DEVELOPMENT OF AUTONOMOUS DEMAND AREA POWER SYSTEM -OPERATION AND CONTROL FOR REGULATION OF SYSTEM VOLTAGE-

Satoshi UEMURA
The Central Research Institute
of Electric Power Industry – Japan
s-uemura@criepi.denken.or.jp

Hiromu KOBAYASHI
The Central Research Institute
of Electric Power Industry – Japan
hiromuk@criepi.denken.or.jp

ABSTRACT

In 6.6kV power distribution system of Japan, the introduction of many distributed power generations (DGs) is expected. Under such circumstances, power flow congestion and voltage fluctuation on distribution lines caused by varied output of the DGs will occur. This will result in a failure to maintain power quality and supply reliability by conventional power system management.

In this paper, we have proposed a new power supply system referred to as the Autonomous Demand Area Power System (ADAPS). ADAPS may be in the loop formation, in addition to the conventional tree branch form. We will try to establish network technology and operation management technology of ADAPS, and identify its effectiveness.

Using actual voltage experimental equipments, we performed reducing the fluctuation caused by changing load and output of DGs, and regulating the system voltage by collecting system information via Supply and Demand Interfaces and controlling Loop Power Flow Controllers.

Therefore, we checked that operation method (by Operation Control System) of ADAPS was effective in the viewpoint of voltage regulation.

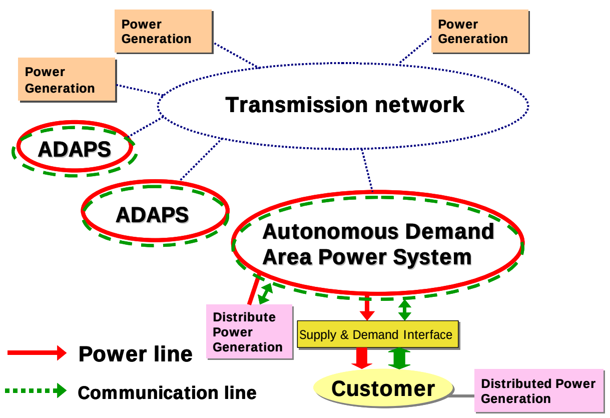

Fig.1 Expected future power system

PURPOSES

In 6.6kV power distribution system of Japan, centered in urban areas with high power demand densities, the introduction of distributed power generations (DGs) including fuel cell and photovoltaic power generation are expected. Under such circumstances where many DGs are incorporated in the existing power system, power flow congestion and voltage fluctuation on distribution lines, caused by varied output of the DGs, will occur. This will make the control of the entire power system operation complicated, and result in a failure to maintain power quality and supply reliability by conventional power system management.

As a strong countermeasure of the issues, we have proposed a unique, new power supply system referred to as the Autonomous Demand Area Power System (ADAPS). ADAPS leads free access of the DGs to the grid and makes full use of the characteristics of the DGs, which feature the effective use of electric power and thermal energy at the demand side. To facilitate this proposed scheme, we'll try to establish network technology and operation management technology of ADAPS, and identify its effectiveness.

BASIC CONCEPT OF ADAPS

Concept of ADAPS

Fig.1 shows expected future utility power system including ADAPSs. ADAPS is defined as the segment that includes the distribution system (=6.6kV) and the secondary system (=66kV) of power supply side in Japan.

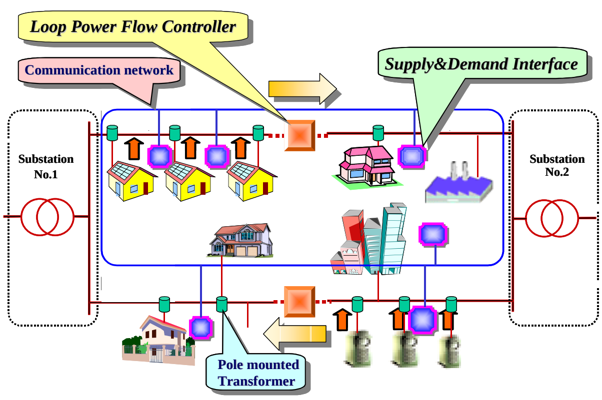

Fig2. Configuration of ADAPS

Configuration of ADAPS

Fig. 2 shows an example of ADAPS configuration, and communication network structure. ADAPS may be in the loop formation, in addition to the conventional tree branch form. Loop Power Flow Controllers (LPC) for controlling power flow and voltage between loops will be needed. Operation Control System (OCS) and Supply and Demand Interfaces (S&D IF) per several customers will be installed for information exchange between supply and demand sides. OCS (central unit) aims for the power flow control of whole of ADAPS. The communication network is consists of optical fibers.

