CRIEPI’s Research on Smart Grid, TIPS

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Outline

Scope for Next-generation Grid:  
**TIPS**  
- Triple I (Intelligent, Interactive and Integrated) Power System

ADAPS  
- Autonomous Demand Area Power System

ICT Infrastructure for TIPS
Scope for Next-generation Grid: TIPS
Future of Power Grids

◆ CO\textsubscript{2} Reduction throughout Grids (from Generation to End Use)
  - Large penetration of unstable renewable energy source (Targeted value of PV in 2010: 4.8GW, 2030 : 53 GW)
  - Increase of inflexible generation (IGCC etc.)
  - Increase of uncertainty in supply/demand control

◆ Demand change
  - Enhancement of energy-conscious in consumers
  - Shift to electricity and Intelligent/ICT society (digital society)

◆ Increase of aged grid apparatus to be replaced
Requirements of Next-generation Grid

*TIPS* - Triple I (Intelligent, Interactive and Integrated) Power System

1. **Integrate supply/demand**
   - Enable conservation and efficient utilization of energy with integration of demand and supply

2. **Utilize DER**
   - Enable large penetration and effective utilization of distributed energy resources

3. **Minimize blackout risk**
   - Minimize the risk of large blackout with secure and stable operation of resilient and self-healing system

4. **Develop asset management**
   - Sophisticate asset management and introduce advanced power system maintenance and devices

**CO₂ reduction**

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# Road Map of TIPS

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<tbody>
<tr>
<td>1. Integrate supply/demand</td>
<td>2. Utilize DER</td>
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<td>4. Develop asset management</td>
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5 Research Areas on TIPS

- Smart Generation (Centralized)
- Smart Delivery (Transmission & Distribution)
- Smart End Use (Industrial/Commercial/Residential/Appliance)
- E & I
- ADAPS
- Bulk Power System Operation
- Demand Response
- Power Apparatus
- ICT Infrastructure

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Research Items (1), 2008-2010

- **ADAPS operation and control under demand/supply integration**
  - Load and storage control techniques according to PV power output
  - Demand/supply integration control techniques in grid emergency
  - Utilization techniques of DG and ADAPS developed

- **Bulk Power System Operation under large penetration of DER**
  - Evaluation of regulation capability of bulk power system and distribution system
  - Generation adequacy assessment method
  - Long-term power system simulation method
Research Items (2), 2008-2010

❖ ICT infrastructure
  ■ Secure communication network for demand area
  ■ Wide area and high-speed networks for monitoring, protection and control
  ■ Sensor networks for facility maintenance and operation

❖ Evaluation of Demand Response (DR)
  ■ Evaluation method of DR program
  ■ Feasibility of DR program in Japan
  ■ Energy management system for DR

❖ Power Apparatus
  ■ 6.6 kV current limiter using superconductivity
  ■ Solid insulation mold transformer
  ■ Hybrid gas insulated bus
ADAPS (Autonomous Demand Area Power System)
– Preceding and Current Projects –
Schematic Configuration of ADAPS

Customers

Communication Network (L2, mobile agents, etc.)

Substation 1

Substation 2

Supply & Demand Interface
to support customer demands and operate emergency DER shedding

Loop Power Controller
to control power flow and voltage of distribution line

Section switch with fault sensor

P/Q control

Operation & Control System
ADAPS: Accomplishment to date

Penetration Area of DER

Penetration Capacity of DER (percentage to feeder capacity)

- Large (100%)
- Middle (50%)
- Small

Locally concentrated

Dispersed and small

Technologies developed applicable to this region

Wide and Large (PV: 53 GW)

Wide and middle

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ADAPS: Accomplishment to date

✓ Centralized Voltage Control

In addition to SVC (STATCOM)

Voltage limit
ADAPS: New project undertaken

Penetration Area of DER

- Locally concentrated
- Dispersed and small
- Wide and middle

Penetration Capacity of DER (percentage to feeder capacity)

- Large (100%)
- Middle (50%)
- Small

Technologies to be developed applicable to this region

(PV: 53 GW)
Problem in large penetration

Reverse power flow

Distribution Substation

LPC
Demand/Supply Integration

- HV/EHV System
- Substation
- Information:
  - Power system
  - Load profile
  - Weather forecast, etc.
- ADAPS
- Controller
- Storage
- Residential Customer
  - Hot Water Supply
  - HVAC
  - Others
- PV
- kW
- Time

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Demand/Supply Integration

- Reduce reverse flow
- Level flow

HV/EHV System

Substation

Information
- Power system
- Load profile
- Weather forecast, etc.

