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Impact of renewable based microgrid supply/demand profiles on low voltage distribution networks

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Abstract

Integration of distributed generation (DG) from renewables into power systems has been one of the major challenges for operators. Impact of bidirectional power flow on the bus voltages and on the power losses is more severe in low voltage networks, due to high R/X ratio of the lines. Operators generally evaluate capacity additions considering the extreme cases. However, extreme cases occur rarely in a long-term operation or their impact is generally less than expected. This study presents daily operation analysis of a low voltage network including a renewable supported microgrid. Using a field-data based virtual test bed, daily variations in DG output power, residential demand and network voltages are simulated. The analysis reveals the occurrence rate of extreme cases in daily operation and changes in the line losses of low voltage networks with microgrids.

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Keywords: distributed generation; distribution network; energy management systems; microgrids; renewable energy, virtual test bed

1. Introduction

The use of renewable sources in electricity generation has gained popularity in recent years. There are technical, environmental and economic drivers that signify the distributed generation from renewables as one of the main alternatives both for the grid operators and for the customers [1]. On the other hand, establishment of generation equipment at the consumer side may have negative impacts on system

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operation. Small scale, LV distribution networks are the ones that can be affected the most, because of their radial topology as well as comprising the lines with smaller cross sections and higher R/X ratios.

Nomenclature

DG	distributed generation
HV	high voltage
LV	low voltage
MV	medium voltage
PV	photovoltaic

Most of the renewable based distributed generators (such as PV panel and wind turbines) are connected to the system through current source inverters. These devices supply current (in relation with the generated power) to the system, while following the network voltage. It is clear that the reverse power flow in a radial network is possible if an only if its voltage is higher than the substation voltage. The amount of voltage difference depends on the network topology and on the point of connection. In some cases, it may cause over voltages not only at the point of connection but also at some other neighboring busses [2]. Furthermore, supply of energy through a path with high R/X ratio can increase the line losses.

Distribution network operators generally take into account the most risky conditions during the integration process of new generation equipment [2]. There are two critical operational cases for most of the integration analysis of distributed generation. The first case is operation at a maximum substation voltage while the network loading is minimum and distributed generator output is maximum. Such an operation can cause over voltages at the generation bus as well as at its neighboring busses. The second critical case is operating at minimum substation voltage for maximum network loading, without any distributed generation supply. It is the case in which there is a risk of under voltage at the point of connection.

While many studies in the literature have focused solely on the extreme cases that can violate the voltage limits, their occurrence rates in daily operation cycle and the changes in the network energy losses have rarely analyzed [2-3]. Limitation of renewable-based generation in a LV network solely with respect to worst-case scenarios may not be very effective from technical and economic point of views. Wind turbines mostly generate less than their rated capacities due to wind speed variations; while PV panels reach their peaks only for a short period of time at midday. Furthermore, typical load factors for buildings are around 40% [4]. Consequently, the number of the first extreme condition (maximum distributed generation supply) occurrences are less than expected and their durations are very short in a long term operation. Moreover, if the local generators are the part of the microgrids, battery groups and the loads at the same bus should also be taken into consideration. Estimation of occurrence rates can enable effective design and implementation of active management options.

This paper focuses on renewable based microgrid impacts on the operation of LV distribution networks. Daily profiles of network voltage, PV outputs and the loads are simulated to investigate the change of the voltage and the line losses. The second section explains the voltage variation in distribution networks with DG. Section 3 describes the virtual test bed used in the analysis. Section 4 is devoted to daily analysis with microgrid and finally section 5 discusses the results.

2. **Steady-State Voltage Variation in Distribution Networks with DG**

Power distribution networks are mostly designed for unidirectional power flows over a radial topology from substation to consumers. LV distribution lines have higher R/X ratios when compared with of the MV distribution and HV transmission lines [2]. Thus, the percentage of voltage drop is greater in these systems. The voltage at the substation ($\widehat{\boldsymbol{V_s}}$) can be defined as in (1).