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In-Depth Analysis of Modern Optimization Strategies for Controllers

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Abstract*: Almost every day, new commercial power electronic controllers are introduced to the market with the goal of enhancing the efficiency and performance of electronic circuits and systems. A simple and sophisticated hysteretic controller governs the fundamental buck, boost, and buck-boost converters in DC–DC switching-mode converters under somewhat diverse topologies. The input current shaping for power factor correction places restrictions on AC-DC converters. However, a number of excellent commercial controllers are proved to accomplish almost flawless power factor adjustment for boost and flyback converters. This study presents a thorough analysis of the several advanced optimization methods used to power electronic controllers.*

Keywords: Performance Improvement, Algorithm Efficiency, Robust Control.

I. INTRODUCTION

Typically, energy storage components and semiconductor switches are the sole components found in power electronics converters. Because non-isolated converters are more dependable, less expensive, and less bulky than isolated converters, they are often used in situations where electrical separation is not required. On the other hand, isolated power converters often use a connected inductor or transformer to achieve a variety of goals, including ground loop avoidance, galvanic isolation, and voltage level shifting. For optimal functioning and to prevent saturation, the AC transformer in converters requires an AC voltage or a square or quasi-square wave voltage at the main side. Buck type converters may employ a transformer to enable the voltage step-up capability. Additionally, using linked inductors or multiple winding transformers is a straightforward method of achieving numerous outputs in a single converter. Additionally, using transformers in the circuit enables galvanic and electrical isolation between the converter's input and output modules. Transformers may be used to prevent the current from one device's return route from interfering with the functioning of other devices when two or more electrical devices share a common ground in a power system.

II. LITERATURE REVIEW

The simulation results of a static voltage compensator (SVC) for enhancing transient stability in an integrated power photo voltaic (PV) system are presented in this research. systems are shown [1]. Blondin et al. [2] developed a unique combination of a simplified Ant Colony Optimization algorithm and Nelder-Mead technique (ACO-NM), together with a new process to restrict NM, to offer an optimum gain tuning solution for PID controllers. An optimization-based tuning technique for real and complicated Fractional-Order Proportional-Integral (FOPI) controllers is proposed by Moghadam et al. [3]. A hybrid fuzzy P+D with Mamdani-type optimization Soylu et al. suggested the controller [4]. Castillo and Angulo [5] provide a Generalized type-2 Fuzzy Logic System (GT2FLS) technique for optimum fuzzy controller design and dynamic parameter adaptation in metaheuristics. Although designing an appropriate optimum tuning approach for the flap control system (FCS) is challenging and the optimization process is often time-consuming, effective flap controller tuning may increase adaptive flap control performance in unpredictable operating settings. In order to address this issue, Li et al. [6] developed a new adaptive flap controller that is based on a composite adaptive internal model control (CAIMC) method and a high-efficient differential evolution (DE) identification technique. The Automatic Generation Control (AGC) of three area multi-source linked power systems that include Battery Energy Storage Systems (BESS) is the subject of this research. Particle Swarm Optimization (PSO)-tuned Integral controllers

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(ICs) are used in the plant's architecture, and they operate on three separate power systems: thermal, gas, and hydro—interconnected power systems with and without Battery Energy Storage Systems (BESS) [7]. The challenge of creating a robust gain-scheduled controller with a hierarchical structure and based on semi-definite programming was given a precise state-space solution by Guo and Scherer [8]. An improved controller was suggested by Kumar et al. [9] and applied to a prototype three-story building that was fastened with an MR damper. Several seismic events have been applied to this building in order to assess its performance. The Extended Kalman Filter (EKF) and Diagonal Recurrent Neural Network (DRNN) used in this paper's new virtual sensing system architecture forecasts the future states of the quadrator system based on its current states and control inputs [10]. In this work, a new time domain performance criteria for the Cuckoo Search (CS) algorithm-based proportional-integral-derivative (PID) controller tuning design in the Automatic Voltage Regulator (AVR) system is presented. The goal of this performance criteria was to reduce the terminal voltage's maximum overshoot, rising time, settling time, and steady state inaccuracy. To ensure that In order to compare CS with other evolutionary algorithms, the suggested objective function was applied to the PSO and ABC algorithms for PID design of the AVR system [11]. The single-input-single-output (SISO) level control system is assigned level control by Laware et al. [12] and is based on the combination of sliding mode control (SMC) and evolutionary or bio-inspired approaches. Two evolutionary strategies are regarded as non-dominated sorting genetic algorithm II (NSGA-II) and multi-objective particle swarm optimization (MOPSO). Here, MATLAB/SIMULINK has been used to compare the performances of an optimum proportional-integral (PI) controller, a proportional-integral-derivative (PID) controller, a standard SMC, a tuned SMC based on NSGA-II, and an SMC parameter adjusted using the MOPSO method. In order to examine and compare three distinct MDO techniques, the authors of this article concurrently took into account plant design and the tuning of a proportional-integral (PI) controller. We use multi-objective optimization to compare such techniques since they may provide competing goals [13].

