A STUDY OF CENTRALIZED VOLTAGE CONTROL METHOD FOR DISTRIBUTION SYSTEM WITH DISTRIBUTED GENERATION

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ABSTRACT

Large volume of distributed power generators (DGs) including renewable distributed generation will be installed in the distribution system in near future. To keep the power quality of the distribution system in case the DGs are installed, a research program of "Demonstrative Project on Power Network Technology" regarding the new electric power system is being carried out under the research contract with the NEDO. The demonstration tests were carried out by use of the control devices such as step voltage regulator (SVR) and static var compensator (SVC) to keep the voltage of the distribution line properly. In this paper, the effectiveness of the centralized control method is shown and improved control method is also considered.

INTRODUCTION

Large volume of distributed power generators (DGs) including renewable distributed generation will be installed in the distribution system in near future. If the penetration capacity of the DGs is increased, the reverse power flow from the distributed power generators may have influence on power quality, reliability and safety of the distribution system.
To cope with such the problems, a research program of “Demonstration Study of Electric Power Network Techniques” regarding the new electric power system is being carried out under the research contract with the New Energy and Industrial Technology Development Organization (NEDO). The purpose of the program is to develop and to demonstrate the control devices and the control methods to keep the voltage of distribution line properly in case the large volume of distributed power generators.
The research items of the program are “Development of the Distribution System Control Device and Measure for Conventional Distribution System” and “Development and Demonstration of Loop Balance Controller for Future Loop Shaped Distribution System”[1].
In the former research item, control devices such as step voltage regulator (SVR) and static var compensator (SVC) and control measures of them were developed and installed in the demonstration test facility. These control devices are designed to be operated by either autonomous and remote control method. In addition, the remote control system of the control devices with communication network are designed and developed[2].
In the latter research item, actual scale Loop Balance Controllers (LBCs) will be developed to clear specifications for compact and light weight manufacturing. The LBC is a power electronics device which consists of two converters connected by BTB (back-to-back) method and enables flexible power flow control between feeders of the distribution system.
In this paper, a centralized control method to keep the line voltage properly is proposed and the demonstration tests of the centralized control method are carried out by use of the control devices SVCs and SVR. Then, the effectiveness of the centralized control method is shown and an improved control method is also considered.

CENTRALIZED CONTROL METHOD BY USE OF CONTROL DEVICES

A centralized control system by use of the centralized control method was developed. A centralized control system calculates control variables by gathered data, and the control devices are operated by calculated control variables.

Control Devices

In the developed control system, SVC and SVR are used as control devices. The SVC controls voltage by output reactive power, and the SVR controls voltage by changing tap position.
The reference value Q* of the SVC and tap position of the SVR are calculated by the control system as control variables. In this calculation, the control blocks of the control devices are considered.

Centralized Control Method

The centralized control method is the remote control method by use of the communication system. The communication system consists of a central system, sensors and control devices. As shown in Fig.1, the central system gathers data from sensors at the distribution line, and calculates control variables of each control devices, then send the calculated control variables to the each control devices.

Calculation for Optimal Control Variables

To calculate the optimal control variables, the central system gathers data of voltage, active power flow and reactive power flow from sensors. The output reactive power of the SVCs and the tap position of the SVR are parameterized. Then, the central system performs the power flow calculation by the round-robin method and picks up the optimal parameters.

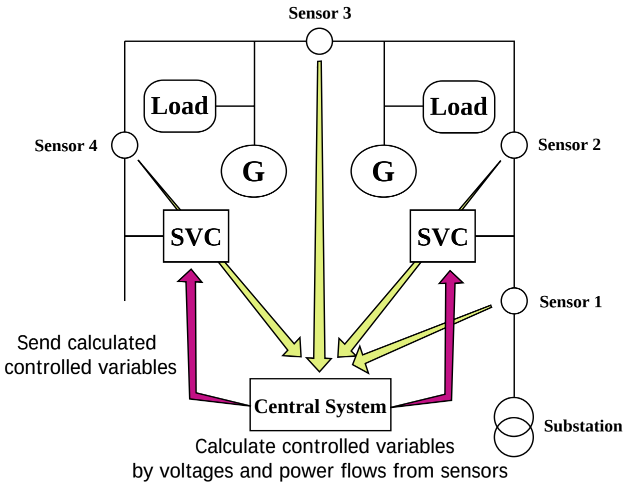

Fig.1 Centralized Control Method

DEMONSTRATION TESTS OF CENTRALIZED CONTROL METHOD

Demonstration tests of the centralized control method were carried out at Akagi testing center of Central Research Institute of Electric Power Industry (CRIEPI).

