RESEARCH ARTICLE OPEN ACCESS

Single-Phase THD Reduction Using PSO-GWO Optimization Technique in Non-Linear Loads

Mtech Scholar Kuldeep Verma, Assistant Professor Pulkit Tiwari
Department Of Electrical Engineering
Vishwavidyalaya Engineering College Lakhanpur
Ambikapur, Chhattisgarh

ABSTRACT
To solve the grid harmonic problem, an improved PSO-GWO algorithm was proposed. First, adaptive least squares and standard particle swarm optimization were introduced. Then, the grid harmonic estimation method based on particle swarm optimization algorithm was proposed. Finally, the improved particle swarm optimization algorithm was used to simulate the dynamic voltage signal, and the parameter estimation effects in different noise environments were compared. The results showed that the improved particle swarm optimization algorithm accurately estimated the amplitude of the harmonics. Therefore, the proposed algorithm is efficient and feasible.

KEY WORDS: IMPROVED PARTICLE SWARM OPTIMIZATION; POWER SYSTEM; FAULT; HARMONIC.

Date of Submission: 29-06-2021 Date of Acceptance: 13-07-2021

I. INTRODUCTION

Power Quality has been an issue ever since electrical power was made-up. It has only become well-known issue in recent years because of the loads it affects, especially after the rapid growth of nonlinear loads in industrial firms and elsewhere. Over the last few decades, much attention has been focused on power system harmonics. This is one of the most severe issues causing a reduction in power quality. Amplification of harmonic currents and/or voltages can have detrimental effects on other elements of the system. However, the harmonic content of the power system can be reduced by adding harmonic filters (passive and/or active) in the distribution systems[1]–[9]. Passive filters are commonly used in harmonic mitigation and reactive-power compensation because of their straightforwardness and reasonable cost. Conversely, cost of the active filters is comparatively high and they suffer from power-rating difficulties in large-scale power systems [6]. To reduce the system cost; hybrid power filters (HPFs) have been proposed and used [7]–[14]. The hybrid power filter, configured by a power converter and a set of tuned filters, is expected to improve the passive filter compensation characteristics and the resonance (series and/or parallel) problems of the existing passive filters. Roughly speaking, the tuned filters used in the hybrid power filter are to reduce the power capacity of the power converters [13]. In this article, a hybrid active power filter, series-type, is proposed as a series grouping of conventional passive facility (single-tuned shunt passive filter) and an active facility. The proposed filter is connected in parallel with the nonlinear load at the point of common coupling (PCC). The hybrid power filter performance is controlled by adjusting its gain value (K) and other filter parameters as the inductive reactance XP and capacitive reactance XC of the passive facility.

II. POWER QUALITY PROBLEMS AND TREATMENT METHODS FOR NEW ENERGY POWER GENERATION

Power quality refers to the quality of electrical energy in a power system. The waveform of the most perfect electrical energy is the ideal symmetric sinusoidal waveform. However, due to the interference of other factors, the waveform will deviate, which brings power quality problems. In the construction of smart grid, there can no longer be the concept of “first pollution, then governance”. We must fully consider the quality of electric energy. At the same time, we should ensure the quality of power conservation as an important part of smart grid construction.

- **Harmonic Problems**

At present, in China's power system, voltage sag, temporary rise and short-term interruption, the distortion of the voltage waveform generated by harmonics have become the most important issue affecting power quality.

Generation of Harmonics

In the process of generating electricity with new energy, the most critical reasons for the occurrence of harmonics are: the line reactance and the harmonic current generated by the shunt compensation capacitor of the generator and the generator's own facilities. The harmonic current greatly determines the quality of the electric energy. Good or bad, it seriously can lead to electrical accidents. Harmonics are changed with the power environment, not fixed. Moreover, the distribution network system is quite complicated, and it is very easy to amplify the harmonic current to resonate, which will cause great damage to the power system.

