Power Quality Improvement in Hybrid Renewable Energy Source Grid-Connected System with Grey Wolf Optimization

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Abstract- Hybrid renewable energy sources (HRES) such as Photovoltaic (PV) system, wind turbine (WT) and battery energy storage system (BESS) into the grid-connected system have been tremendously increasing its importance to meet the global energy demand. The integrated design mainly focuses on power quality (PQ) issues due to the non-linear load condition. Hence this paper proposes the grey wolf optimization (GWO) with unified power quality conditioner (UPQC) to solve the PQ problems in HRES system. The UPQC performance is increased by fractional order proportional integral derivative (FOPID) with GWO. The obtained results indicate that the proposed GWO algorithm has many advantages in various aspects such as early convergence and obtaining optimized fitness value compared to other algorithms like biogeography based optimization (BBO), genetic algorithm (GA), genetic search algorithm (GSA) with existing PI controller. The proposed system is implemented in MATLAB/Simulink platform to validate the performance during voltage sag, current sag, real power, reactive power and in terms of total harmonic distortions (THD's).

Keywords PV, Wind, Battery, GWO, BBO, GSA, GA, UPQC, Shunt active power filter, Series active power filter

1. Introduction

Nowadays renewable energy sources (RES) are playing an important role as the conventional sources are experiencing many problems which are creating a greater impact on the environment. RES have greater ability to limit pollution and global warming [1]. RES based distributed generation (DG) is increasing to a greater significance because of the progress in innovation and environmental concerns [2]. Numerous optimization techniques have been designed to control different power electronic devices for better adaptability while integrating different alternative sources like Solar, Wind, Battery etc. which are playing a vital role in satisfying the enormous power needs [3-4]. Because of the limitations of power generation from conventional energy sources DG's has more importance because they give more productive, good quality and maximum demand of power required by the end-users continuously [5]. With the increase in population and power demand, generation of power became a challenging task, so RES has taken its role since conventional sources alone cannot meet the requirements.

Among various sources, solar and wind are commonly used [6-7]. The efficiency of RES can be increased with the utilization of power electronic devices in the power system. HRES system is designed with one or more resources in the distribution system to meet the required load demand and increase the quality of power to the consumers [8]. The main drawback is this combination may increase more PQ issues in the system like sags, swell, interruption harmonics etc., which causes the voltage level to oscillate which leads to continuous fluctuation which creates continuous tripping [9-10].

In this paper, the hybrid system is considered with the combination of PV, Wind and Battery Energy Storage System (BESS) coupled with the distribution system to meet the required load demand. Hybrid DG's creates the problem of instability. Mainly power quality problems are created in the system such as sag, swell, harmonics and so on. These PQ issues mostly occur in HRES system since the sources solar and wind are intermittent due to the effect on environmental conditions These power quality issues can be mitigated by the flexible AC transmission systems (FACT) devices and filter circuits in the system. With the advancement of power electronics device and control techniques numerous devices are available and classified based on series devices and shunt devices. Static Synchronous series compensator (SSSC) and dynamic voltage restorer (DVR) are the devices used to compensate for the voltage. Static compensators (STATCOM), distribution STATCOM (DSTATCOM), thyristor controlled reactor (TCR) used to regulate the load voltage in voltage control mode and inject reactive and harmonic components in current mode [11-16]. To maintain stability and mitigate power quality problems in HRES based DG's a proper controlling technique must be required. This paper mainly focusses to compensate for PQ issues in HRES Grid-connected load system. The following are the main contributions:

- HRES system is designed with PV, Wind and Battery. The inputs to the PV and Wind are irradiance and Wind speed from which the powers are generated. The battery is used as an energy storage unit to store the excess energy produced and can be used to meet the load demand under critical and environmental conditions.
- UPQC device is to mitigate the power quality related problems like sag, swell, harmonics and so on in HRES grid-connected system mainly due to the non-linear load condition.
- FOPID controller with GWO based control techniques is implemented in the UPQC device which operated the HRES to compensate for the PQ problems and meet the required load demand. This controller is mainly operating in two different controlling techniques such as series active power filter and shunt active power filter.

- In this proposed paper the control technique designed by connecting non-linear load in the grid side. Sag condition for both current and voltage are observed. Also, THD's before connecting with UPQC and after connecting with UPQC device was executed. The performance of the proposed method is compared with the existing methods BBO, GA, GSA with PI controller and obtained the best results in terms of THD. The proposed framework is developed and examined in MATLAB/ Simulink. The rest of the paper is composed as follows; section 2 recent research works, section 3 proposed HRE framework with GWO, in section 4 GW optimization, in section 5 results and discussions and section 6 conclusion

2. Recent Research Works: A Brief Review

M. Amir et al. [16] has proposed the intelligence-based control framework, which is designed with the help fuzzy-logic based controller for the PWM based inverter control. In this paper, a microgrid with HRES based grid-connected system with PV/WT combination with hill-climbing based MPPT techniques is used. A battery is also used to meet the desired load under critical conditions.

J. Arkhangelski et al. [17] in this paper HRES based grid-connected system is proposed to compensate for the power losses and harmonics. To solve various PQ issues usage of multiple control systems and subsystem, current control, harmonics compensation, synchronization, etc. are used. The important attention was shown to interact with system signs in the storage system of the HRES. The lifetime of the HRES is increased by the integration batteries and supercapacitors. To smooth out the power of the batteries and to absorb/inject the high-frequency fluctuations of power these supers capacitors are utilized in the proposed system. For this purpose low-pass, second-order filters are used which separates the high-frequency components of the storage system reference for the supercapacitor and the low- frequency component for the battery system. This results in increasing the reliability and durability of the HRES.

M. E. Meral *et al.*[18] have implemented the synchronization algorithms based Proportional-Resonant controller is proposed to the hybrid system with the combinations of (SC+WT+Grid), Dual Second Order Generalized Integrator-Phase Locked Loop based PR controller in a stationary reference frame which provides a good solution to mitigate the PQ problems

R. Muthukumar *et al.*[19] have given a detailed theory of a PV-WT hybrid system and a generalized predictive controller to improve the power quality and stability of the hybrid system. A three-level inverter was implemented to fine-tune the power factor which is a combined power factor in the proposed work. An FFT analysis of the power indicates a reduced THD's was justified over the conventional MPPT-based power generation systems without a properly designed controlling method. The constraints in designing a hybrid system concerning power quality act as input to the model predictive controller in the exhibited work.

