EVALUATION OF OPERATION CHARACTERISTICS IN MULTIPLE INTERCONNECTION OF PV SYSTEMS

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ABSTRACT

In Japan, PV systems must be maintained within 101V±6V for the standard voltage of 100V according to “the technical recommendations for the grid connection of dispersed power generating”. So, PV systems are provided with an automatic voltage control. The output power of PV systems will be reduced by the voltage control. Therefore, we develop a tool that analyzes the operation characteristic of grid-connected PV systems. Using this tool, we obtain the electric energy of PV system per year, and evaluate loss of electric energy which is reduced by the automatic voltage control.

1. INTRODUCTION

Grid-connected PV systems must follow the technical recommendations for the grid connection of dispersed power generating, The technical recommendations show that the voltage at consumers must be maintained within 101V±6V for the standard voltage of 100V. To maintain an adequate voltage, PV systems must be provided with an automatic voltage control. Therefore, PV systems control their output to maintain an adequate voltage, when the voltage of the distribution-line is raised. However, the controlled electric energy of a PV system, which is loss of electric energy by automatic voltage control with a PV system, isn't precisely known yet. So, this paper describes models of PV systems provided with automatic voltage controls, and an analysis of the PV system's operation characteristics, when many PV systems are connected to distribution-lines.

2. SIMULATION MODEL

2.1 Distribution system model

A distribution system model is shown in Figure 1, and the configuration is shown in Table 1. This model is constructed with a 4 distribution line feeder. The distribution lines are connected to the distribution substation, and their feeder is shown in detail, where the others join together. This distribution system model is assumed to be in a residential area, and the form is basically straight. The voltage of a grid-line is generally regulated at a distribution substation, so the following functions of the voltage regulation are set with the distribution-line model.

1. Regulating the supplying voltage at a distribution substation.
2. Switching the voltage transformation ratio of pole mounted transformers in the distribution network.
3. Installing a power factor improvement capacitor.

The first function which regulates the supplying voltage depends on the fluctuant load of a grid-line, and the supplying voltage is controlled by two methods; one is the Line Drop Compensation (LDC) method, and the other is the program method. In this simulation, the LDC method is used.

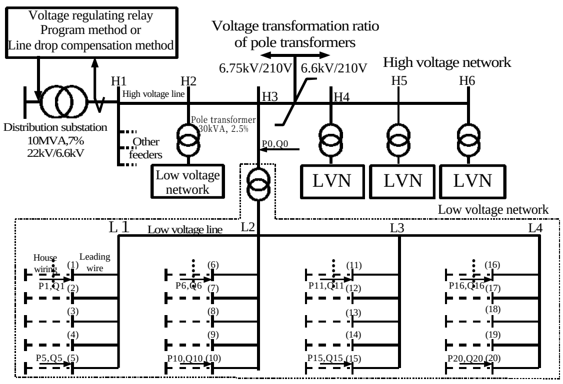

Figure 1 Distribution system model

Table 1 Distribution-line model Configuration

High Voltage Distribution Line Impedance	0.313+j0.377 Ω/km
Low Voltage Distribution Line Impedance	0.025+j0.02 Ω/40m
Distribution Line Length	6km
Total High Voltage Load	800kW
Total Low Voltage Load	1300kW
Consumer's Houses	1800
Power Factor Improvement Capacitor	345kVA

2.2 PV system model

A function of an automatic voltage control with PV systems is shown in Figure 2. This function regulates voltage at the output of the PV inverter, to control the leading reactive power or active power. When the voltage exceeds the upper limit and the power-factor is the within limit, the leading reactive power is increased. Moreover, when the power-factor exceeds the limit, the active power of a PV system is decreased. In this simulation, the PV system model is given the function of automatic voltage control, the PV inverter capacity is 3.3kW, the upper voltage limit is 214V, and the limited power-factor is 0.85.

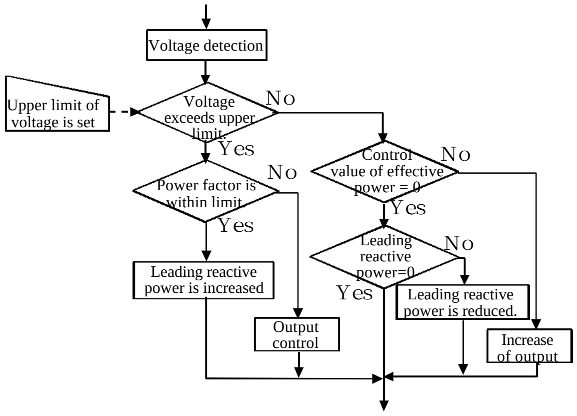

Figure 2 Function of automatic voltage control

3. SIMULATION RESULTS

3.1 Operation characteristics in the multiple inter-connection of PV systems

Operation characteristics of PV systems in some places are shown in Figure 3. In this case, the rate of PV systems is 50%, and the solar irradiance trend is for a clear day in autumn. At the end of a grid-line (H6(16)), The voltage exceeds the upper limit (214V) in the daytime, therefore this PV system which connects to this point controls the leading reactive power. On the other hand, at the point (H2(16)) nearer the distribution substation, some PV systems do not need to control this.

