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Application of Empirical Bode Analysis for Delay-Margin Evaluation of Fractional-Order PI Controller in a Renewable Distributed Hybrid System

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Abstract: For an uninterrupted power supply, renewable energy promises to be a suitable alternative compared to the conventional sources. System delays or communication delays may cause significant synchronization imbalances between various components in big electrical grids. Since the properties of solar and wind generation constantly change with climatic circumstances, engineers encounter many difficulties when substituting sustainable power with conventional electricity. The computation delay margin may be leveraged to handle a time-delayed automatic generation control (AGC) system. In order to regulate a distributed hybrid renewable energy system in a three-area AGC configuration, this paper investigates the influence of the fractional integral order on the stable system's delay parameter region. By changing the fractional order range, the delay margin can be increased, potentially broadening the time-delayed system's stability region. The controller's stability region has dependency on the order of fraction and the time delay. For this purpose, the asymptotic Bode diagram of the time-delayed fractional proportional-integral controller is determined. The gain and phase margins are used to calculate the delay margin for the application in discussion. The Honey Badger algorithm helps to adjust the controller parameters. It is also confirmed that the suggested controller is resilient to random load perturbations, nonlinearities, and parameter variations.

Keywords: deregulation; fractional-order controller; honey badger algorithm; renewable-based distributed hybrid system; time-delay

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1. Introduction

For the past few decades, renewable-resource research has been creating a roadmap for green energy [1] across 143 countries in order to battle the greenhouse effect and environmental pollution and to improve energy stability. The issues posed by global warming inspire energy policymakers to continue their research in this field. Due to the rapid change in characteristics of diverse RERs such as solar [2] and wind into the current power system, some issues and constraints on the system's stability, security, operation, and control have become major factors. With a big interconnected grid, this may result in a large synchronising imbalance between different units, considerable system latency, or communication delay. Hence, researchers devote a large span of time and effort to identifying control strategies to balance supply and demand.

Automatic generation control (AGC) ensures the overall system's reliability and power quality in the power sector. For the past few decades, an open communication channel [3] has been allocated to exchange information between the control unit and the generating station via a remote terminal unit. To run a deregulated market using open communication [4] channels between generation companies (GENCOs) and distribution companies (DISCOs), communication delay may be acceptable during the construction and operation of vast