E. Jamil *et al.* [20] have explained the power quality improvement for best power transfer in solar PV-WE grid-connected hybrid system. The system undergoes continuous disturbances in AC loads and power output from the hybrid system. This causes reactive power mismatch and raises voltage instability and power quality issues. In the proposed system SSSC was implemented.

3. Proposed HRES System with GWO

With the rapid development in industrialization and urbanization, the distribution companies are increased to meet the energy demand. The generation of electricity from fossil fuels is not enough to compensate for the required demand. These conventional sources are creating serious problems for the environment and leading to warming. To overcome these problems renewable energy sources have been encouraged to generate the energy required to meet the load demand. Renewable energy sources like Solar and Wind are very widely used in the distribution system. HRES is considered to be the best choice with the combination of PV and WT for better efficiency and reliability of the system. HRES in the distribution system can meet the required load demand from the consumers which involves flexibility and stability problems of power quality. These PQ issues must be avoided for stable operation of the system [37]. To mitigate the power quality problems like sag, swell, harmonics so on FACT devices are introduced with the advancement of power electronics. In this paper, UPQC is designed to mitigate the power quality problems like voltage sag, current sag and THD.

In the proposed HRES system is the combination of PV and WT interfaced with the grid. BESS is designed to meet the load demand under critical environmental conditions since the sources considered are intermittent. Because of the non-linear loads and sudden loads, PQ issues are created in the HRES system. [21]. Due to these problems voltage instability and reactive power mismatches are created. In this paper, PQ problems such as voltage sag, current sag, real power, reactive power and THD's are addressed [25-30]. To overcome such issues, HRES system is designed using UPQC to improve the voltage regulation with FOPID controller. The control operation of the system is done using optimization technique like GWO.

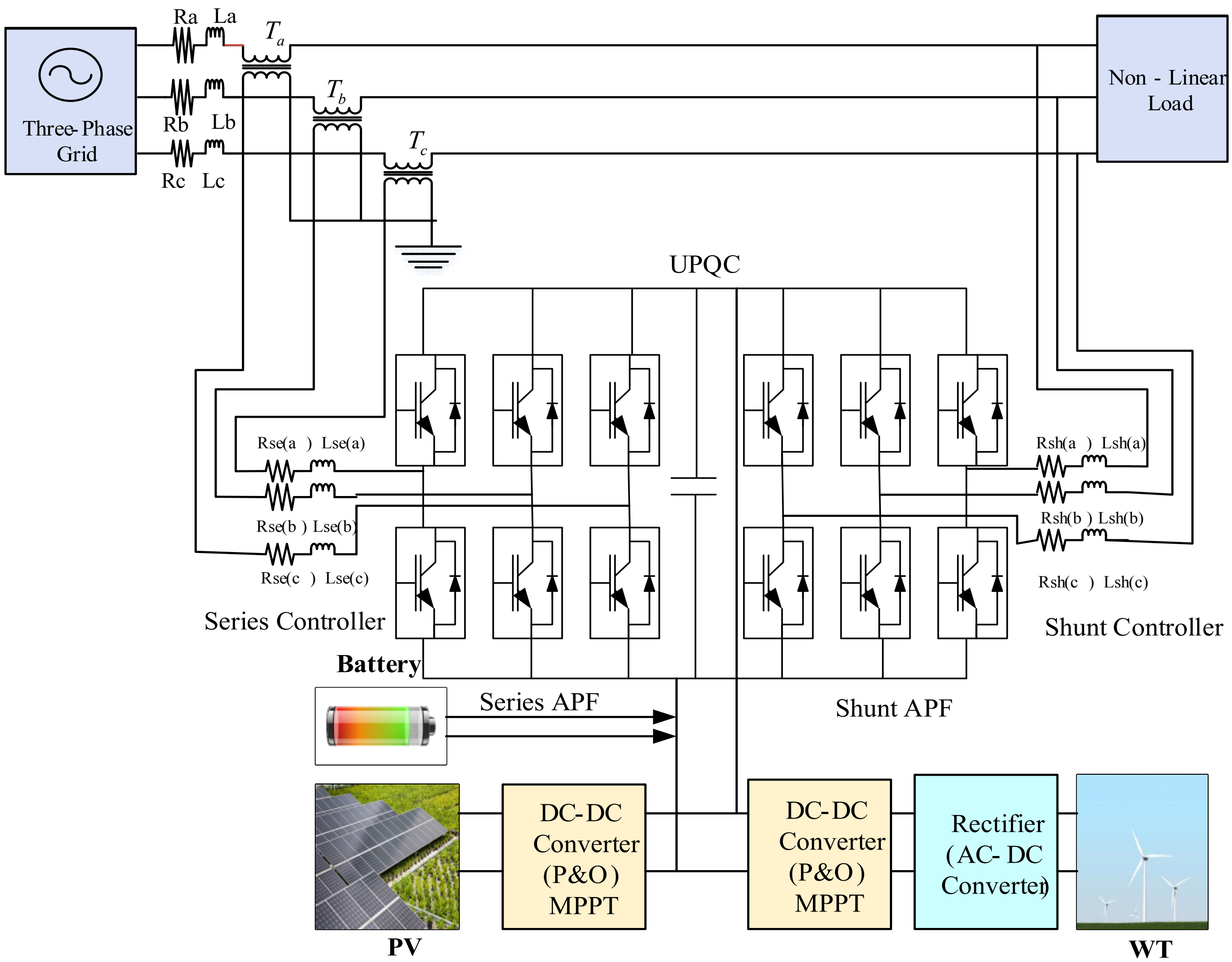

Fig.1: Block diagram of grid-connected HRES

The proposed system block diagram is as shown in Fig.1, which mainly consists of distributed generation with the combination of PV-Wind connected to the inverter to interface the grid via DC-link capacitor [22-23]. BESS is designed for storing power and supplies during system failures. By implementing perturb and observe (P&O) MPPT, the PV and Wind power is extracted. From GWO a reference DC link voltage is created. The reference DC link voltage is set to its default value at the time when solar energy is absent. The power quality issues of the HRES are considered which are mainly due to faults, non-linear load, sudden loads on grid side [31-33].

