Research and Development of Japanese style Smart Grid for Smooth Introduction of Renewable Energy Sources

October 12, 2010

Hiromu Kobayashi

Central Research institute of Electric Power Industry (CRIEPI)

Contents

1. Background
2. Expected problem in large penetration of DG
3. CRIEPI's R&D activities
   - ADAPS project - *Advanced distribution system*
   - TIPS project - *Integration of supply side and demand side*
4. Conclusions

Background

- DG (RES) will be penetrated largely according to Japanese governmental target toward 2030.
  - ✓ Photovoltaic (PV) power generation : 53 GW
  - ✓ Wind turbine : 0.6 GW
  - ✓ Biomas (Waste): 0.4 GW

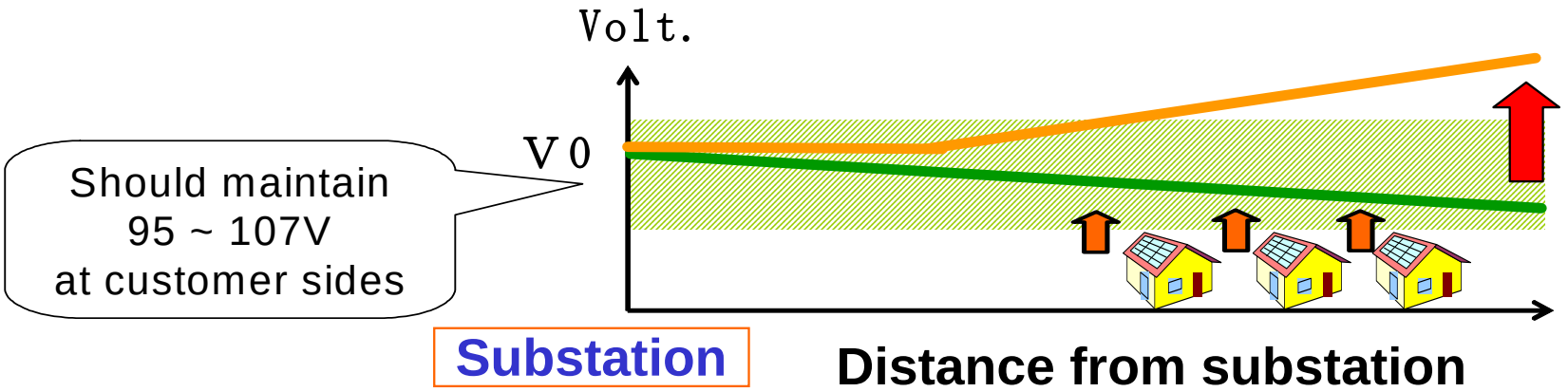
- *Power quality*, *stability and safety* on the utility system may be degraded.
  - ✓ Distribution system : *Voltage variation, Islanding*
    - ➡ Fundamental measures have been developed by past R&D of ADAPS (Autonomous Demand Area Power System) and other governmental projects.
  - ✓ Whole system : *Surplus power*, *Reserve margin, FRT*

Expected problem in large penetration of DG
- Voltage deviation from proper range -

When reverse power flow from DG occurs, distribution line voltage generally goes up by the distribution line impedance.

-- Line voltage may exceed upper limitation.

-- Large energy loss of DG may occur caused by regulated function reducing real power to prevent the voltage rise.



Expected technical problems and possible penetration rate of DG

- *Results of demonstration test and simulation*
- *Possible penetration rate is restricted 5% to 20% in the worst case.*

Expected technical problems	Penetration rate of DG when problems occur (Note ; under the worst case)
- *Voltage variation* on distribution line due to reverse power flow.	More than 5 to 20%
- *Deterioration of safety* in case of distribution line fault.	
-- Increase short circuit capacity	More than 40%
-- Give a bad influence to the grid protective relay operation	More than 20%
-- Cause islanding phenomena	More than 20 to 30%

Note) Penetration rate ; Ratio to distribution line capacity

Contents

1. Background
2. Expected problem in large penetration of DG
3. CRIEPI's R&D activities
   - ADAPS project - *Advanced distribution system*
   - TIPS project - *Integration of supply side and demand side*
4. Conclusions

CRIEPI's research items of distribution system for smooth introduction of DG (2003 –)

1. Short term issues

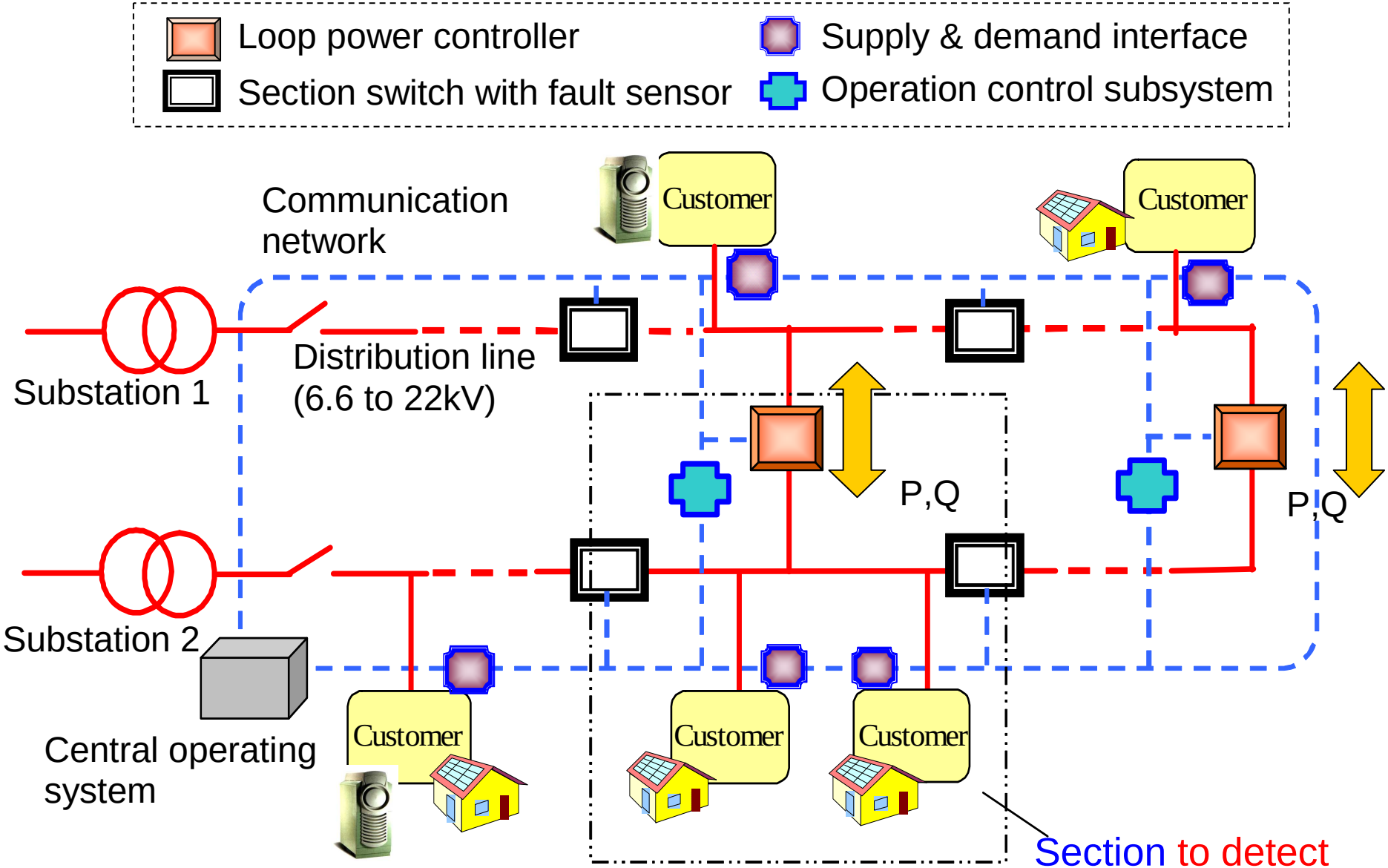
- *Basic experiments on grid interconnection problems of DG and measures for current radial distribution line (*).*
  - Voltage, protection and safety problems.
  - Conventional voltage control techniques such as SVC, SVR and islanding detection method installed in DG.

