timestamp in the referenced dataset was updated regardless of Data or Quality change		DER interface	16-Apr-14 OPEN	ISSUE	
10	Br3  DUT didn't send the buffered data change event before GI report.		DER interface	16-Apr-14 CLOSED	ISSUE	
11	Br14  Allowable minimum PDU size should be described in PIXIT.		DER interface	16-Apr-14 OPEN	ISSUE	
12	Br5  After Br10, dataset reference in BRCB was changed, but when RptEnaNot, DUT transmitted the buffered report. The changed dataset means purging buffer. Initial value for position is required to show the normal status.		DER interface	16-Apr-14 OPEN	ISSUE	
13	Br11  Error code of Addcause should be "Object-Not-selected" instead of "Select-failed". Command termination was not mapped to "Object-Not-selected" in CDT.		DER interface	16-Apr-14 OPEN	ISSUE	
14	CIN(Dons)  Addcause should be "Object-Not-supported" or "Object-Inconsistent" instead of "Select-failed". Command termination was not mapped to "Object-Not-supported" in CDT.		DER interface	17-Apr-14 OPEN	ISSUE	
15	CIN(SBDes)  Addcause should be "Object-Not-supported" or "Object-Inconsistent" instead of "Select-failed". Command termination was not mapped to "Object-Not-supported" in CDT.		DER interface	17-Apr-14 OPEN	ISSUE	
16	CIN(SBDes)  Addcause should be "Object-Not-supported" or "Object-Inconsistent" instead of "Select-failed". Command termination was not mapped to "Object-Not-supported" in CDT.		DER interface	17-Apr-14 OPEN	ISSUE	
17	SBDes1  Addcause were not correct. It should be "Time-limited-over" or "Invalid position". Command Termination didn't include the same offsetNum, OrCat, and offsetValue.		DER interface	17-Apr-14 OPEN	ISSUE	
18	SBDes2  Addcause were not correct. It should be "Time-limited-over" or "Invalid position". Command Termination didn't include the same offsetNum, OrCat, and offsetValue.		DER interface	17-Apr-14 OPEN	ISSUE	
19	SBDes3  Addcause were not correct. It should be "Time-limited-over" or "Invalid position". Command Termination didn't include the same offsetNum, OrCat, and offsetValue.		DER interface	17-Apr-14 OPEN	ISSUE	
20	TmN1  If SvcName is not present, DUT should return all files in root directory.		DER interface	17-Apr-14 OPEN	ISSUE	
21	Ft1  The negative response for Getfile request with unknown file should be described in PIXIT.		DER interface	17-Apr-14 OPEN	ISSUE	
22	FIN1ab  The negative response for Getfile request with unknown file should be described in PIXIT.		DER interface	17-Apr-14 OPEN	ISSUE	

#	Test Procedure / Description	Problem	DER interface	IED Discovered	S-Suite	SP
1	Srv6  All quality values have the normal values. FCN<="1" is required if the function is not implemented. The name space field is required, when LN or CDD or DB is differently defined from the standard.		DER interface	16-Apr-14 OPEN	ISSUE	
2	GopN1  DER interface, all components in GoCBs are not allowed to write for changing. If GoEna is changeable, GOOSE message should follow GoEna.		DER interface	16-Apr-14 OPEN	ISSUE	
3	Ass1  ED<="1" is required if the function is not implemented. In association, "ServiceSupporteded" field should reflect only for which service DUT can provide.		DER interface	16-Apr-14 OPEN	ISSUE	
4	AssN4  DUT didn't transmit any packet for KEEP ALIVE checking.		DER interface	16-Apr-14 OPEN	ISSUE	
5	SrvN2  The initial value of SUlt was "0", but there is no definition of "0" in ENUM. DUT could make more datasets than PIXIT described		DER interface	16-Apr-14 OPEN	ISSUE	
6	DsetN5  DUT could make more datasets than PIXIT described		DER interface	16-Apr-14 OPEN	ISSUE	
7	DsetN7, 11  Correct error code should be mapped instead of "service other".		DER interface	16-Apr-14 OPEN	ISSUE	
8	DsetN10, 11  Timestamp in the referenced dataset was updated regardless of Data or Quality change		DER interface	16-Apr-14 OPEN	ISSUE	
9	Br3  DUT didn't send the buffered data change event before GI report.		DER interface	16-Apr-14 CLOSED	ISSUE	
10	Br14  Allowable minimum PDU size should be described in PIXIT.		DER interface	16-Apr-14 OPEN	ISSUE	
11	Br5  After Br10, dataset reference in BRCB was changed, but when RptEnaNot, DUT transmitted the buffered report. The changed dataset means purging buffer. Initial value for position is required to show the normal status.		DER interface	16-Apr-14 OPEN	ISSUE	
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16	SBDes1  Addcause were not correct. It should be "Time-limited-over" or "Invalid position". Command Termination didn't include the same offsetNum, OrCat, and offsetValue.		DER interface	17-Apr-14 OPEN	ISSUE	
17	SBDes2  Addcause were not correct. It should be "Time-limited-over" or "Invalid position". Command Termination didn't include the same offsetNum, OrCat, and offsetValue.		DER interface	17-Apr-14 OPEN	ISSUE	
18	SBDes3  Addcause were not correct. It should be "Time-limited-over" or "Invalid position". Command Termination didn't include the same offsetNum, OrCat, and offsetValue.		DER interface	17-Apr-14 OPEN	ISSUE	
19	TmN1  If SvcName is not present, DUT should return all files in root directory.		DER interface	17-Apr-14 OPEN	ISSUE	
20	Ft1  The negative response for Getfile request with unknown file should be described in PIXIT.		DER interface	17-Apr-14 OPEN	ISSUE	
21	FIN1ab  The negative response for Getfile request with unknown file should be described in PIXIT.		DER interface	17-Apr-14 OPEN	ISSUE	