To overcome all the issues, and stable operation the proposed system is designed with UPQC which compensates the problems by control techniques with the help of series and shunt controllers. Power compensation during sag condition can be done by providing the best gain parameters for the FOPID controller which filters and injects the required power by choosing the best gain parameters to the FOPID controller. FOPID controller is operated with GWO which is designed to select the required values to operate the control operation during PQ conditions [34-38].

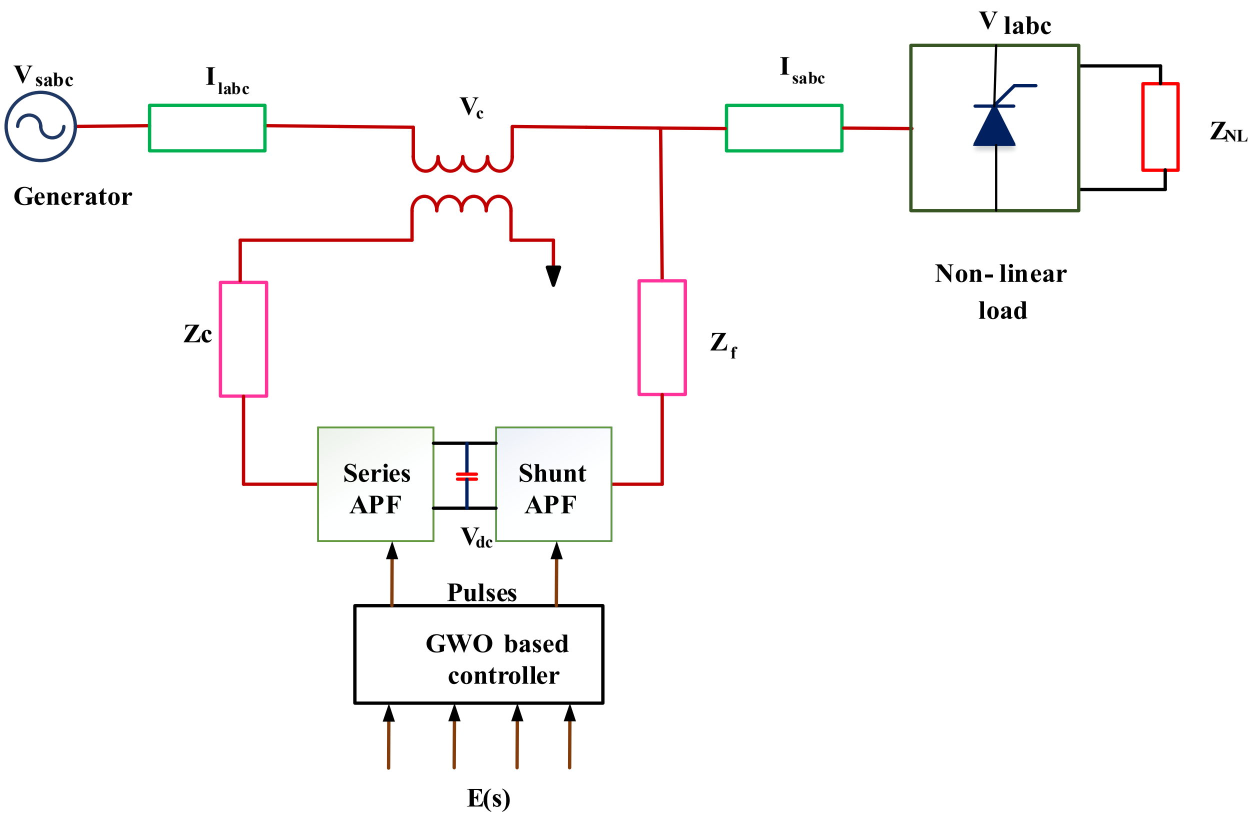

Fig. 2 Architecture of UPQC

3.1 Design Model of UPQC:

FACT devices are playing an important role in the power system for the improvement of power quality with the advancement of power electronics. In the proposed HRES grid-connected model UPQC design is used to mitigate the PQ problems.

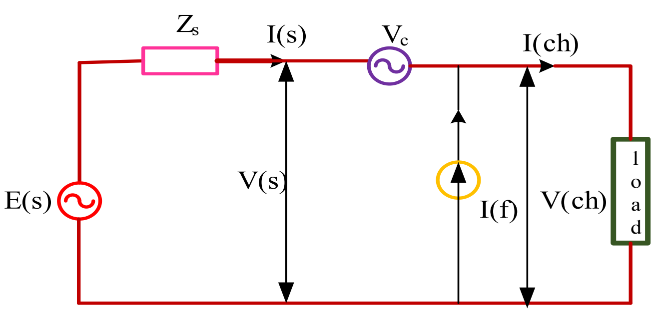

Fig. 3 Equivalent circuit of UPQC

Generally, the proposed device is the combination of shunt and series active power filters as shown in Fig.2 and its equivalent circuit in the Fig.3. The mathematical model of UPQC under controlling operation is represented with the equation (1).

$$V(c) = V(ch) - V(s) = -kV(ch)\angle 0^0 \qquad (1)$$

Where E(s), V(s) input and output voltage, V(ch) is injected voltage of series active power filter. The equation (1) can be solved by using the equation (2)

$$K = \frac{V(s) - V(ch)}{V(ch)} \qquad (2)$$

The losses are neglected in the UPQC. The active power and load considered to be same at the point of common coupling (PCC). The current expression at the PCC is given as (3-6)

$$I(s) = \frac{I(ch)}{1+k}\cos\phi(n) \tag{3}$$

The real power in the proposed UPQC design is given as

$$A(c) = P(c) + jQ(c) \tag{4}$$

$$A(f) = V(ch)I(f) \tag{5}$$

$$P(c) = V(c)I(s); Q(c) = V(c)I(s)\cos\phi(s), \tag{6}$$

P (c) is the active power and Q (c) is the reactive power of the series filter. $I(f)$ is the difference of input load current and source current concerning load harmonics and reactive component current. FOPID controller-based GWO algorithm is used to compensate for the power quality problems.