  ** Almost are carried out under the commitment of utility companies*

2. Middle and long term issues

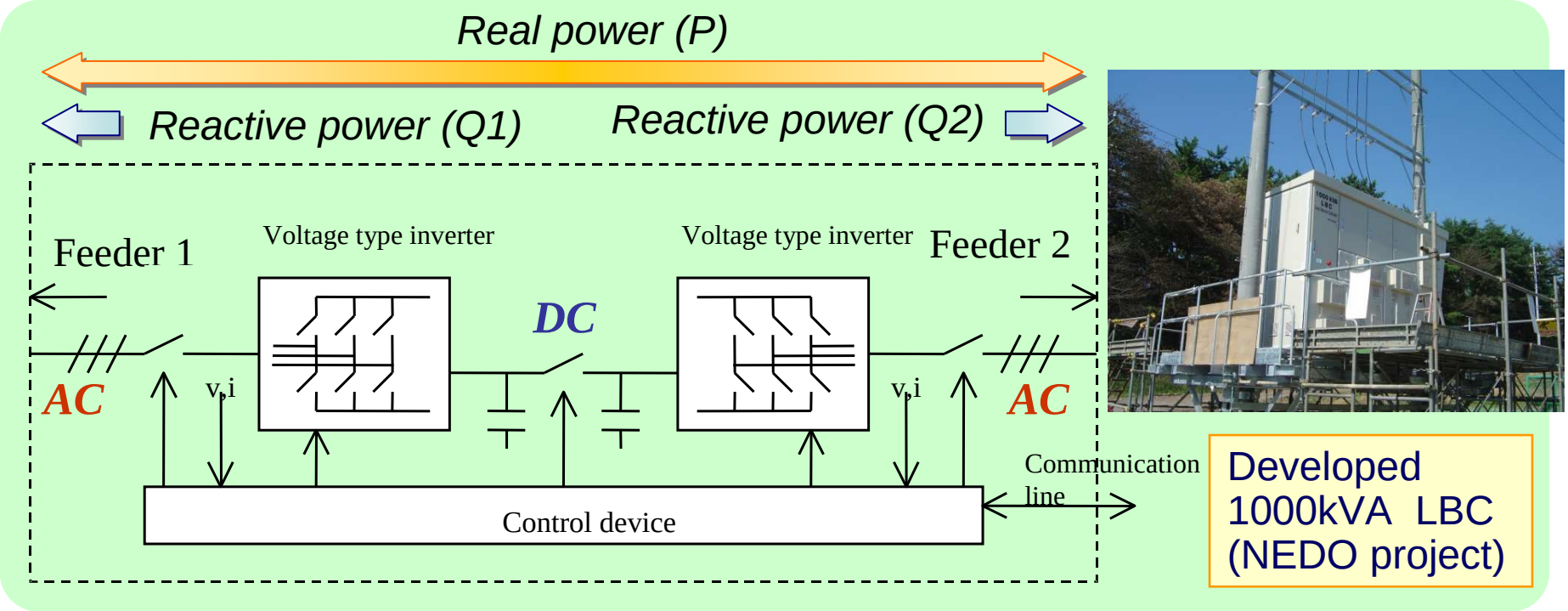
- *To develop **ADAPS** techniques.*
  - Voltage and load flow control method using a new device "LPC".
  - Protection and safety methods using communication network.
  - Methods for effective use of DG to get power quality and reliability.
- *Research project under contract with the NEDO (2004 - 2007)*
  - To develop concentrated voltage control method using SVC,SVR.
  - To develop actual scale 500kVA and 1MVA LBCs.

Basic configuration of *ADAPS* using LPC



Loop shaped config. is adopted, LPC installed to control voltage&current of D.L. including fault condition. SDI installed at each customer to control DG autonomously using communication network. Central operation system installed.

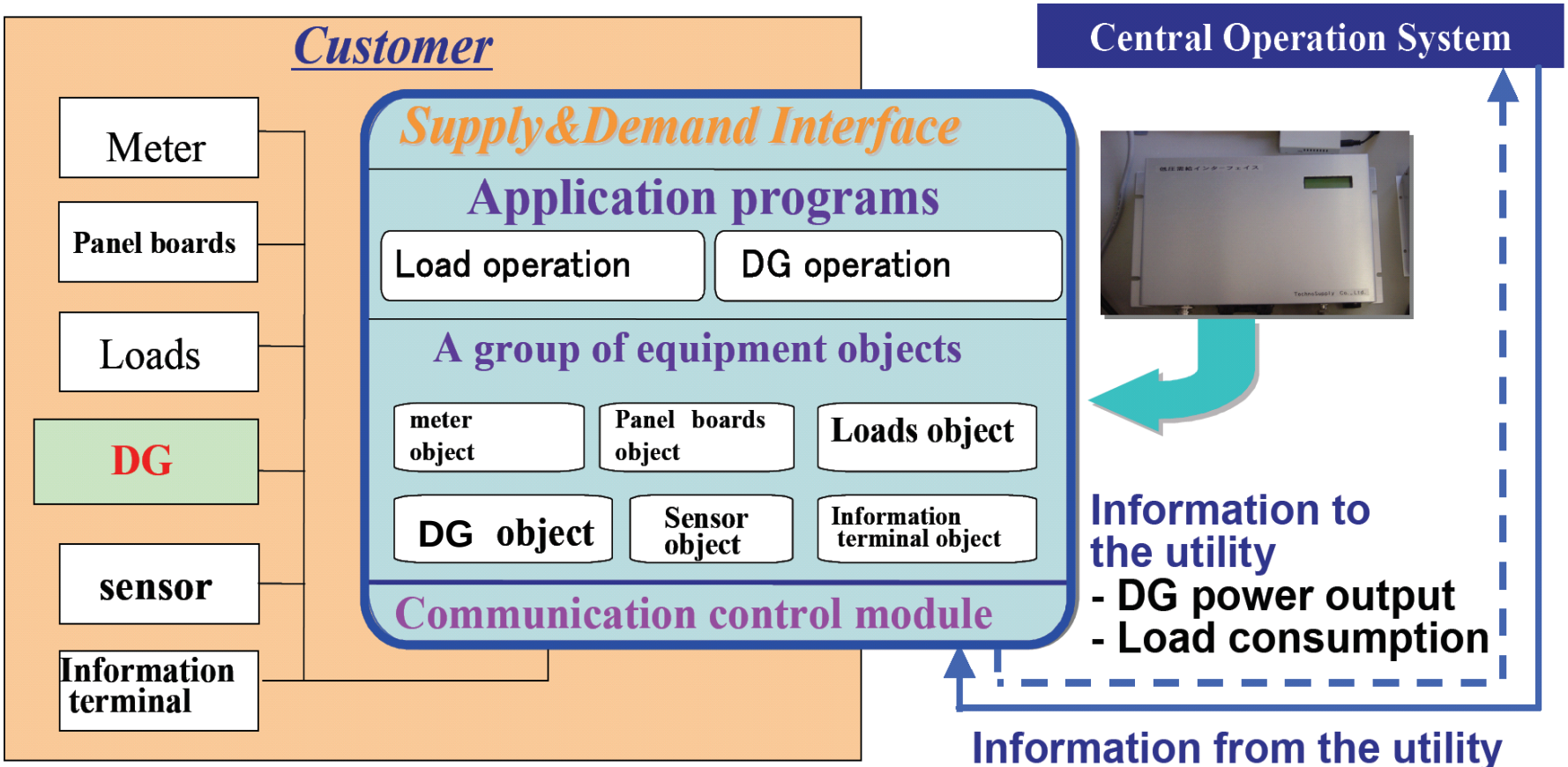
Loop Power Controller (LPC or LBC) for controlling distribution line voltage and load flow