Controller

Control load and energy storage according to PV power output

ADAPS

Residential Customer

- Hot Water Supply
- HVAC
- Others

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ICT Infrastructure for TIPS
ICT Infrastructure for TIPS

Smart Generation (Centralized)

Smart Delivery (Transmission & Distribution)

Smart End Use (Industrial/Commercial/Residential/Appliance)

Efficient Energy Supply & Utilization
  – Demand Area Secure Communication Network –

Resilient and Self-healing Power System
  – Wide Area and High Speed Control Network –

Facility Operation and Management
  – Sensor Networks for Facility Maintenance and Operation –
Scope of ICT Infrastructure

- **Demand Area Secure Communication Network**
  for distribution and DER management, smart metering, demand response, customer access, energy management, and premises communication

- **Wide Area and High Speed Control Network**
  for power system monitoring, adaptive protection and emergency control to prevent large blackout and localize disruption

- **Sensor Network for Facility Maintenance and Operation**
  based on DRNA (Distributed computer Network Architecture) and field network technologies and the concept of Plug-and-Play
Demand Area Secure Network

- Media-integrated (wireless and/or wired) structure
- IP-based communication protocols and data management
- Security measures for embedded and easily accessible equipment
- Customer gateway
Wide Area and High Speed Control Network

- Ethernet-based network with extremely high reliability and low latency for data exchange and time synchronization
- Intelligent device with modular functions (monitoring, processing, control, communication)

Flexible and scalable to various schemes of monitoring, protection and control, and to power system configurations

: Precise simultaneous sampling
: Intelligent modular device
Sensor Network for Facility Maintenance and Operation

Facility Maintenance (Patrol, inspection, monitoring, diagnosis)

Facility Operation (SCADA/EMS)

IP-based Network

Wireless sensor network

Lightning

 Preservation and Operation

- Wired/wireless sensor and access network for field information collection
- Wide area and premises networks (DRNA-based)
- Data exchange and management

Plug-and-Play and Ad Hoc schemes

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Conclusion
TIPS to support CO$_2$ reduction and stable power supply

**TIPS** - Triple I (Intelligent, Interactive and Integrated) Power System
Comments, questions?
Trends toward 2050

- Nuclear
- thermal
- WP
- PV
- Battery
- PEHV
- IGCC
- CCS

60Hz ↔ 50Hz
5 Research Areas on TIPS
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<table>
<thead>
<tr>
<th>Short term (2010)</th>
<th>Mid term (2030)</th>
<th>Long term</th>
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<tbody>
<tr>
<td>ICT Infrastructure</td>
<td>ADAPS</td>
<td>Demand Response</td>
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</table>

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Japanese typical distribution system

Proper supply voltage range for customer is regulated within
101 +/- 6V in 100V system and
202 +/- 20V in 200V system by Japanese electrical utility's law.

SVR (Step voltage regulator);
- installed when D.L. length more than about 5km.

Substation

6.6kV distribution line

100V/200V

Communication for sensor and remote operation of SWs

Tap changing of main transformer
LDC (Line voltage drop compensator);
controlling sending voltage automatically according to feeder current.

Program control;
- sending voltage is programmed beforehand.

Tap ratio adjustment of pole mounted transformer by manual setting.
Testing and Demonstration Site

Akagi Testing Center

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Testing and Demonstration Site

Whole configuration of the test facility

Composition of distributed power generators

<table>
<thead>
<tr>
<th>Component</th>
<th>Power</th>
<th>Units</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotating generator</td>
<td>150kW</td>
<td>6 units</td>
<td>600kW</td>
</tr>
<tr>
<td>PV system</td>
<td>5kW</td>
<td>16 units</td>
<td>80kW</td>
</tr>
<tr>
<td>Simulated FC, PV, Storage battery</td>
<td>20kW</td>
<td>12 units</td>
<td>240kW</td>
</tr>
<tr>
<td>MGT</td>
<td>30kW</td>
<td>1 unit</td>
<td>30kW</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>1250kW</td>
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Wide-area Emergency Control System

Control Device

Integrated Device

Monitoring Device

High Speed Control Network