In their investigation of computer-regulated propofol administration in anesthesia during medical operations, Kuti and Galambos [14] take output feedback and strong PID control into consideration. The proper polytopic quasi-LPV representation of the closed-loop dynamics is derived by the study using the Affine Tensor Product Model Transformation. Khan et al.'s study [15] focuses on employing a PID (Proportional-Integral-Derivative) Controller to regulate the dissolved oxygen in a biological fermenter. This fermenter's output is used to make a vaccine against a disease. Enrique together with others.

[16] suggests using a scheduled-gain PID controller, which is included into a microcontroller, to precisely modify the weight on the bit (WOB) and prevent disruptions. LabVIEW was used to get high-frequency data, which was then instantly evaluated using the MATLAB programming environment. The controller design challenges for multiple input multiple output (MIMO) square fractional-order plants are expanded to use the parameter optimization approach for multivariable systems. With or without time delays, the approach may be used to find the ideal integer-order controller settings for fractional-order plants (Xue et al., 2017). The controller design suggested by Kang and Yan [18] is converted into a convex optimization problem and solved using the proper optimization technique. The primary-secondary user resource-management controller in cognitive radio vehicular networks under hard and soft collision limits was created and tested by the authors of this research. The best steady-state controllers are derived by converting the resource management issue into a stochastic network utility maximization problem and distributing the access time windows to the secondary users in an adaptive manner [19]. Haemers et al. [20] provide an optimum control for a full-car electromechanical active suspension in this study. This study proposes an optimal fuzzy PID controller for load frequency control (LFC) of an interconnected power system, taking nonlinearity into account, using a new evolution (MDE) technique. Various techniques of the DE algorithm are used to maximize the gains of the fuzzy PID controller. Then, in order to achieve better performance, it is suggested that the DE algorithm be modified using a simple yet efficient technique that alters two of its most crucial control parameters, step size and crossover probability [21]. Dynamic modeling and design of the hose-drogue control system in this study by Sun et al. [22] on the system (HDS) at the docking stage of autonomous aerial refueling (AAR). In order to get the optimal step-response performance, the authors first parameterize each controller that leads to the specified performance criteria (cross-over frequency, phase margin, and iso-damping) and then optimize the cross-over frequency and phase margin [23]. Energy storage devices may play a significant role in supporting autonomous generation management in a power

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system by preserving the grid frequency and power balance in the event of abrupt interruptions. Therefore, Dhundhara et al.'s paper [24] examines the function of a thyristor-controlled phase shifter and a capacitive energy storage unit as energy storage devices in the automatic generation control of a two-area interconnected power system with multiple gas-hydro-thermal mixed generating units in a deregulated power environment. This work proposes a fuzzy assisted PID controller for frequency management of power systems. An Improved Grey Wolf Optimization (IGWO) technique is used to maximize the controller gains. The GWO technique is improved by a way that simplifies the algorithm and requires less execution time by not taking into account delta wolves, which are less significant while updating the position vector throughout the program's hunting phases. The proposed IGWO is first assessed using a few common test functions. To demonstrate its superiority, the results are compared to GWO, modified GWO (MGWO), Differential Evolution (DE), Gravitational Search Algorithm (GSA), and Particle Swarm Optimization (PSO) approaches [25]. The design process for a fractional order proportional-integral-derivative (FO-PID) controller is briefly described in this study. It uses an indirect approximation method that makes use of the constant phase methodology. To determine controller settings, a novel method called modified dynamic particle swarm optimization (IdPSO) is put forward [26]. Sahu and associates.

Load frequency control (LFC) in an islanded two area AC micro grid (MC) system is covered in [27]. The suggested two-area MG system in this research is made up of several micro sources, such as fuel cells (FC), diesel engine generators (DEG), and microturbines (MT). These sources are mainly in charge of balancing power supply and load in an interconnected system. The active presence of the utility grid reduces the likelihood of frequency control issues for MG operating in grid-connected mode. In a deregulated environment, Tashin et al. [28] highlight the attempt to integrate the conventional thermal system with the geothermal power plant (GTPP), dish-Shirling solar thermal system (DSTS), and high voltage direct current transmission (HVDC) link.

This is done through automatic generation control of an interconnected power system. In thermal systems, suitable generation rate limitations are supplied. In order to manage different linear inequality constraints in a multi-variable control framework, this research suggests developing a restricted next generation RTDA controller [29]. This study suggests an optimization strategy for adjusting the parameters of dynamic sliding mode controllers, which are generated from a simplified model employing optimization criteria and constraints provided by performance variables that the process has to meet, as stated by Baez et al. [30].