Developed 1000kVA LBC (NEDO project)

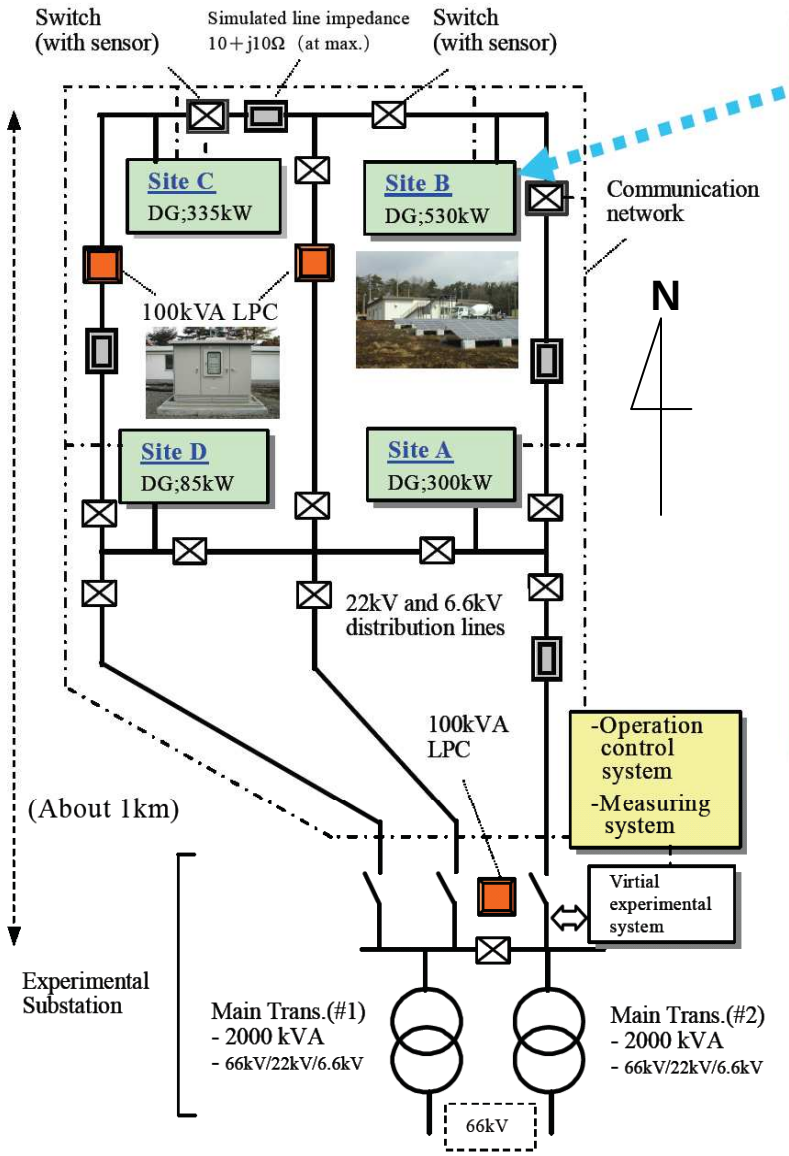
- Consists of 2 inverters linked DC part (***BTB type***)
- Controls both ***power flow*** and ***voltage*** of both distribution lines by controlling P,Q
- It is expected that total device capacity becomes smaller than SVC in whole ADAPS when DG penetrated in wide area .

Configuration of Supply/demand Interface



- *consists of micro computer and communication modem.*
- *exchanges information with utility*
- *controls customer's* ***DG*** *and load automatically* ***to obtain energy saving, cost minimum, improvement of power quality (local area) and load leveling.***

ADAPS Demonstration Test Facility in Akagi Testing Center



Whole configuration of the test facility

Distributed power generations in a site

150kW rotating type generator
(simulates WP, Co-generation)

20kW Inverter type generator
(simulates PV,FC, etc.)

4 to 5 kW power conditioner
for PV power generation

Composition of distributed power generators

Rotating generator	150kW etc.	6 units	600kW
PV system	5kW etc.	16 units	80kW
Simulated FC, PV, Storage battery	20kW 100kW	12 units 3 units	240kW 300kW
MGT	30kW	1 unit	30kW
Total			1250kW

Summary of R&D results on ADAPS

Following basic techniques concerning *Autonomous Demand Area Power System (*ADAPS*)* were developed.

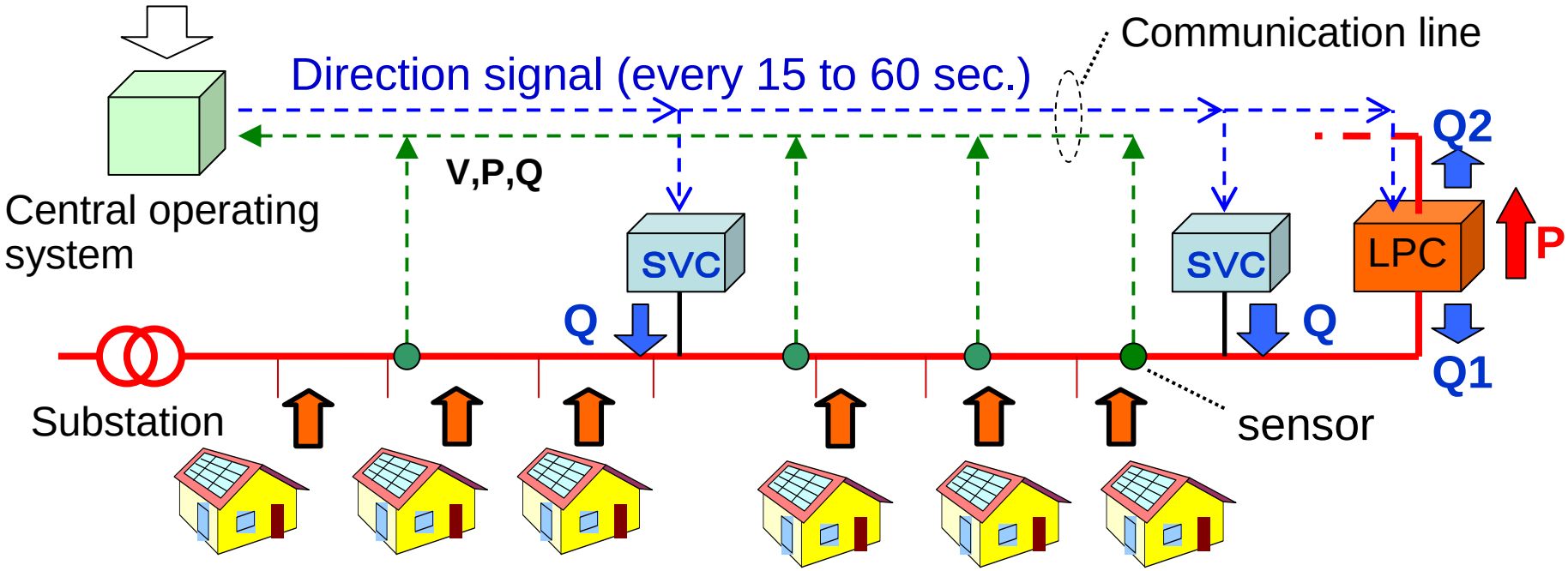
- Centralized voltage control technique using a new device Loop Power Controller (LPC).
- Proper protection and safety methods using communication network.
  - Fast separation of fault section and preventing islanding phenomena.
  - Uninterruptible isolated operation of normal section using LPC and DG.

