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Smart meter as a voltage censor for OLTC operation : Mitigation of voltage violation under massive penetration of PV

In Japan, the installation of the first smart meter is scheduled to be completed in 2024, and the electricity consumption of all consumers will be measured in 30-minute units. In the past 10 years, the electric power industry has changed drastically, such as the separation of electricity transmission and the full liberalization of retail sales. During this period, the introduction of the Photovoltaic Generation System (PV) has progressed toward decarbonization, and problems such as voltage violation have become apparent. How to increase the hosting capacity of PV without expanding equipment has become an important issue. Furthermore, in order to meet the needs for bidding in the balancing market utilizing resources on the demand side, the specifications of next-generation smart meters were examined in 2022 with the aim of starting introduction from 2025. Whereas conventional smart meters treat only 30-minute power consumption as measured values, next-generation smart meters measure not only power consumption but also reactive power and voltage. Furthermore, in addition to the 30-minute resolution, each value of the 5-minute resolution is prepared. Here, the 5-minute value is not collected immediately after measurement, but the specification is that 10% of consumers are selected in advance and 5-minute data is provided within a few days.

This paper describes a study that attempts to avoid voltage violation when PV introduction is expanded by optimizing the control parameters of OLTC (On Load Tap Changer), that controls the transmission voltage of the distribution substation, using a smart meter as a voltage sensor.

First, as a preliminary study, we evaluated the distribution system voltage control by distributed cooperative EMS. The distribution system is realistically simulated, including the geographical distribution, and the consumer load estimated from the actual and reactive power of the feeder and the land use statistics is set in the network model. The power flow calculation is executed with the PV introduction amount, EV diffusion amount, etc. as parameters, and the voltage distribution, Joule loss density distribution, etc. are calculated. There are consumers such as buildings and houses in the model, and they have BEMS and HEMS, respectively, and these EMS measure the voltage at the connection point with the distribution system. The distribution system has GEMS (Grid EMS), which has the function of setting OLTC control parameters based on various measurement data. In the convetional method, OLTC parameters are determined based on the feeder's actual / reactive power and voltage (30-minute value, LDC method). In the improved method, the BEMS / HEMS voltage value (2.5-minute value) are additionally imported into GEMS to determine the parameters. Simulations were conducted for these two methods to compare voltage control performance. As a result, in the conventional method, when the PV introduction amount of the feeder exceeds 40% of the maximum load, a voltage violation occurs and the violation increases with the PV introduction amount. On the other hand, in the improved method, the voltage violation does not occure up to 100% of the PV penetration. From this, it was found that the voltage violation by the control of OLTC can be effectively avoided and the hosting capacity of PV can be improved by using the voltage data of the minute order resolution in the consumer.

From this result, the function of the next-generation smart meter, that is, the voltage value of all low-voltage consumers can be obtained with a 30-minute resolution, and 10% of the voltage values of the low-voltage consumers can be obtained with a 5-minute resolution. It is expected that voltage maintenance will be advanced by OLTC control utilizing this. In order to quantitatively understand the effect, a standard distribution substation model (6 feeders) was used, and PV was introduced to 25% of low-voltage consumers (from the end of the feeder). 4 cases (data of smart meter used / change of control parameters of OLTC) were compared and evaluated. a) 30 min voltage data / seasonal, b) 30 min voltage data / seasonal and day-night, c) 30 min voltage data and 5 min voltage data (10%) / seasonal, d) 30 min voltage data and 5 min voltage data (10%) ) / seasonal and day-night. For the evaluation, representative 5 days are selected for each of the three seasons of spring, summer, and winter, and the OLTC control parameters that minimize voltage violation are determined based on the actual values one year ago. This was set in OLTC, and a simulation was performed for 5 days to evaluate the amount of voltage violation and the number of tap operations of OLTC. As a result, the amount of voltage violation (V・min) is about a) 1/4000, b) 1/10000, c) 1/20000, d)1/40000 in each case, compared to the conventional control that does not use the voltage data of the smart meter. In addition, there was no significant difference between cases in the number of tap operations of OLTC.

From the above, the amount of voltage violation can be significantly reduced by measuring the voltage value with a smart meter and applying it to voltage control, and the effect can be increased by adding the 5-minute value of 10% of consumers. It was suggested that the effect could be further increased by changing the control parameters day and night in addition to seasons.