Test Distribution System with Distributed Generators

The test distribution system with distributed power generators is shown in Fig.2. The test distribution system consists of a substation, 6.6 kV distribution lines, distributed generators, loads control system and communication network. The actual length of the distribution line is about 2 km, and the equivalent line length is about 5 km by use of three simulated line impedance equipments. The distributed generators and 200kVA class loads are installed at three points in the test distribution system. The distributed generators are the 100kW inverter type ones which simulate photovoltaic (PV) generation. The loads consist of the resistance and reactor. The maximum resistive load of them is 200kW and the maximum inductive load of them is 100kVar.

Control Devices

The control devices such as a 3000kVA step voltage regulator (SVR) and two 300kVA static var compensators (SVCs) are installed in the test distribution system. The SVR is installed at the middle of the distribution line. The SVCs are installed at the middle and the end of the distribution line, and they are called SVC1 and SVC2, respectively. In the tests of this study, the SVCs are used as control devices.

Test Conditions

The distributed generators and the loads are operated by the preset patterns to simulate the daily change. The output pattern of the distributed generator is shown in Fig.3. The distributed generator simulates PV generation in fine weather. Fig.4 shows the load curve, which simulates the load of the intermediate period distributed evenly over the distribution line.

Test Result without Control Devices

The distributed generators and the loads are operated by the preset patterns mentioned above. In the tests, the penetration capacity of DGs is 50% of the distribution line capacity. The voltages are measured at the middle and end of the distribution line.

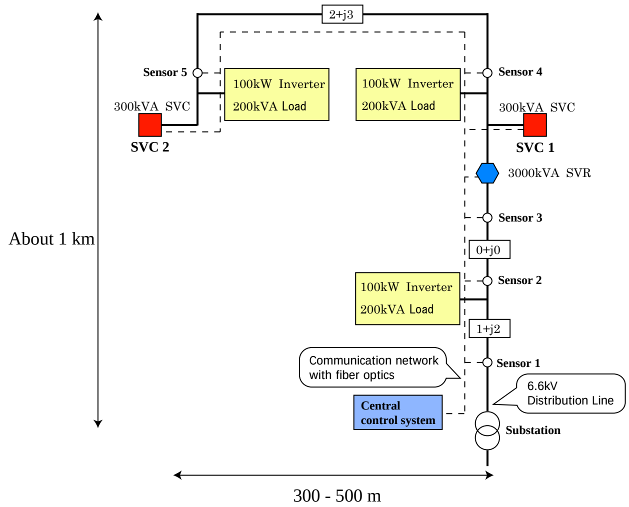

Fig.2 Test Facility

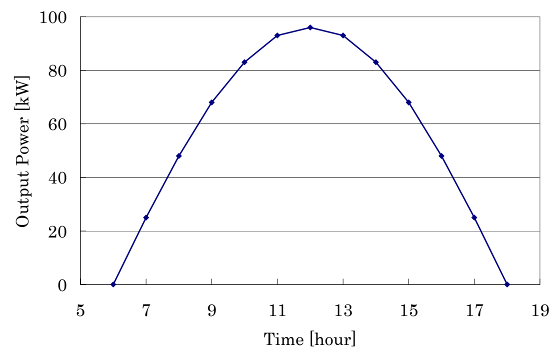

Fig.3 Output Curve of distributed generator

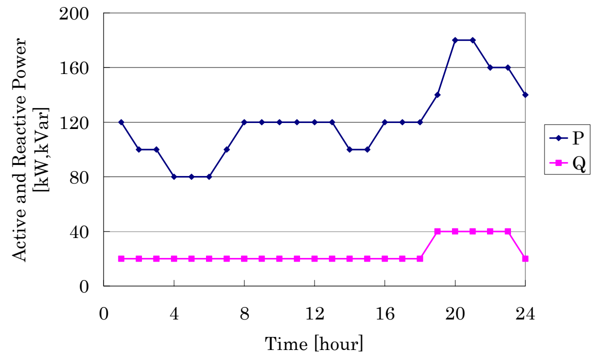

Fig.4 Load Curve

The voltages of the distribution line without the control device are shown in Fig.5, and the power flow from the substation is shown in Fig.6. When output power of the DGs become larger, the voltages at the middle and the end of the distribution line exceed the upper limit 6725V (107V in low-voltage).

Test Result with a Centralized Controlled SVC

To confirm the usefulness of the centralized control method, the SVC2 is controlled by the centralized control method. The voltages of the distribution line are shown in Fig.7, and the output reactive power of the SVC2 is shown in Fig.8. In this case, the control variables are calculated every 5 seconds.

As a result, the voltages of the distribution line are reduced under the upper limit. The output reactive power of the SVC2 is selected to minimize it.