➢ *From those results, possible penetration rate of DG in a distribution feeder can reach 100% .*

Centralized control measure of voltage control in distribution line

Central operating system

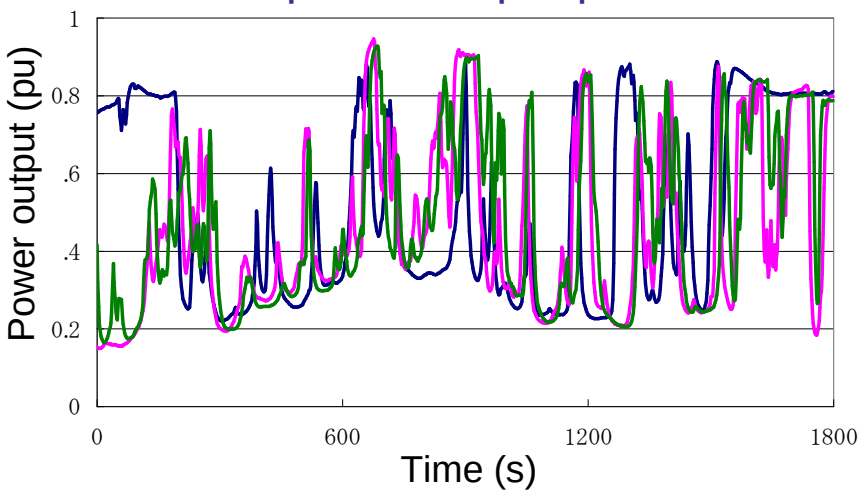
- monitors line voltage and P,Q
- decides proper control value of the devices.

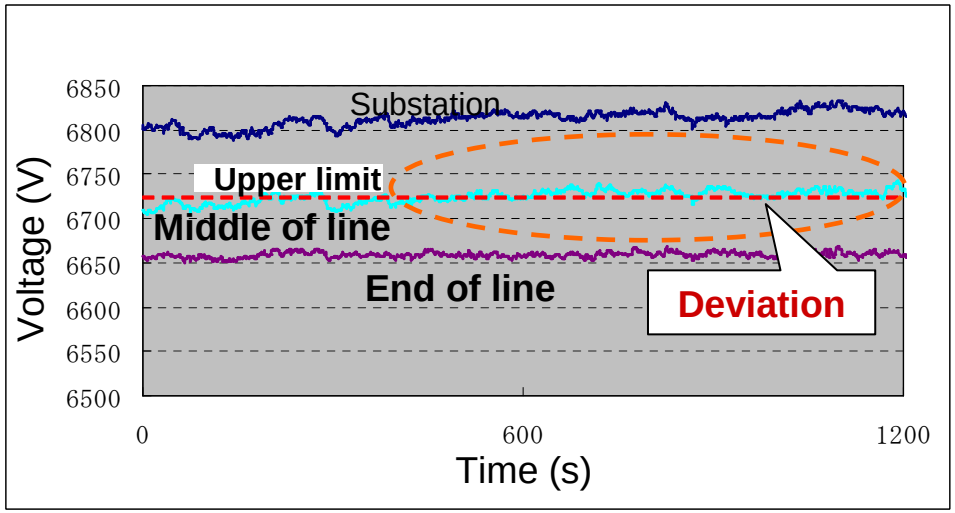


Test result of centralized voltage control method

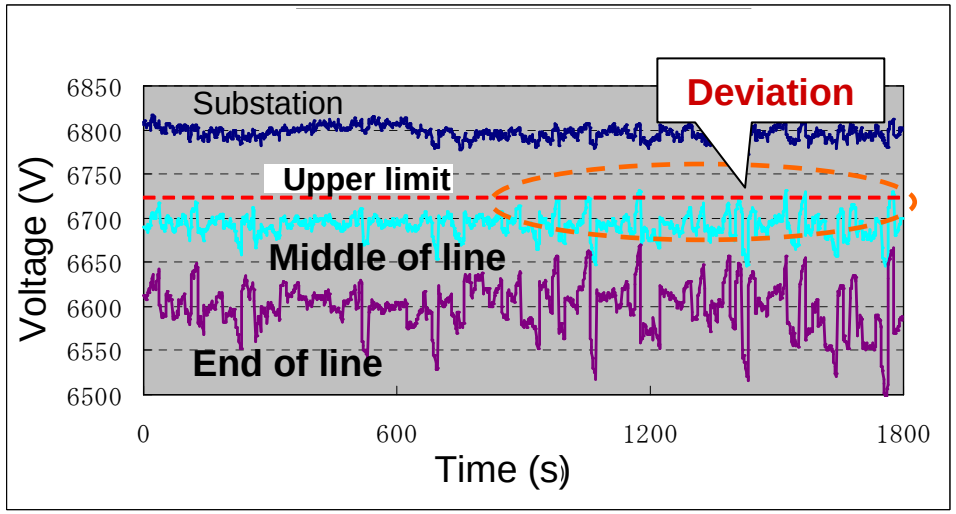
（Residential area in case of PV rapid change, Penetration rate: 33%）

PV power output patterns

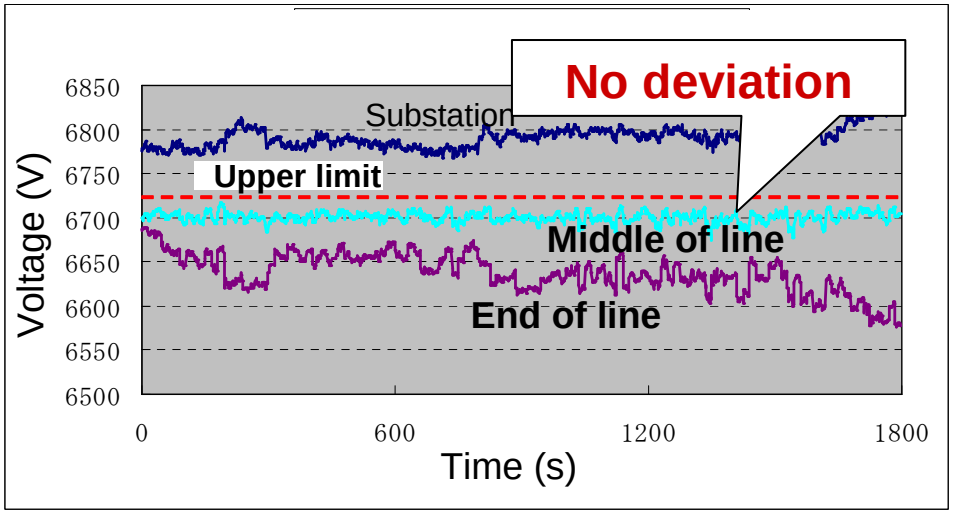




Line voltage changes (Local control)