In order to improve the damping of oscillations in the output power and voltage, the MFO-based design of blade pitch controllers (BPCs) for wind energy conversion systems (WECS) is presented in this study. The benefit of the suggested hybrid referential integrity MFO approach by Ebrahim et al. [31] is realized by the employment of the straightforward Proportional-Integral- Differential (PID). The Integral-Proportional Derivative (I-PD) controller has been discussed in this article.

created and put into use for the nonlinear, unstable Magnetic Levitation (Maglev) system in both simulation and real life. The linearized model transfer function has been obtained by linearizing the nonlinear Maglev plant around the equilibrium point. The newly developed Jaya method [32] was used to minimize the objective function, which was formed by considering the modulus of the plant's characteristic polynomial together with the controller at the dominating pole site.

A self-adaptive means, or forgetting factor recursive least squares (FFRLS) mechanism, is embedded into state-space predictive functional control (PFC) and is used to address the difficult issue of the weighting factors of the APFC technique lacking analytical knowledge. Lu et al. [33] proposes a self-adaptive state-space predictive functional control (APFC) based on extremal optimization method to design PID controller called EO-APFC-PID.

For Automatic Generation Control (AGC) in a two area interconnected thermal power system, Nayak et al. [34] present a maiden comparative performance analysis of interval type-2 fuzzy-PID controller with & without derivative filter (T2FPIDF & T2FPID), type-1 fuzzy-PID controller (T1FPID), and conventional PID controller. By using cutting-edge adaptive symbiotic organism search (ASOS) and symbiotic organism search (SOS) optimization methodologies, the suggested controllers are ideally developed. The strategy for creating a fuzzy controller rule base utilizing a novel swarm intelligence algorithm based on the Bat algorithm is provided by the authors in this study. One of the newest swarm intelligence-based algorithms, the Bat algorithm mimics the clever hunting techniques of real-world bats. The primary goal is to provide a fuzzy rule foundation for a fuzzy controller while maintaining the intended level of performance [35].

A fuzzy logic controller (FLC) was suggested by Farajdadian et al. [36]. for solar systems' MPPT. This study presents four optimization techniques for producing an appropriate duty cycle for MPPT and optimizing fuzzy membership functions (MFs). In this research, a low complexity control strategy for dynamic voltage restorer (DVR) voltage regulation is presented in a unique way. In order to ensure improved power quality performance in terms of voltage enhancement and bus stabilization, energy-efficient utilization, and harmonic distortion reduction in a distribution network, the suggested scheme makes use of an error-driven proportional–integral–derivative (PID) controller [37].

According to Lee et al. [38], a self-tuned HVAC controller that minimizes energy usage and offers personalized thermal conditions to accommodate user preferences (like online learning) has been developed. The controller has also been implemented in an actual, inhabited office space. A closed-loop is formed by the development of individualized thermal preference models and the model predictive control (MPC)-assisted supply of thermal conditions. Ahmed et al. In a grid-connected photovoltaic (PV) power system that supplies a pulse AC demand, [39] offers an adaptive controller for a grid-tie DC-AC converter. The suggested controller is in charge of controlling the injected power into the grid, limiting the injected harmonics, and regulating the dc-bus voltage. In order to address the criteria for robustness and stability as well as quick time response characteristics, Blondin et al. [40] present a novel optimization framework based on a simple performance criterion. By comparing the approach's outcomes with those attained using two previously published performance metrics, the approach's effectiveness is validated. produced using the MathWorks PID tuning technique and the Matlab systune tool. This study offers a N−1 multi-contingency AC optimum power flow (OPF) that incorporates a set of transient stability constraints (TSC) that ensure rotor angle and angular velocity fluctuation within technical bounds, for given N−1 contingencies, inside the same mathematical optimization model. In order to further enhance the performance of the EPS at specified demand and generation levels, the suggested model also takes into account the functioning of volt/var controls, such as shunt elements and OLTC transformers [41].

In order to restrict the extracted power atrated value while enhancing its quality and to lessen the stresses placed on the turbine and drive train during full load situations, Zamzoum et al. [42] suggested an adaptive controller based on fuzzy logic idea. This controller adjusts the pitch angle. The purpose of this paper is to review the various controllers used in LFM power systems that are based on renewable energy sources as well as conventional energy sources.

