DEVELOPMENT OF VOLTAGE REGULATION METHOD INCLUDING VOLTAGE CONTROL BY SWITCHING CAPACITORS OF CUSTOMERS IN AUTONOMOUS DEMAND AREA POWER SYSTEM

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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 failure to maintain power quality and supply reliability by conventional power system management.

Especially, in residential, commercial and industrial mixed area of Japan, the distribution system voltage will rise at the end of feeder because of reverse power flow by photovoltaic (PV) generations and capacitors (SC) for power factor control by 6.6kV customers.

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 formation. We try to establish network technology and operation management technology of ADAPS, and identify its effectiveness.

In this paper, we studied voltage regulation method by using Static Var Compensator (SVC), Step Voltage Regulator (SVR) and customer's SCs controlled to improve power factor and to regulate voltage at connection point as power distribution system in transition period from conventional system to ADAPS.

BACKGROUND AND PURPOSE OF ADAPS RESEARCH

We have promoted a study of the Autonomous Demand Area Power System (ADAPS) that is highly efficient power distribution system. Moreover, future power system including ADAPS is called Triple I Power System (Intelligent, Interactive, Integrated: TIPS) and we are promoting a study of TIPS in CRIEPI (Fig.1). We think that TIPS is Japanese Type Smart Grid, the research items are operation/control to cope with large penetration of distributed power generations (DGs), protection system of power distribution system and DG, ICT infrastructure, evaluation of demand response, demand side integration and advanced transmission equipments.

The purpose of the ADAPS is to establish smooth introduction and effective use of the DG. In the research of ADAPS, we have established network technology and operation management technology of ADAPS including system in transition period, and identify its effectiveness.

In this paper, we present that we carried out computer simulation by using developing analysis and estimation tool, and studied voltage regulation method by using Static Var Compensator (SVC) and Step Voltage Regulator (SVR) as power distribution system in transition period from conventional system to 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 or 154kV) of power supply side in Japan.

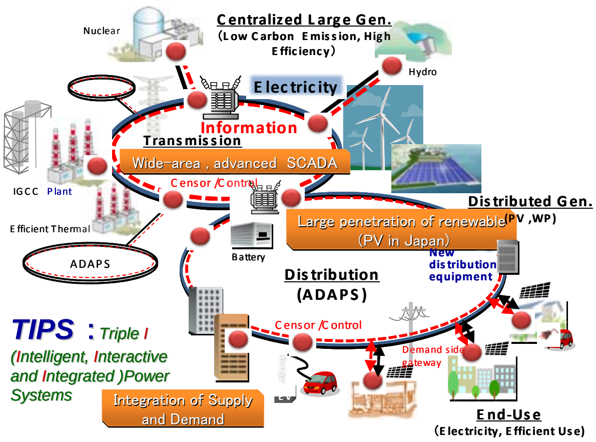

Fig.1 Expected future power system (TIPS)

Configuration of ADAPS

ADAPS may be in the loop formation by using Loop Power Flow Controller (LPC) as shown in Fig.2 (c), in addition to the conventional tree branch formation as shown in Fig.2 (b). LPC controls power flow and voltage between feeders at loop point. Operation Control System (OCS) and Supply and Demand Interface (S&D IF) per every customer will be installed for information exchange between supply and demand sides. The function of S&D IF adds load and PVs output control to the basic function of meter, and is highly intelligent smart meter. OCS (central unit) aims for the power flow control of whole of ADAPS. The communication network is consists of optical fibers.

Power distribution system in transition period from conventional system to ADAPS

Currently, 6.6kV power distribution system of Japan is shaped like tree branch as shown in Fig.2 (a). The distribution automation system controls section switches in order to perform fault operation by communication system that is consists of metal line or/and power line carrier system. Each feeder connects adjoining feeders by using usually open switches. Only long feeder has SVR as shown in Fig.3 in order to regulate the system voltage.

In transition period to ADAPS, power distribution system will be shaped like tree branch as shown in Fig.2 (b). The distribution automation system will control section switches in order to perform fault operation, and will control SVR and SVC in order to regulate the system voltage by communication system that is consists of metal line or/and optical fibers from the sensors information.