3.2 Control Structure of UPQC: Series and Shunt active power filter

3.2.1 Series Active power filter control strategy

Initially with the help of PLL reference voltage is evaluated. After calculating all the three-phase voltage then they are converted into d-q axes by Clarke transformation which is given as equation (7) and series active power filter is depicted in Fig.4.

$$\begin{bmatrix} V^0 \\ V^d \\ V^q \end{bmatrix} = \frac{2}{3}\begin{bmatrix} \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \\ \sin(\alpha t) & \sin\left(\alpha t - \frac{2\Pi}{3}\right) & \sin\left(\alpha t + \frac{2\Pi}{3}\right) \\ \cos(\alpha t) & \cos\left(\alpha t - \frac{2\Pi}{3}\right) & \cos\left(\alpha t + \frac{2\Pi}{3}\right) \end{bmatrix}\begin{bmatrix} V^a \\ V^b \\ V^C \end{bmatrix} \tag{7}$$

V^d is direct axes voltage, V^q is quadrature axes voltage, and three-phase voltages V^a, V^b, V^c. With the help of low pass filter, d axis voltage can be smoothed and is mathematically given as (8)

$$V^{d(dc)} = V^d - V^{d(ac)} \tag{8}$$

$V^{d(ac)}$ is AC component voltage and $V^{d(dC)}$ is the DC component voltage. Next, the voltage is converted into three phases,

$$\begin{bmatrix} V^{Ra} \\ V^{Rb} \\ V^{Rc} \end{bmatrix} = \frac{2}{3}\begin{bmatrix} \sin(\alpha t) & \frac{1}{2} & 1 \\ \sin(\alpha t) & \sin\left(\alpha t - \frac{2\Pi}{3}\right) & 1 \\ \cos(\alpha t) & \cos\left(\alpha t - \frac{2\Pi}{3}\right) & 1 \end{bmatrix}\begin{bmatrix} V^{d(dc)} \\ V^q \\ V^o \end{bmatrix} \tag{9}$$

V^{Ra}, V^{Rb}, V^{Rc} are the three-phase reference voltages (9). The hysteresis voltage is controlled using the pulses which are tuned with the help of FOPID with GWO.

3.2.2 Shunt Active power filter control strategy

Three-Phase voltages and currents are converted into α and β as shown in equations (10-11) and shunt active power filter design is depicted in the Fig.5.

$$\begin{bmatrix} V^{s0} \\ V^{s\alpha} \\ V^{s\beta} \end{bmatrix} = \sqrt{\frac{2}{3}}\begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix}\begin{bmatrix} V^{sa} \\ V^{sb} \\ V^{sc} \end{bmatrix} \tag{10}$$

$$\begin{bmatrix} I^{l0} \\ I^{l\alpha} \\ I^{l\beta} \end{bmatrix} = \sqrt{\frac{2}{3}}\begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix}\begin{bmatrix} I^{La} \\ I^{Lb} \\ I^{Lc} \end{bmatrix} \tag{11}$$

$I^{l\alpha}, I^{l\beta}$ are phase neutral currents, $I^{La}; I^{Lb}; I^{Lc}$ are three-phase load currents, $V^{s\alpha}; V^{s\beta}$ are phase neutral voltages and $V^{sa}; V^{sb}; V^{sc}$ are three-phase supply voltages [14]. With the help of PNV and load currents, the instantaneous values of power are calculated. The real and reactive power are calculated from equations (12-13)

$$\begin{bmatrix} P \\ Q \end{bmatrix} = \begin{bmatrix} V^{s\alpha} & V^{s\beta} \\ -V^{s\beta} & V^{s\alpha} \end{bmatrix}\begin{bmatrix} I^{l\alpha} \\ I^{l\beta} \end{bmatrix} \tag{12}$$

The reference currents expression is given as

$$\begin{bmatrix} I^{Ra} \\ I^{Rb} \\ I^{Rc} \end{bmatrix} = \sqrt{\frac{2}{3}}\begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix}\begin{bmatrix} I^{R\alpha} \\ I^{R\beta} \end{bmatrix} \tag{13}$$

I^{Ra}, I^{Rb}, I^{Rc} the reference currents of the SAPF. By comparing reference current, the error current is computed which is to be compensated with the help of FOPID based controller with GWO which generates the pulses required by the SAPF.