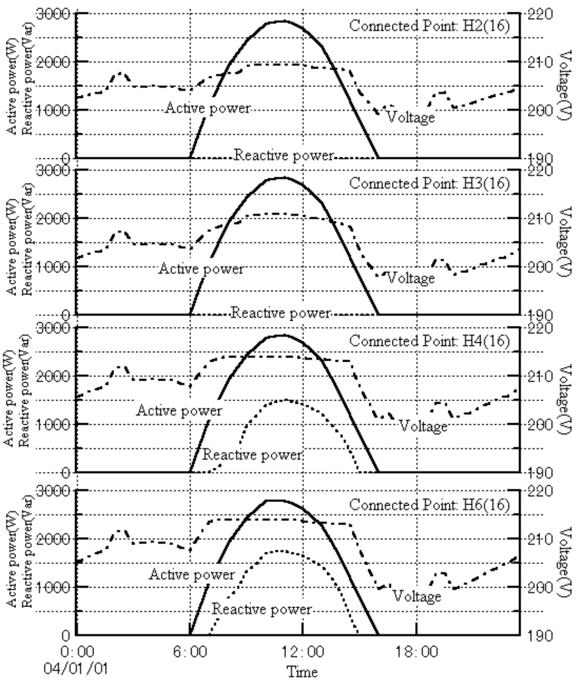

Figure 3 Operation Characteristic of PV systems

3.2 Rate of the controlled electric energy of a PV system for a day

The rate of the controlled electric energy of a PV system, where the end of a grid-line (H6(16)), for a day is shown in Figure 4. It is defined as the rate to the maximum electric energy for a day. The PV system starts to control the reactive power, when the rate of PV systems exceeds 30%, then, it starts to control the active power, when the rate of PV systems exceeds 50%.

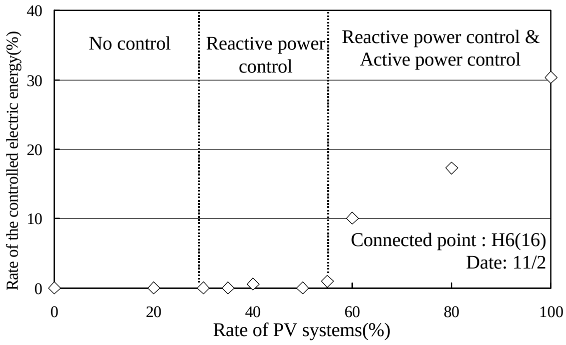

Figure 4 Rate of the controlled electric energy of a PV system for a day

3.3 Rate of the controlled electric energy of a PV system for a month

The maximum and average rate of the controlled electric energy of a PV system, where the end of grid-line (H6(16)), is shown in Figure 5. In spring and autumn, the rate of the controlled electric energy increases, because in these seasons load is lower than in the other seasons. In particular, the maximum rate of controlled electric energy on April is 8% for a day. In this case, the average rate is 0.47% for a year.

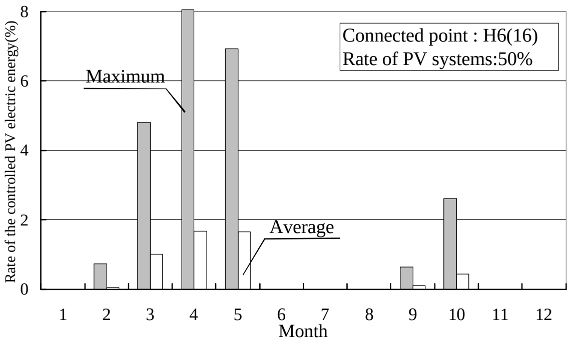

Figure 5 Maximum and average rate of the controlled electric energy of a PV system for a month

4. CONCLUSION

This paper presented a model of PV systems provided with automatic voltage controls and an analysis of PV systems' operation characteristics when many PV systems are connected to grid-lines. The following results were obtained.

1. Under same conditions, it makes a difference to the output power. PV systems at the end of a grid-line reduce more.
2. In spring and autumn, the rate of the controlled electric energy tends to increase. In this case, the maximum rate of controlled electric energy on April is 8% for a day, and the average rate of controlled electric energy is 0.47% for a year.