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Impact of Solar Photovoltaic System on Transformer Tap Changer in Low Voltage Distribution Networks

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Abstract

This paper investigates the impact of solar resource variability on the operation of a low-voltage On-Load-Tap-Changer (OLTC) in a generic distribution network from the Malaysian grid. The OLTC's operation is studied in two different weather conditions—sunny and cloudy days. The aspects analysed are the OLTC's time delay setting, PV penetration levels and PV installation location. The results suggest that the number of tap changes in a cloudy day is approximately 1.5 times higher than in a sunny day. In addition, at 50% PV penetration level on a cloudy day, the OLTC operation increases by 38% and it is doubled at 100% penetration.

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Keywords: Solar Photovoltaic; OLTC; LV distribution network

1. Introduction

Intermittent renewable generation in the distribution network can lead to severe adverse effects such as power fluctuation, voltage fluctuation and reverse power flow [1]–[5]. Furthermore, large PV penetration is expected to significantly affect the voltage regulation for operational devices such as the transformer's On-Load Tap Changer (OLTC). This is because the variation of voltage can increase the operation of transformer OLTC to bring the voltage back to the normal range. [6], [7]. Present studies on the effect of passing cloud on the operation of OLTC appears to be inadequate. Previous work in [8] indicates that passing-cloud may potentially cause more frequent operation of the control devices. This may reduce the

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effectiveness of the control setting, consequently reducing the OLTC's lifetime. However, there is no conclusive results on how the weather condition affects the transformer's OLTC tap changer. In this respect, there is a need to investigate the tap changer operation of voltage regulator devices such as OLTC, particularly during high PV penetration level [9]. In addition, the intermittency of PV generation may cause voltage fluctuation problem, especially during a cloudy day. This may result in a high number of tap changes in OLTC to regulate the voltage level. This paper simulates the PV impact on the distribution side based on irradiance variability, OLTC's Time Delay (TD) setting, penetration levels and PV installation locations. The finding of the case study is expected to benefit the distribution network operators and power utilities that incorporates substantial amount of distributed PV systems.

2. Methodology

A generic distribution network model in Malaysia has been considered in this study. The network was modeled in OpenDSS [10] interfaced with MATLAB. The control element (regulators), PV generation and loads have been modelled and implemented for various scenarios. A total of four scenarios were considered in the case study, namely (a) Effect of weather condition, (b) Effect of TD setting, (b) PV penetration levels, and (c) Effect of PV installed location.

First, two day types, namely sunny day and cloudy day profiles were utilized to analyze the effect of weather conditions (direct correlation with PV generation output) on the number of tap changes on a transformer. For the second case, simulations were carried out in OpenDSS with different TD settings on transformer OLTC. TD settings used in this study were varied from 15s until 3600s. Comparisons of the number of transformer tap changes were made between different TD settings and different percentage of penetration level for both sunny and cloudy day.

The last scenario studies the installation of PV system on different locations for the fixed feeders and scattered feeders. The first part has all the PV system installed at feeder D, while the second part considers random allocation of PV system between feeders A, B, C, and D. All the details are discussed in Subsections 2.1 to 2.4.

2.1. Distribution network modeling

All the PV integration studies were performed at the LV side of the generic distribution network in Malaysia. The generic network has four main feeders at the LV side of the distribution network with the total connected load of 349 kW, as shown in Figure 1. The LV distribution network parameters include cable types, cable rating, the number of feeders, and transformer rating. The 1000kVA (11/0.4 kV) distribution transformer was connected at the LV side. There are 18 consumers at the LV side where the PV system is installed.

A regulator is located at the Reg. bus (Bus 20) to study the effect on the number of tap changes before and after the PV integration. The controller base voltage of 120V with a bandwidth of 2V was used in this study and the default time delay was 15s.

2.2. Transformer OLTC control setting

There are three main control settings for the OLTC operation which are voltage set-point, bandwidth and TD [7]. Figure 2 illustrates the relationship of the basic OLTC control settings. As can be seen, voltage profile A goes beyond the lower voltage boundary for a period longer than the TD setting (t_{delay}). The OLTC will operate, which then results in a step change for voltage profile A to bring the voltage within

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