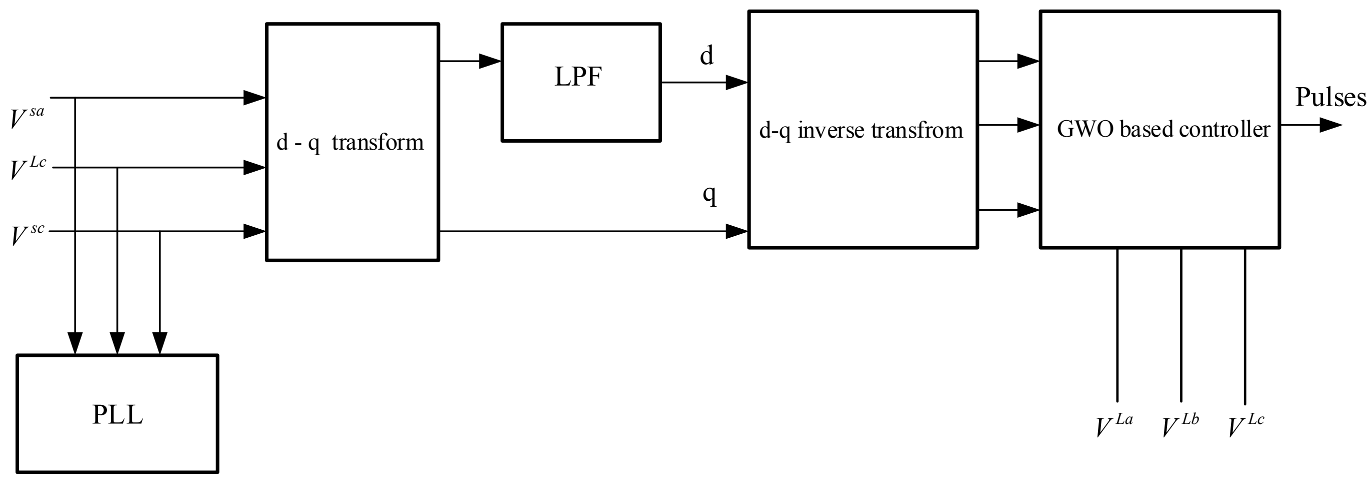

Fig. 4 Series active Power filter

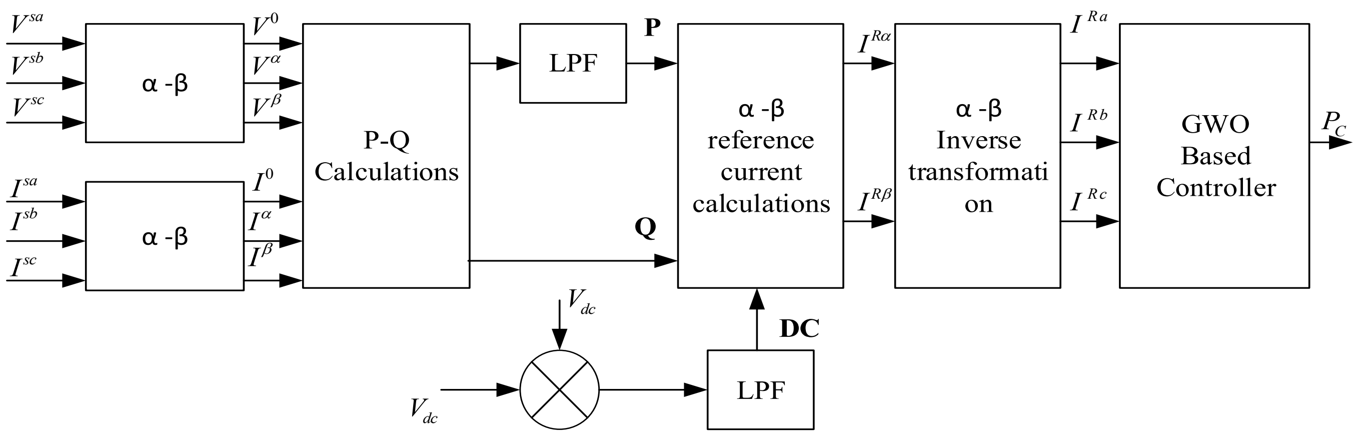

Fig. 5 Shunt active power filter

4. Grey wolf optimization algorithm

Grey wolves are generally called apex predators which means that they are at the top of the food chain. They generally live in groups on an average size of 5-12 and have a strict social dominant hierarchy. They generally categorized into three levels: First level: Alphas, Second level: Betas, Lowest level: Delta

Alphas: Here the leaders are a male and female who are most responsible to take decisions about hunting, place for shelter when to wake up, and so on. The decision is dictated among the group and sometimes the behaviors of others among the wolf group are also followed by alphas. The rest of the wolf acknowledges the alpha by holding their tails down as the alpha is the dominant one. This shows how organized and discipline of the group.

Beta: They are the subordinate's wolves that help alpha in decision making or the other activities of the group. They can be either male/female which is the best candidate in case the alpha wolves die or become very old. In other words, they have to respect alpha and also have command over the lowest level and also acts as a feedback to the alpha.

Delta: They are ranked as the lowest which plays the role of scapegoat. They are allowed to eat at the last as all others were dominant. Even though they are not having individual importance but due to not causing problems they are not lost in the group. Sometimes they are called babysitters in the group [24].

This GWO shown in Fig. 6 is a new metaheuristic technique depended on the swarm cleverness which is motivated by the mindset of Grey-Wolf when they are hunting prey [31]. They stay together like a pack and are set in a position to perform the hunting procedure. To design the process mathematically, the best fittest solution is given to the α group and followed by β, γ and δ groups. They create a closed path around the injured to begin the hunting of the prey and given as equations (14-15)

$$\vec{D} = \left|\vec{C}.\vec{X}_P(t) - \vec{X}(t)\right| \quad (14)$$

$$\vec{X}(t+1) = \left|\vec{X}_P(t) - \vec{A}.\vec{D}\right| \quad (15)$$

In equation (14) 't' indicates the current iteration. X and X_P vectors indicate the Grey wolf and the injury position respectively where A and C are the coefficient vectors given in equations (16) and (17)

$$\vec{A} = 2.\vec{a}.\vec{r}_1 - \vec{a} \quad (16)$$

$$\vec{C} = 2.\vec{r}_2 \quad (17)$$

In equations (16) -(17), r_1 and r_2 indicate the random vector which changes in the range of [0, 1] and the component 'a' decreases from 2 to 0 during the iteration. The hunting process can be evaluated with the mathematical expression from equations (18-23)

$$\vec{D}_\alpha = \left|\vec{C}_1.\vec{X}_\alpha - \vec{X}\right| \quad (18)$$

$$\vec{D}_\beta = \left|\vec{C}_2.\vec{X}_\beta - \vec{X}\right| \quad (19)$$

$$\vec{D}_\delta = \left|\vec{C}_3.\vec{X}_\delta - \vec{X}\right| \quad (20)$$

$$\vec{X}_1 = \vec{X}_\alpha - \vec{A}_1\left(\vec{D}_\alpha\right) \quad (21)$$

$$\vec{X}_2 = \vec{X}_\beta - \vec{A}_2\left(\vec{D}_\beta\right) \quad (22)$$

$$\vec{X}_3 = \vec{X}_\delta - \vec{A}_3\left(\vec{D}_\delta\right) \quad (23)$$

The average value of positions of α, β and δ wolves are found to be the best position of prey which is given as (14)

$$\vec{X}(t+1) = \frac{\vec{X}_1 + \vec{X}_2 + \vec{X}_3}{3} \quad (24)$$

4.1 FOPID controller :

The basic diagram of FOPID is illustrated in Fig. 7. The error signal e (s) helps in producing the control output u(s). FOPID with GWO optimization is designed to mitigate the power quality issues of voltage and current fluctuations in the HRES system. The control signal of the FOPID controller is mathematically formulated as,

$$u(s) = K_p + K_i D^{-\lambda} e(s) + K_d D^{\mu} e(s)$$

Following steps are required during the design of the controller:

