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Performance enhancement of renewable based deregulated system using distributed power flow controller, Redox flow battery, and Tesla power wall battery

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ABSTRACT

In the upcoming era, when conventional sources will mostly be replaced by renewable energy sources, engineers may face huge problem during controller design. For this large interconnected hybrid automatic generation control (AGC) system, high proficient and intelligent control techniques are needed. Hence, a newly developed fractional order tilt integral derivative double integral filter plus (FOTIDF-II) controller has been proposed in this research work. To overcome slow convergence feature of moth swarm algorithm (MSA), chaotic-based moth swarm algorithm (CMSA) is introduced by incorporating chaos into the MSA algorithm. Afterward, to upgrade the performance of AGC, the newly proposed controller is incorporated to the said system. The gains and fractional order parameters such as order of integrator, differentiator and filter coefficients of the proposed controller are optimized using CMSA optimizing technique. It is observed that the dynamic performance of the proposed CMSA optimized FOTIDF-II controller is better than the CMSA optimized PID. Furthermore, the performance of CMSA in the presence of different flexible AC transmission system (FACTs) and storage devices such as distributed power flow controller (DPFC), redox flow battery (RFB), and Tesla power wall (TPWA) battery (*i.e* Storage devices) along with proposed controller is compared with MSA-based PID controller with same combination of FACTs controller. Afterwards, superiority of the proposed controller has been judged in three area renewable-based AGC system under realistic environment.

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1. Introduction

The primary objective of the power generating sector is always to maintain continuous power supply at their schedule frequency level to operate the generation unit at most economical level Biswas, Kumar Roy, and Chatterjee (2021). To decentralize the control of the electric power industry in order to keep the tariff of each unit at economic value, government has imposed restructure rules, called deregulation. In the conventional method, generation companies (GENCOs), transmission companies (TRANSCOs), and distribution companies (DISCOs) supply power at their specified rate. In a deregulated market, GENCOs always maintain the physical flow of power by satisfying consumer demand at proper voltage and frequency level. On the other hand, a DISCO may or may not have the contract with a particular GENCO as independent power producers Ghasemi-Marzbali (2020). There are two primary control mechanisms for balancing the active power and reactive power. Controlling voltage level by balancing reactive power is known as an automatic voltage regulator (AVR). On the other side, automatic generation control (AGC) always tries to maintain the frequency at its schedule level by balancing active power (Gupta, Pal Verma, and Chauhan 2020). In this context, researchers take different AGC schemes by incorporating non-conventional unit like wind turbine and solar unit with the conventional thermal power plant (Biswas, Kumar Roy, and Chatterjee 2021). Moreover, many researchers incorporated non-conventional units like wind turbine Dewangan and Vadhera (2020); Lakshmi Narayanan and Ramakrishnan (2021); Sun et al. (2021); Sun, Li, and You (2020) and diesel unit along with the conventional unit to maintain the nominal frequency level at their scheduled value. A control strategy (Mohanty, Panda, and Hota 2014) is designed for tie-line bias control in the bilateral-based deregulated scenario. When contract violations are made by the DISCOs, AGC helps to generate power and maintains the nominal frequency level and minimizes the unscheduled power exchanges within the areas (Goswami et al. 2017).

Since the last few decades, various numerical methods such as quadratic programming, interior point method, nonlinear programming, and gradient technique having the ability to handle difficult constraints are widely implemented to solve different types of AGC problems. These techniques have very high efficient convergence features, but on the other hand, they have some limitations to solve the nonlinear problem having discontinuous objectives and constraints. To avoid local optimality and low convergence rate, researchers are applying different heuristic techniques to solve the AGC problem. Elgerd and Fosha suggested a modern optimal control concept on AGC problem (Elgerd and Fosha 1970). Teaching learning-based optimization (TLBO) is one kind of heuristic optimization technique proposed by Panda *et al.* to control smart power generation systems using machine learning and data-driven

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