PROBLEMS OF SVR OPERATION IN LARGE PENETRATION OF PHOTOVOLTAIC POWER GENERATION AND PROPOSAL OF IMPROVED OPERATION

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ABSTRACT

In Japan, reduction method of voltage fluctuation in large penetration of photovoltaic power generation by using step voltage regulator (SVR) has been proposed. In this study, we clarified problems of SVR operation in large penetration of photovoltaic power generation through numerical simulation and propose improved operation method of SVR. And the effectiveness of the proposed method for improvement of the distribution voltage management and reduction of the tap changing counts is presented.

INTRODUCTION

For realization of Low-carbon society, Renewable energy such as photovoltaic power generation is becoming widespread. However, the output power of Photovoltaic power generation changes rapidly. Therefore, large penetration of photovoltaic power generation will cause frequency fluctuation, demand and supply adjustment, and voltage rise. Among of these problems, the voltage rise in distribution system is urgent problem. In order to solve this problem, reduction method of voltage fluctuation by using step voltage regulator (SVR) has been proposed. Therefore, we carry out numerical simulation in order to clarify the problems of SVR operation in large penetration of photovoltaic power generation and we propose improved operation.

CHARACTERISTICS OF SVR

Voltage management system of distribution network regulates the sending voltage of feeder at substation according to load curve. But, the regulation of sending voltage at substation cannot completely control the distribution voltage within permissible range. Therefore, in Japan, distribution voltage is controlled by the SVR installed in distribution system. Fig.1 shows picture of SVR. Fig.2 shows structure of SVR. The SVR consists of control transformer, on-load tap changer, and line drop compensator (LDC). By detecting the voltage drop from SVR output terminal to the predetermined reference point of distribution line, SVR regulates the voltage of the

Fig.1 Picture of SVR

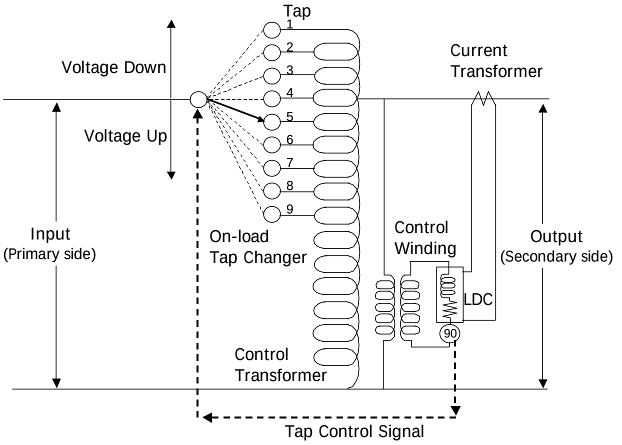


Fig.2 Structure of SVR

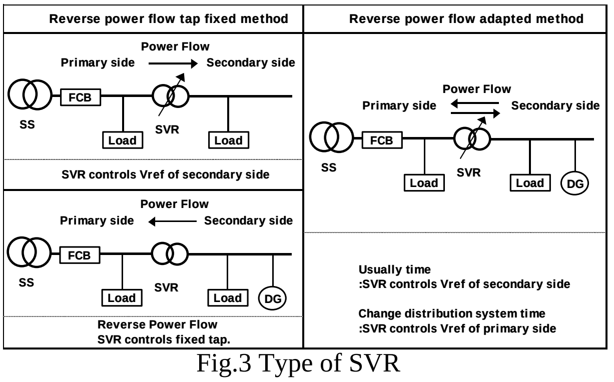


Fig.3 Type of SVR

reference point to be constant by controlling the tap position. Conventional type of SVR installed in Japan fix the tap position when the reverse power flow occurred. When the tap is fixed, terminal voltage of distribution line rises, because SVR does not regulate the voltage by controlling the tap position. Therefore, new type SVR, which can adapt to the reverse power flow from distributed generation, is considered. Fig.3 shows type of SVR.

PROBLEM OF SVR OPERATION

We have carried out the numerical simulation to evaluate the relationship between changes of solar radiation and SVR operation in past study. One example of the simulation results is shown in Fig.4. It is cleared that tap changing counts increase when the solar radiation changes widely. In such case, the replacement period is shortened because SVR has mechanical contacts. Therefore, we carried out the numerical simulation in order to clarify the problems of SVR operation in large penetration of photovoltaic power generation.