#	Test Procedure / Description	Problem	DER interface	IED Discovered	S-Suite	SP
1	Srv6  DUT didn't transmit any packet for KEEP ALIVE checking.		DER interface	16-Apr-14 CLOSED	ISSUE	
2	SrvN2  The initial value of SUlt was "0", but there is no definition of "0" in ENUM. DUT could make more datasets than PIXIT described		DER interface	16-Apr-14 CLOSED	ISSUE	
3	DsetN5  DUT could make more datasets than PIXIT described		DER interface	16-Apr-14 CLOSED	ISSUE	
4	DsetN6, 7  Correct error code should be mapped instead of "definition invalid address". DUT could make more datasets with dataset member than PIXIT described		DER interface	16-Apr-14 CLOSED	ISSUE	
5	DsetN10, 11  Timestamp in the referenced dataset was updated regardless of Date or Quality change.		DER interface	16-Apr-14 CLOSED	ISSUE	
6	Br3  Time stamp in the referenced dataset was updated regardless of Date or Quality change.		DER interface	16-Apr-14 CLOSED	ISSUE	
7	Br14  DUT didn't send the buffered data change event before GI report.		DER interface	16-Apr-14 CLOSED	ISSUE	
8	Br15  After Br10, dataset reference in BRCB was changed, but when RptEnaNot, DUT transmitted the buffered report. The changed dataset means purging buffer. Initial value for position is required to show the normal status.		DER interface	16-Apr-14 CLOSED	ISSUE	
9	CIN(Dons)  Initial value for position is required to show the normal status.		DER interface	17-Apr-14 CLOSED	ISSUE	
10	CIN(SBDes)  Initial value for position is required to show the normal status.		DER interface	17-Apr-14 CLOSED	ISSUE	
11	SBDes1  Initial value for position is required to show the normal status.		DER interface	17-Apr-14 CLOSED	ISSUE	
12	SBDes2  Initial value for position is required to show the normal status.		DER interface	17-Apr-14 CLOSED	ISSUE	
13	SBDes3  Initial value for position is required to show the normal status.		DER interface	17-Apr-14 CLOSED	ISSUE	
14	TmN1  If SvcName is not present, DUT should return all files in root directory.		DER interface	17-Apr-14 CLOSED	ISSUE	
15	Ft1  The negative response for Getfile request with unknown file should be described in PIXIT.		DER interface	17-Apr-14 CLOSED	ISSUE	
16	FIN1ab  The negative response for Getfile request with unknown file should be described in PIXIT.		DER interface	17-Apr-14 CLOSED	ISSUE	

