Large-scale PV Demonstration Projects in Japan

2nd International Symposium for Distributed Electricity Generation and Smart Grids
17th – 18th October 2007
TECHbase Vienna – arsenal research

Satoshi Morozumi, Yasuyuki Arashiro and Nobuyoshi Inoue
New Energy and Industrial Technology Development Organization, Japan
New Energy Technology Development Department
Table of Contents

1. Background
- PV introduction
- NEDO’s projects

2. PV projects
- Demonstrative Project on Grid-interconnection of Clustered Photovoltaic Power Generation Systems
- Verification of Grid Stabilization with Large Scale PV Power Generation Systems

3. Summary
Promoting renewable energy is essential.

- Security of energy supply (Oil-alternative energy)
- Harmony with environment (Lowering CO₂ emission)

New energy introduction target
- ex. PV: 4.82GW (FY2010)
- 102GW (FY2030)

Renewable energy resources are increasing in electric power system.

Power quality issues
Introduction of PV

Price of PV system
(10^4 Yen/kW)

<table>
<thead>
<tr>
<th>Year</th>
<th>Installation cost / kW</th>
<th>Generation cost / kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>2.4</td>
<td>260</td>
</tr>
<tr>
<td>1994</td>
<td>3.1</td>
<td>200</td>
</tr>
<tr>
<td>1995</td>
<td>4.3</td>
<td>120</td>
</tr>
<tr>
<td>1996</td>
<td>6.0</td>
<td>170</td>
</tr>
<tr>
<td>1997</td>
<td>8.3</td>
<td>82</td>
</tr>
<tr>
<td>1998</td>
<td>12.0</td>
<td>72</td>
</tr>
<tr>
<td>1999</td>
<td>13.3</td>
<td>71</td>
</tr>
<tr>
<td>2000</td>
<td>14.3</td>
<td>65</td>
</tr>
<tr>
<td>2001</td>
<td>15.3</td>
<td>58</td>
</tr>
<tr>
<td>2002</td>
<td>16.3</td>
<td>45.2</td>
</tr>
<tr>
<td>2003</td>
<td>17.3</td>
<td>33.0</td>
</tr>
<tr>
<td>2004</td>
<td>18.3</td>
<td>28.0</td>
</tr>
</tbody>
</table>

Installed PV capacity
(10^4 kW)

Data Source: NEF
What is NEDO?

The New Energy and Industrial Technology Development Organization (NEDO) is Japan’s largest public R&D management organization for promoting the development of advanced industrial, environmental, new energy and energy conservation technologies.
Development and Demonstration of new energy-related grid-connecting technology

One of the important objectives of NEDO’s R&D is solving problems that arise when distributed and renewable resources are connected to power grids.

These issues arise because the power output from most renewable energy resources fluctuates with weather conditions and connecting them to traditional power grids may create power quality issues.

1) Frequency Stabilization
2) Voltage Control
3) Protection
4) Other Power Quality Issues
5) Technology Development
Grid-Connection related Projects in NEDO

- **Voltage control technology for clustered PV systems**
- **Control of supply system with several new energy and dispersed generators**
- **Voltage control technologies for distribution system when many DGs are connected**
- **Development of supply system with different power quality**
- **Demonstrative Project of Regional Power Grids with Various New Energies (FY2003-2007)**
- **Energy storage system for new energy**
- **Verification of Grid Stabilization with Large Scale PV Power Generation Systems (FY2006-2010)**
- **Development of an Electric Energy Storage System for Grid-connection with New Energy Resources (FY2006-2010)**

- **Power Control Technology for wind farm**
- **Interconnection technology for large scale PV generation system**

- **FY2005 and Before**
- **FY2006**
- **FY2007**
- **FY2008 and After**
Demonstrative Project on Grid-interconnection of clustered Photovoltaic Power Generation (FY2002-2007)

Background
Clustered installation of Photovoltaic on the distribution network is expected.

There are tangible problems, such as voltage swell by output from PV systems.

