Oppositional artificial rabbit optimization for the optimal tunning of single input power system stabilizer

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The methodology of Oppositional Artificial Rabbit Optimization (OARO) has been effectively applied in this study to a single input power system stabilizer for the most effective tuning to lessen volatility at low frequencies. A single machine infinite bus (SMIB) system has been used to test the suggested algorithm's efficacy using the Heffron-Phillips framework. To assert the relevance of OARO in an adaptable situation, the implementation of the suggested method is tested for a wide loading environment. The novelity and superiority of the present work has been validated by comparing the result with other work.

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I. Introduction

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***Index Terms*—Power System Stabilizer, Single Machine Infinite Bus System, Low Frequency Oscillation, Oppositional based learning, Artificial rabbit optimization**

I. Introduction

A power system stabilizer (PSS), which stabilizes the signal aAROss the excitation system, was introduced by the power industry to address low-frequency (0.1–2 Hz) oscillations that were caused by the transfer of massive amounts of power over weak transmission lines. This issue was first encountered in the 1920s. The two-level scheme, proportional integral (PI) controllers, dynamic pole assignment, two-level control strategy with order reduction, model matching methodology for determining PID controller settings, and other methods were presented in addition to this one [1].

Power system stabilizers (PSS) are used to damp the oscillations, categorized into local (0.8–2 Hz) and inter-area modes (0.2–0.8 Hz). Classical PSS design based on linear control theory often struggles with varying conditions and high loads. Advanced metaheuristic algorithms such as genetic algorithms, PSO, and artificial intelligence techniques like ANN and fuzzy logic, address these challenges but have limitations. A novel algorithm, Collective Decision Optimization (CDO), enhances small-signal stability, demonstrated through eigenvalue analysis on WSCC 3-machine 9-bus and IEEE 14-bus systems, outperforming existing techniques like GWO and DE [2]. This is when PSS becomes important i.e the complexity and interconnectedness of today's power networks make it difficult to maintain reliability and safe operations. Transient events can give birth to instabilities in voltage, rotor-angle and frequency instability, hence leading to cascading failures or system collapse. One major issue that necessitates power oscillation damping is rotor-angle instability, which is frequently brought on by power oscillations. Although power system stabilizers (PSSs) are frequently employed to reduce these oscillations, inter-area oscillations are more difficult for traditional PSSs to control. Oscillations are also caused by elements such as regional power imbalances and poor power transfer cables. PSSs, such as the 2021 Colombo outage that affected 21 million people, improve stability. Modern grid complexity made sophisticated security techniques crucial [3].

The application of traditional power system stabilizers (PSSs) in modern voltage regulators offers cost-effective solutions for improving power system stability compared to alternatives like FACTS systems. After properly tuned, PSSs can provide stability benefits comparable to advanced systems, though they may slightly compromise voltage regulation quality. Single-input stabilizers, such as PSS1A, are simpler but prone to drawbacks like amplifying torsional vibrations, which can be mitigated with multi-input designs at the cost of more complex tuning. Incorrect PSS tuning may worsen electromechanical transients. Research divides into four key areas: general PS stabilization, technical aspects of PSSs, interactions with renewable sources, and mathematical modeling for accurate simulations. Reliable models are essential for optimal PSS design, tuning, and PS stability [4]. Artificial intelligence (AI) methods, including neural networks, fuzzy logic, and