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Evaluation on voltage control performance by updating power factor setting of photovoltaic in distribution system

Toward realization of sustainable society, photovoltaic (PV) penetration will increase in distribution systems. The voltage regulation is one of the challenges in the distribution system with massive PVs. The generation from PV may cause voltage violation from acceptable range in low-voltage networks and voltage fluctuation. In present condition, the voltage in distribution systems are mainly regulated by tap operation of OLTC (On-Load Tap Changer) and SVR (Step Voltage Regulator). These devices regulates the voltage in several feeders or one feeder and the regulation speed is slow. The regulation by these devices are sometimes not suitable for clearing the voltage violation casued by PV penetration in terms of the regulation speed and area range. PV generation causes the local voltage violation in short term depending on weather condition. Therefore, distribution system operators (DSO) need to develop voltage control scheme to clear voltage violation. One of the voltage control schemes employed by DSO is reactive power control by PV-PCS (Power Conditioning System), such as fixed power factor control and volt-var control. DSO in Japan especially focuses on fixed power factor control, because the burden of the reactive power injection become fair among PV customers. Here, the fairness means that the same reactive power is injected when the active power from PV is same. Currently, the power factor value is determined by DSO for each voltage class of distribution system. The present PF values for PV-PCS are defined are 0.9 lagging for medium-voltage(6.6 kV) and 0.95 lagging for low-voltage(100/200V) system, respectively. However, the suitable power factor setting for clearing voltage violation may change depending on the characteristics of network topology such as line length, and condition of PV penetration. To evaluate the voltage control performance, the detailed distribution system model is required for simulation. Therefore, this presentation demonstrates the evaluation results of the voltage control performance by updating PF setting in terms of the hosting capacity considering PV penetration scenario from 2025 to 2040.

The distribution system model was constructed based on the actual distribution system in Japan. The selected model is severe model in terms of voltage control, with line length substantially longer average and the amount of PV installation larger than average. The model has seven feeders including the medium and low-voltage classes. The total length of medium-voltage distribution line in each feeder is from 5.2 km to 9.8 km and the feeders type is residential and industrial. The total load capacity is 15.1 MW. Voltage control devices are OLTC and one SVR. The tap operations of OLTC and SVR are performed with Z-charactaristics and vector LDC (Line Drop Compensation) control, respectively. PV penetration scenario is constructed from 2025 to 2040 based on the energy basic plan. The amount of PV capacity is 25.4 MW in 2020 and 30.2 MW in 2040. For verification, 4 days in each year were selected in terms of combination of load type (heavy and light) and weather type (sunny and cloudy). In the simulation, at first, the voltage control performance of default PF setting is evaluated based on hosting capacity where the PF values in medium-voltage and low-voltage PV are 0.90 and 0.95 lagging, respectively. If the voltage violation occur, the PF setting is adjusted to clear voltage violation. The judgement of voltage violation is based on the voltage, 10 minuites moving average, in low-voltage customers. The accpectable range is from 95 V to 107 V based on Japanese rules.

According to the simulation results, the voltage violation did not occur by 2035 under the default PF settings. However, in 2040 PV penetration condition, the voltage violation occured on the heavy load and cloudy PV day under the defalut setting. The voltage fluctuation by PV genration caused the voltage violation during daytime.Thus, DSO needs to update the PF settings to increase PV penetration by eliminating voltage violation. In 2040 PV penetration setting, the PF settings of medium-voltage are adjusted from 0.90 based on the voltage condition in each feeder. Then, the voltage violation was cleared on the heavy load and cloudy PV day. Updating the PF setting seems to be a useful scheme because DSO does not have to install the new equipment nor to reinforce the network.

As conclusion, this study evaluated the voltage control performance by updating power factor setting of PV-PCS in distribution system in terms of the hosting capacity. The evaluation was performed using the seven-feeders medium and low-voltage distribution system model based on the actual distribution system in Japan. From the results, the voltage control performance by default PF setting caused voltage violation for high penetration of PV. The performance was improved by sellecting PF numbers based on the voltage condition in each feeder. The result shows the importance of harmonization between OLTC / SVR operation and PF settings for PV-PCS.

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