Investigation of Method to Reduce Voltage Fluctuation on High Photovoltaic Generation

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1. Introduction

In these recent years, there have been a rise in interest in natural resources such as renewable energy. Renewable energy such as solar power contributes to the reduction of carbon dioxide (CO_2) which will also supports Japan efforts in achieving carbon naturality by 2050. However, high photovoltaic (PV) penetration usually results to reverse power flow, which then causes voltage rise. This leads to reduction of the quality of grid power and may lead to output curtailment of PV generation.

To overcome the problem above, Flexible Alternating Current Transmission System (FACTS) device such as Static VAR Compensator (SVC) is widely used in solving the lack of reactive power which causes by the imbalance between power generation and load demand. However, initial cost and maintenance of SVC is high, and it takes a huge space for installation.

In this research, an investigation of a method using droop control is implied to reduce SVC capacity when supressing the voltage fluctuation during massive installation of PV power generation and ensure the voltage fluctuation is within the range of ±2%.

2. Methodology

Controller that is used in this paper, according to [1] is the volt/VAR(Q-V) control which characteristic is shown as in Fig.1.

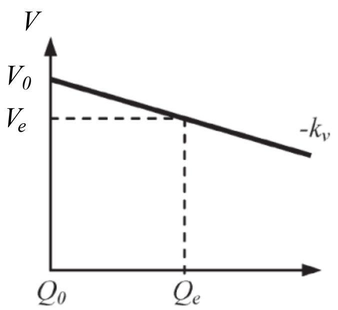

Fig 1. Voltage Droop Control Characteristic[1]

Droop control is a technique which loads are driven at lower voltages than those provided by the source. In case of overvoltage conditions, the control will decrease the voltage to a certain degree. Assuming there is sufficient power from the PV, Q-V droop control will be used, which means the reactive power generated is governed by the voltage value. The power generated should correspond to the Equation (1).

$$V = V_0 - k_v(Q - Q_0) \qquad (1)$$

Where E is voltage at PCC, Q is reactive power, k_v is the voltage proportional drooping coefficient and illustrated in Fig 2.

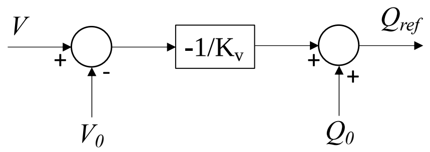

Fig 2. Droop Control Block of PV Inverter [3]

The droop control from Fig 2 is applied in the reactive power control as shown in Fig 3.

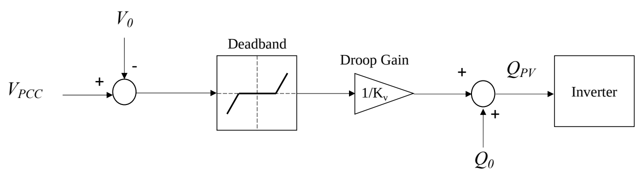

Fig 3. Structure of Inverter

3. System Model

Fig 4. shows the example of hourly trends in PV output and electricity demand over a 365-day period of 8760 hours in Japan's Kyushu area.

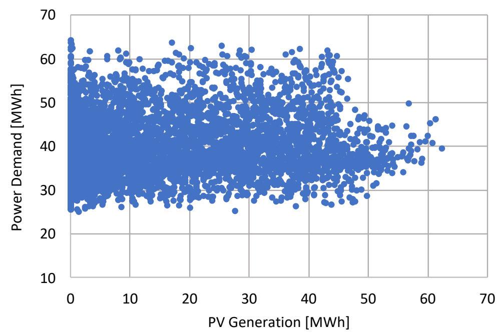

Fig 4. Power Demand and Double PV Generation in Kyushu Area (March 2020 – April 2021) [2]

Fig.5 shows the model design used in the MATLAB/Simulink R2022b software.