<IEC61850 Conformance Test Result>



# IEC61850 based Microgrid

PV Controller



RS-422

IEC61850 DG I/F #1



WT Controller



RS-422

IEC61850

IEC61850 DG I/F #2

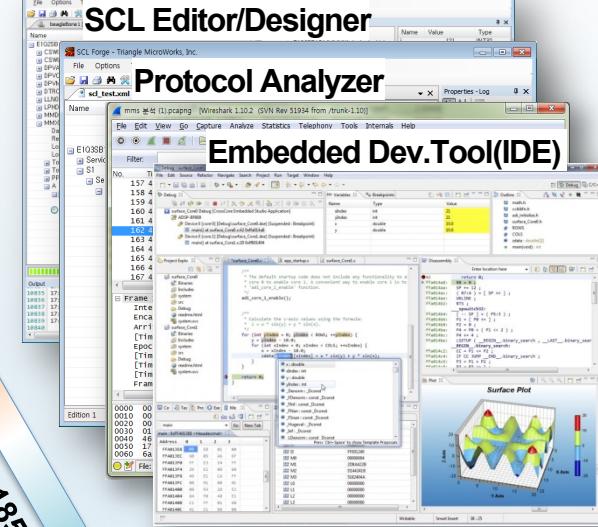


IEC61850

## IEC61850 based Microgrid Demonstration System

### Development Environment

IEC61850 Client Simulator



SCL Editor/Designer

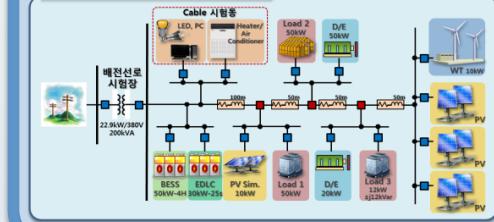
Protocol Analyzer

Embedded Dev.Tool(IDE)

SCADA (GE iFix)



