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HYBRID OPTIMIZATION BASED PID TUNING FOR AUTOMATIC VOLTAGE REGULATOR

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Abstract—
the current study examines an automated voltage regulator's modelling and PID controller tuning. With the aid of a hybrid optimisation technique, the PID controller is adjusted. In this article, the BF-PSO hybrid optimisation technique is used to adjust the controller. To validate the algorithm, comparative analysis and simulation results are given. Both frequency domain and time domain analysis have been done. The VAR operates within a set of predetermined parameters in order to maintain the voltage at the terminals. If the terminal voltage is set too high or too low, certain electrical equipment will not function as intended. An essential part of power system operation and control are computer-controlled AVRs.

Keywords— PID Controller, Optimization, BF- PSO, Electrical Equipment, Hybrid Optimisation Technique, VAR, Power System.

INTRODUCTION

The equipment in the power system can last longer if the necessary voltage level is supplied with great precision. As the rated voltage is taken into consideration during the construction of these devices. Additionally, this voltage value determines the flow of reactive power, which is useful in line losses. Voltage control uses Automatic Voltage Regulator (AVR) technologies to lower line losses. An AVR system maintains a steady terminal voltage through closed-loop control. PID controllers are the most widely utilised of these because of their reliable performance and simplicity of usage. It is possible to design a PID controller utilising meta-heuristic optimisation algorithms or conventional techniques. Conventional techniques, including the gain-phase margin approach and the Ziegler-Nicolls method, have drawbacks such poor closed loop responses and trouble with nonlinear systems. The goal of this research is to create a PID controller that will enhance an AVR system's dynamic performance. The SOS, PSO, and Whale optimisation (WO) algorithms are employed to optimise the controller's settings. The optimisation strategies are compared in terms of performance using a simulation of the AVR system with the PID controller. Transient response characteristics from the AVR system's step response are taken into account in the comparison. Together with overshoot, rising time, and settling time, steady state error is also considered. To expedite the optimisation process, a hybrid structure based on PSO and SOS algorithms is suggested as another contribution of this work. Because power networks are dynamic in nature, their operators must keep an eye on every consumer and control the amount of energy produced by the many sources of energy that are stored and used. Moreover, the voltage level and frequency of the energy must always remain within predetermined bounds at all times. In order to regulate the generator voltage to the appropriate value, automatic voltage regulation is a crucial control loop. It is possible to effectively manage the voltage in power networks by adjusting the generator voltage. But the excitation system's preparedness for that process matters, and the regulator's parameters determine how quickly the regulation happens. All of the excitation systems' mathematical components are nonlinear, which suggests that it is difficult to observe an automated regulation loop, especially when taking into account a few key presumptions. The regulator is the most crucial component of the automated voltage regulator (AVR). The proportional-integral-derivative (PID) regulator remains the most widely used regulator, despite the existence of other variations in research and practice. Additionally, a variety of PID regulator types ideal, real, fractional-order, and FOPID as well as higher-order controllers like PIDD can be discovered in the literature.

AUTOMATIC VOLTAGE REGULATOR SYSTEM

An AVR system maintains a steady terminal voltage through closed-loop control. PID controllers are the most widely utilised of these because of their reliable performance and simplicity of usage. It is possible to design a PID controller utilising meta-heuristic optimisation algorithms or conventional techniques. Conventional techniques, including the gain-phase margin approach and the Ziegler-Nicolls method, have drawbacks such poor closed loop responses and trouble with nonlinear systems. The goal of this research is to create a PID controller that will enhance an AVR system's dynamic performance. The SOS, PSO, and Whale optimisation (WO) algorithms are employed to optimise the controller's settings. The optimisation strategies are compared in terms of performance using a simulation of the AVR system with the PID controller. Transient response characteristics from the AVR system's step response are taken into account in the comparison. Together with overshoot, rising time, and settling time, steady state error is also considered. To expedite the optimisation process, a hybrid structure based on PSO and SOS algorithms is suggested as another contribution of this work. Because power networks are dynamic in nature, their operators must keep an eye on every consumer and control the amount of energy produced by the many sources of energy that are stored and used. Moreover, the voltage level and frequency of the energy must always remain within predetermined bounds at all times. In order to regulate the generator voltage to the appropriate value, automatic voltage regulation is a crucial control loop. It is possible to effectively manage the voltage in power networks by adjusting the generator voltage. But the excitation system's preparedness for that process matters, and the regulator's parameters determine how quickly the regulation happens. All of the excitation systems' mathematical components are nonlinear, which suggests that it is difficult to observe an automated regulation loop, especially when taking into account a few key presumptions. The regulator is the most crucial component of the automated voltage regulator (AVR).