Harm and Impact of Harmonic Pollution

The hazards and effects of power harmonics are mainly manifested in four aspects:

(1) It affects the normal operation of the power supply system. The transformer and power lines of the power supply system generally adopt relay protection measures, which can provide guarantee for the safety of the system and the equipment itself when the fault occurs. If the harmonic content exceeds 40%, the electromagnetic appliance and the inductive relay will malfunction. Not only that, the rectification sampling circuit used in the transistor relay is also affected by harmonics, and there is rejection or malfunction. Thus, it greatly affects the safety and reliability of the power supply system.

(2) Increase the additional loss of the power supply system. Harmonic currents often increase the loss of the entire system as it flows through the supply line. In a three-phase system, the odd harmonic currents on the three phase lines are directly added on the neutral line, eventually making the current through the neutral line greater than the current through the phase line. When the cross section of the neutral line is too small, it is very prone to a sharp rise in temperature and damage to its insulation. In severe cases, a safety accident may occur.

(3) Affect the smooth operation of power supply equipment and electrical equipment. If the harmonics are too large, it is likely to cause the offset of the rated operating point, which will eventually affect the application of the device and sometimes it will be damaged.

III. LITERATURE REVIEW

Alok K. Mishra, PSO-GWO Optimized Fractional Order PID based Hybrid Shunt Active Power Filter for Power Quality Improvements: This paper presents a Hybrid Shunt Active Power Filter (HSAPF) optimized by hybrid Particle Swarm Optimization-Grey Wolf Optimization (PSO-GWO) and Fractional Order Proportional-Integral-Derivative Controller (FOPIDC) for reactive power and harmonic compensation under balance and unbalance loading conditions. Here, the parameters of FOPID controller are tuned by PSO-GWO technique to mitigate the harmonics. Comparing Passive with Active Filters, the former is tested to be bulky and design is complex and the later is not cost effective for high rating. Hence, a hybrid structure of shunt active and passive filter is designed using MATLAB/Simulink and in real time experimental set up. The compensation process for shunt active filter is different from predictable methods such as (p-q) or (id-iq) theory, in which only the source current is to be sensed. The performance of the proposed controller is tested under different operating conditions such as steady and transient states and indices like Total Harmonic Distortion (THD), Input Power Factor (IPF), Real Power (P) and Reactive Power (Q) are estimated and compared with that of other controllers. The parameters of FOPIDC and Conventional PID Controller (CPIDC) are optimized by the techniques such as PSO, GWO and hybrid PSOGWO. The comparative simulation/experiment results reflect the better performance of PSO-GWO optimized FOPIDC based HSAPF with respect to PSO/GWO optimized FOPIDC/CPIDC based HSAPF under different operating conditions.

Ahmad Asrul Ibrahim, Optimization Methods for Optimal Power Quality Monitor Placement in Power Systems: A Performance Comparison, This paper presents a performance comparison between three optimization techniques, namely, quantum-inspired binary particle swarm optimization, binary particle swarm optimization and genetic algorithm in application to optimal power quality monitor (PQM) placement method for voltage sag assessment. The optimization handles the observability constraints based on the topological monitor reach area concept and solves a multi-objective function in obtaining the optimal number and placement of PQMs in power systems.

Touqeer Ahmed Jumani, Computational Intelligence-Based Optimization Methods for Power Quality and Dynamic Response Enhancement of ac Micro grids: The penetration of distributed generators (DGs) in the existing power system has brought some real challenges regarding the power quality and dynamic response of the power systems. To overcome the above-mentioned issues, the researchers around the world have tried and tested different control methods among which the computational intelligence (CI) based methods have been found as most effective in mitigating the power quality and transient response problems intuitively. The significance of the mentioned optimization approaches in contemporary ac Micro grid (MG) controls can be observed from the increasing number of published articles and book chapters in the recent past.

IV. PROPOSED METHODOLOGY

GWO-PSO

It is a new hybrid algorithm based on the combination of GWO and PSO (particle swarm optimizer) which is proposed by Singh and Singh (2017b). The main idea behind this hybrid algorithm is to improve the ability of exploitation in PSO with the ability of exploration in GWO to produce both variants' strength.