Objects
- Development of the technology to avoid restriction of PV system output.
- Development of function to prevent unintentional islanding.
- Development of applied simulation technologies.

Results
- 553 PV systems were installed.
- Effect of battery for avoiding restriction of PV output was examined.
- Possibility of interferences among the equipments for preventing islanding were detected.
- New equipment, which can avoid such interferences is now being developing.
Outline of the project

- Development of the technology to avoid restriction of PV system output.
- Development of function to prevent unintentional islanding.
- Development of applied simulation technologies.
Demonstration sites

Location of Ota city

Research facility in Maebashi city

Demonstration site in Ota city
Demonstrative project site

Installed PV : 553
Total PV Capacity : 2,129kW
Average PV Capacity : 3.85kW
History of installation

Number of installed PV system
Number of installed battery system
Final Number of installed PV system
Monthly generated energy (MWh)
Monthly consumed energy (MWh)
Monthly reversed flow energy (MWh)

Generated energy, Consumed energy and Reverse flow energy (MWh/Month)

Number of houses
A system of battery management system

A type of system which has one PCS for PV and battery system.

(1) Separate Type
Battery and PCS for battery system are added to market base PV system.

(2) All in One Type
A type of system which has one PCS for PV and battery system.

(3) Central Controller
Remotely controlling each external battery box

(4) New Type islanding protection equipment
New type of islanding protection which can detect islanding rapidly when clustered PV systems are installed.
External battery box

- Ventilation fan
- Inverter (4kVA)
- Lead-Acid battery (4,704Ah·cell)
- Control terminal

External Battery BOX
Development of technology to avoid restriction of PV system output

The voltages in distribution line sometimes becomes higher than the maximum nominal voltage of 107V or 222V because too much power injection from PV system.

Output of PV is restricted to keep line voltage within operational range (101±6V, 202±20V).

Various suppressions of the PV output are analyzed, and then several battery operation modes to reduce such suppressions are developed in this project.
A sample of voltage control operation

If line voltage violate upper limit of operation voltage, then battery started charging.
Development of function to prevent unintentional islanding

- A function to prevent islanding operation disconnects the PV system from the power grid in the case of service interruptions. Interferences among the equipments for preventing islanding are induced when the clustered PV systems are installed.

- Methods to avoid mis-actuations of such function in the clustered PV systems are developed, the methods will be verified through demonstration.

- Developing new islanding detection method.
- Testing this method at the test facility in Maebashi City.
- Installing field-test equipment at the demonstrative site in Ota city
- Installing quality improved facility at the demonstrative site in Ota city

Test facility in Maebashi
New method of prevent islanding

All of PCSs output an active signal synchronously by Wave clock signal.
Verification of Grid Stabilization with large-scale PV Power Generation Systems (FY2006-2010)

**Background**

If PV becomes popular in future, large scale (MW level) PV power station will be introduced to power system.

It is possible that such large scale PV power station may influence voltage and frequency in the utility system.

**Objects**

(1) Technology for reduction of fluctuation of voltage and frequency using battery storage will be demonstrated. Also, countermeasure of harmonic will be developed and demonstrated.

(2) Developing simulation method related technologies mentioned above.
Demonstrative projects site

The first Japanese Mega-Solar

Wakkanai Site completion forecast figure

Hokuto Site completion forecast figure
## Comparative table

<table>
<thead>
<tr>
<th></th>
<th>Wakkanai City</th>
<th>Hokuto City</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV capacity</td>
<td>~5MW</td>
<td>~2MW</td>
</tr>
<tr>
<td>Module type</td>
<td>crystal type</td>
<td>advanced type</td>
</tr>
<tr>
<td>Energy storage</td>
<td>NaS: 1.5MW - 11.8MWh</td>
<td></td>
</tr>
<tr>
<td></td>
<td>EDLC: 1.5MW - 25kWh</td>
<td></td>
</tr>
<tr>
<td>PCS</td>
<td>250kW (commercialized product)</td>
<td>400kW (developing)</td>
</tr>
<tr>
<td>Grid connection</td>
<td>33kV transmission line</td>
<td>66kV transmission line</td>
</tr>
<tr>
<td>Forcast</td>
<td>solar radiation forecast</td>
<td></td>
</tr>
</tbody>
</table>
# Schedule