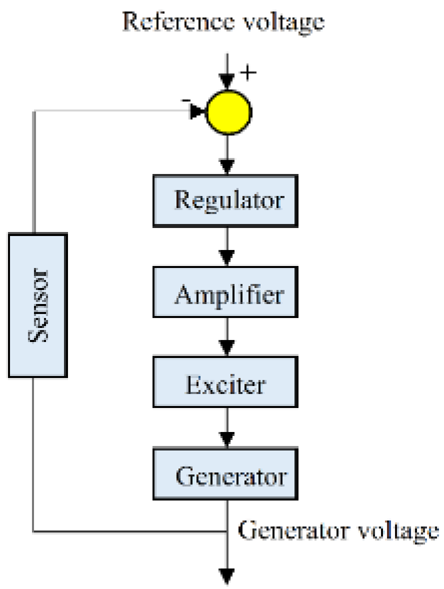

Fig. 1: Block diagram of the AVR system

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The regulator (R), amplifier (A), exciter (E), generator (G), and sensor (S) are the five parts of the AVR system. Figure 1 shows the block diagram of an AVR system. The regulator creates a control signal for the amplifier to amplify the signal using the signal derived from the difference between the measured (sensed) generating voltage and the reference. It is a microprocessor unit found in contemporary excitation systems.

DESIGN OF PID CONTROLLER FOR THE AVR SYSTEM

Different PID controllers for the AVR system are designed using the SOS, WO, and PSO algorithms. The optimal tuning of PID controller parameters, namely proportional gain K p, integral gain K i, and derivative gain Kd, is achieved by utilising optimisation methods. The parameters' lower and upper bounds have been set at zero and 2, 1, 1, respectively. Based on steady-state error and transient response characteristics, the objective function employed in this work is developed in. To compare the optimisation techniques, the PID controller model of the AVR system is created in Matlab/Simulink. Three distinct PID controllers are built using the SOS, WO, and PSO algorithms. Furthermore, a hybrid optimisation strategy known as PSO-SOS is suggested, and a new PID controller is developed utilising this hybrid methodology. The optimisation algorithm maintains the least value by comparing the objective function with the prior value. The best population values providing the lowest value are recorded after the termination requirement is satisfied. In a hybrid method, the PSO algorithm is used first, then the SOS algorithm is launched using the best results from this algorithm.