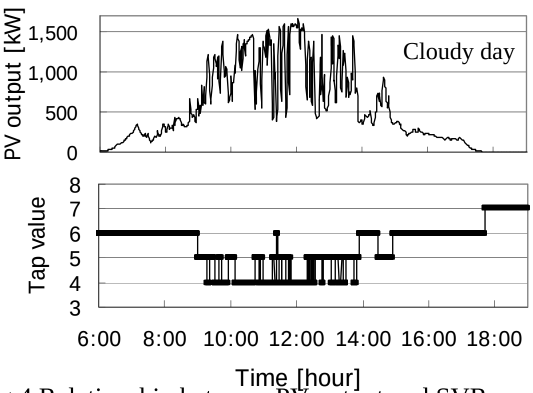


Fig.4 Relationship between PV output and SVR operation

SIMULATION CONDITIONS

Fig.5 shows simulation model and simulation conditions. This model is one example of a feeder in distribution system. This feeder has twelve nodes. The length of trunk line is 16.6km and three SVR was installed. The specification of the distribution line such as the distance between nodes and type of the wire are shown in the figure. The capacity of the feeder is 8.2MW, which is relatively large in Japan. This simulation model uses a real distribution system data.

Solar radiation data measured at our Akagi test center of CRIEPI is used in the simulation analysis. And distribution load data having peak load of 4,200kW, which is measured on the typical day in Kyushu area, is used. PV and load is equally distributed in the distribution line.

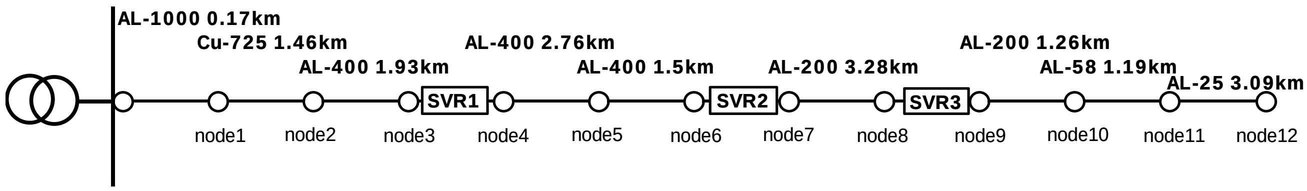
The reference point of SVR is determined as the point where the voltage drop to the reference point is the half of the voltage drop through SVR voltage regulation area. And the dead zone of SVR is 1.5%. Permissible voltage range at secondary side of the pole transformer is from 103V to 107V. The pole transformer has two type of tap ratio (6,750V/105V, 6,600V/105V). The simulation was carried out at intervals of one minute.

We carry out the numerical simulation in order to clarify the following three.

At first, we evaluate the change of the voltage at the node10 for the case using for each type of SVR, when the reverse power flow occurred, so that we clarified the difference of SVR type.

Next, we evaluate the relationship between the PV interconnected amount and the tap changing counts of SVR in order to clarified the difference of clear day and cloudy day.

Finally, we evaluate the voltage deviation rate of each node in order to clarify the influence of SVR installed in multistage.



Distribution system		SVR (step voltage regulator)				PV (photovolatic voltage)	
line capacity	8.2MW		SVR1	SVR2	SVR3	interconnected amount	0~2,500kW
trunk line length	16.6km	rated capacity	4,000kVA	4,000kVA	4,000kVA	solar radiation intensity	clear: 8/17,cloudy: 8/20
voltage control	proglam control	reference voltage	111V	111.5V	111V	interconnected point	equal
daily load peak	4,200kW	dead zone	1.5%	1.5%	1.5%	interval data	1min
		stabilized %R	2	2	3		
		stabilized %X	4	4	7		
		limiting motion	45sec	60sec	90sec		

	node1	node2	node3	node4	node5	node6	node7	node8	node9	node10	node11	node12
pole transformer tap	6750	6750	6600	6750	6600	6600	6750	6600	6750	6750	6600	6600

Fig.5 Simulation Model (Real Distribution system Data) and Simulation Conditions

SIMULATION RESULTS

From the simulation results, we clarified the following three.

