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Voltage Instability and Voltage Regulating Distribution Transformer Assessment Under Renewable Energy Penetration For Low Voltage Distribution System

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Abstract
The Voltage Regulating Distribution Transformer (VRDT) is a tap-changing transformer that regulates the voltage across all three phases. However, its application in the context of renewable energy penetration into low-voltage grids remains understudied. This paper addresses this research gap by presenting a refined voltage drop model tailored for the International Islamic University Malaysia (IIUM) distribution network. Based on a derived mathematical equation, the model is validated and analyzed using Simulink's modeling platform. Simulations are performed without and with the VRDT, revealing that renewable energy penetration can cause instability, leading to voltage deviations proportional to the injected renewable energy. Incorporating the VRDT in the low-voltage grid allows for voltage adjustment under loaded conditions, ensuring uninterrupted renewable energy injection. Voltage stability analysis is conducted using actual load consumption data from the IIUM network for 2020 and 2021, offering valuable insights despite assuming equal energy consumption across buildings. Most hostels exhibit stable distribution systems with solar energy, but instability arises when solar energy comprises 100% of the input for the Safiyyah and Zubair hostels' 11kV distribution transformers. Implementing the VRDT regulates this instability, restoring system stability. This study highlights the importance of VRDT integration in high renewable energy proportion low-voltage grids, enabling voltage regulation and stability under variable renewable energy injection scenarios. The findings demonstrate that VRDTs mitigate voltage instability caused by renewable energy, providing a reliable solution for incorporating renewables into low-voltage distribution networks. It contributes to understanding renewable energy's impact on distribution system stability and offers guidance for VRDT implementation in similar contexts.

Author Keywords
Low Voltage (LV); Transformer (VRDT); Voltage Drop Model; Voltage stability; Voltage-Regulated Distribution

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