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HARNESSING THE POTENTIAL OF HYBRID GREY WOLF OPTIMIZATION FOR POWER QUALITY ASSESSMENT

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Abstract: The present investigation introduces a new method for evaluating power quality that combines particle swarm optimization technique with Grey Wolf Optimization (GWO). Because it has such a direct effect on the efficiency and dependability of the grid and the functioning of different electrical equipment. Power quality assessment is an essential part of maintaining reliable and efficient electrical power systems. A lot of the older approaches to evaluating power quality use heuristic algorithms, which can have poor convergence rates and produce less-than-ideal results. To improve the efficacy and precision of power quality evaluation, this research suggests a hybrid strategy that merges GWO's advantages with particle swarm optimization (PSO). In order to improve convergence speed and solution quality, the hybridization process seeks to utilize both the exploration-exploitation balance of GWO and the diversification capabilities of particle swarm optimization. Extensive simulations and comparison with existing approaches using common power quality assessment standards show that the suggested strategy is effective. The hybrid GWO-based technique shows promise for practical use in power systems engineering and management, as it beats standard methods in convergence time, solution quality, and resilience. To lessen the impact of harmonics and voltage imbalance, the PID controller's parameters are fine-tuned using the PSO-GWO method. The results show that active filters are not cost-effective for high ratings and are complicated and cumbersome, while passive filters are large and easy to use. Therefore, MATLAB/Simulink model is used to build a hybrid structure that combines a shunt active filter for meeting the desired objective.

***IndexTerms* – Power Quality,Optimization technique ,Hybridization,Covergence time,Resilience.**

1. INTRODUCTION

1.1 IMPORTANCE OF MICROGRID

These days, power electronics based loads are ubiquitous. The power supply, from which all of these power electronics-based devices draw current, is non-linear and harmonically unstable [1]. The huge quantity of reactive power required by the utility system is a direct result of this non-linear current. Harmonics impact systems and loads linked at the Point of Common Coupling (PCC) because the supply current is not sinusoidal and the source voltage and current are out of phase. One of the many options for mitigating harmonic distortion is the passive filter [4]. Passive filters have numerous benefits, but they aren't always the best choice. For example, they may not be able to handle transients, higher order harmonics, resonance problems, huge sizes, or fixed compensation features [5]-[7]. Active Power Filters (APFs) are a novel power electronics interface device that researchers have created to address reactive power and harmonic compensations. It is designed to alleviate the drawbacks of passive filters [4], [8].Hybrid power systems can't close the gap between electricity supply and demand without improved control architecture [4-5]. Renewable power is unstable and could produce an imbalance because it is so reliant on weather.

When operating a hybrid system over a wide area, it could be difficult to keep the power and frequency constant [6]. System performance can be enhanced by hybridizing with other controllers, including fuzzy logic, although this approach can be challenging to develop and execute. It is widely believed that the fractional-order controller is the most effective method for handling power fluctuations in a hybrid system. To get the most out of PID controllers, optimization methods abound. There are a number of optimization methods that could make dynamic voltages more stable [7]. The present seismic change in the global energy landscape is characterized by the rapid integration of renewable energy sources, breakthroughs in energy storage technologies [10], and an increasing focus on sustainable energy solutions. During this time of profound change, hybrid microgrids have been a game-changer, representing the wave of green, decentralized power that is here to stay [9].

1.2 GOALS OF STUDY AND REASONS FOR CONDUCTING OPTIMIZATION DRIVEN EVALUATION

Within this framework, the primary objective of this research is to create and apply optimization-driven evaluation techniques for reducing harmonics and voltage fluctuations in hybrid microgrids [3]. This endeavor is being undertaken for two distinct reasons. In hybrid microgrids, consumers must be able to rely on consistent, high-quality power regardless of fluctuations in output or other operational factors [5].

Secondly, by utilizing sophisticated mathematical methods and control strategies, the optimization-driven approach offers an attractive option to fix power quality problems. Upgrading power quality, grid stability, and energy efficiency are our end goals in implementing this strategy, which aims to bring mathematical optimization's accuracy into harmony with the intricacy of contemporary energy systems [2].

