Development and Demonstrations of Microgrid Energy Management Solutions in Korea

Smart Grid Laboratory
Contents

I. Microgrid EMS Solution in Korea
II. Microgrid Project - 1st Phase
III. Microgrid Project – 2nd Phase
IV. Smart Renewable Project

Case Study : LSIS EMS Solutions
Microgrid EMS (Energy Management System) Solution in Korea

**General Configuration**

- Renewables Gen. Forecast
- Elec/Heat Load Forecast
- Fluctuation Stabilization
- Demand Response
- SCADA
- Generation Schedule
- Economic Dispatch
- Automatic Gen. Control

**Test-beds**

**Microgrid Project – 1st Phase**
- **Period**: '07.08~'09.07
- **Location**: KERI (Changwon, Korea)
- **Functions**: SCADA, AGC

**Microgrid Project – 2nd Phase (On-Grid)**
- **Period**: '10.02~'13.01
- **Location**: KEPRI (Daejon, Korea)
- **Functions**: On-Grid (Full Functions)

**Microgrid Project – 2nd Phase (Off-Grid)**
- **Period**: '10.02~'13.01
- **Location**: Mara-island, Korea
- **Functions**: Off-Grid (Stabilization, Gen Schedule)

**Smart Renewable Project**
- **Period**: '09.12~'13.05
- **Location**: Cheju-island, Korea
- **Functions**: On-Grid (Stabilization, BESS Schedule, Electricity Transaction for Market)
Microgrid Project, 1st Phase

Components

- Renewable Energy: Photovoltaics, Wind Simulator
- Dispatchable Generations: 2 x Diesel Engines (50kW, 20kW)
- Energy Storages: Battery (10kW)
- Controllable Load

System Configuration

Equipment in Laboratory

Green Innovators of Innovation
Off-grid transition test

- AGC Mode: Constant Tieline Flow Control & Constant Frequency Control
- Set Flow: within 5% of full load
- Control Unit: 2 x Diesel Engines
Overview

Microgrid Project, 2nd Phase

- KEPRI, Daejon / `10.02~`13.01 (3 years)

Components

<table>
<thead>
<tr>
<th>System Configuration</th>
<th>Air view</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCADA</td>
<td>Micro Turbine(60kVA)</td>
</tr>
<tr>
<td>Load/Gen Forecasting</td>
<td>Diesel Engine(82kVA)</td>
</tr>
<tr>
<td>Generation Schedule</td>
<td>PV+ PCS(30kVA)</td>
</tr>
<tr>
<td>Economic Dispatch</td>
<td>-STS(300kVA)</td>
</tr>
<tr>
<td>Automatic Gen. Control</td>
<td>-UPQC+ Battery(100kVA)</td>
</tr>
<tr>
<td>Demand Response</td>
<td>-PV PCS*2</td>
</tr>
</tbody>
</table>

Renewable Energy
- Photovoltaics

Dispatchable Generations
- Micro Gas Turbine, Diesel Engine

Energy Storages
- Battery, Super Capacitor

Power Quality Compensator
- UPQC
Microgrid Project, 2nd Phase

Functions: Load, Generation Forecast

Load Forecasting

Electric Load Forecasting Results
- TSELF method has lowest mean error.

<table>
<thead>
<tr>
<th>Forecast Method</th>
<th>Mean Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moving Average</td>
<td>1.57%</td>
</tr>
<tr>
<td>Exponential Smoothing</td>
<td>1.71%</td>
</tr>
<tr>
<td>Regression Analysis</td>
<td>1.43%</td>
</tr>
<tr>
<td>Trend Method</td>
<td>1.88%</td>
</tr>
<tr>
<td>TSELF</td>
<td>0.87%</td>
</tr>
</tbody>
</table>

Heat Load Forecasting Results
- TSELF method has lowest mean error.

<table>
<thead>
<tr>
<th>Forecast Method</th>
<th>Mean Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moving Average</td>
<td>28.75%</td>
</tr>
<tr>
<td>Exponential Smoothing</td>
<td>25.87%</td>
</tr>
<tr>
<td>Regression Analysis</td>
<td>22.26%</td>
</tr>
<tr>
<td>Trend Method</td>
<td>31.62%</td>
</tr>
<tr>
<td>TSELF</td>
<td>15.25%</td>
</tr>
</tbody>
</table>

Generation Forecasting

PV Generation Forecasting Results
- KMA Connection Method has lowest mean error.

<table>
<thead>
<tr>
<th>Forecast Method</th>
<th>Mean Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>KMA Connection</td>
<td>2.65%</td>
</tr>
<tr>
<td>KMA Disconnection</td>
<td>14.45%</td>
</tr>
<tr>
<td>3 Days Average</td>
<td>4.34%</td>
</tr>
</tbody>
</table>

Wind Generation Forecasting Results
- KMA Connection Method has lowest mean error.