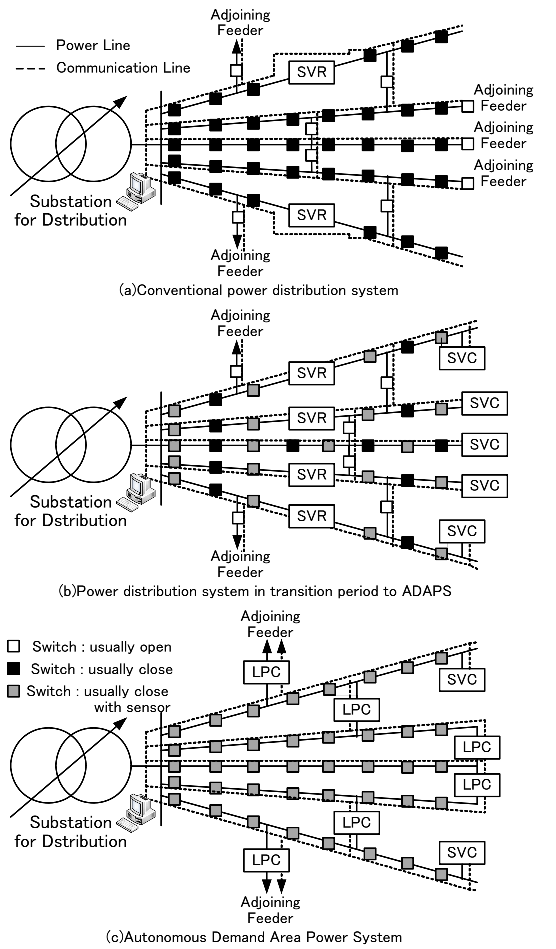

Fig2. Transition process of power distribution system

In ADAPS, power distribution system will be shaped like loop or mesh as shown in Fig.2 (c) by using LPCs. The distribution automation system will control section switches, LPC and SVC in order to regulate the system voltage and perform fault operation, by high-speed communication system that is consists of optical fibers from the sensors information.

STUDY ON VOLTAGE REGULATION METHOD IN TRANSITION PERIOD

Distribution model and load model

Distribution model is shown in Fig.4. The feeder length is 3.65km, the feeder capacity is 4MVA, many 200V customers are connected to every node, two 6.6kV customers are connected to middle point (A) and end (B) of the feeder, SVC connected to A and/or B, SVR is connected to A.

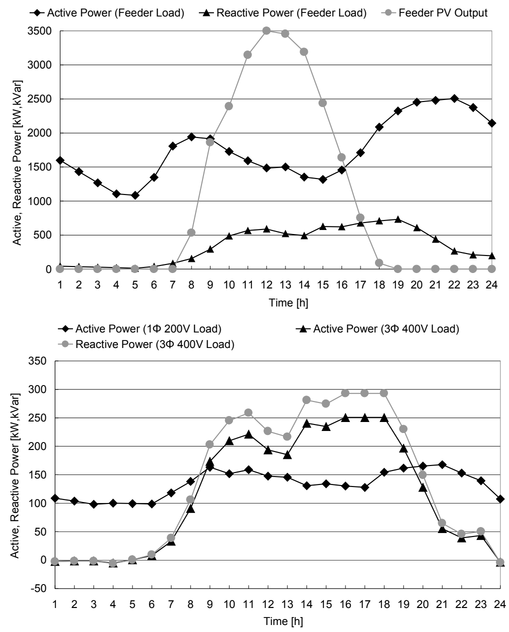

Fig.3 Feeder load and customer load curve

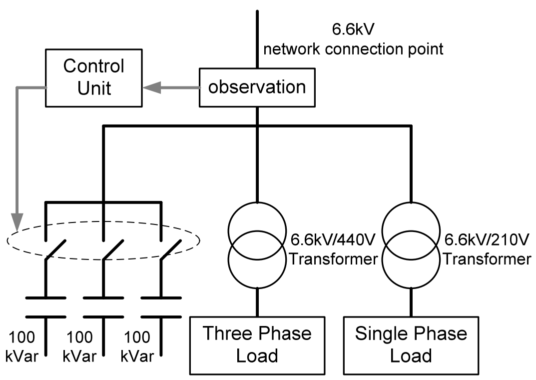

Fig.5 Configuration of customer circuit

The feeder load model of 200V customers and 6.6kV customers, and PV output at fine day are shown in the upper half of Fig.3. The 6.6kV customer load model is shown in the lower half of Fig.3, and the load consists of single-phase 200V load and three-phase 400V load.