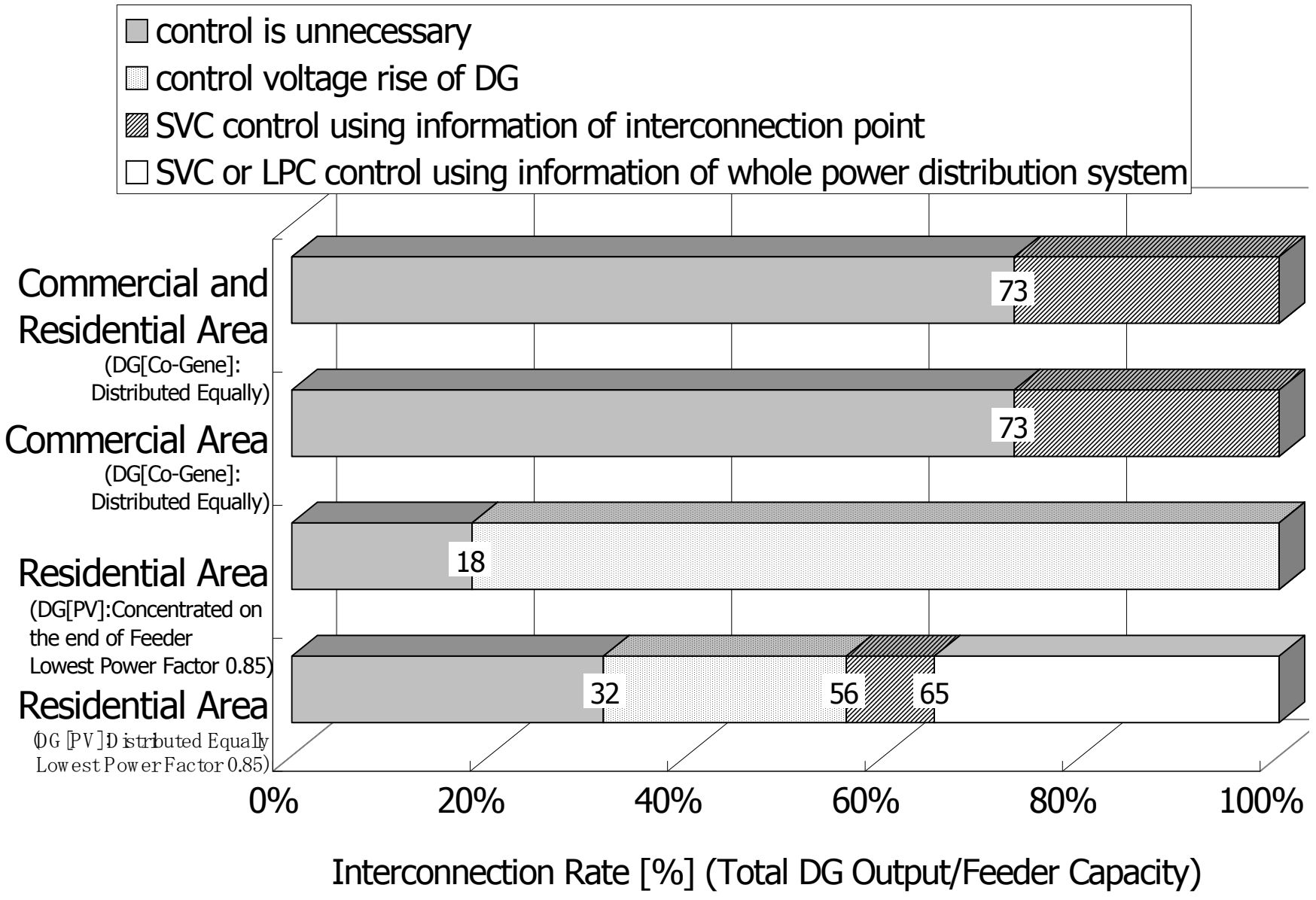
Line voltage changes (Q control)



Line voltage changes (V control)

Note) One 300kVar SVC set at the middle of distribution line in all test cases.

Evaluation result of proper voltage regulation methods



Contents

1. Background
2. Expected problem in large penetration of DG
3. CRIEPI's R&D activities
   - ADAPS project - *Advanced distribution system*
   - TIPS project - *Integration of supply side and demand side*
4. Conclusions

Requirements of Next Generation Grid for larger and wider penetration in whole system

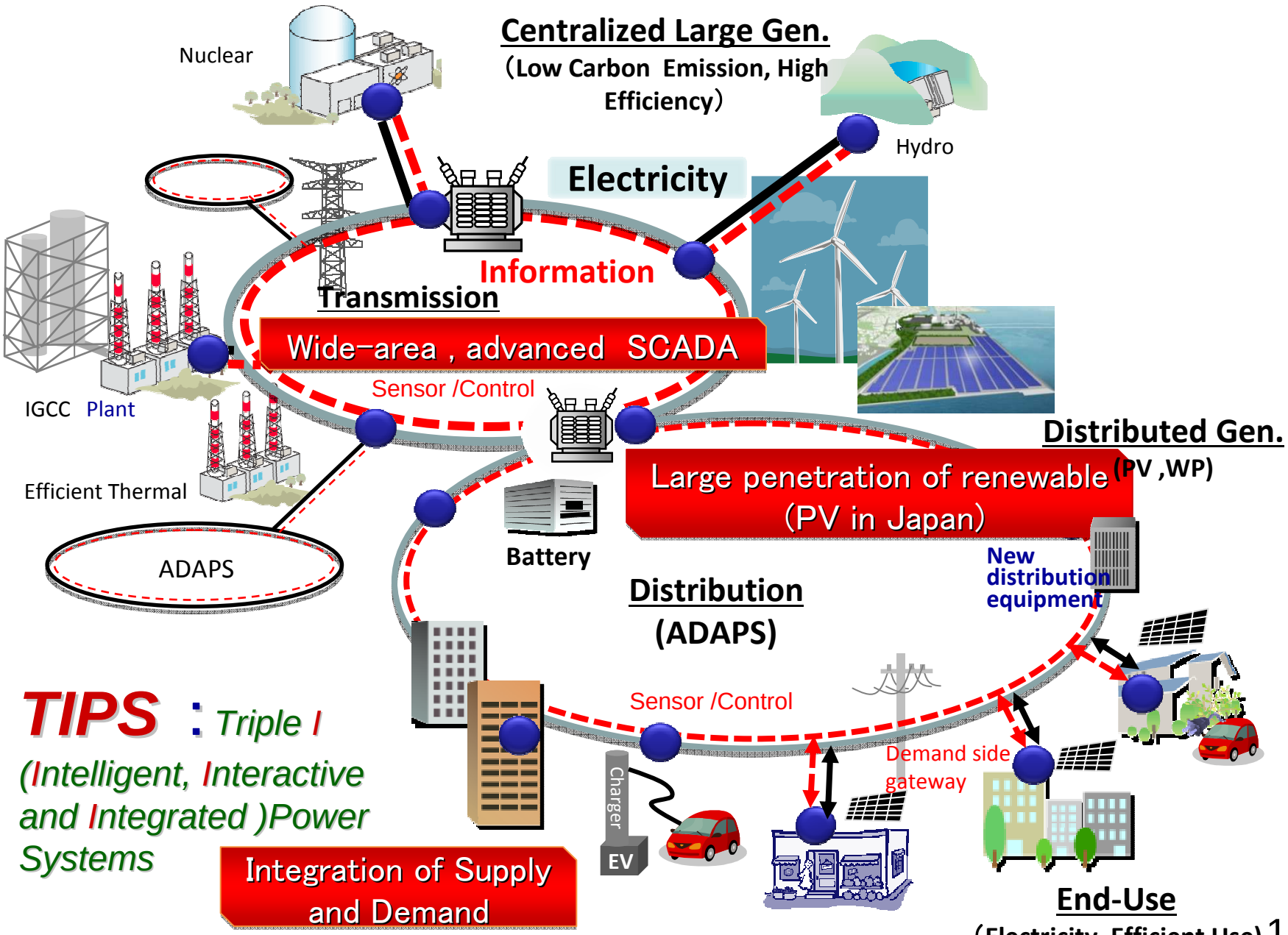
To keep both grid stability and effective energy utilization with low social cost under the condition of large penetration of unstable renewable energy sources.

1. **Minimize the risk of large blackout with securing stable operation. Resilient and self-healing system.**
2. **Enable large penetration and effective utilization of distributed generation using renewable energy.**
3. **Enable conservation and efficient utilization of energy with integration of demand and supply side.**

We are carrying out R&D of Japanese style smart grid :

TIPS: **T**riple **I** (**I**ntelligent, **I**nteractive and **I**ntegrated) **P**ower **S**ystems

Proposed Japanese Style Smart Grid (TIPS)



Research items of TIPS (Phase I to 2011)

ADAPS operation method with supply/demand integration

- Development control techniques of customer's appliances and storage system to cope with *surplus power* due to large PV penetration.