Test Result with Centralized Controlled SVCs

Next, the SVC1 and the SVC2 is controlled by the centralized control method. In this case, the transmission loss is considered in the calculation at the central system. The voltages of the distribution line are shown in Fig.9. and the output reactive power of the SVCs are shown in Fig.10. In this case, the control variables are calculated every 15 seconds.

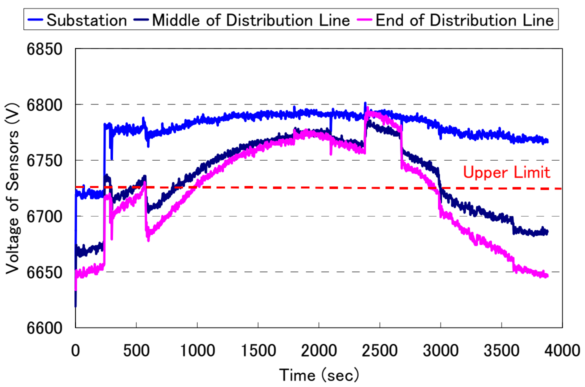

Fig.5 Voltage of Distribution Line (without Devices)

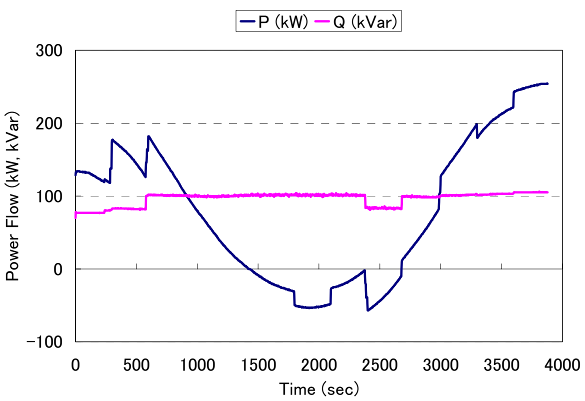

Fig.6 Power Flow from Substation (without Devices)

As a result, the output reactive power of the SVCs are selected to minimize the transmission loss. As shown in Fig.11, the SVCs improve the power factor of the distribution line compared with Fig.6 when the voltage of the distribution line is in proper range.

As shown in Fig.9, the voltages of the distribution line are controlled under the upper limit almost all of the test period. But the voltage exceeds the upper limit within the control period (15 seconds).

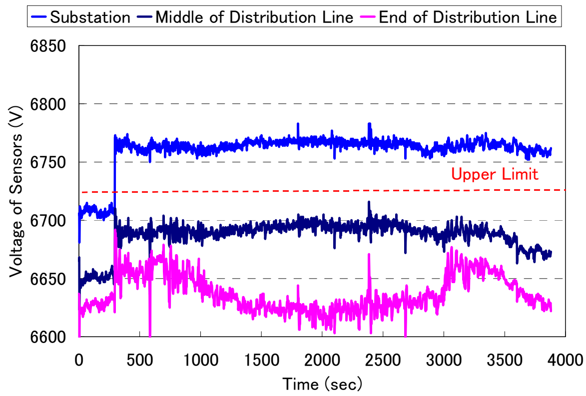

Fig.7 Voltage of Distribution Line (with SVC2)

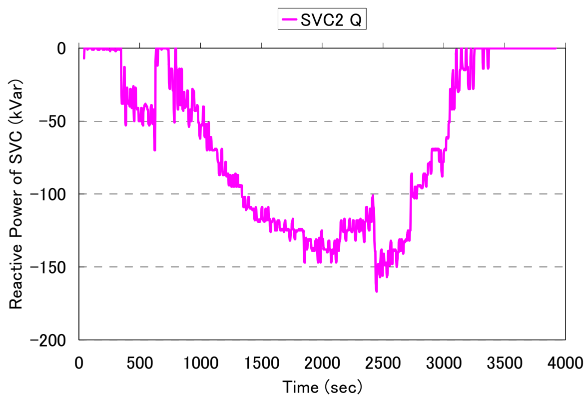

Fig.8 Reactive Power of SVC (with SVC2)

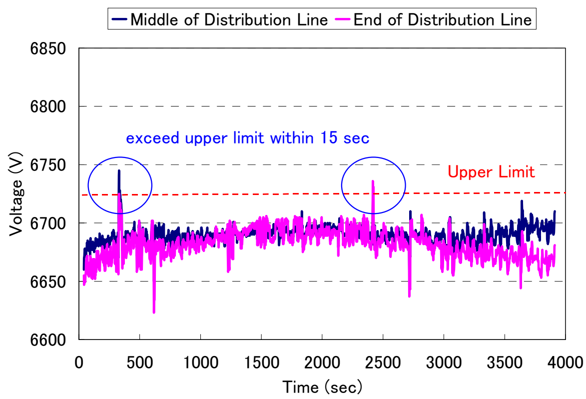

Fig.9 Voltage of Distribution Line (with SVC1 and SVC2)