(1)Differences among types of SVR

Fig.6 shows the voltage at node10 in distribution line when the reverse power flow occurred. Upper figure shows the case of using reverse power flow tap fixed method. Another figure shows the case of reverse power flow adapted method. The SVR of Tap Fixed Method cannot control the distribution voltage in permissible voltage range. By contrast, the SVR of Reverse Power Flow Adapted Method can control the voltage successfully.

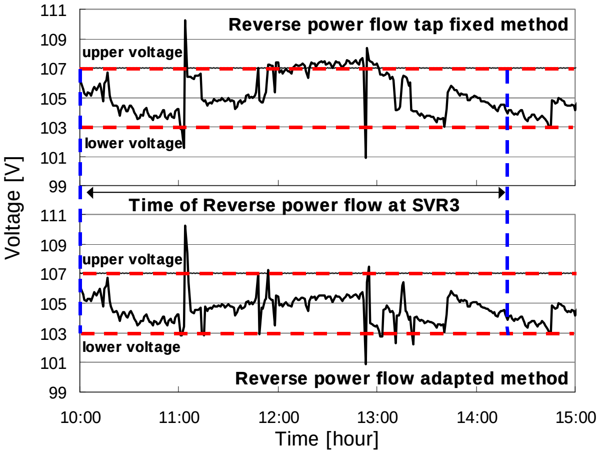


Fig.6 Simulation Results of Right Voltage Effect of Each Type of SVR

(2) Differences of Tap changing counts of clear day and cloudy day

Fig.7 shows the relationship between tap changing counts and the PV interconnected amount. Upper figure shows the case of the clear day. Another figure shows the case of the cloudy day. It can be seen that the tap changing counts does not become over 30 times on the clear day. On the other hand, the tap changing counts become over 30 times on the cloudy day when the PV interconnected amount is over 1,500kW. Since the tap change counts of SVR were significantly influenced by the fluctuation of solar radiation, tap change counts significantly increased in a cloudy day.

(3) Influence of SVR installed in multistage

Fig.8 shows the relationship between the voltage deviation rate and PV interconnected amount. . Upper figure shows the case of the clear day. Another figure shows the case of the cloudy day. In case of SVR installed in multistage, the rate of the voltage deviations of the secondary voltage of SVR at the back stage is larger than that of SVR at the forward stage.

