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RESEARCH ARTICLE

Techno–Economic Feasibility Analysis of a Solar Photovoltaic System for Optimized Power Distribution Network

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ABSTRACT: This study presents a comprehensive techno-economic feasibility analysis of a solar photovoltaic (PV) system integrated into a 7-bus power distribution network. By employing an improved analytical technique, the research strategically determines the optimal placement and sizing of distributed generation (DG) units to minimize power losses and enhance voltage profiles. The analysis focuses on a single-location deployment of a solar PV system with a capacity of 7678 kW, positioned at bus-2. The study compares the system's economic performance with conventional grid-supplied power over a projected 25-year lifespan, considering variables such as fixed charges, variable energy charges, taxes, and a 10% annual inflation rate. Initial power losses without DG integration amount to 128.05 kW, which are reduced to 55.00 kW after incorporating the PV system—a 57.05% reduction. The system operates for 8 hours daily, with an alternative scenario of 5 hours to account for practical limitations. Transmission losses of 10% are considered, emphasizing the system's ability to meet local demand while reducing dependency on centralized grids. The economic analysis reveals significant savings in operational costs, supported by a tariff rate of Rs. 3.10/kWh ($0.037). The findings indicate that the optimized solar PV system not only enhances technical performance by reducing power losses and improving voltage profiles but also proves to be a cost-effective and sustainable alternative to conventional power sources. This work demonstrates the potential of well-planned solar PV systems in addressing the dual challenges of energy efficiency and economic sustainability in modern power networks.

Keywords: Solar Photovoltaics, Distributed Generation, Power Losses, Distribution Network, Voltage Profile.

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1. INTRODUCTION

The incorporation of distributed generations (DGs), particularly solar photovoltaic (PV) systems, into distribution networks has gained significant attention due to their potential to enhance network performance and sustainability. Solar PV systems utilize semiconductor materials to directly convert sunlight into electricity, providing a renewable and sustainable energy source. Technological advancements have led to significant improvements in the efficiency of solar panels, making them a competitive choice for electricity generation [1]. The cost-effectiveness of solar PV systems has improved considerably due to reductions in the cost of solar panels and other associated technologies [2]. Distributed generation (DG) has increased the share of renewable energy generation owing to its closeness to load centres, rapid installation, and utilization of existing roofs for PV systems [3]. DGs can address challenges like power loss, low reliability, poor power quality, and transmission congestion, while meeting energy needs [4]. However, improper deployment can cause issues like reverse power flow, poor protection coordination, voltage imbalance, and increased losses [5]. Additionally, improper placement and size of DG can affect power quality and fault current at the point of common coupling (PCC) [6]. Thus, optimizing DG use is crucial to maximizing its benefits, requiring a strategic approach to planning and deployment. This involves identifying the most effective installation locations, selecting the appropriate types of DG systems, and correctly sizing

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