ICT infrastructure for TIPS

- Secure communication network system for demand area
- Sensor network for grid maintenance and operation
- Wide area and fast control network

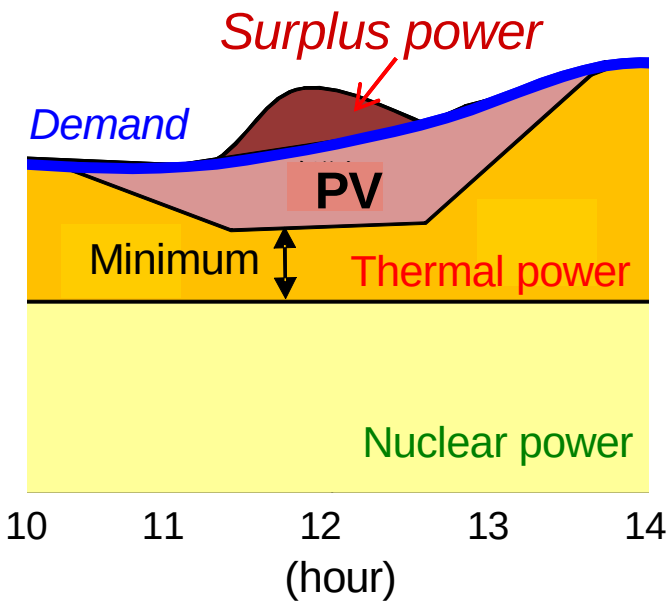
Upper system operation/control method

- Development of simulation method of whole grid characteristic with DG.
- Clarification of operation role between upper system and ADAPS

Evaluation of Demand Response

- Evaluation method of DR program merit
- Feasibility of DR program
- Energy management system for DR

Overview of surplus power issue and proposed measure



Surplus power may occur in intermediate seasons of low demand.

In Japan, surplus power among whole system may occur due to PV more than 20 to 30GW under conventional power plants operating with constant power.

Government considers the measure of combination of large scale storage battery installation and restraining PV power output.

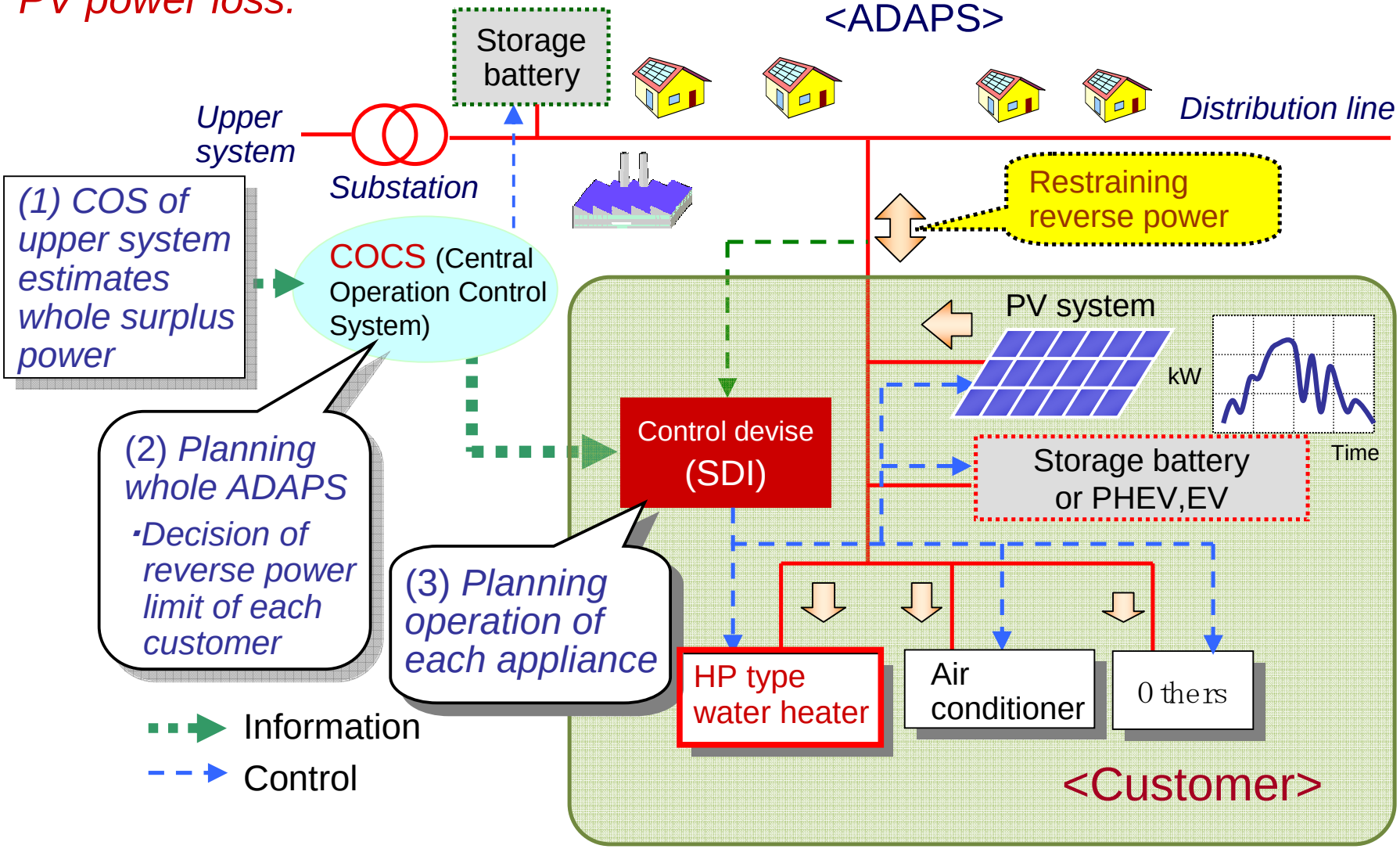
- bring high cost and large energy loss

We propose *a new customer's appliances control method* as a supplement of above measures.

- Both utility requirement and customer convenience are taken into account.

Proposed Integrated control method of supply side and demand side

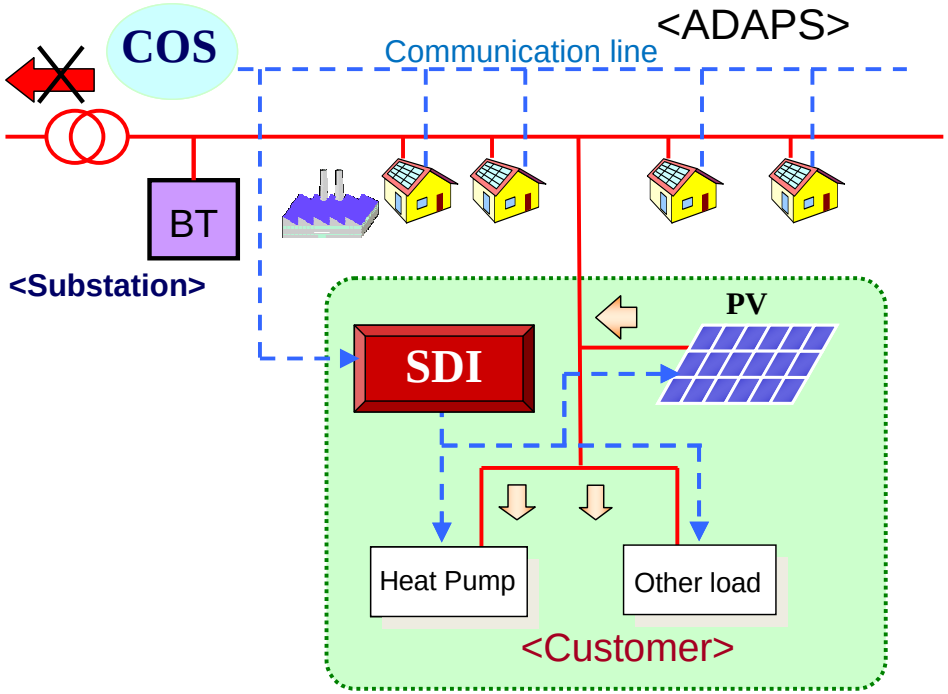
For coping with surplus power with minimum storage battery capacity and PV power loss.

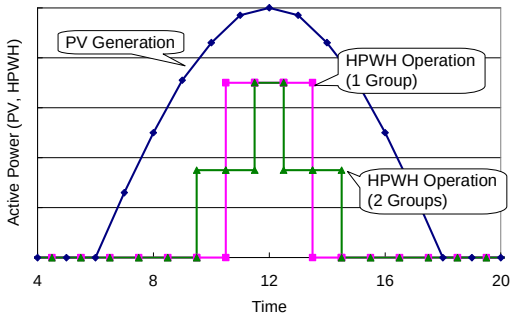


Effect of proposed operation method

- Reduction of storage battery capacity in substation -

Assumed condition: Reverse power flow from ADAPS to the upper system is prohibited.