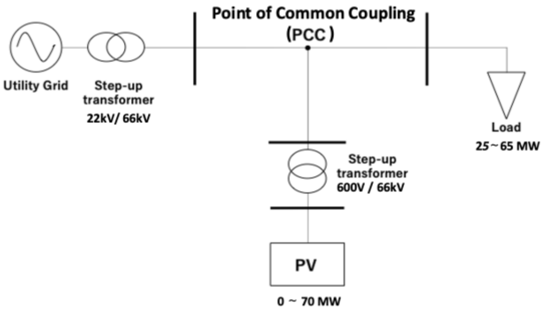

Fig 5. Model Design

The PV is assumed to be placed in the middle of transmission line. PV power data with a maximum power of 70MW and a maximum load of 65MW is used. PV inverter is 70MW, and the power factor is set to 0.85. In addition, the control target for voltage fluctuations is ±2% of the standard voltage. This research is carried out as following cases:

Case 1: PV generation without curtailment.

Case 2: PV generation with curtailment.

3. Simulation Results

The simulation is tested and the voltage fluctuations are measured by observing the voltage values at PCC. Table 1 concludes the results of the effect of Q-V control on voltage fluctuations and SVC capacity required when PV power with curtailment and without curtailment is set in the system.

Table 1. Before and After SVC Compensation

Inverter Capacity: 70MW	Before SVC compensation						After	
	$Q_{inverter}$ (MVAR)			Over (h)	Curtailment& SVC(h)	Only SVC (h)	Q_{SVC} (MVAR)	
	Min	Max	Average				Min	Max
1.Without Curtailment								
No Q-V	-0.005	0.003	0	993	-	993	-15.10	0
Q-V	-8.171	5.805	0.255	895	-	895	-14.77	0
2.With Curtailment								
No Q-V	-0.004	0.004	0	971	971	-	-9.223	0
Q-V	-6.858	5.806	0.192	866	866	-	-8.185	0

Based on results in Table 1, it can be concluded that there are 993 voltage fluctuations in 1-year operation, without curtailment and without Q-V control. Number of voltage fluctuation is decreased to 895 after implementing Q-V control on inverter. Without using Q-V control, SVC up to 15.10 MVAR is needed to compensate 993 violations. By using Q-V control, SVC up to 14.77 MVAR is necessary installed to compensate 895 violations.

On the other hand, when using curtailment, the number of voltage fluctuation decreased compared to the results without curtailment. Since the curtailment is applied, the reactive power sent by the inverter is changed from -8.171MVAR to -6.859 MVAR. It suggests the curtailment of PV active power alone has reduced the increasing voltage, affecting the inverter reactive power. For other violations that could not be covered by inverter, SVC installation is required. For the application of volt-VAR control, the curtailment leads to reducing installed SVC, making it from 14.77 MVAR to 8.185 MVAR.

4. Conclusion and Future Works

Comparison results of the effect of Q-V control on voltage fluctuations and SVC capacity required when PV power with curtailment and without curtailment has been presented in this paper. From the results, it can be concluded that after applying the droop control, the number of voltage violation is reduced. This also means that, even if SVC is still needed to compensate the reactive power in the system, the capacity of SVC required to compensate the voltage fluctuation will be lesser. However, there are still some violations occur, so improvement on droop control is needed. As for further study, this research can be done by analysing the results when different capacity of inverter is applied to the system.

References

[1] M. E. Susetyo, N. Hariyanto, A. Rizqiawan and S. A. Sitompul, "Droop control implementation on hybrid microgrid PV-diesel-battery," 2017 International Conference on High Voltage Engineering and Power Systems (ICHVEPS), Denpasar, Indonesia, 2017, pp. 295-300, doi: 10.1109/ICHVEPS.2017.8225960.

[2] Energy Data Visualization Project. ISEP Energy Chart. (2018, December 4). Retrieved November 22, 2022, from https://isep-energychart.com/en/

[3] S. Sitompul, K. Shimomukai and G. Fujita, "Enhancement of Volt-VAR Control Using Voltage Sensitivity in Grid-Connected Photovoltaics System," 2022 IEEE PES Innovative Smart Grid Technologies - Asia (ISGT Asia), Singapore, Singapore, 2022, pp. 46-50, doi: 10.1109/ISGTAsia54193.2022.10003605.