마이크로그리드 Pilot Plant



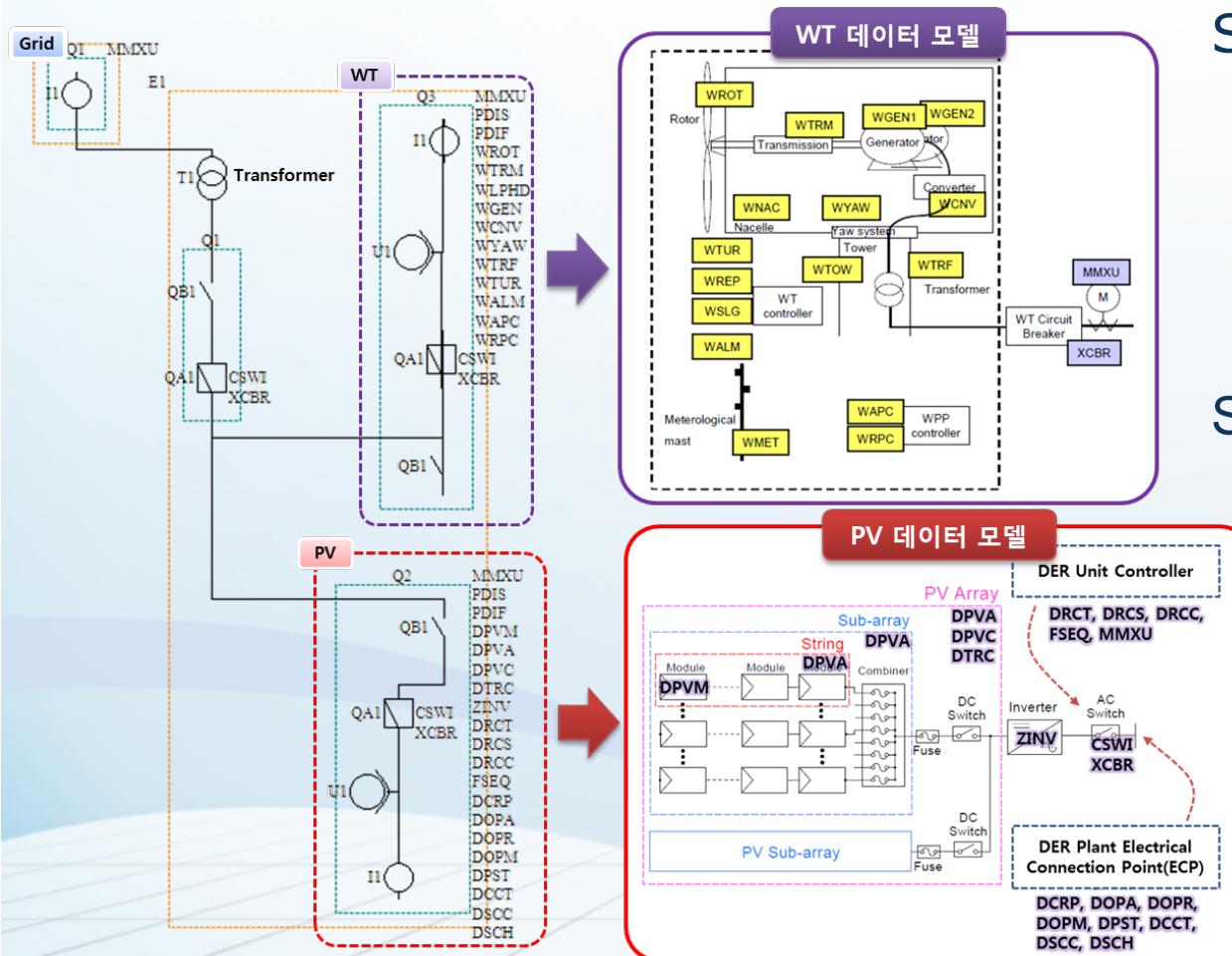
OPC DA

SCADA Data Gateway



TMW SCADA  
Data Gateway

# DG Models & SCL Design



## Simple Microgrid for Test

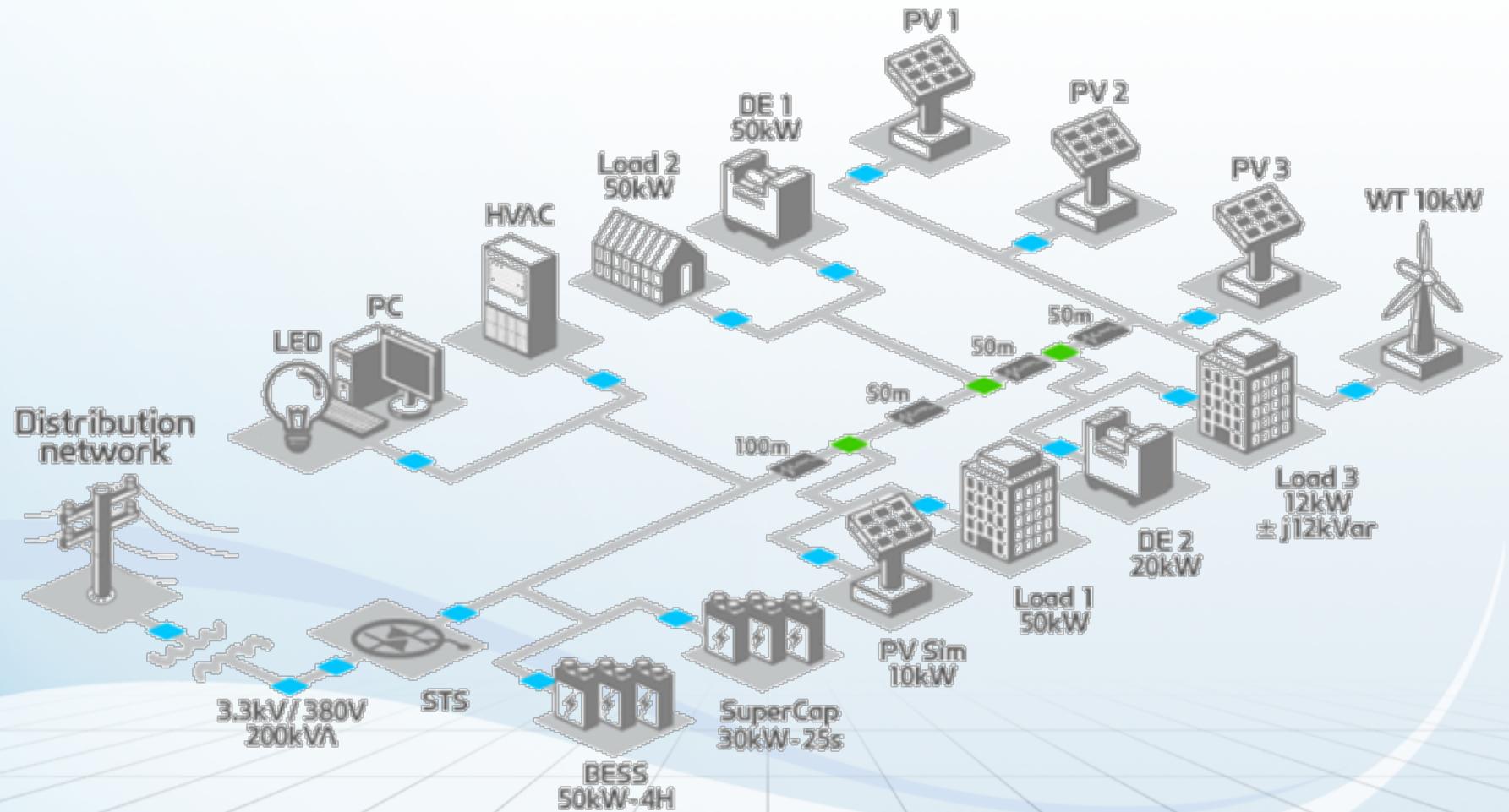
- ❖ Transformer/Switch/Feeder
- ❖ 1 WT, 1 PV (DGs)
- ❖ 1 Seg Ethernet Network
- ❖ IEC 61400-25 based WT Model
- ❖ IEC 61850-7-420 basd PVModl

## SCL Engineering Design

- ❖ SCL Forge Tool
- ❖ Visual SCL
- ❖ DG Interface (Embedded Srv)