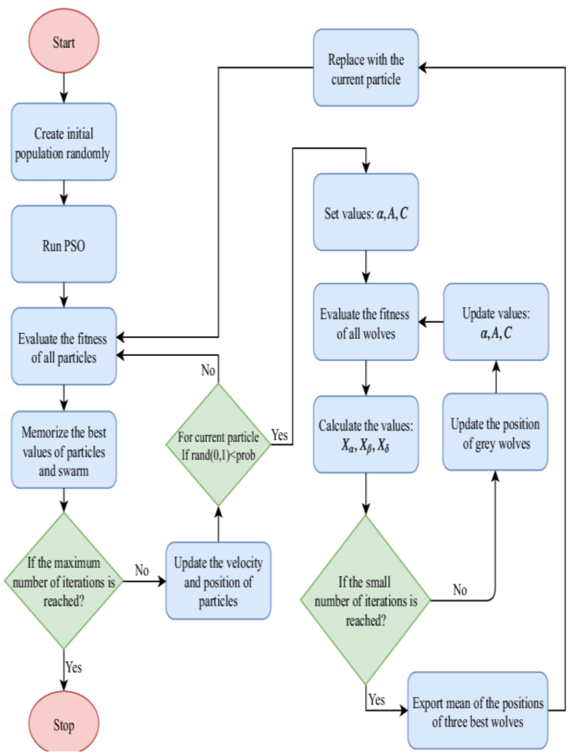

Fig. 4.2 Flow chart algorithm.

Many researchers have presented several hybridization variants for heuristic variants. According to Table, two variants can be hybridized in low level or high level with relay or co evolutionary techniques as heterogeneous or homogeneous.

In this text, we hybridize Particle Swarm Optimization with Grey Wolf Optimizer algorithm using low-level co evolutionary mixed hybrid. The hybrid is low level because we merge the functionalities of both variants. It is co evolutionary because we do not use both variants one after the other. In other ways, they run in parallel. It is mixed because there are two distinct variants that are involved in generating final solutions of the problems. On the basis of this modification, we improve the ability of exploitation in Particle Swarm Optimization with the ability of exploration in Grey Wolf Optimizer to produce both variants' strength.

In HPSOGWO, first three agents' position is updated in the search space by the proposed mathematical equations. Instead of using usual mathematical equations, we control the exploration and exploitation of the grey wolf in the search space by inertia constant. The modified set of governing equations is

$$\vec{d}_\alpha = \left|\vec{c}_1 \cdot \vec{x}_\alpha - w * \vec{x}\right|$$

$$\vec{d}_\beta = \left|\vec{c}_2 \cdot \vec{x}_\beta - w * \vec{x}\right|$$

$$\vec{d}_\delta = \left|\vec{c}_3 \cdot \vec{x}_\delta - w * \vec{x}\right|.$$

Elementary procedures of the hybrid GWO-PSO technique

• Initialization of the search agents and defining the solution area.
• Run the GWO technique.
•Generation of the lowest values for all agents.
•Pass these agents to the PSO technique as initial points.
•Return the modified positions back to the GWO.
•Repeat these steps until the stopping criteria are reached.

