Overview of Microgrid R&D in Japan

Akihiko Yokoyama
The University of Tokyo
Concept of Advanced Power Supply Network

From 2001 to 2003

Technical Committee supported by METI
Voltage Control of a Feeder with a Large Penetration of PV Generations by Batteries

From 2002 to 2007

NEDO Ohta City Project
Independent and Islanding Operation of Microgrid

From 2003 to 2008

Tohoku Electric Power Co.

Wasted Water Process Center

Bio Gas Engine

Photovoltaic Generation (50kW)

Control System

Battery

Bio Gas

Distribution Line

Tohoku Electric Power Co.

City Hall (360kW)

Junior High School (49kW)

Primary School (47kW)

Junior High School (49kW)

Primary School (50kW)

PV

Wind Power

Wind Power

Wind Power

PV

Peak load 600kW

NEDO  Hachi-no-he City Project
Operation of DGs including RES as a Virtual Power Plant

From 2003 to 2008

Commercial Power System, Utility Power System

Supply side
- Bio Gas Generation
- Fuel Cell

Wind Power Generation

Photovoltaic Power Generation

Balance Control System

Internet

Demand side
- City Hall
- Hospital
- School
- Apartment House

Supply & Demand Balance Control

NEDO Kyoto Project
Multiple Power-Quality Electricity Supply Network

Utility (Tohoku Electric Power Co.)

From 2003 to 2008

DVR : Dynamic Voltage Restorer

- Normal-Quality Load
- High-Quality (B3) Load
- High-Quality (B2) Load
- High-Quality (B1) Load
- High-Quality (A) Load
- DC Load

Sendai City

Tohoku Fukushi Univ.
Energy Center

3-phase 6.6kV Bus
Integrated High-Quality Power Supply Device

Measuring point (Total 22 pts)

DVR : Dynamic Voltage Restorer

NEDO Sendai City Project
Supply and Demand Integrated Distribution System
--- Autonomous Demand Area Power System ---

From 2003 to 2008

Main trans.
- 2000kVA (2 units)

Experimental substation

66kV commercial line

Loop Power Controller

Supply & Demand Interface

DG & Load

Site A

DG & Load

Site B

DG & Load

Site C

DG & Load

Site D

Communication network

6.6kV and 22kV Distribution line
(Total length: 5km)

- Many types of DGs installed in 4 places separately
- Communication Network

Operation system

NEDO Akagi Project by CRIEPI
Shimizu Microgrid System

**Microgrid control system**

- **Power generation**
  - Gas engine gen. 350kW
  - Gas engine gen. 90kW
  - Nickel metal hydrite battery 40kW x 10hrs
  - Electric double layer capacitor 100kW x ±2 sec
  - Solar photovoltaics 10kW

- **Exhaust heat utilization**
  - Absorption water heater-chiller

- **Thermal energy storage**
  - Heat pump chiller
  - Heat storage tank

- **Laboratory buildings**

- **Chilled/hot water**

**Electric power flow**

- Purchased power from Utility Co. (TEPCO)

**Thermal energy flow**
Tokyo Gas Microgrid System

- 3φ3W 200V
- 100kVA transformer
- 1φ3W 200/100V

- Gas engine CHP: 25kW × 2
- Solar photovoltaic: 10kW
- Lead acid battery: 50kW-30min
- Nickel hydrogen battery: 50kW-2hrs
- Triplet effect absorption chiller
- Air-conditioning
- Wind turbine: 6kW × 2
- Gas engine CHP: 9.9kW
- Biogas engine generator: 9.9kW (Planned)

Sensitive load
- Most sensitive load

Islanding operation of multiple DERs
Simulation Study on Islanding Operation of Microgrid with DC based DGs and AC Feeder

From 2004 to 2006

Fault on Commercial Line

Islanding Operation

PV: 15kW
Fuel Cell: 6kW
Fuel Cell: 6kW
Fuel Cell: 6kW

Battery: 20kW
Load: 0~18kW
Load: 0~18kW
Load: 0~18kW

3-Phase 3-line 200V 50Hz

About 10 Residential Houses

Minimization of the required capacity of Battery

Joint Project of Univ. of Tokyo and Mitsubishi
Autonomous Decentralized Control by use of AC Feeder Frequency

- The System Frequency is used for Active Power Balance Control of Fuel Cell and Battery.
- The Battery changes the frequency according to its output power and each FC detects the frequency change and decides its output.
Contribution of Microgrid to Utility Grid

- How much is the excess capacity used?
- How is the microgrid controlled?
- How is an ancillary service cost defined?

Expected total capacity of Microgrid will be 20% of total utility load demand.

Excess capacity of Microgrid may be used for the contribution.

Joint Project of Univ. of Tokyo and Tokyo Gas
Concept of Advanced Smarter Grid in Japan (Ubiquitous Power Grid)

Proposed by The Univ. of Tokyo
Contribution of Heat Pump based Water Heater to LFC for Reduction of Battery Capacity

Wind Power Output

HP Water Heater

BESS(Battery)

LFC Generator

Power consumption

Type (b)

HP Water Heater

Heat Pump Consumption [MW]

BESS Output [MW]

Battery
Coordinated Control of PHEV, EV, Battery, RES and Thermal Power Plant

Large-scale Network
- Hydro
- Nuclear
- Thermal
- Wind

Small-scale Network
- Microgrid
- Distribution Network
- Battery
- Super Capacitor
- Wind
- PV

Load
- Micro Gas Engine
- Gas Turbine

PHEV, EV

Charging & Discharging

- When?
- How?
- How much?
Outline of Battery System R&D for Grid Integration of RES Generations

**Purpose**

Development of Technologies Required for Low-Cost, Long-Lifetime and Large-Capacity Battery System for Grid Integration of RES Based Generations

**Topics and Final Targets**

1. **Technology Development for Practical Use**
   - Large-Capacity Battery System and Output Power Control Technology
   - Final target = Field test for more than 6 months

2. **Elemental Technology Development**
   - Materials for High Performance
   - Final target = Cost $400/kWh, Lifetime 10 years

3. **Next Generation Technology Development**
   - New Materials and Their Production Methods, etc.
   - Final target = Feasible Cost $150/kWh, Lifetime 20 years

4. **Fundamental Research for Common Use**
   - Assessment Methods Applied to Battery Produced in the Above Projects
   - Final target = Assessment methods for Cost, Safety, Lifetime, Performance

NEDO Project from 2008 to 2010
New National Projects in Japan
From 2009 to 2014

Remote Island Microgrid Project with a Large Penetration of PV and Wind Power Generations

Simulation Study using Analog type Power System Simulator with DGs such as PV and Controllable Load