Our goals for this research are twofold: first, to pinpoint and evaluate hybrid microgrid power quality challenges; and second, to plot a course toward practical solutions. This study makes a big contribution to the dynamic energy systems by considerably enhancing the integration of renewable energy sources while preserving the highest power quality criteria. Part 2 of this paper lays out the microgrid model that will help achieve them, and Part 3 explains the research's aims of this article will go over the basics of a hybrid microgrid, including its components and their interconnections, using a block diagram. Section four describes a hybrid shunt active power filter.

To reduce harmonics and enhance voltage quality, Section 5 will examine how the PID controller's fine-tuning parameters are affected by the hybrid Grey Wolf optimizer and Particle Swarm Optimizer (GWO-PSO).Sections 6 and 7 of the results and conclusions section compare voltage quality at different busses and various performance parameters.

2. OVERVIEW OF THE APPROACH

2.1 VARIOUS ELEMENTS OF THE PROPOSED SYSTEM

Here we lay out the proposed three-stage paradigm in extensive detail. The final model was simulated using MATLAB/Simulink R2019a. The dynamics of MG under various operating conditions can be better understood with the use of a detailed model. Here are the steps to create a model of MG and what goes into making it:

Photovoltaic System: Solar panels, or photovoltaic (PV) panels, are an essential part of a microgrid since they increase the system's sustainability, resilience, and power generation and storage capabilities [3]. Solar electricity, being a renewable energy source, can reduce the microgrid's environmental impact.

You can find the details of the solar panel in Table 1.

Table 1: Model of solar panel: 1SOLTECH1 1STH-230-P

Num	Measure	Values
1	Power maximum value	228.735W
2	No of cells	60
3	Open ckt voltage	29.9V
4	Short ckt current	8.18A
5	Peak power voltage	29.9V
6	Peak power current	7.65A
7	Irradiance	1000
8	Frequency	50Hz

Wind Turbine: Microgrids rely on wind turbines, which collect wind energy and transform it into electricity. The integration of wind turbines into the microgrid can reduce its dependence on a singular power source by utilizing renewable energy sources. Table 2 displays the wind turbine specifications.

Table 3. Dimensions of wind generators

Num	Measure	Values
1	Initial wind velocity	12m/s
2	Initial angular velocity	0.4m/s
3	Maximum elevation angle	45 deg
4	Maximum rate of change of pitch angle	2 deg/s
5	Universal Bridge	

Battery: Energy storage, improved system resilience, and efficient use of renewable energy sources are three of the most important functions of batteries in a microgrid.To compensate for the unpredictability of renewable power sources, batteries can store excess energy and release it when needed. In Table 3 you can see the battery details.

Table 4. Battery parameters

Num	Measure	Values
1	Battery response time	30 Sec
2	Nominal voltage	1.5 V
3	Original charge status	100%
4	Group	NIMH batteries
5	Rated capacity	6.5 Ah

Number of loads: We put the suggested microgrid concept through its paces by testing its stability under nonlinear and unbalanced loads. The proposed filter's characteristics have been fine-tuned to work optimally in a broad range of environments. The design incorporates antiparallel diode switches, a DC link, and a battery to ensure that no harmonics are present.

2.2 SIGNIFICANCE OF CHOSEN CONTROLLER

By utilizing nonlinear and unbalanced loads, we demonstrate how a PID controller and an alternative controller can more effectively decrease total harmonic distortion (THD) compared to a passive filter (PF) or an active power filter (APF). The study's most noteworthy finding is that harmonic distortion at different significant busses was minimized and voltage quality metrics were improved. You can see the controller's intricate design in Figure 1. The DG is equipped with energy storage batteries, wind turbines, and solar panels. Batteries allow for the storage of surplus electricity, which can subsequently be utilized to decrease demand. A unique, high-performance PID controller is proposed to address PQ issues, reduce total harmonic distortion (THD), and improve voltage regulation. A hybrid metaheuristic method, GWO+PSO, is created to generate the optimal signal for the controller.

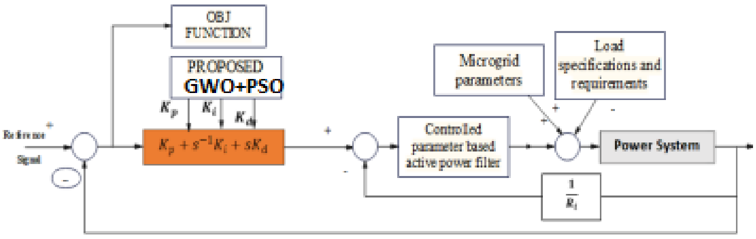

Figure 1: PID controller tuning as per objectives

The steps required for designing the controller are:

(i) Regulate k_p for reducing the rise time and steady-state error.