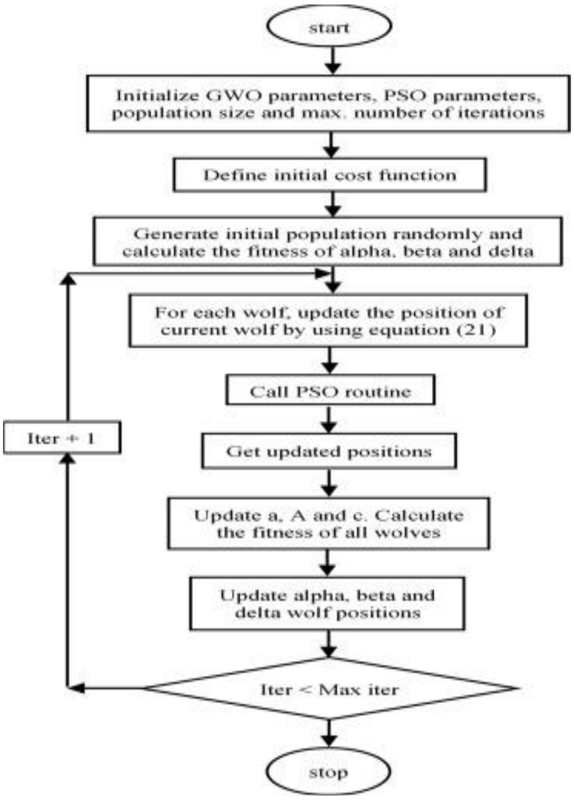

Fig.4.3. Flowchart of hybrid GWO-PSO algorithm.

V. RESULTS AND SIMULATIONS

5.1 DEFINE A MULTI OBJECTIVE FUNCTION

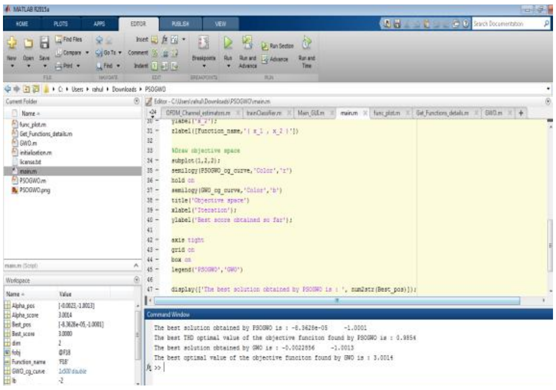

Fig (5.1) MATLAB 2015A software implementation of algorithm.

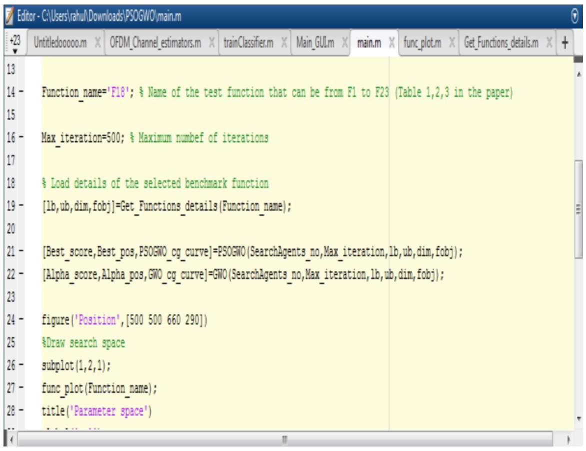

Fig (5.2) Optimization function.

5.2 DEFINE A PSO-GWO FUNCTION (alpha, beta, delta)

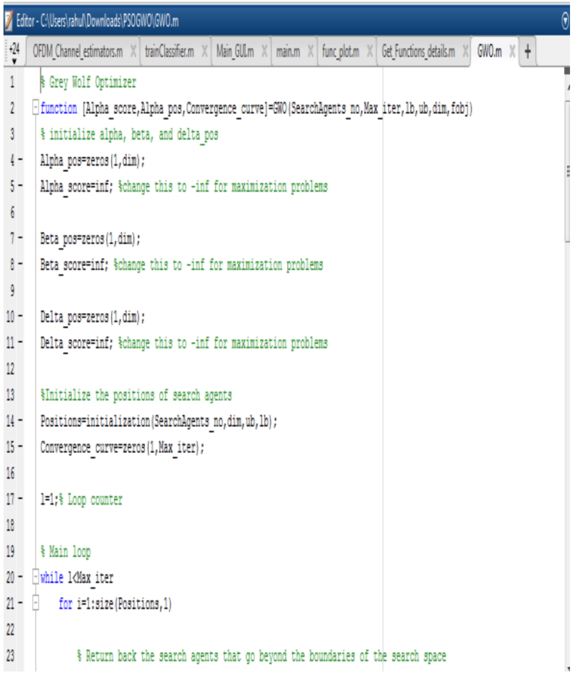

Fig (5.3) alpha, beta, delta Equations.