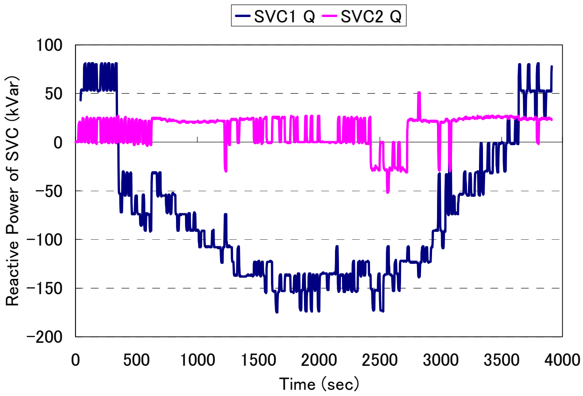

Fig.10 Reactive Power of SVC (with SVC1 and SVC2)

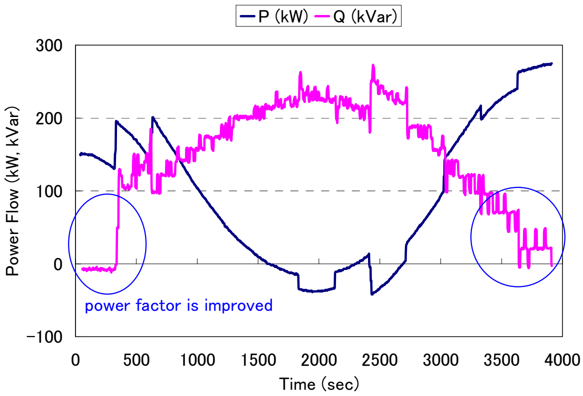

Fig.11 Power Flow from Substation (with SVC1 and SVC2)

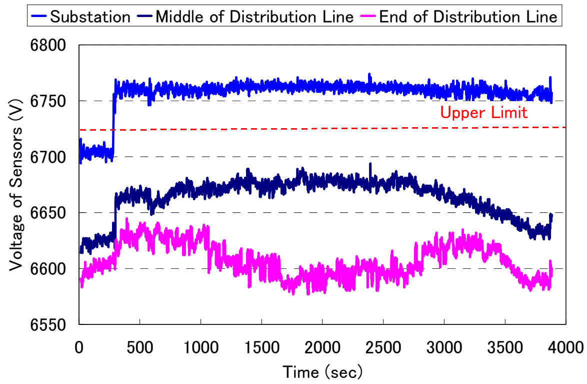

Fig.12 Voltage of Distribution Line (with SVC1 and SVC2 controlled by combined method)

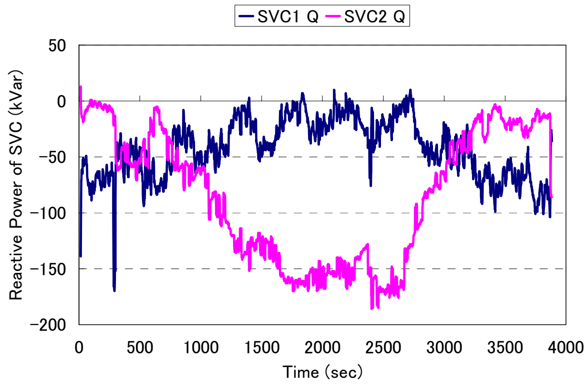

Fig.13 Reactive Power of SVC (with SVC1 and SVC2 controlled by combined method)

IMPROVEMENT OF CENTRALIZED CONTROL METHOD

It is pointed out that the voltage may exceed the proper range within the control period when the voltage fluctuation occurs. Therefore, an improved control method, which is combined method of autonomous and centralized control, is considered.

In this method, the central system calculate the voltage of the SVC as the control variable, and the SVC is controlled as an automatic voltage regulator. Then, the line voltage is controlled if the voltage fluctuation occurs.

A demonstration test is carried out. In this test, the control variables are calculated every 15 seconds to minimize the output reactive power of the SVCs. The line voltage and the output reactive power of the SVCs are shown in Fig.12 and Fig.13, respectively. The line voltage is controlled properly by this method.

CONCLUSIONS

In this paper, a centralized control method to keep the line voltage properly is proposed. The demonstration tests of the centralized control method to keep the voltage of the distribution line properly were carried out.

The effectiveness of the centralized control method is shown and the line voltage is controlled almost properly by the centralized control method. In addition, the improved control method is considered and tested. The line voltage is controlled properly during the test period by this method.

Fast algorithm for the centralized control methods and the demonstration of sudden voltage fluctuation are future works.

Acknowledgments

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