## Wakkanai site

<table>
<thead>
<tr>
<th></th>
<th>FY</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV capacity (MW)</td>
<td></td>
<td>Nov. 80kW</td>
<td>Nov. 1.7MW</td>
<td>Oct. 4.0MW</td>
<td>Oct. 5.0MW</td>
<td></td>
</tr>
<tr>
<td>NaS battery (MW)</td>
<td></td>
<td>Nov. 0.5MW</td>
<td></td>
<td>Oct. 1.5MW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EDLC (MW)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grid connection</td>
<td>FY</td>
<td>2006</td>
<td>2007</td>
<td>2008</td>
<td>2009</td>
<td>2010</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mar. 6.6kV</td>
<td>Nov. 33kV</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Hokuto site

<table>
<thead>
<tr>
<th></th>
<th>FY</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV capacity (MW)</td>
<td></td>
<td>Feb. 0.6MW</td>
<td></td>
<td>Nov. 2.0MW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grid connection</td>
<td></td>
<td>Feb. 6.6kV</td>
<td></td>
<td>Nov. 33kV</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Configuration of Wakkanai site

Weather forecast
Control system
Monitoring & Control
Extra high voltage bus
Transformer
High voltage bus
Inverter
Large scale PV plant
PV

Establishing extra-high voltage grid connection technologies

Comparison of several types of PV cell

Large scale PV plant system structure

Reforming output from PV by battery storage
How battery system operates

Output from Mega-solar Plant

Smoothing by battery

Planned transmission by battery
Wakkanai site PV system under construction

Typical output pattern in a week
Wakkanai site PV system under construction

2007 July
(PV: 80kW)

2009 October
(PV: 5MW)
Configuration of Hokuto site

FY2007

PV : 0.6MW
PCS
210V/6.6kV

FY2009

PV : 0.1MW
PCS
210V/6.6kV

Output Power: 400kW
Function:
- to suppress voltage fluctuation by controlling reactive power
- to have voltage sag ride-through capability
- to have suppressed harmonic function

FY2008-2009

PV : 0.4MW
PCS 400kW
420V/6.6kV

PV : 0.4MW
PCS 400kW

PV : 0.4MW
PCS 400kW

Development of large-scale PCS
Hokuto site
under land forming

2007 October

2009 November
(PV ~2MW)
PV application in micro-grid project

Hachinohe project

Structure of supply system with local private Grid.

The Sewage plant

- Wooden waste
- Steam boiler
- Digestion Chamber
- Digestion gas tank
- Gas engine 170kW*3
- Battery 100kw
- PV 50kW

PV 10kW
- Junior high school (60kw)
- Hachinohe city hall (360kw)
- Wind turbine 2kW*2

Elementary school (46kw)
- Wind turbine 8kW

Junior high school (53kw)

PV 10kW

Elementary school (46kw)
- Wind turbine 8kW

Hachinohe city hall new building

Hachinohe regional water supply authority (50kw)

Utility line

Private distribution line (5.4km)

- Gas engine
- Wood waste
- Digestion Chamber
- Battery
- PV
- Wind turbine
- Junior high school
- Elementary school
- Hachinohe city hall
- Hachinohe regional water supply authority
- Utility line
- Private distribution line
Compensating imbalance of three phase by PV power conditioner in Hachinohe

Diagram showing a PV system with three inverters, each rated at 50 kW, connected to the AC and DC sides of a control system. The inverters are connected to the utility network through CB7, CB4, and CB3, with schools and the city office also connected to the network.
Summary

- PV has potential to change electric power system.

- To achieve such a paradigm shift, solving grid-connection issues is necessary.

- NEDO thinks such technology development shown in our presentation is very important.
Thank You for your attention!!

Nobuyoshi INOUE
inouenby@nedo.go.jp

New Energy and Industrial Technology Development Organization