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A review on voltage control methods using on-load tap changer transformers for networks with renewable energy sources

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ABSTRACT

Voltage control is an important method for regulating the feeder voltages in a distribution network. Various voltage control methods are used by distribution network operators (DNOs) in order to maintain the network voltages to be within an acceptable voltage level. Traditionally, on-load tap changer (OLTC) and automatic voltage control (AVC) relays are often employed in regulating the network voltages. However, the traditional voltage control techniques are no longer suitable when renewable energy (RE) sources are connected to the network because of the possibility of bidirectional power flows. The presence of reverse power flow will affect the feeder voltage profiles and influence the voltage control scheme practiced in the distribution system. This paper presents an overview on the various OLTC voltage control schemes which are used to control the voltage in distribution networks containing RE sources.

Contents

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1. Introduction

Electrical power distribution systems are normally operated at multiple voltage level. The voltage levels differ based on the amount of power generated by RE sources and load variations in the network. These different voltage levels are kept within acceptable limits by including an OLTC transformer where the substation secondary bus voltage is kept stable by adjusting the tap position [1]. Tap position adjustment is necessary to physically alter the ratios of the transformer for voltage regulation. The OLTC operate by changing the number of turns in one winding of the transformer to keep the transformer output voltage within predicted limits.

The OLTCs are motorized mechanical switching arrangements that adjust the transformer turns ratio, typically in steps of 1.25% or 1.43%, whilst the transformers are in use and carrying a load [2]. The OLTC transformer is normally applied in the distribution networks to step down from 33 kV to 11 kV or 6.6 kV. Each OLTC transformer is linked to an AVC relay in order to increase or decrease the voltage by changing the tap position of transformer [3].

However, the operation of AVC relay can be affected by the possible existence of bidirectional power flows when RE sources are connected to the network. Innovation is required in OLTC voltage control scheme in order to support the current implementation of smart grid incorporating RE sources such as wind, solar and hydrogen [4]. Studies on the size, operating power factor mode [5,6], and location of RE sources in the network are needed in order to design an innovative OLTC voltage control scheme to cope with the increasing RE sources connected into the distribution network.

2. Traditional voltage control scheme

Traditionally, the voltage control in distribution networks without RE sources is performed using OLTC, shunt capacitors, shunt reactors, static var compensation etc. This paper will focus on voltage control strategies involving OLTCs in distribution network connected with RE sources. Without RE sources connected in a distribution system, the power flow is assumed to be unidirectional and the set-values for the OLTCs are chosen according to the voltage drop along the feeder. Based on the set-values, the voltage at the secondary of the OLTC transformer is changed in order to prevent the voltage along the feeder from breaching the lower voltage limit and not exceeding the upper voltage limit. The change in voltage at the secondary of the OLTC transformer is achieved when the AVC relay initiates a signal to the tap changer system to change its tap position.

2.1. Voltage control with load tap changer (LTC)

The basic arrangement of voltage control with LTC regulation is shown in Fig. 1. Since the voltage on a conventional distribution network (without RE source connection) decreases towards the end of feeder, the LTC shall then be set to ensure that the voltage at the feeder end is higher than the minimum allowed voltage and the sending-end voltage is lower than the maximum allowed voltage. The AVC relay determines whether to adjust the tap position or not in order to maintain the voltage level which is assumed to be equal to 1 p.u at the end of feeder [7]. An AVC relay normally consists of initial delay and inter tap delay. The initial delay ranges from 10 to 120 s and the inter tap delay for each step tap changer operation is from 5 to 60 s [8].

2.2. Voltage control with line drop compensation (LDC)

In an OLTC operation, normally LTC is provided with LDC function to control the voltage at a remote point. Besides monitoring the transformer's terminal voltage, this function includes the measurement of the secondary current [9]. The measurement is used to simulate the voltage drop along the feeder impedance that exists between the transformer terminal and the load point [10].

In order to keep the correct voltage level at the load side, line resistance *R* and line reactance *X* is used to increase the regulated voltage at the transformer terminal. Voltage control at a nominal load point rather than at the transformer terminal is achieved using LDC.

2.3. Grading time (GT)

AVC relay with LDC function operates in between different voltage levels in power supply networks. If a downstream tap changer is allowed to operate before an upstream tap changer, then the OLTCs might work against one another and become unstable. In order to correct this situation, the GT is introduced (Figs. 2 and 3).

GT ensures that the initial time delay is longer for the downstream controllers compared to the upstream controllers. The different initial time delay for downstream and upstream controllers are required to ensure that upstream operations are given preference and carried out first. This time grading strategy requires the upstream transformer to finish its operation before the down-stream transformer restores the voltage level.

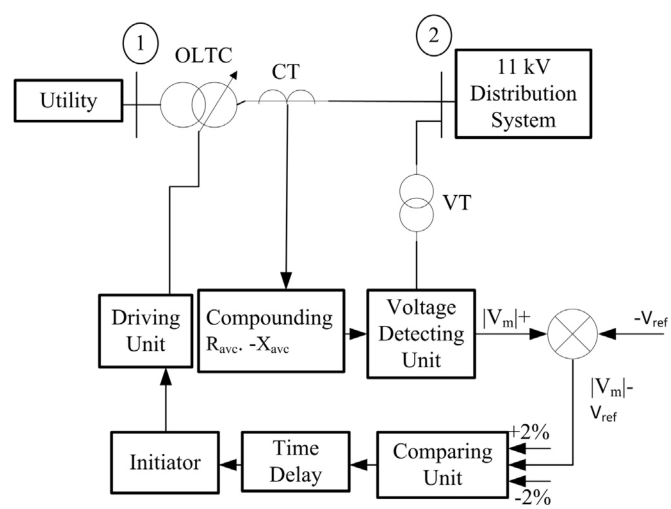

Fig. 1. Basic LTC arrangement [7].