1. K_P is regulated for minimizing steady-state error and rise time

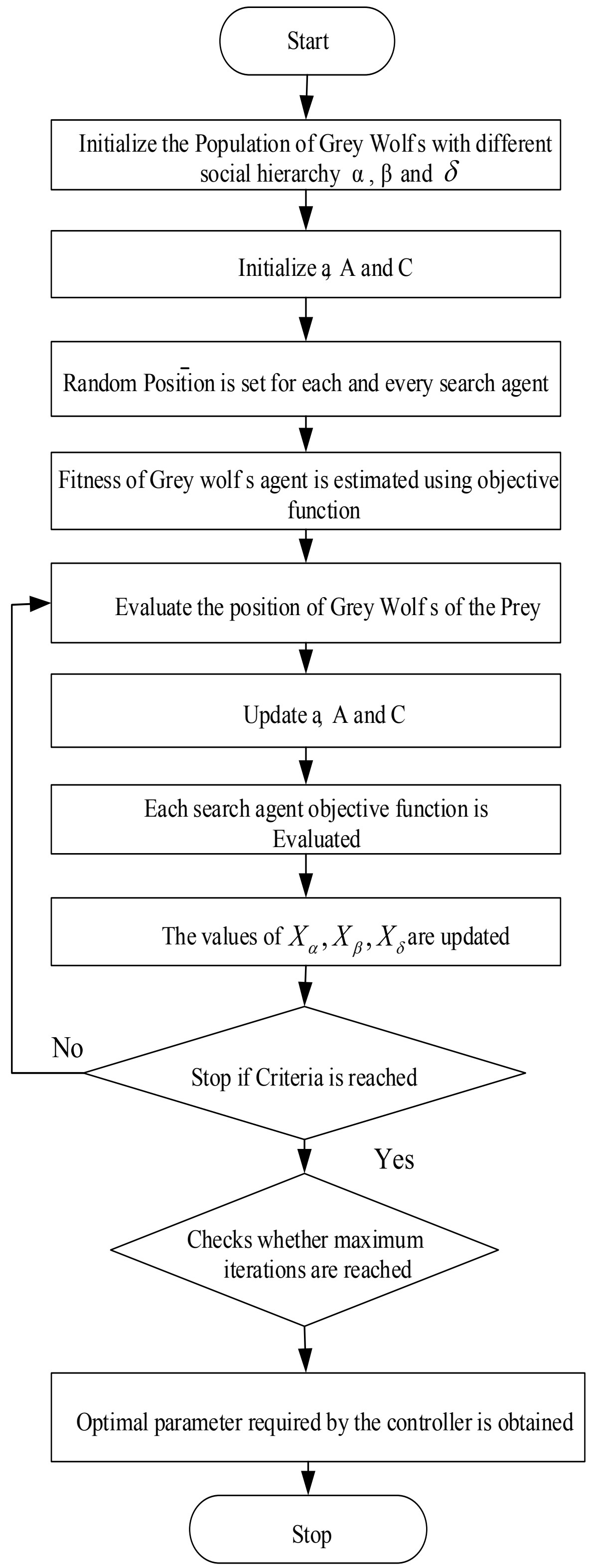

Fig. 6 Flow chart of GWO

2. K_d is regulated for minimizing the settling time and overshoot
3. K_i is regulated for eliminating the steady-state error.
4. $D^{-\lambda}$ and D^{μ} are fractional order parameters

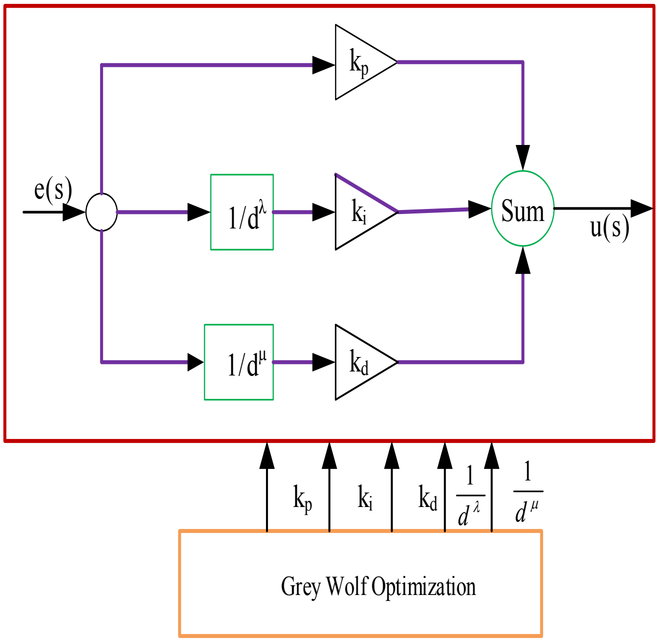

Fig. 7 Fractional order proportional integral derivative controller

5. Results and Discussions

The PV and WT frameworks are considered as the wellspring of the framework. For this situation investigation, the PV and WT base boundaries of irradiance and wind speed are fixed as a steady level just as an examination of the control structure attributes. The PV irradiance conditions are taken as 1000W/m^2. Identified with the irradiance level of PV, the vitality is created in a framework that is utilized to reward the heap request. The WT speed is taken as 12m/s, because of the speed the WT to produce power. Thus, HRES has produced the necessary capacity to satisfy the maximum need and minimize PQ issues. The battery likewise associated in the framework which is empowered just basic states of PV and WT vitality frameworks. The PV and WT boundaries with produced power are shown in Fig. 8. The real, reactive power and THD of different harmonics with BBO, GA, GSA and PI controller is depicted in Fig. 11, Fig. 12 and Fig. 13. The system designed parameters are given in Table. 1

5.1 Voltage and current sag condition during Non-Linear Load

Due to the installation of non-linear loads in the proposed HRES grid-connected systems sag faults are created. To mitigate and compensate load demand proposed systems is designed with FOPID-GWO based controlling technique. In these systems, PV and WT irradiance and speed are fixed to a constant level. The irradiance of PV is 1000W/m^2 and WT speed is considered to be 12m/s. This hybrid system is designed to meet the load demand and mitigate PQ problems. The battery is added in addition to meet the required under critical conditions of PV and WT. The generated power of PV and WT is depicted in Fig. 8.