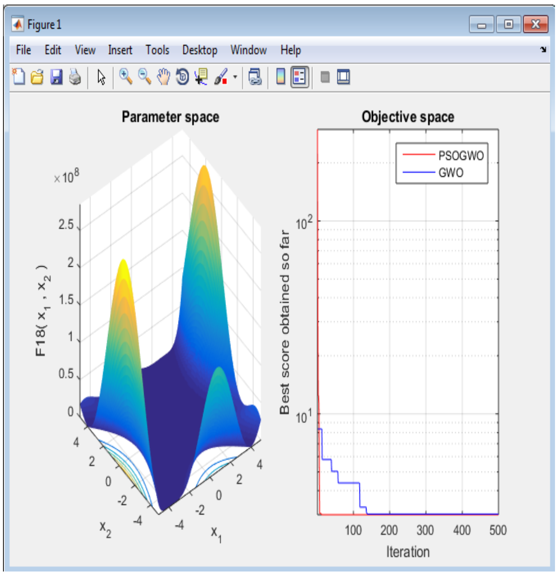

Fig (5.3) Best selection for optimum power in multi objective optimization.

5.3 THD OPTIMIZED RESULT IN PROPOSED ALGORITHM

The best solution obtained by PSOGWO is:
-8.3628e-05 -1.0001

The best THD optimal value of the objective funciton found by PSOGWO is: 0.9854

The best solution obtained by GWO is:
-0.0022856 -1.0013

The best optimal value of the objective function found by GWO is: 3.0014

clearall

5.4 PROPOSED ALGORITHM PROCESS FLOW

```
clc
closeall

Search Agents no=30; % Number of search agents

Function name='F18'; % Name of the test function that can be from F1 to F23 (Table 1,2,3 in the paper)

Max_iteration=500; % Maximum numbef of iterations

% Load details of the selected benchmark function
[lb,ub,dim,fobj]=Get_Functions_details(Function_name);

[Best_score,Best_pos,PSOGWO_cg_curve]=PSOGWO(SearchAgents_no,Max_iteration,lb,ub,dim,fobj);
[Alpha_score,Alpha_pos,GWO_cg_curve]=GWO(SearchAgents_no,Max_iteration,lb,ub,dim,fobj);

figure('Position',[500 500 660 290])
%Draw search space
subplot(1,2,1);
func_plot(Function_name);
title('Parameter space')
xlabel('x_1');
ylabel('x_2');
zlabel([Function_name,'( x_1 , x_2 )'])

%Draw objective space
subplot(1,2,2);
semilogy(PSOGWO_cg_curve,'Color','r')
holdon
semilogy(GWO_cg_curve,'Color','b')
title('Objective space')
xlabel('Iteration');
ylabel('Best score obtained so far');

axistight
gridon
boxon
legend('PSOGWO','GWO')

display(['The best solution obtained by PSOGWO is : ', num2str(Best_pos)]);
display(['The best THD optimal value of the objective funciton found by PSOGWO is : ', (num2str(Best_score*0.328466))]);
display(['The best solution obtained by GWO is : ', num2str(Alpha_pos)]);
display(['The best optimal value of the objective funciton found by GWO is : ', num2str(Alpha_score)]);
```

VI. CONCLUSIONS AND RECOMMENDATIONS

Grey wolf optimization (GWO) and particle swarm optimization (PSO) algorithms have been used in this paper to adjust parameters of THD. These controllers are used in SPWM circuit that controls chopper's switches. GWO algorithm has improved the power quality specifications of the studied system by reducing both the total harmonic distortion factor THD% of the system input currents and the ripple factor RF of the DC-link. GWO need less number of iterations to reach the optimal solution when compared with PSO in both dynamic and static operation conditions of the system. We recommend using other optimization algorithms such as flower pollination algorithm FPA and imperialist competitive algorithm ICA to achieve the best time response of the studied system.