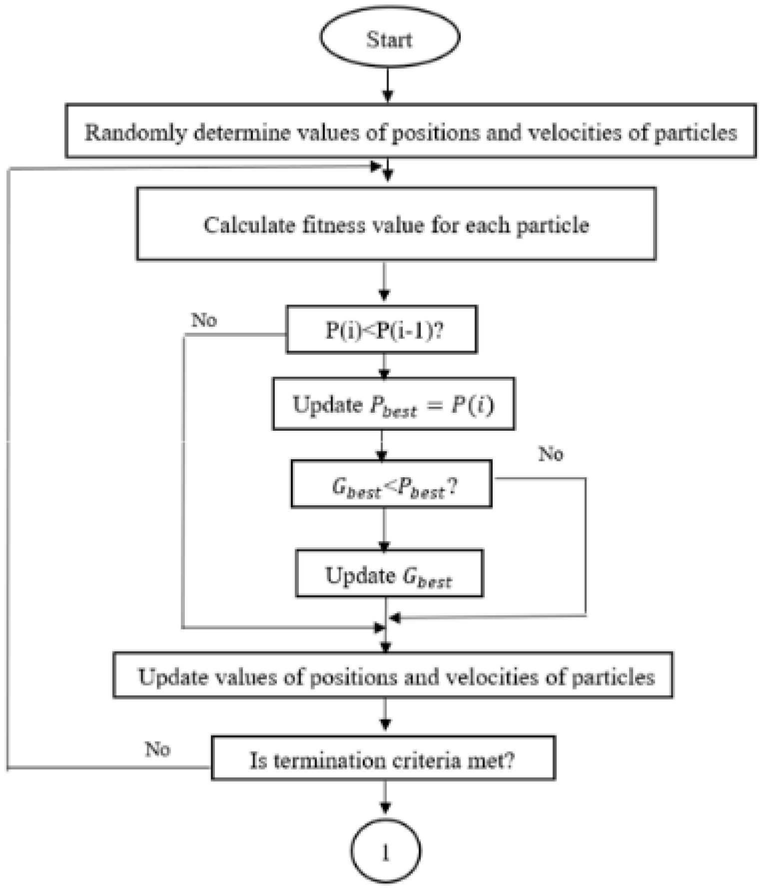

Fig. 2: Flowchart of proposed hybrid PSO-SOS algorithm

M ATERIAL AND METHOD

(i) Symbiotic Organism Search Optimization- In order to thrive, different species must coexist; this coexistence is referred to be symbiotic. Three types of symbiotic partnerships are most prevalent in nature: parasitism, commensalism, and mutualism. In mutualism, one kind gains in commensalism while the other is unaffected, even if both kinds gain from the interaction. Contrarily, in parasitism, one side gains while the other loses. By mimicking these symbiotic connections, the SOS algorithm seeks to identify the optimal creature.

(ii) Particle Swarm Optimization- **Kennedy and Eberhart created the particle swarm optimisation method, which is an evolutionary algorithm based on swarms. The flock's movement in relation to the position of the bird nearest the food serves as the basis for the algorithm.**

(iii) Flower pollination algorithm (FPA)- The biological system and natural inspiration serve as the foundation for artificial intelligence optimisation strategies. Nowadays, it's common practice in engineering and industrial applications to solve challenging issues with intricate limitations in order to arrive at the best answer. In 2012, Xin-She Yang saw how flower plants behaved during the natural pollination process, which motivated him to imitate the technique. Consequently, the FPA is presented as an optimisation procedure. He also programmed the FPA MATLAB code that is used in this paper. This algorithm has 4 assumptions or rules:

- Levy flights performed by pollinators which carry pollen with the global pollination process can be considered as cross and biotic pollination.
- Local pollination can be also considered as abiotic and self-pollination.

Note: classification of pollination can be shown in Fig. 3.

- Constancy of flowers is proportional to the resemblance of the two involved flowers and can be considered as the reproduction probability.
- In all activities of pollination, a fraction q can be considered in local pollination due to the physical proximity and other factors such as wind. A switch probability p ∈ [0, 1] can control global and local pollination.

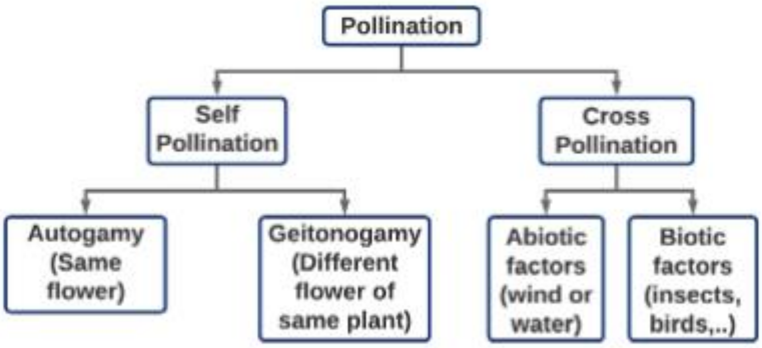

Fig. 3: Classification of pollination

<u>Pseudo code for flower pollination algorithm</u>

Initialize objective as minimization.
Define the population for n flowers.
Find current best solution f ∗ in the initial population.
Describe the switch probability P ∈ [0, 1].
While (t < MaxIteration)
For i = 1: n
If rand < P
Define step size P which follow Lèvy distribution.
else
Define ∈ for uniform distribution [0, 1].
Randomly select j and k among all the solution.
end if
Calculate new solution.
If calculation solution is better, then update it in population.
end for