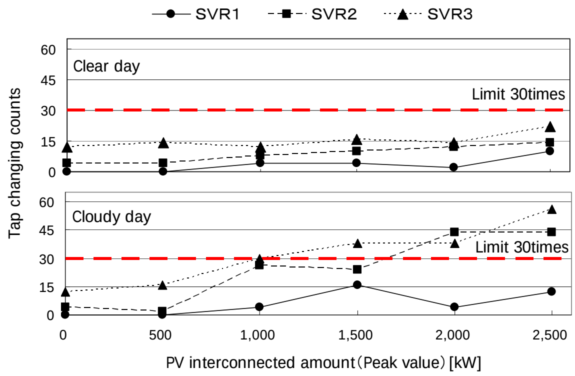


Fig.7 Simulation Results of Tap Changing Counts of SVR

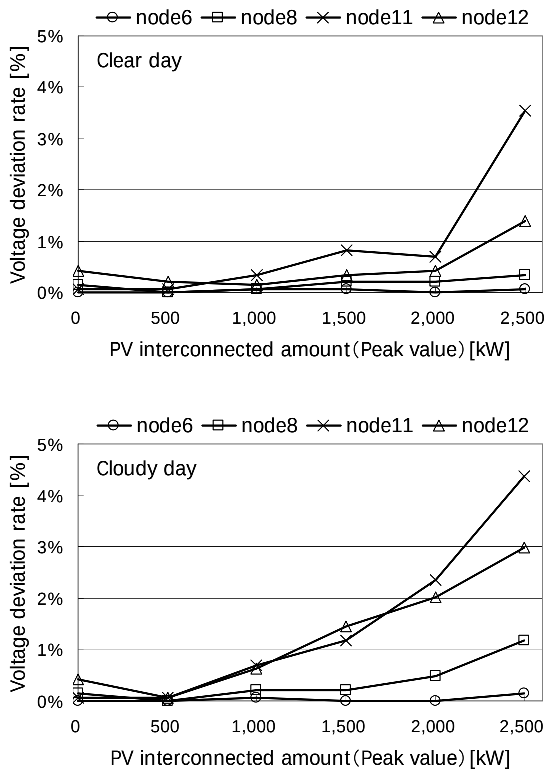


Fig.8 Relationship between PV Interconnected Amount and Voltage Deviation Rate

PROPOSAL OF IMPROVED OPERATION

In order to solve above problems, we carried out the numerical simulation to evaluate the relationship between tap changing counts and voltage deviation rate according to each Limiting motion. The results are shown in Fig.9. Fig.9-(a) shows the case of tap width 120V. Fig.9-(b) shows the case of 100V. In Fig.9, it can be seen that when limiting motion is increased the tap changing counts is decreased beside the voltage deviation is increase. By changing the tap width from 120V to 100V, the tap changing counts can be reduced under 40 times and the voltage deviation is suppressed under 5%.

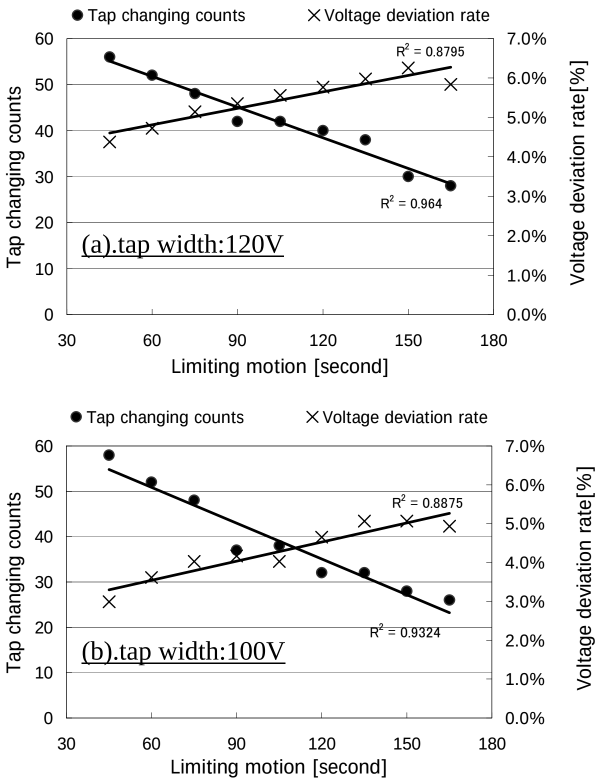


Fig.9 Relationship between Tap Changing Counts, Voltage Deviation Rate and Limiting Motion

CONCLUSION

In Japan, reduction method of voltage fluctuation in large penetration of photovoltaic power generation by Using step voltage regulator (SVR) has been proposed. Therefore, we carried out the numerical simulation and clarified the problems of increase of the tap changing counts and the voltage deviation. By change of tap width and adjustment of limiting motion, the tap changing counts can be reduced and the voltage deviation rate is suppressed. From the results of simulations, we show that proposed method can improve the SVR operation in large penetration of photovoltaic power generation. Challenges for the future, we will study the operation method of distribution system considering other voltage control equipments to respond appropriately in concentrated penetration of photovoltaic power generation.

REFERENCES

[1] T.Ishikawa, 1999, "Development of Load Flow Calculation Program for Distribution Lines with Dispersed Generations",CRIEPI Report, T99006, 1999.11 (in Japanese)

[2] H.Kajita, A.Kanbe, K.Fugawa, S.Kadokura 2005, "Development of SVR control system for dispersed power supply", Aichi Electric Technical Report No. 26, 10-16.(in Japanese)

[3] S.Taniguchi, S.Uemura, H.Kobayashi, 2010, "Development of Support system for Operation and Control in Power Distribution system", Institute of Electrical Engineers of Japan, Electric power Energy section convention. No. 200, 21-1-21-2.(in Japanese)