These controllers include H-infinity, cascaded, sliding mode controllers (SMC), tilt-integral-derivative controllers, classical controllers, fractional order controllers, and other recently developed controllers [43]. This research proposes a revolutionary Grasshopper optimized fuzzy logic control (FLC) strategy using MPPT technology. The membership functions (MFs) of FLC are tuned via grasshopper optimization in this suggested MPPT in order to address all uncertainties resulting from changing temperatures and irradiances. Under rapidly changing irradiance and temperature conditions, the performance of the suggested grasshopper optimized FLC based MPPT is investigated [44]. The multi-area (five areas: area 1, area 2, area 3, area 4, and area 5) reheat thermal power systems that Jagatheesan et al. [45] suggested are taken into account by an additional proportional-integral-derivative (PID) controller. This work provides an optimization method for induction motor (IM) drive speed management based on the quantum lightning search algorithm (QLSA). To provide an appropriate input and output fuzzy membership function for the IM drive speed controller, the created QLSA is implemented in a fuzzy logic controller [46]. The use of multi-objective optimization approaches for the modification of controller settings is presented by Pajares et al. [47].

An off-road electric vehicle's PI cruise controller tuning is compared in this research. To get an accurate EV speed monitoring while taking safety precautions such not having a reverse speed, a cost function is created. It has been shown that the ACO- NM algorithm is the most effective when compared to GA, ALO, DE, and PSO. In fact, Blondin et al.'s ACO-NM achieved excellent results at less computational cost for three driving cycles [48]. This work proposes a voltage-frequency control strategy to keep these numbers within reasonable bounds in distant islanded microgrids (MGs).

When current methods for regulating energy storage or modifying generator set-points are unsuccessful, the suggested method is triggered, according to Arefi et al. [49]. This paper proposes, for the first time, a developed fractional high order differential feedback controller (FHODFC) and a high order differential feedback controller (HODFC) for the LFC issue in multi-area power systems. The particle swarm optimization (PSO) approach, which aims to minimize the

integral of time weighted absolute error (ITAE) performance index by Sahin et al. [50], optimally tunes the gains of the HODFC and FHODFC. Ramya together with others. [51] focuses on fuzzy logic (FL)-based adaptive controller design. controller to provide improved dynamic performance in the presence of parameter uncertainties and non-linearities. The membership function (MF) settings in the suggested controller are adjusted in accordance with the changes in the motor's parameters. This work presents the first use of one plus fractional-order derivative (1+FOD) and cascade proportional-integral-derivative with filter (PIDF), i.e. The load frequency control technique is suggested to use the PIDF(1+FOD) controller. Increasing the degree of freedom and rejecting disturbances more quickly are the primary goals of the fractional order controller and cascade. Prakash et al.'s innovative effort to model a static synchronous series compensator (SSSC) using AC and HVDC tie-lines was also made [52]. Mishra and associates. [53] describes a hybrid Particle Swarm Optimization-Grey Wolf Optimization (PSO-GWO) and Fractional Order Proportional- Integral-Derivative Controller (FOPIDC) optimized Hybrid Shunt Active Power Filter (HSAPF) for reactive power and harmonic compensation under balance and unbalance loading conditions.
In order to minimize the converter storage capacitance, Soares et al. [54] provide an optimization technique for creating an offline light-emitting diode (LED) driver with a wide-bandwidth controller. In order to design the power circuit elements and the controller simultaneously and optimize a given parameter, like the filtering capacitance or the total harmonic distortion, the approach is based on modeling the entire designing process as a nonlinear constrained optimization problem. This work proposes a computational methodology based on Genetic Algorithm for coordinated tuning of the power system controllers that acts to maximize two objective functions simultaneously, one of which is the improvement of the automatic voltage regulator responses and the other is the damping of electromechanical oscillations, while taking into account multiple critical operating conditions [55].

A revolutionary line-voltage regulator and its optimal management of power quality are discussed by Holt et al. [56]. Three important comments are made by Taha et al. [57] in relation to the tuning problem related to VOC. First, an algebraic solution (PI-parameters) is created, together with approximate relationships and methods, based on the first-order-plus-time-delay (FOPTD) approximations of the plant dynamics. Movahedi and associates.
In the presence of two 200 MW wind farms based on a doubly fed induction generator (DFIG) and a 120 MW photovoltaic (PV) solar plant, [58] examines the effects of three FACTS controllers, static synchronous series compensator (SSSC), thyristor-controlled series compensator (TCSC), and static synchronous compensator (STATCOM), on the transient stability of a multi-machine power system.

III. CONCLUSION

Power electronic converters provide effective electrical power conversion and control. Although phase-controlled converters are not as good as pulse width modulated converters in terms of operational characteristics, the high-frequency switching process itself has unfavorable side effects. It seems that ac voltage controllers and phase-controlled rectifiers will continue to be used in power electronics for many years to come. In order to achieve maximum control, improved efficiency, and increased reliability in power electronic controllers, this work has provided a thorough analysis of the many sophisticated optimization strategies.

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