# IEC61850 based Microgrid



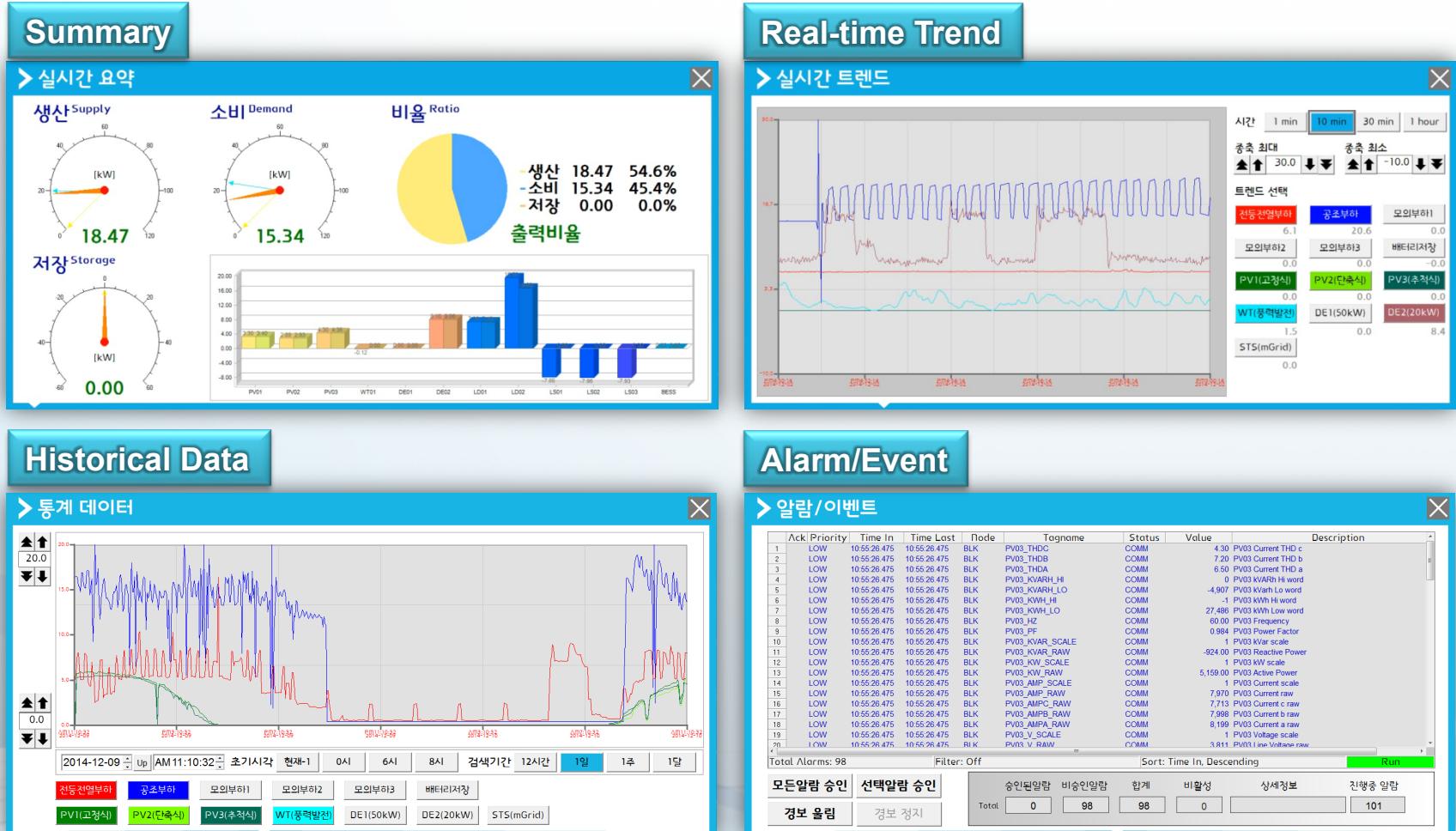
KERI 마이크로그리드 테스트베드

# IEC61850 based Microgrid



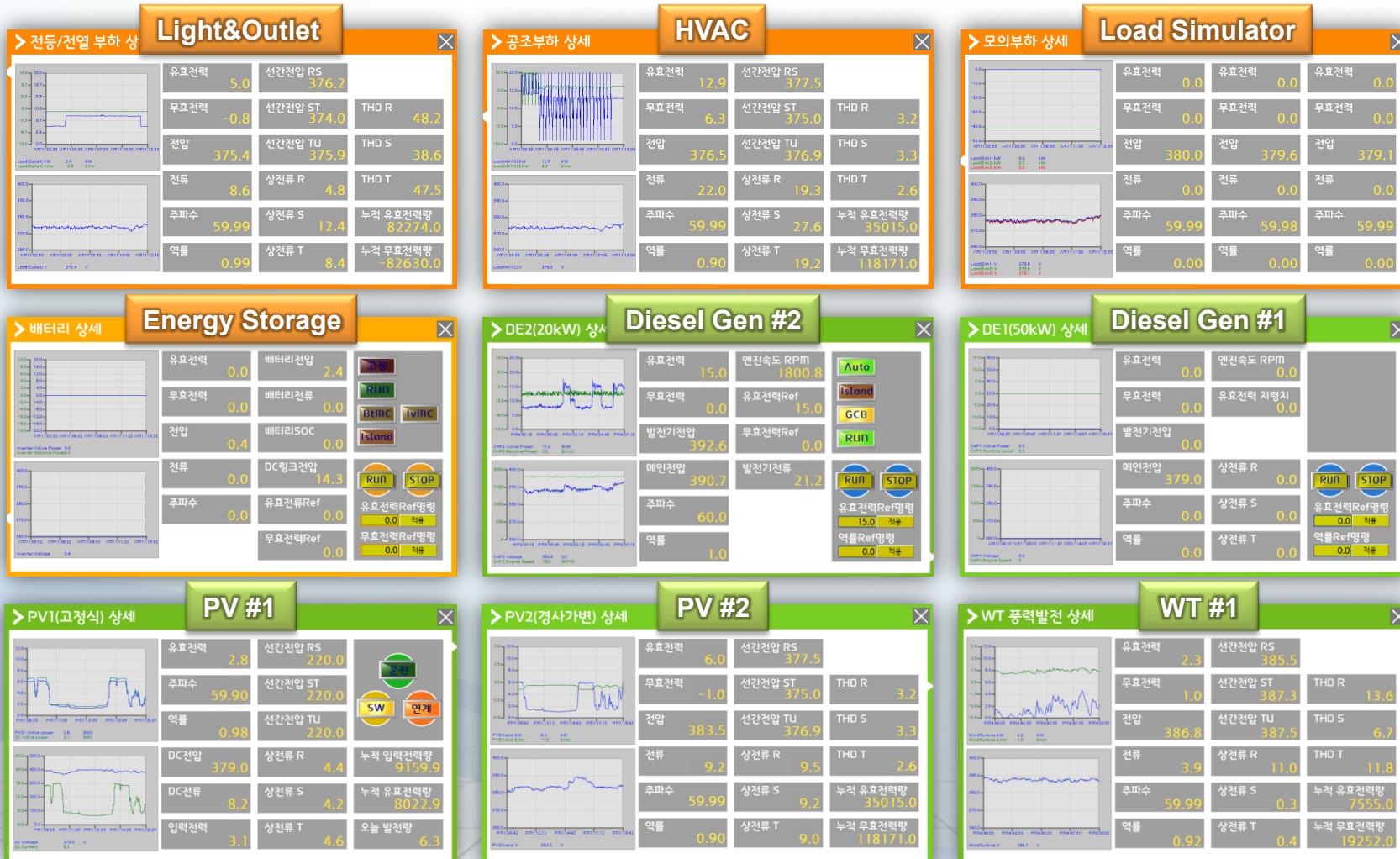
Main View of IEC61850 based Microgrid SCADA

