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Analytical method to estimate the steady-state voltage impact of Non-Utility Distributed Energy Resources ☆

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ABSTRACT

The Non-Utility Distributed Energy Resources (nDERs) are those not responsible for supporting the distribution system operation. These resources are crucial for improving the Energy mix's sustainability due to their majority renewable nature. However, integrating these resources into distribution systems has become a challenge for Distribution Companies (DisCos) due to their intermittent behavior. This challenge is even more significant when a gap in distribution system modernization (smart meters and communication systems) exists. This paper proposes an approximate method to evaluate the nDERs' impact on the distribution system's steady-state voltage. The method is based on a linear approximation of voltage drop/rise and the impedance matrix. It has been validated on two distribution systems considering five scenarios. Numerical comparison with exact solution has shown good results in four scenarios with maximum absolute errors around 0.01 p.u. in low-risk and high-risk voltage violation situations. The proposed method can be used in the planning or operation stage as a first estimation where no real-time monitoring is available, or the power-flow calculation is difficult to obtain.

1. Introduction

Recently an impressive increase in the number of Distributed Energy Resources (DERs) has been observed, driven by various factors such as government incentives, economic gains, and changes in environmental policies. Some of these DERs cannot be fully controlled by distribution utilities and cannot be used to support the distribution system's operation. In this paper, these DERs are called Non-Utility Distributed Energy Resources (nDERs).

The increase of nDERs can bring benefits to the distribution systems [1], however, without the proper planning regarding the location and operation, negative effects may arise from the bi-directional power flow of active power in the feeders, resulting in large voltage variations. There is a possibility that these resources can hinder the proper functioning of the voltage control equipment [2].

However, when properly designed, these problems can be mitigated if the Distribution Company (DisCo) takes part in controlling these resources [2]. Effective management of nDERs depends on having as much qualified information as possible, normally translated with different meters and sensors throughout the distribution system, to provide constant measurements and reports of the current state. One important piece of information is the steady-state voltage, as it plays an essential role in assessing the quality of energy supplied to the consumer [1]. When measurement and a SCADA system are available, the application of state estimation has been considered for real-time monitoring of distribution systems [3–5]. However, the use of metering systems along the feeders is not yet widely implemented, resulting in some difficulties in applying state estimation.

On the other hand, the impacts of the nDERs can also be analyzed before the nDER installation using sensitivity analysis (also known as perturb-and-observe). One of these approaches was applied in [6], where an analysis of DERs' impacts was performed in the Brazilian scenario. That paper uses an electromagnetic transients program to get the data on the impacts. In [7], an optimal power flow was used to plan the location of energy storage systems using voltage limits as a constraint. These two approaches represent the base idea of running several power flows or electromagnetic transient simulations to analyze the impacts of DERs. The sensitivity analysis approach can provide detailed information on how DERs impact the distribution system. However, it demands time to solve, which can be a problem in the DERs operation.

Sensitivity indexes based on the Jacobian matrix of the power flow equations were proposed to evaluate only the DERs' impacts in

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