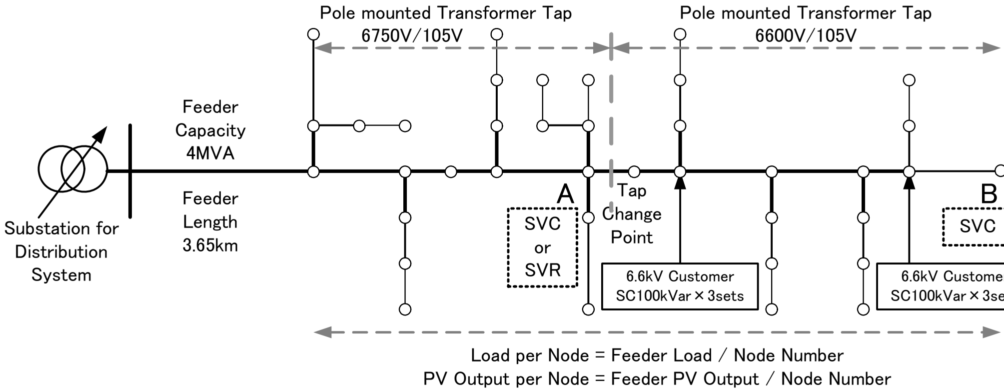

Fig.4 Residential, commercial and industrial distribution model for comparing voltage regulation method

Moreover, capacitor for power factor (pf) and voltage control is 100kVar * 3 sets with automatic capacitors (SC) control function (Fig.5). The pf control method by 6.6kV customers is shown in Fig.6 (refer to paper No.0830 [2011 CIRED] for details.).

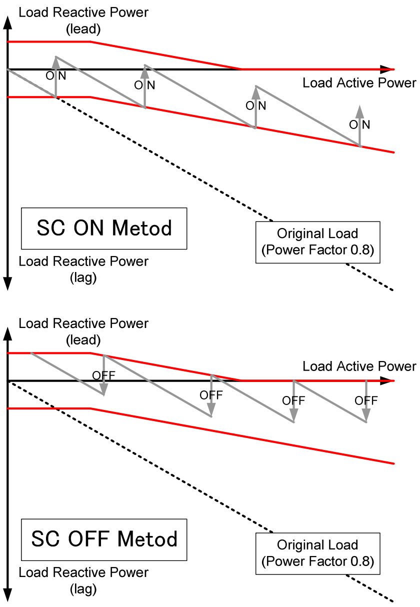

Fig.6 Pf control method by customer

The flow chart of the operation we propose in this paper is shown in Fig.7.

In addition to the pf control (Fig.6), the operation of voltage control opens capacitor in order with small capacity when the customer voltage overs upper limit voltage. If the customer voltage becomes under upper limit voltage or all SCs open, the voltage control stops. In some cases, pf become under target pf (=0.98).

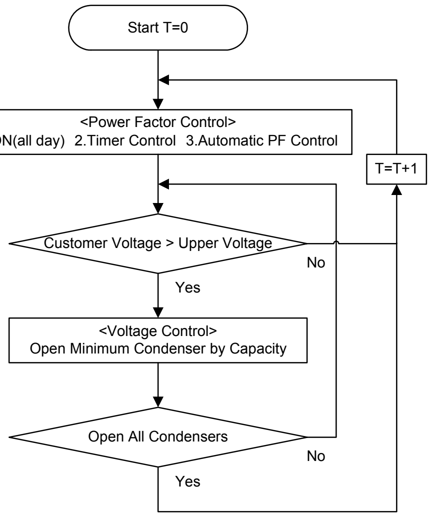

Fig.7 Pf and voltage control method by customer

STUDY RESULTS OF EFFECT OF THE OPERATION ADDED VOLTAGE CONTROL BY CUSTOMER'S CAPACITORS

The system voltage curve and open or close state of SCs is shown in Fig.8 in case of pf control mode and voltage control mode. In the pf control mode, SCs are controlled according to pf of each customer.