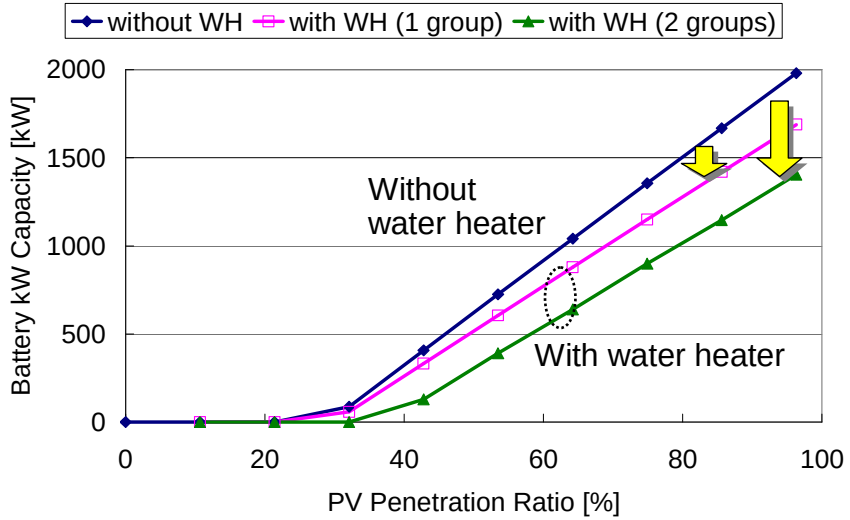




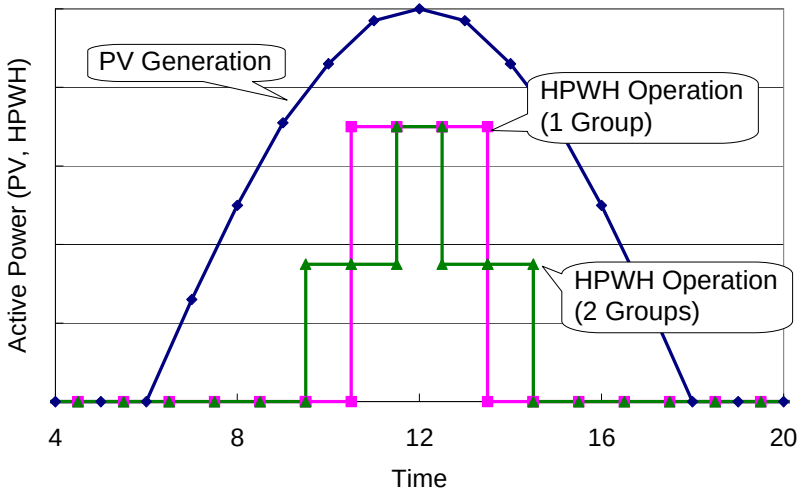
Simulation models

- 6.6kV distribution feeder
  - Length: 4 km
  - Capacity: 3000 kVA
  - The number of customer: 1500 houses
  - Consumption in daytime: 1.0 to 1.2 MW
- PV system
  - Capacity of a unit: 3 kW
  - Penetration ratio: 0 to 100% of feeder capacity
- Controlled load
  - Type: Heat pump type water heater
    - Rated consumption power: 1 kW
    - Hot water storage capacity: 3 kWh
    - operated in daytime

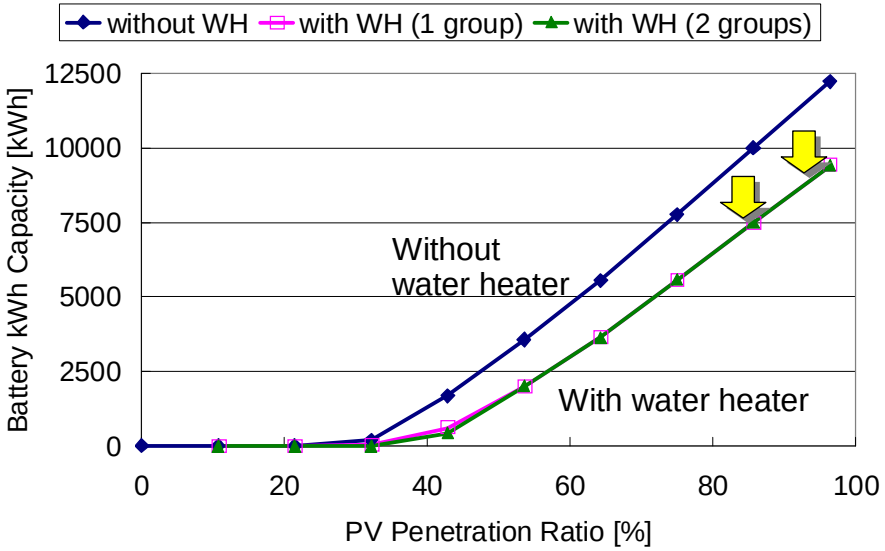
Simulation results on required storage battery kW rating and kWh capacity



Changes of storage battery kW Capacity



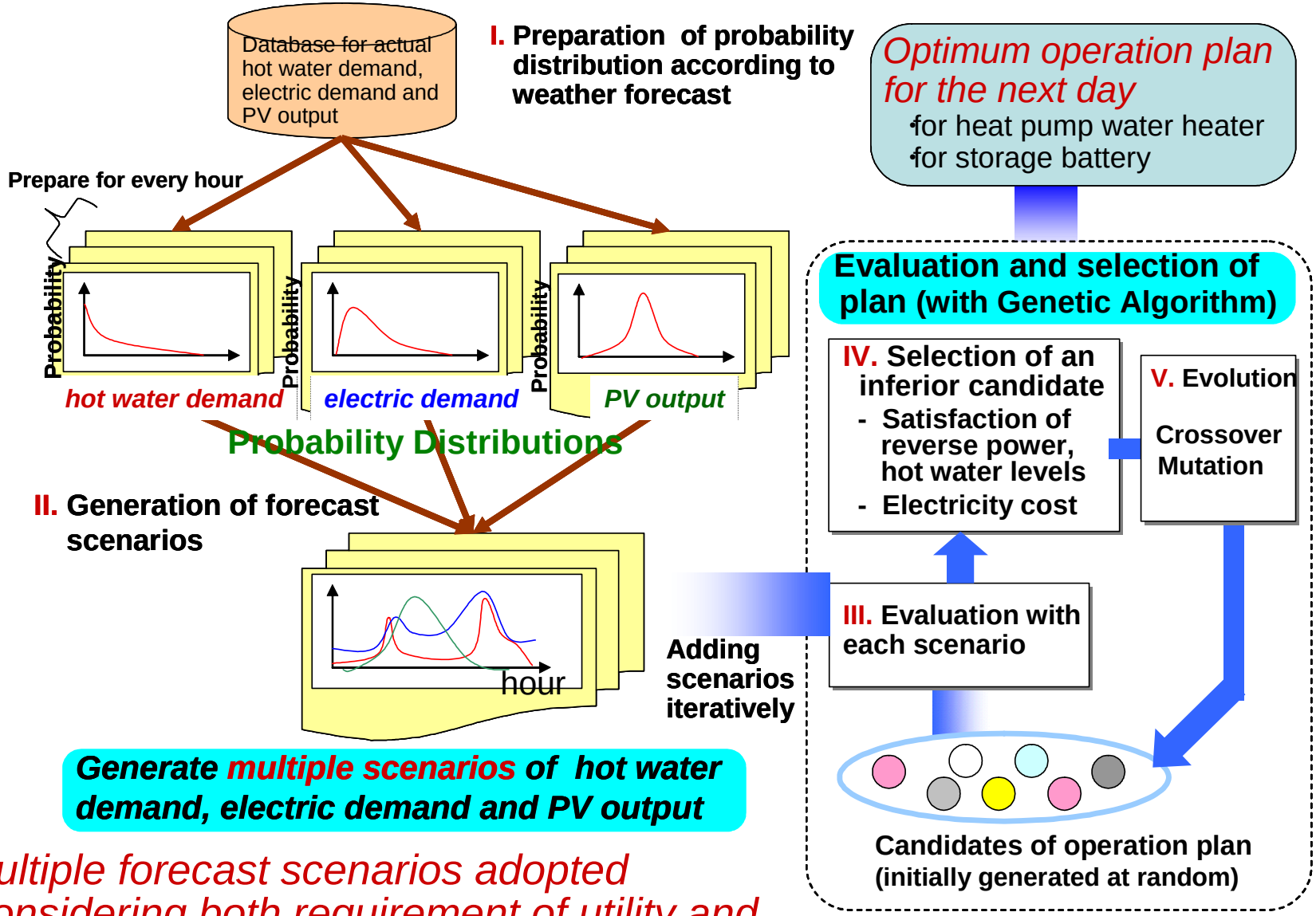
Operation Patterns of PV system and HP type water heater (WH)