(ii) Regulate k_d for reducing the overshoot and settling time.

(iii) Regulate k_i for eliminating the steady-state error. Regulate k_p , k_i , k_d , to get the desired output.

(iv) The optimal parameters of PID controller are obtained using hybrid GWO-PSO technique

3. HYBRIDIZATION

3.1 PSO

Popular and simple optimizations include PSO. This technique allows a multitude of particles to traverse a multi-dimensional search space. All particles' velocities need to be refreshed throughout the search. However, when confronted with a significant constraint, the PSO approach becomes stuck in the local minima, despite its simple, sturdy, and easy-to-apply nature. For its part, GWO is able to evade local traps by keeping exploration and exploitation in balance [5]. The result is an algorithm that combines the best parts of both the GWO and PSO methods. Figure 4 depicts the flow diagram of the Hybrid GWO-PSO method, and the following steps explain the GWO-PSO technique's execution.

Running the PSO

1. First step is to assess each particle's fitness function.
2. Calculate individual Pbest and global Gbest
3. All swarm velocities are revised using equation (1).
4. Fourth, we calculate the fitness values of all the particles
5. By comparing the fitness values of each particle, we choose the optimal solution for the next iteration using equation (3).

$$V_i^{k+1} = \omega v_i^k + C_1 rand_1\left(P_{i,pbest}^k - x_i^k\right) + C_2 rand_2\left(P_{i,gbest}^k - x_i^k\right) \quad (1)$$

$$X_i^{new} = X_i + V_i \quad (2)$$

$$X_i^{k+1} = \left\{\frac{X_{i,new} iff\left(X_{i,new}\right) \leq f\left(X_i\right)}{X_i otherwise}\right\} \quad (3)$$

3.2 GWO SEQUENCE

1. The starting point for GWO's population is the endpoint for PSO's population.
2. Equations (17) and (18) are used to update the parameters A, C, and a.
3. Each search agent is given a randomly selected position.

4. The objective function is used to determine the fitness values for the grey wolf population.
5. The parameters A, C, and a have been adjusted, and the positions of the grey wolves have been revised as well.
6. One way to pick the optimal answer for the next iteration is to compare the fitness functions.
7. When comparing solutions with fitness functions, the optimal one should be selected for subsequent iterations
8. X_α, X_β and X_δ are updated.
9. All the way up to the halting criterion, the preceding processes are repeated.
10. A set of appropriate controller parameters is finally derived

$$\vec{D} = \left|\vec{C}.\overrightarrow{X_p}(t) - \vec{X}(t)\right| \quad (4)$$

$$\vec{X}(t+1) = \left|\overrightarrow{X_p}(t) - \vec{A}.\vec{D}\right| \quad (5)$$

$$\vec{A} = 2.\vec{a}.\overrightarrow{r_1} - \vec{a} \quad (6)$$

$$\vec{C} = 2.\overrightarrow{r_2}\vec{a} \quad (7)$$

$$\overrightarrow{D_\alpha} = \left|\overrightarrow{C_1}.\overrightarrow{X_\alpha} - \vec{X}\right| \quad (8)$$

$$\overrightarrow{D_\beta} = \left|\overrightarrow{C_2}.\overrightarrow{X_\beta} - \vec{X}\right| \quad (9)$$

$$\overrightarrow{D_\delta} = \left|\overrightarrow{C_3}.\overrightarrow{X_\delta} - \vec{X}\right| \quad (10)$$

$$\overrightarrow{X_1} = \overrightarrow{X_\alpha} - \overrightarrow{A_1}.\left[\overrightarrow{D_\alpha}\right] \quad (11)$$

$$\overrightarrow{X_2} = \overrightarrow{X_\beta} - \overrightarrow{A_2}.\left[\overrightarrow{D_\beta}\right] \quad (12)$$

$$\overrightarrow{X_3} = \overrightarrow{X_\delta} - \overrightarrow{A_3}.\left[\overrightarrow{D_\delta}\right] \quad (13)$$

We build a Simulink model to study the HSPAPF's performance under balanced and unbalanced loading situations for our simulation investigation. Here, we assume that the non-linear load that necessitates filtering is a three-phase diode bridge rectifier that has a resistive load on its DC side. It is common practice to detect harmonic voltage and current dispersion at separate busses in such a scenario. One drawback of the PSO technique is that it tends to get stuck in local minima when faced with strong constraints. On the plus side, it's simple, robust, and easy to apply. Alternatively, GWO maintains equilibrium between exploration and exploitation, which helps it avoid local traps. Hybrid PSO-GWO algorithms bring together the best features of PSO and GWO in this manner.