ADAPS OPERATION TEST BY USING ACTUAL VOLTAGE EQUIPMENT

Configuration of test power system

Fig.3 shows 6.6kV test power distribution system consist of some feeders and three LPCs. The main feeder of the system consists of three sections divided by sensors (No.2,3), and each section is connected by LPC with another feeder. The second section is interconnected with load-A and generation-A as a high voltage customer, the third section is interconnected with load-B and generation-B as a high voltage customer.

The communication network consists of optical fibers, media converters and hubs, and connects OCS with other components such as LPCs and S&D IFs.

As ADAPS components except LPC, OCS is set in the control room of a substation, and S&D IFs is set in the load and generator rooms, both components consist of personal computers.

Configuration of LPC

LPC consists of two ac/dc converters linked to direct current (=Back To Back method), and enables the simultaneous control of power flow and terminal voltage at both power line sides. The two power lines can be connected together by the LPC even though voltages and phases between two lines are quite different. As the results, loop or mesh configuration can be composed in demand area. Additionally, because fault current of loop network can be isolated by LPCs, reliability of protection and safety of the network will be able to be maintained.

The composition, the rating and the appearance of LPC using this test are shown in Fig.4, Table1 and Fig.5.

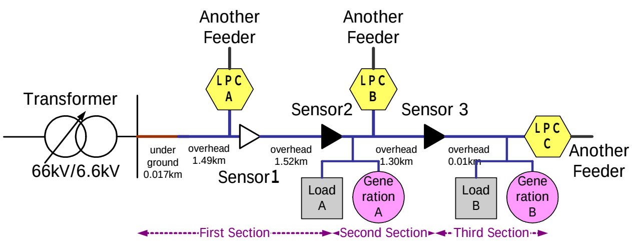

Fig.3 Test Power Distribution System

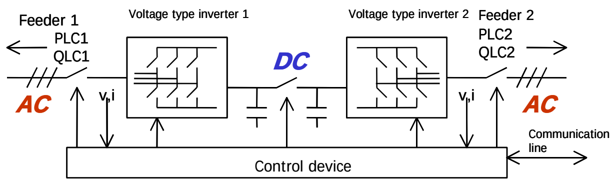

Fig.4 Composition of LPC

Table1 Rating of LPC and Transformers

Main Circuit

Rated Capacity	100kVA	Rated Voltage	369V
Rated Current	225A	Control Range	258〜480V
Switching Device		IGBT	1200V
Carrier Frequency		10kHz	

Transformer for connection

Primary	Rated Voltage	6900V	Rated Current	11A
Secondary		369V		225A

*Rated Capacity (100kVA) is converted to 750kVA by the system capacity

Fig.5 Appearance of LPC

Table2 Rating of a Synchronous Generator

Rated Capacity	187.5kVA	Rated Voltage	400V
Number of Poles	4	Rated Current	271A
Rated Speed	1500rpm	Power Factor	0.8

*Rated Capacity (187.5kVA) is converted to 1406kVA by the system capacity

Fig.6 Appearance of a Synchronous Generator

Configuration of load and DG

The loads are consists of resistances, reactors, capacitors and motor load. However, resistance loads are used in this case.

The DG is consists of photovoltaic power generators, three phase inverter-type generators, synchronous generators and induction generators. However, synchronous generator is used in this case.

The rating and the appearance of the synchronous generator are shown in Table2 and Fig.6.

Test method and results

Regulation tests for output variation of the DG

System voltage fluctuation is caused by output variation (max 800kW) of the synchronous generator set in the generation-A as shown in Fig.7.

OCS collects information of every load and generation output by the communication network. OCS calculates optimal voltage profile while changing LPCs output by using collecting the information. OCS orders LPCs to change active power and reactive power output to the calculation results at a 180s interval. Fig.9 shows active power and reactive power output of LPC-C in this test, and these powers are changed according to voltage fluctuation as shown in Fig.8.

Fig.8 shows the voltage fluctuation with control and without control. In the case of without control, maximum voltage was 106.2V in low voltage system. In the case of with control, maximum voltage was 105.7V in low voltage system. OCS regulated raising system voltage under the range allowed (106V). From these test results, we checked regulation effect by OCS operation and LPC control.

Comparing regulation effect of one LPC with three LPCs for load variation

System voltage variation is caused by heavy load set in the load-A (750kW) and load-B (750kW).

The system voltage profile was regulated by OCS operation such as the regulation tests. We checked regulation effect with control by using one LPC (LPC-B) and three LPCs as shown in Fig.10. In the case of one LPC, the system voltage rose at 3km distance from substation and the system voltage fell at the end of feeder. In the case of three LPCs, the system voltage falls gradually. At the end of feeder, the system voltage in the case of three LPCs higher than one LPC. From these test results, we checked regulation effect by OCS operation and some LPCs control.