<table>
<thead>
<tr>
<th>Forecast Method</th>
<th>Mean Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>KMA Connection</td>
<td>44.50%</td>
</tr>
<tr>
<td>KMA Disconnection</td>
<td>57.30%</td>
</tr>
<tr>
<td>3 Days Average</td>
<td>51.70%</td>
</tr>
</tbody>
</table>

Under Further Development for better performance.
General Setting

- Operate run and stop
- Input and change data about generation output characteristic

Special setting for each function

- Generation Schedule
- Economic Dispatch
- Automatic Generation Control
Microgrid Project, 2nd Phase

Functions: Demand Response

Comparison to tariff
- Select one load source and multi tariff
- Compare total cost each tariff

Load Shedding
- Decide to order of priority for load shedding in advance
- Set load shedding reference curve
- Monitor real time load
- Over the reference amount, load will be shedded
On-Grid Tieline Flow Control Test

Microgrid Project, 2nd Phase

Grid connected test

- AGC Mode: Constant Tieline Flow Control
- Set Flow: 0kW
- Control Unit: Diesel Engine
- Change to active power of BESS

![Trend Chart]

- PV active power
- BESS active power
- Diesel active power (AGC Control)
- Tieline Flow (AGC Result)
**Microgrid Project, 2nd Phase**

**Off-Grid Stand-alone Frequency Control Test**

**Stand alone test**

- **AGC Mode:** Constant Frequency Control
- **Set Frequency:** 60Hz
- **Control Unit:** Diesel Engine
- **Change to active load of dispatchable load**

**Trend**

Graph showing trend lines for PV active power, BESS active power, Diesel active power (AGC Control), Tieline Flow, Load, and Frequency (AGC Result).
The most noticeable plan in South Korea’s smart grid project is the construction of a Smart Grid Test-bed on Jeju Island on 2009.

### Project Overview

| Entity          | Administrator: Korean Government  
<table>
<thead>
<tr>
<th></th>
<th>Participants: Over 168 Companies in five areas</th>
</tr>
</thead>
</table>
| Goal            | Construction of state-of-the-art Smart Grid reference site  
|                 | Early commercialization of Smart Grid technology |
| Period          | Total 42 Months: ’09.12.01 ~ ’13.05.31  
|                 | 1st phase: ’09.12.01 ~ ’11.05.31  
|                 | 2nd phase: ’11.06.01 ~ ’13.05.31 |
| Funds           | Matching fund between the government and participating companies  
|                 | Government contribution: ₩37billion |

### Jeju Test Bed

- **Location & Size**
  - Location: Gujwaup, Jeju Island
  - Size: Total Number of Test Bed households about 3000
  - D/L: 2 Substations and 4 Distribution lines
  - Note: Utilizes existing wind farm for the Test Bed Project

- **Funds**
  - Matching fund between the government and participating companies
  - Government contribution: ₩37billion
SmartGrid Test-bed, Smart Renewable Project

- Smart Place, Transportation, Renewable, PowerGird, and Electricity Service
- LSIS is leading and participating in all areas

### Test Bed Areas

<table>
<thead>
<tr>
<th>Smart Place</th>
<th>Smart Renewable</th>
<th>Smart Transportation</th>
<th>Smart Power Grid</th>
<th>Smart Electricity Market</th>
</tr>
</thead>
</table>

### Key Tasks in each area

- **Smart Place**
  - Improve energy consumption efficiency
  - Development of AMI
  - Development of DR mechanism

- **Smart Transportation**
  - Enhance EV and charging infrastructure
  - Establish & upgrade of charging infra
  - Network based monitoring and control of EV operation information

- **Smart Renewable**
  - Experiment renewable energy technology
  - Regarding renewable energy sources
  - Including energy storage, PCS, EMS, SATCOM, Stabilizer for renewable generation

- **Smart PowerGrid**
  - Upgrade T&D System
  - Intelligent distribution, digitalized substation
  - T&D real-time monitoring for wide area

- **Smart Electricity Service**
  - Operate energy trading market
  - Various bi-directional power trading service
  - Total Operating Center (TOC) in test bed
Smart Renewable

- Experiment renewable energy technology
  - Regarding renewable energy sources
  - Including energy storage, PCS, EMS, SATCOM, Stabilizer for renewable generation

System Configuration

Smart Renewable EMS

same as

Microgrid EMS

Overview

SmartGrid Test-bed, Smart Renewable Project

- Experiment renewable energy technology
  - Regarding renewable energy sources
  - Including energy storage, PCS, EMS, SATCOM, Stabilizer for renewable generation
BESS Schedule

- Automatic system
- Optimize battery charging/discharging schedule using wind power and electricity price forecasting information
- Generate bidding data combining wind power and battery schedule
PCS Control

- Operate mode: smoothing, unit power control, feed flow control
- Stop if battery SOC is over than 95% or under than 5%
- FFC is a powerful function for power stabilization