4. RESULTS AND DISCUSSION

Several factors influence the voltage quality at each and every bus. Check these indicators to see how good the voltage is. Problems with PQ could have a negative impact on both grid-connected and end-user devices [4]. Producing electricity of poor quality is due to a number of factors, including voltage fluctuations, imbalanced loads, low power factor (PF), droop, surge, excessive neutral current, low power factor, and short interruptions [5]. While other PQ events can be easily incorporated into the proposed method, this study primarily focuses on evaluating voltage quality approaches.

There are a lot of variables that can affect the voltage quality at any particular bus. The quality of a voltage can be evaluated by referring to these criteria. A set of criteria for gauging voltage quality has been established and the advantages of the proposed system are shown with two parameters as shown in *Table 5.*

Table 5 Advantages of proposed system

Control Variables	Bus Number	Base Case				
		PID	PID+ GWO	PID+ PSO	PID+ GWO-PSO	% Variation in THD
V_H(%)	14	3.8	3.5	3.1	3.3	28.94
	7	4.5	4.2	3.9	4.1	20
	10	6.8	6.3	5.9	6.1	23.52
	9	8.7	8.5	8.1	8.2	48.27
I_H(%)	14	4.6	4.2	3.9	3.8	19.56
	7	5.2	4.10	4.4	4.9	5.76
	10	7.1	6.89	6.2	6.92	4.2
	9	8.9	8.6	8.2	7.2	19.10

In order to assess the voltage quality, the proposed controller was adjusted to simulate the broadest possible range of possible changes to the microgrid design. When attempting to eliminate voltage differences using voltage quality indices, four separate situations must be considered.

We consider the loading-dependent variation in voltage imbalance in the first case (Figure 2). At t=107.4 ms, the PID controller decreases voltage imbalance. Optimal tuning parameters and fluctuations in load cause GWO+PSO performance to increase over time. The optimized controller's performance is demonstrated at t=146.7 ms, when the voltage imbalance changes from 4% to 2%, an approximately 50% change.

To determine the voltage sag rank in Case 2, we add several DG sources sequentially, as shown in Figure 3. Using the entire DG capacity, the PID controller has a sag rank of 0.02 at launch while the GWO+PSO controller has a sag rank of 0.16. At t=146.7 ms, the sag rank increases gradually due to the adjustment of %DG. The sag rank has been reduced to an incredibly low value using the FOPID Controller.