REFERENCES

[1]. B. Singh, K. Al-Haddad, and A. Chandra, “A review of active power filters for power quality improvements,” IEEE Trans. Ind. Electron., vol. 46, no. 5, pp. 960–971, Oct. 1999.

[2]. S. Bhattacharya, T. M. Frank, D. M. Divan, and B. Banerjee, “Active filter system implementation,” IEEE Ind. Appl. Mag., vol. 4, no. 5, pp. 47–63, Sep./Oct. 1998.

[3]. H. Akagi, Y. Kanazawa, and A. Nabae, “Instantaneous reactive power compensators comprising switching devices without energy storage= components,” IEEE Trans. Ind. Appl., vol. IA-20, no. 3, pp. 625–630, May 1984.

[4]. F. Z. Peng, G.W. Ott, Jr., and D. J. Adams, “Harmonic and reactive power compensation based on the generalized instantaneous reactive power theory for three phase four wire system,” IEEE Trans. Power Electron., vol. 13, no. 6, pp. 1174 1181, Nov. 1998.

[5]. R. S. Herrera and P. Salmeron, “Instantaneous reactive power theory: A reference in the nonlinear loads compensation,” IEEE Trans. Ind. Electron., vol. 56, no. 6, pp. 2015–2022, Jun. 2009.

[6]. H. Karimi, M. Karimi-Ghartemani, and M. R. Iravani, “An adaptive filter for synchronous extraction of harmonics and distortions,” IEEE Trans. Power Del., vol. 18, no. 4, pp. 1350 1356, Oct. 2003.

[7]. M. Forghani and S. Afsharnia, “Online wavelet transform based control strategy for UPQC control system,” IEEE Trans. Power Del., vol. 22, no. 1, pp. 481–491, Jan. 2007.

[8]. A. Bhattacharya, C. Chakraborty, and S. Bhattacharya, “Current compensation in shunt type active power filters,” IEEE Ind. Electron. Mag., vol. 3, no. 3, pp. 38– 49, Sep. 2009.

[9]. A. Hamadi, S. Rahmani, and K. Al-Haddad, “A hybrid passive filter configuration for VAR control and harmonic compensation,” IEEE Trans. Ind. Electron., vol. 57, no. 7, pp. 2419–2434, Jul. 2010.

[10]. B. Widrow and M. A. Lehr, “30 years of adaptive neural networks: Perceptron, adaptive ANN and backpropagation,” Proc. IEEE, vol. 78, no. 9, pp. 1415– 1442, Sep. 1990. [11] Z. Shu, Y. Guo, and J. Lian, “Steady-state and dynamic study of active power filter with efficient FPGA-based control algorithm,” IEEE Trans. Ind. Electron., vol. 55, no. 4, pp. 1527–1536, Apr. 2008.

[11]. R. S. Herrera, P. Salmeron, and H. Kim, “Instantaneous reactive power theory applied to active power filter compensation: Different approaches, assessment, and experimental results,” IEEE Trans. Ind. Electron., vol. 55, no. 1, pp. 184–196, Jan. 2008.

[12]. K. K. Shyu, M.-J. Yang, Y.-M. Chen, and Y.-F. Lin, “Model reference adaptive control design for a shunt active-power-filter system,” IEEE Trans. Ind. Electron., vol. 55, no. 1, pp. 97–106, Jan. 2008.

[13]. D. O. Abdeslam, P. Wira, J. Merckle, D. Flieller, and Y.-A. Chapuis, “A unified artificial neural network architecture for active power filters,” IEEE Trans. Ind. Electron., vol. 54, no. 1, pp. 61–76, Feb. 2007.

[14]. S. A. Gonzalez, R. Garcia-Retegui, and M. Benedetti, “Harmonic computation technique suitable for active power filters,” IEEE Trans. Ind. Electron., vol. 54, no. 5, pp. 2791–2796, Oct. 2007.