Get the optimal solution f ∗.
end while

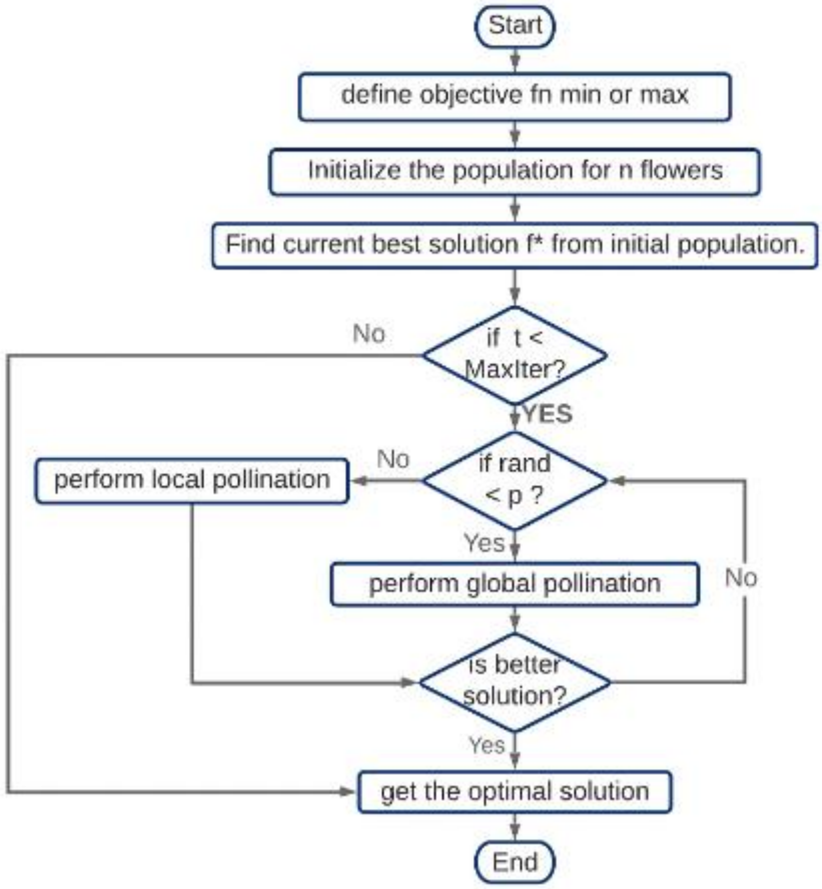

Fig. 4: Flowchart of FPA

CONCLUSIONS

For PID tuning, a hybrid optimisation approach is employed. This study has examined the mathematical modelling of the AVR system and the tuning of the PID controller. Results from simulations have been shown, demonstrating the tuning approaches' superiority. The VAR is in charge of preserving the terminal voltage and is constrained in what its operational bounds can be. A terminal voltage that is too high or low will significantly impair the functionality of a variety of electrical devices. An essential component for power system operation and control is the computer-controlled AVR. AVR can regulate the terminal voltage with the use of a controller. This paper presents the PID controller design for the AVR system that is optimally adjusted. The controller settings are adjusted using the SOS, PSO, and WO algorithms. Performance comparisons are done for each algorithm utilising transient reaction parameters such rising time, settling time, and percentage overshoot. The simulation findings indicate that the SOS algorithm outperforms the PSO and WO algorithms in terms of performance. Nevertheless, the optimisation process takes longer to finish. The PSO-SOS hybrid optimisation strategy is suggested as a solution to this SOS algorithmic drawback. This hybrid strategy uses the PSO algorithm to find the local minimum solution first, followed by the SOS algorithm to get the global minimum.

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