# IEC61850 based Microgrid



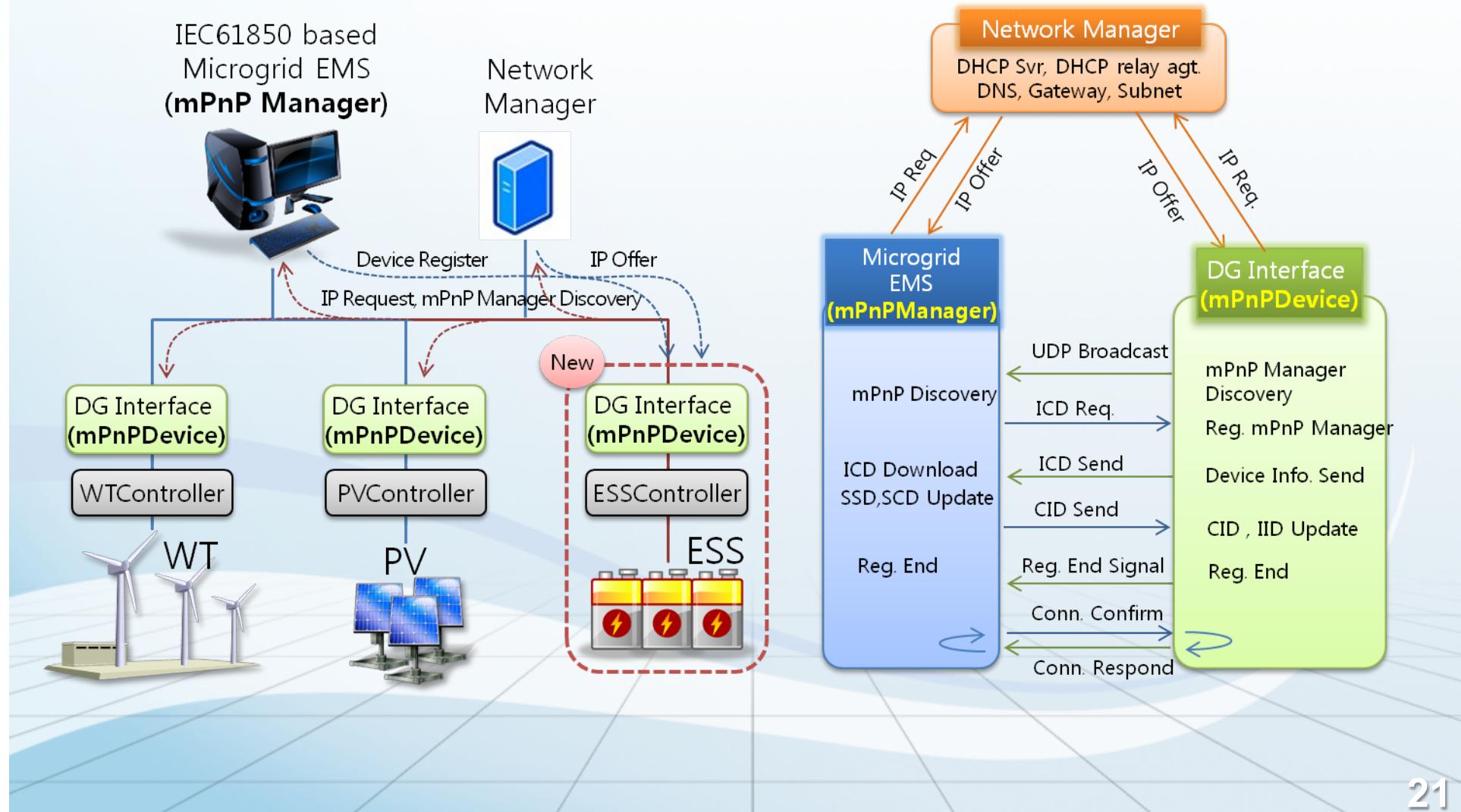
Sub View of IEC61850 based Microgrid SCADA