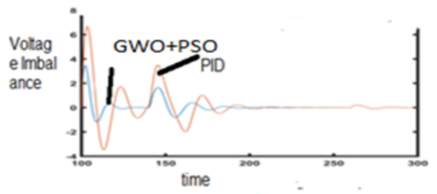

Figure 2: voltage imbalance variation with PID and GWO+PSO

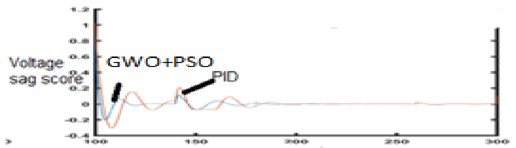

Figure 3: voltage sag score variation with PID & gwo+pso

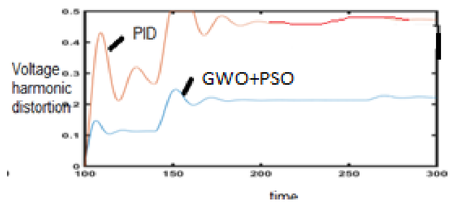

Figure 4 voltage harmonic factor with PID & gwo+pso

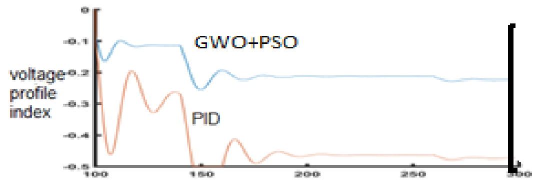

Figure 5: voltage profile index with PID & gwo+pso

In case 3 as shown in Figure 4, the voltage harmonic factor is assessed in relation to the chosen load type and its behavior. When a nonlinear load was applied and the PID and GWO+PSO controllers were used, the system's behavior altered. The system as a whole is susceptible to harmonic distortion, the severity of which increases as the nonlinear load does. The investigated GWO+PSO controller claims that compared to a non-adjusted controller, distortion is reduced.
The voltage profile index is considered in Case 4 when the system undergoes changes due to the load or the source, as seen in Figure 5. The plot clearly shows that the GWO+PSO controller is superior than the PID controller. The chosen hybrid GWO+PSO controller performed better than the competitors when testing voltage quality and improving system performance. Locating the voltage quality indices at various busses allows one to ascertain the ideal loading and system utilization site. The percentage change in load is used to measure the effect of reactive power and also to evaluate the voltage quality. Last but not least, the optimization approach derived from the selected control strategy works well with microgrid voltage regulation.

To load and use the system efficiently, voltage quality indices at different busses must be identified. The effect of reactive power is determined by the percentage change in load, which is also used to evaluate voltage quality. Finally, the optimization method based on the chosen hybrid control strategy is quite suitable for microgrid voltage assessment. Finally, the optimization method based on the chosen control strategy is a good fit for microgrid voltage regulation.

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References

[1] M. Bajaj, A. K. Singh, M. Alowaidi, N. K. Sharma, S. K. Sharma and S. Mishra, "Power Quality Assessment of Distorted Distribution Networks Incorporating Renewable Distributed Generation Systems Based on the Analytic Hierarchy Process," in IEEE Access, vol. 8, pp. 145713-145737,2020,doi: 10.1109/ACCESS.2020.3014288.

[2] Azimi, A., Hashemi-Dezaki, H. (2023).Optimized protection coordination of microgrids considering power quality-based voltage indices incorporating optimal sizing and placement of fault current limiters. Sustainable Cities and Society, 96: 104634. https://doi.org/10.1016/j.scs.2023.104634.

[3] Kumar, R. (2022). Fuzzy particle swarm optimization control algorithm implementation in photovoltaic integrated shunt active power filter for power quality improvement using hardware-in-the-loop. Sustainable Energy Technologies and Assessments, 50: 101820. https://doi.org/10.1016/j.seta.2021.101820.

[4] Meng Wu, Xingyan Niu, Shiqiao Gao, Junyong Wu, Power Quality Assessment for AC/DC Hybrid Micro Grid Based on On-Site Measurements,Energy Procedia, Volume 156, 2019, Pages 396-400, ISSN 1876-6102, https://doi.org/10.1016/j.egypro.2018.11.105

[5] Zhao, C., Xue, D., & Chen, Y. (2005, July) A fractional order PID tuning algorithm for a class of fractional order plants. In Mechatronics and automation, 2005 IEEE international conference (Vol. 1, pp. 216-221). IEEE.

[6] Motukuri, D.R., Prakash, P., Rao, M.V.G. (2023). A novel optimization-based approach for harmonic assessment in hybrid microgrids. Journal of Theoretical and Applied Information Technology, 101(16).

[7] R. E. I. Shat, M. Kazerani, and M. M. A. Salama, "Power quality improvement in 3-phase 3-wire distribution systems using modular active power filter." Elsevier Electric Power Systems Research, vol.61, no. 5, pp.876-880, Apr-2002.

[8] Motukuri, D.R., Prakash, P.S., Rao, M.V.G. (2023). Hybrid optimization for power quality assessment in hybrid microgrids: A focus on harmonics and voltage. Journal Européen des Systèmes Automatisés, Vol. 56, No. 6, pp. 917-927. https://doi.org/10.18280/jesa.560603.

[9] A. Herreros, E. Baeyens, J.R. Perán, "Design of PID-type controllers using multiobjective genetic algorithms." ISA Trans. 2002;vol. 41, no. 4, pp. 457-472.

[10] Amir, M., Prajapati, A.K., Refaat, S.S. (2022). Dynamic performance evaluation of grid-connected hybrid renewable energy-based power generation for stability and power quality enhancement in smart grid. Frontiers in Energy Research, 10: 861282. https://doi.org/10.3389/fenrg.2022.861282