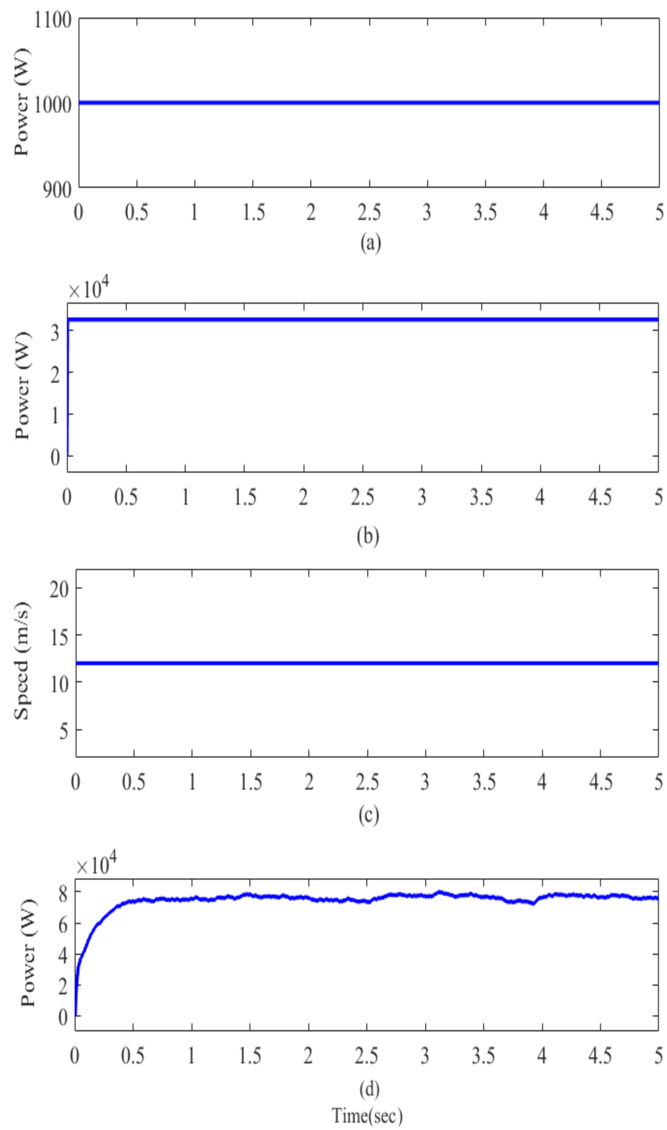

Fig. 8 HRES system Performance

The produced power from PV is 30kW at 1000W/m^2 and 80kW from the WT with a constant wind speed of about 12m/s. The condition for voltage and current sag is observed when there is a non-linear load in the grid-connected system. The UPQC device is used to compensate for the PQ issues caused due to non-linear loads with the control structure of FOPID-GWO. The voltage sag during t= 0.75s to 0.85s compensated by injecting the voltage shown in the Fig.9. In the same way current sag and injected current during t= 0.75s to 0.85s shown in Fig. 10 is resolved with the help of proposed UPQC under sag conditions in both the voltage and current. Here both shunt and series active power filters are used to mainly control the voltage and current