# IEC61850 based Microgrid



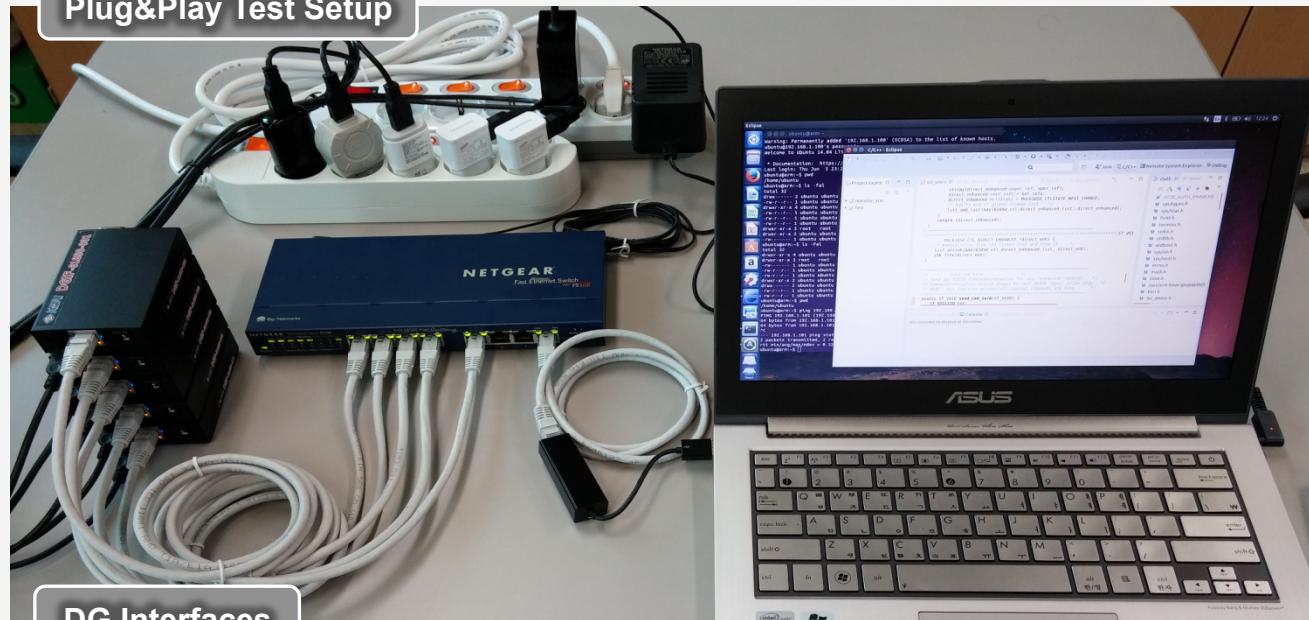
Detailed View of DGs and Loads

# IEC61850 Plug&Play Concept



# IEC61850 Plug&Play Test Setup

Plug&Play Test Setup



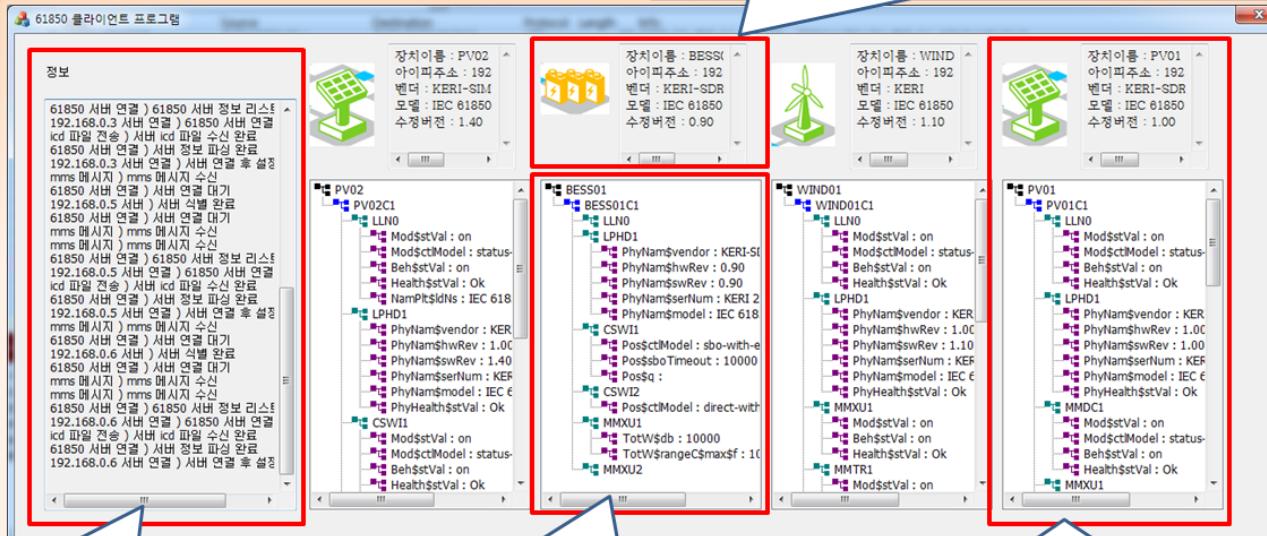
DG Interfaces



# Plug&Play Test Result

Microgrid EMS (mPnP Manager)

mPnP device basic info  
(Name, Type, IP addr., Vender, Model, Version)

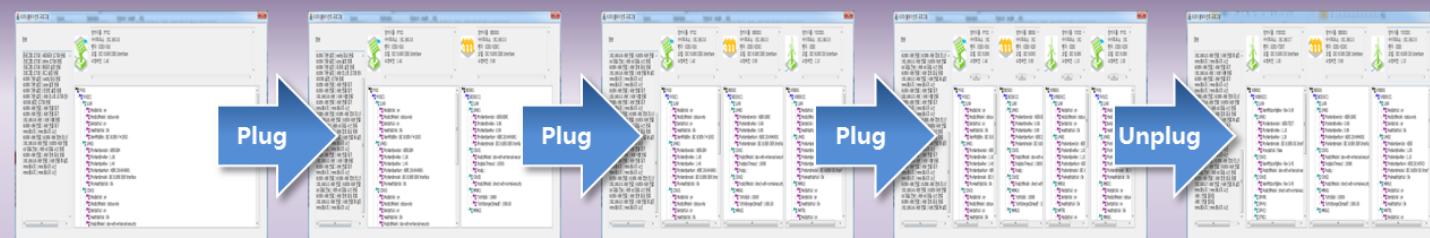


mPnP status report

mPnP device information  
(Data model)

Dynamic display according to  
connected mPnP devices

mPnP Manager display change according to the plug & unplug of mPnP devices



# Recap & What's next?

## ● IEC 61850 Summary

- Definition, Characteristics, Benefit
- Expansion of the standard, IEC 61850 in Smart Grid

## ● KERI Microgrid

- Definition, History, Microgrid Pilot Plant
- IEC 61850 Roadmap in KERI microgrid

## ● IEC 61850 based Microgrid Demonstraion

- IEC 61850 DG interface module, Conformance test
- Microgrid SCADA

## ● IEC 61850 Plug&Play

- IEC 61850 Plug&play concept, Test setup
- mPnP (Microgrid plug&play) test result

## ● What's next?

- Development of Smart DER and coordinated management system based on IEC 61850
- Development of Intelligent Multi-microgrid Energy Network Technology



Mange tak !

감사합니다

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Thank You !