Changes of storage battery kWh Capacity

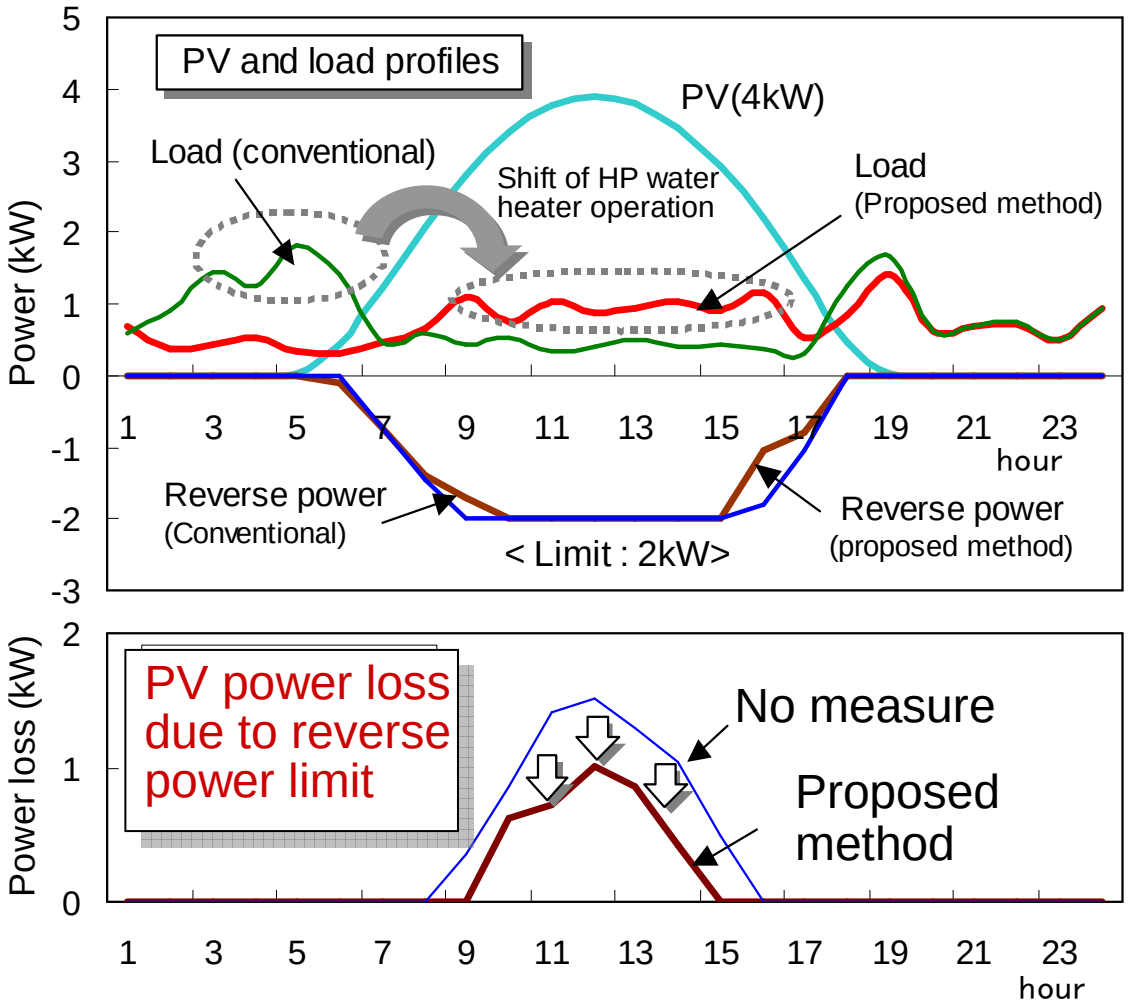
- Both kW capacity and kWh capacity can be reduced to about 40% when the penetration ratio of PV is 60%.
- Required storage battery kW capacity can be reduced when WH operation period is divided into 2 groups among customers .

Operation planning method of customer's appliances considering uncertainty of forecast



- *Multiple forecast scenarios adopted*
- *Considering both requirement of utility and customer's conveniences*

Simulation results on PV power loss reduction by proposed operation planning method for customer



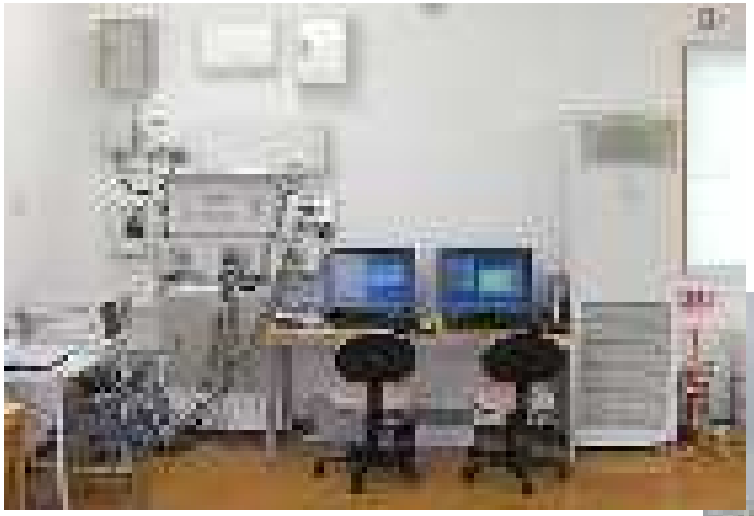
Conditions

- PV system : 4kW
- Heat pump type water heater: 1kW (3kWh).
- No storage battery
- Imposed reverse power limit :2kW
- **Target** : minimize PV power loss due to reverse power limit.

Results

- Water heater operation shifts to the day times automatically.
- PV power kWh loss in a day is reduced to about 50%

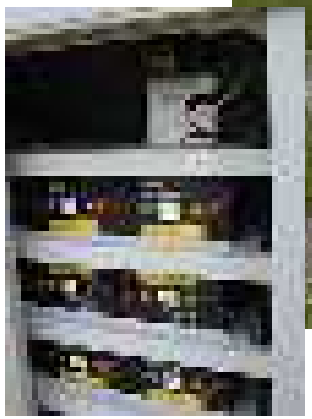
Demonstration facility for customer's operation planning method.



S&D Interface

4 kW PV array

HP water heater



10 kWh storage baterry

Conclusions

R&D results concerning advanced distribution system (*ADAPS*) to cope with DG interconnection were introduced.

R&D of new proposed future power system (*TIPS*) to cope with larger and wider penetration of RES (PV) in future were introduced.

Integration control technique of supply side and demand side to cope with surplus power were proposed and being demonstrated.

- More detailed demonstration test will be carried out in a joint research project supported by government with 28 organizations (3 universities, 9 utilities, 15 manufacturers and CRIEPI) from FY 2010 to 2012.