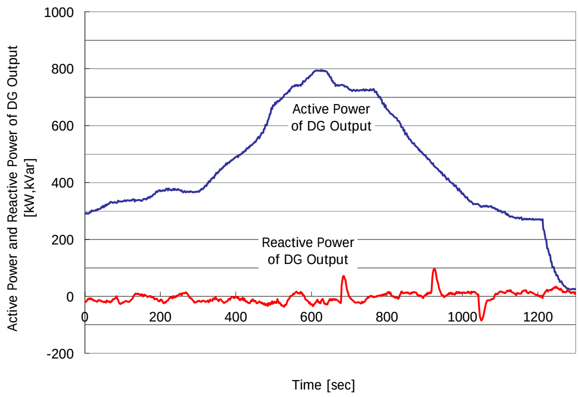

Fig.7 Output Variation of a Synchronous Generator

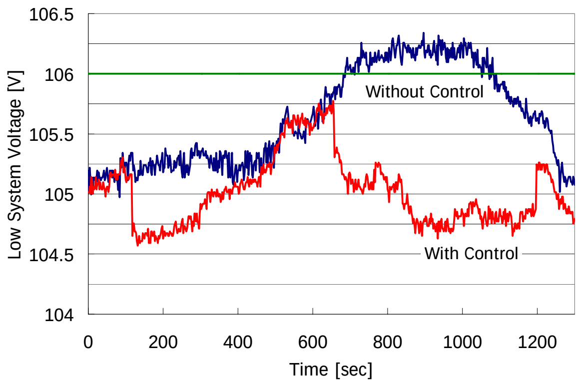

Fig.8 System Voltage Variation with Control and without Control by using LPC

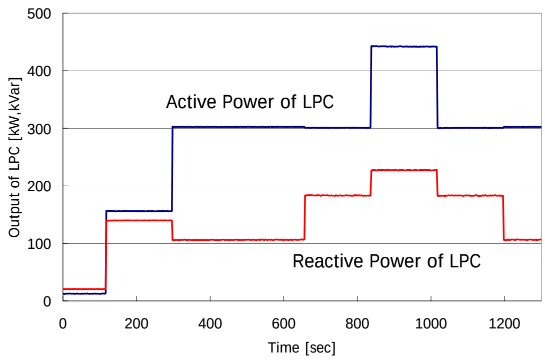

Fig.9 Active Power and Reactive Power Output of LPC-C in the case of with control

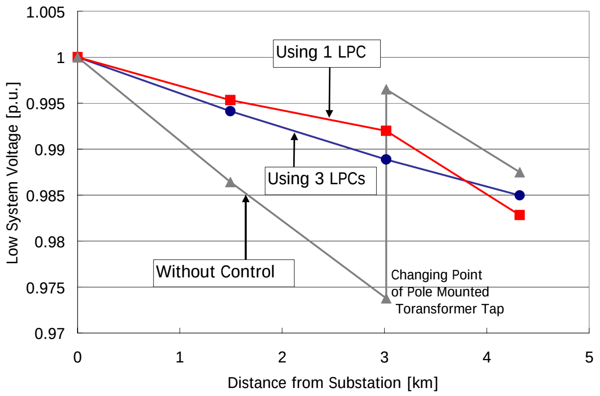

Fig.10 System Voltage Profiles without Control and with Control by using 1 or 3LPC

CONCLUSIONS

Using the actual voltage experimental equipments, we performed reducing the fluctuation caused by changing load and output of DG, and regulating the system voltage by collecting the system information (system voltage, load and DG) via S&D IF and controlling LPCs. Therefore, we checked that the operation method (by OCS) of ADAPS was effective to the voltage fluctuation at the time of extensive introduction of DG. Moreover, we showed that ADAPS might be able to apply to a real distribution system of Japan in the viewpoint of voltage regulation.
In addition, we have completed the test in actual voltage experimental equipments and computer simulation about the method of processing power system failure by using LPCs.

REFERENCES

[1] S.Uemura, H.Kobayashi, 2004, "Development of Autonomous Demand Area Power System", *Proceedings on cigre session 40 Paris,France*, International Council on Large Electric Systems, C6-108

[2] S.Uemura, H.Kobayashi, 2004, "Development of Operation and Control Method for Autonomous Demand Area Power System", *CRIEPI Report, R04025,2004.10 (in Japanese)*

[3] N.Okada, S.Uemura, 2002, "Basic study on installation and control method for loop power flow controller in distribution system", *The 14th Conference of the Electric Power Supply Industry, 2002, pp46-51*