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Assessment of energy storage and renewable energy sources-based two-area microgrid system using optimized fractional order controllers

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ABSTRACT

The stability of modern power systems faces significant challenges due to intermittent renewable generation and fluctuating load demands, resulting in excessive frequency variations. To address this issue and prevent potential blackouts, implementing a robust control strategy is crucial. This study introduces a cascaded control system, combining a novel fractional order integral derivative (FOID) with a fractional order proportional integral derivative with filter (FOPIDN) controllers, denoted as CFOID-FOPIDN. The gain parameters for CFOID-FOPIDN are determined using the Archimedes optimization algorithm (AOA). The proposed two-area microgrid system incorporates various power-generating sources, including solar, wind turbine generators, fuel cells, micro-turbines, and battery energy storage technologies. To assess the AOA-tuned CFOID-FOPIDN controller's effectiveness, the system is tested under five different conditions: load fluctuations, changes in wind speed, variations in irradiance, combined wind and irradiance variations, and comprehensive changes across all conditions. Simulation results reveal that the AOA-based CFOID-FOPIDN outperforms other existing algorithms, such as particle swarm optimization (PSO), bat algorithm (BAT), moth flame optimization (MFO), and whale optimization algorithm (WOA). In dynamic variations across all sources, the AOA-tuned strategy demonstrates shorter settling times in area-1 (2.5 s), area-2 (2.2 s), and tie-line power (2.1 s) compared to PSO (3.5 s, 3.8 s, 3.4 s), WOA (3.2 s, 3.4 s, 3.1 s), BA (3.0 s, 3.1 s, 3.0 s), and MFO (2.9 s, 2.8 s, 2.9 s). Across all five scenarios, the AOA-tuned CFOID-FOPIDN strategy consistently demonstrates superior performance compared to the other strategies under consideration.

1. Introduction

Since the industrial revolution and the increasing population, fossil fuels have dominated the energy industry worldwide. These fossil fuels significantly impact both the global climate and human health. Fossil fuel combustion for energy contributes approximately 75 % of worldwide greenhouse gas emissions. Additionally, fossil fuels are responsible for large amounts of local air pollution, a public health issue that causes at least 5 million premature deaths annually [1,2]. Therefore, the energy industry needs advancements, and sustainable energy technologies are needed for transformation to a viable society. Three major changes need to be implemented to accomplish sustainable energy development: reducing emissions; transitioning to renewable energy (RE) in place of fossil fuel-based energy; and increasing energy efficiency [3]. The use of renewable energy sources (RESs) in power production has increased dramatically in recent years, reaching double-digit percentages in several countries while many others are still in the early stages of RE integration [4,5].

Despite this planet's abundance of renewable energy sources, 13 % of the population lives in remote areas without access to electricity [6,7]. The number of people worldwide who have access to electricity and those who do not are depicted in Fig. 1. In order to overcome these challenges and improve the accessibility of electrical energy to remote areas, RE-based microgrid implementation is appropriate. Microgrids can produce electric power from diverse energy sources, namely, conventional generators, solar photovoltaic panels, micro turbines, wind turbines, battery energy storage (BES) and fuel cells (FC) [8,9]. These energy sources are prevalently utilized in remote locations as the utility grid has limited access; however, they can also be utilized in urban locations to yield backup power in the event of grid outages. Ongoing

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