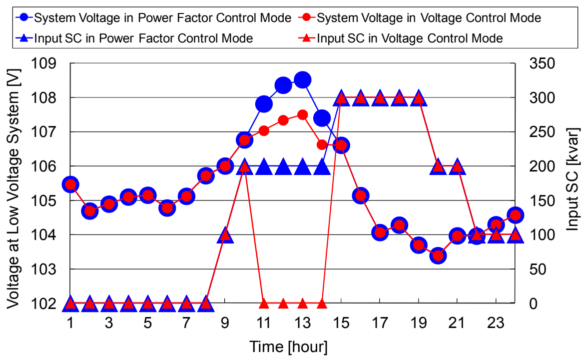

Fig.8 Calculation results of voltage control

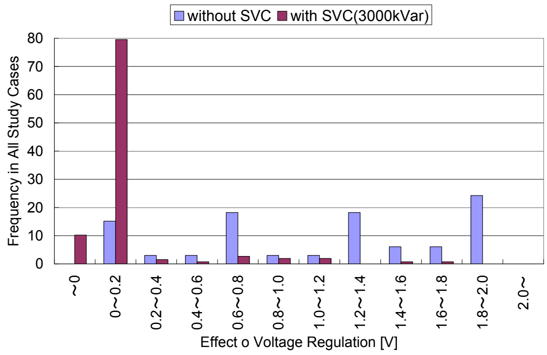

Fig.9 Effect of voltage regulation method

As a result, the system voltage rises up to 108.5V. On the other hand, in the voltage control mode, SCs are controlled according to the pf and the system voltage of each customer. As a result, the system voltage rises up to 107.5V. In this case, the amount of improvement (aoi) is 1.0V. The aoi in all study cases is shown in Fig.9. In case without SVC, the frequency is 20 or more when the aoi is 2.0V.

Table1 shows distribution loss, SVC output and pf of customer A and B in both control modes. In case of the pf mode, SVC control the system voltage and the pf of customer A and B are lead. In case of the pf and voltage regulation mode, SVC do not control the system voltage and the pf of customer A and B are lag. In distribution loss, we compared the pf mode with the pf and voltage regulation mode. The distribution loss of the former is larger than one of the latter, therefore the latter is effective to regulate system voltage.

Table 1 comparison pf control only and pf and voltage control

SC Control Mode	Distriburtion Loss	SVC output	Power Factor	
			Customer A	Customer B
Power Factoer	734.2[kWh/feeder]	454.6[kvar]	(lead)	(lead)
Power Facter and Voltage Regulation	712.7[kWh/feeder]	0[kvar]	0.822(lag)	0.937(lag)

CONCLUSION AND FUTURE WORK

In this paper, we studied voltage regulation system in transition period from conventional system to ADAPS when many PV systems interconnect to power distribution system. We cleared that customer control and the system operation control using SVR and SVC using voltage information from some sensors installed in the distribution line was suitable. In the future, we will clear most suitable system to regulate system voltage at cloudy day, and study method to regulate system voltage including low voltage distribution line. In Japan, PV system has the function of voltage regulation using generating reactive power and decreasing active power automatically.

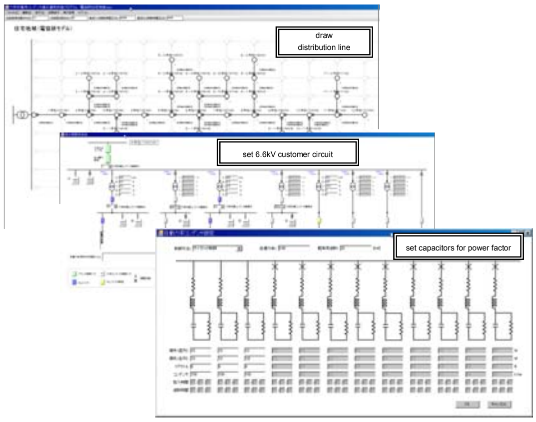

Fig.9 Analysis tool for power distribution system

Fig.9 shows an analysis program that we are developing to estimate voltage regulation method. We can simulate power distribution line, transformer of substation, SVR, SVC, LPC, SC and DG by using the program. The program is called "CALDG" and is used many electric power companies in Japan.

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