NAME : Yuya TACHIBANA
COUNTRY : JAPAN
REGISTRATION NUMBER : 7314

GROUP REF. : C6
PREF. SUBJECT : 2
QUESTION N° : Q2.1

Title : Voltage drop phenomenon due to large-scale DERs integration and countermeasures

1. Background

In Japan, an increasing number of grid-connected DERs (mainly PV) have been deployed owing to the feed-in tariff regulations. The distribution voltage is generally risen because of the reverse power flow from DERs. On the other hand, when large-scale DERs are integrated into the distribution system including a long distribution line, the distribution voltage does not only rise, but also drop (voltage drop phenomenon) due to a large phase change in the current. In Japan, this voltage drop phenomenon has occurred on some long distribution lines with large-scale PV integrated at the end of the distribution line.This voltage drop phenomenon causes non-linear voltage fluctuations as shown in Fig.1.

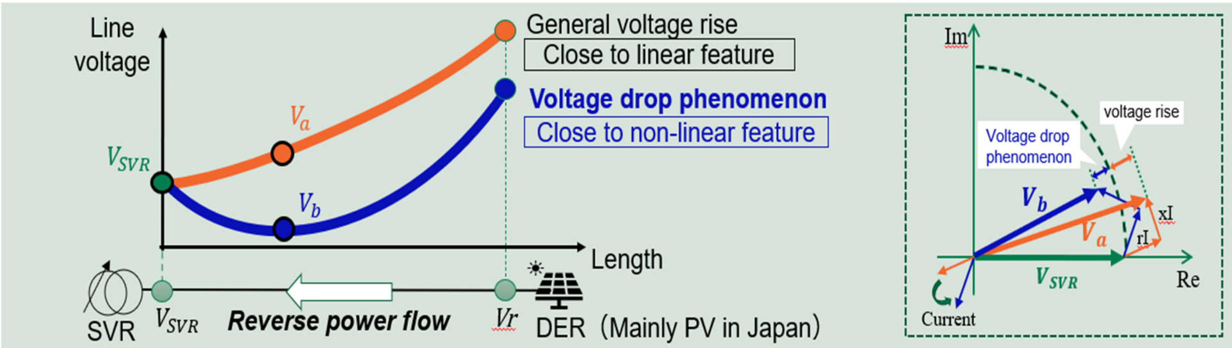

Fig 1. The voltage drop phenomenon based on DER.

2.Issue

When the distribution voltage deviates from a proper voltage range, a voltage regulation equipment, such as step voltage regulator (SVR) that is one of tranformers applied in Japan, is installed in the distribution system. A conventional control method for SVR is Line Drop Compensator method (LDC method). This method estimates a reference voltage as a representative voltage of a power distribution system and controls the reference voltage to control the distribution voltage in the secondary side of SVR. The reference voltage is estimated by a secondary voltage, passing current, and power factor measured in SVR assuming the distribution voltage changes linearly. However an error between the reference voltage and the actual voltage is increasing under the voltage-drop phenomenon with non-linear voltage fluctuation. Therefore, the conventional method of SVR is difficult to estimate and control the distribution voltage.

3. Development of the new voltage-estimation method for SVR

We have developed the new voltage-estimation method based on a simple calculation using own measuring information in SVR and the unit line impedances in the distribution system. This new voltage-estimation method for SVR equipment can address the non-linear voltage fluctuations. The reference voltage $V_{ref}(L)$ at a representative point L in the secondary side of SVR is calculated by the following equation. The LDC method estimates the distribution voltage by assuming a linear voltage change, on the other hand, the new method estimates the non-linear voltage fluctuation that is difficult to estimate by the conventional method.

$$V_{ref}(L) = \sqrt{V_{SVR}^2 + \frac{L^2(P_{SVR}^2+Q_{SVR}^2)(r^2+x^2)}{V_{SVR}^2} - 2L(P_{SVR}r + Q_{SVR}x)}$$

where $V_{SVR}$is the secondary voltage of the SVR, P_{SVR} is the active power measured in SVR, Q_{SVR} is the reactive power measured in SVR, r is the resistance of the distribution line per km, x is the reactance of the distribution line per km.

4. Field test with prototype of new SVR

As shown in Fig.2, we fabricated a prototype of new SVR with both the new method and the LDC method. The new SVR can be produced simply by rewriting only the software of the voltage control system.

(1) Demonstration using the experimental 6kV distribution system (Fig. 3)

We carried out field tests in the 6 kV experimental distribution system to verify the validation of the new method in comparison with the LDC method. We evaluated the voltage control performance and the lifespan of SVR using the total amount of voltage deviation and the total number of tap switching of the SVR. These results are shown in Table 1. These results indicated that the performance of the voltage control and the lifespan of SVR were improved by applying the new method.

(2) Demonstration using the commercial 6kV distribution system (Fig. 4)

The new SVR will be demonstrated in the commercial distribution system in the fall of 2022. The distribution system is located in the rural area, the distribution line length is 16km, and 2MPV is integrated at the end.

Table 1. Evaluation results

		LDC method	New method
Amount of the voltage deviation [kV·s]	Sunny	118.1	**8.8**
	Cloudy	172.4	**10.6**
Total number of tap switching	Sunny	6	**2**
	Cloudy	53	**2**


Fig 2. Prototype of new SVR

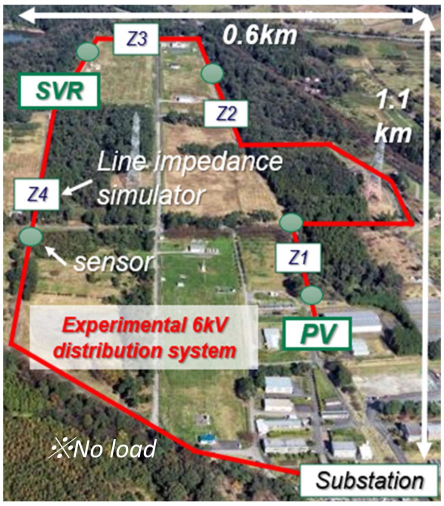

Fig 3. Experimental 6kV distribution system

Fig 4.Commercial 6kV distribution system