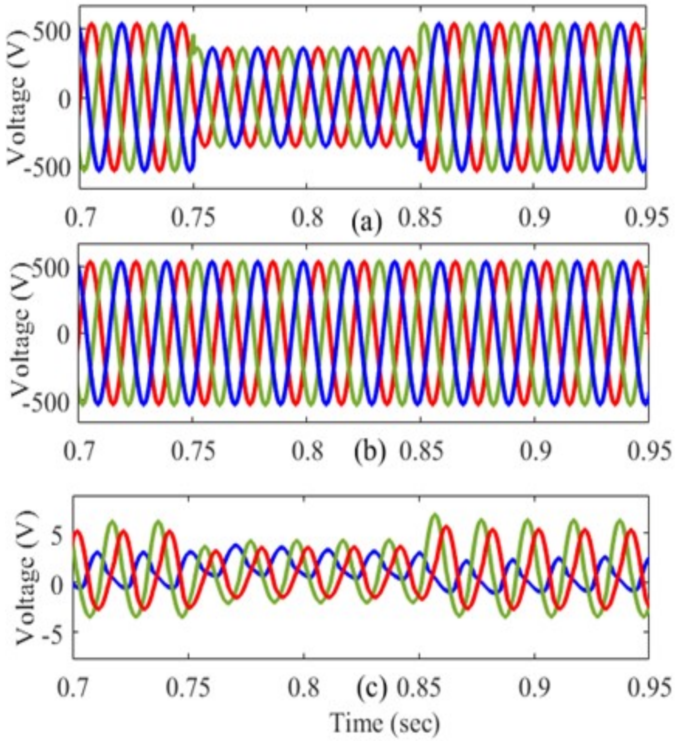

Fig. 9 Condition for voltage sag

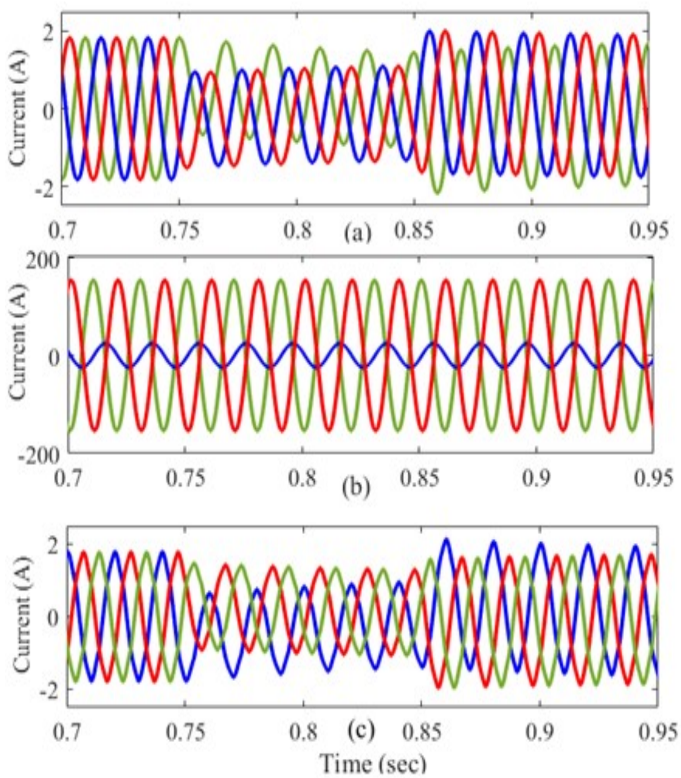

Fig. 10 Condition for current Sag

5.2 Comparative Analysis

The results of the proposed method are compared under sag condition for non-linear load and THD's before and after connection of UPQC. The real power, reactive powers and THD's of the system is compared with the various methods like GA, GSA, BBO and GWO with the existing PI controller. From the analysis, the proposed method maintains the best real power and reactive power without any oscillations in the system. The harmonics of the voltage signals are evaluated with and without connection of UPQC. The normal power quality issues signals which contain a large number of harmonics. These harmonics are reduced with the help of UPQC and proposed controller. The THD's before and after UPQQC is illustrated in Table.2 These obtained THD's are compared with various existing methods. The UPQC is most suitable to reduce the harmonics and mitigate the power quality issues in the HRES system. in the proposed controller Compared with the other techniques.

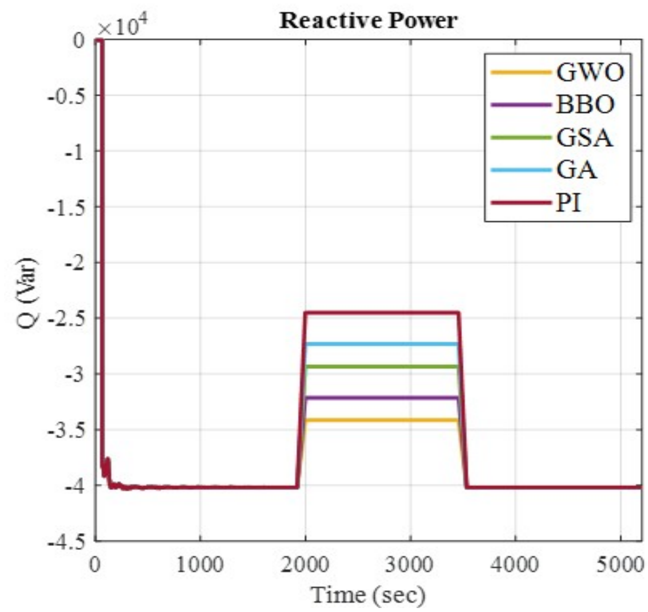

Fig. 11 Reactive power supplied by HRES

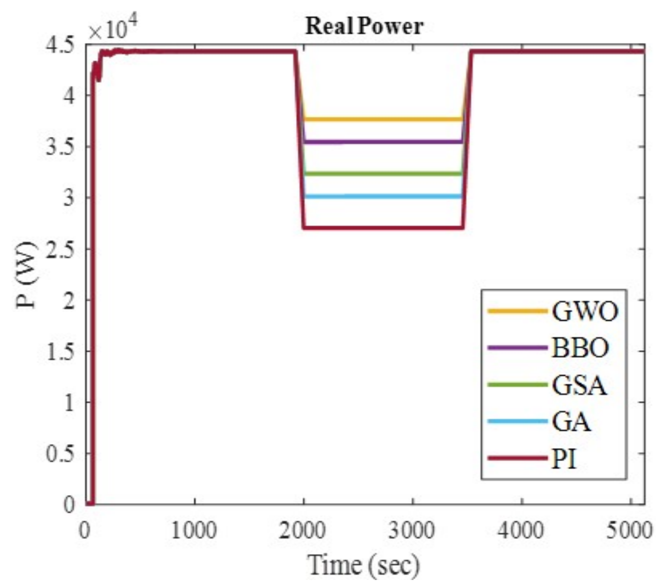

Fig. 12 Real power supplied by the HRES

Table. I: System Design Parameters

Sl.No	Description	Parameters	Values
1	PV	Irradiance	1000
2		Diode resistance	595.5 Ω
3		Forward Voltage	0.8V
4		Generated Power	33kW
5	Wind	Base Wind Speed	12m/s
6		Base rotational speed	0.4m/s
7		Stator Phase resistance	1.5 Ω
8		Armature Inductance	8.5e-3H
9		Nominal mechanical output power	80kW
10		Base Power of Electrical Generator	80kW/0.9
11	Battery	Type	Nickel-metal-hydride
12		The initial state of charge	100
13	Grid	Phase Voltage	550V
14		Frequency	50Hz
15	Load	Nominal Voltage	550V
16		Active Power	1000e-3 W
	GWO	No. of Search Agents	30
17		No. of Iterations	500
18		Alpha	50
19		Beta	0.2
21		Index Function	1
22	BBO	No. of Populations	50
23		No. of Iterations	1000
24		Alpha	0.9
25		Mutation	0.1
26	GSA	No. of Populations	50
27		No. of Iterations	50
28		Alpha	0.85
29		Mutation	0.1
30	GA	No. of populations	50
31		No. of iterations	50
32		Alpha	0.85
33		Mutation	0.1

Table. II: THD comparison of existing and proposed methods

Sl. No	Methods	Before UPQC									After UPQC								
		5	7	11	13	17	19	23	25	29	5	7	11	13	17	19	23	25	29
1	GWO	42	35	41	36	41	71	41	34	35	21	6	9	12	18	6	9	5	6
2	BBO	51	38	36	25	32	51	32	40	26	25	8	12	15	21	9	12	8	12
3	GSA	65	34	28	36	51	42	38	42	32	35	15	17	18	22	12	15	11	15
4	GA	71	38	22	32	45	38	35	48	36	37	16	18	21	22	10	8	6	4
5	PI	82	35	25	12	48	41	38	45	32	35	12	13	17	21	12	7	5	1

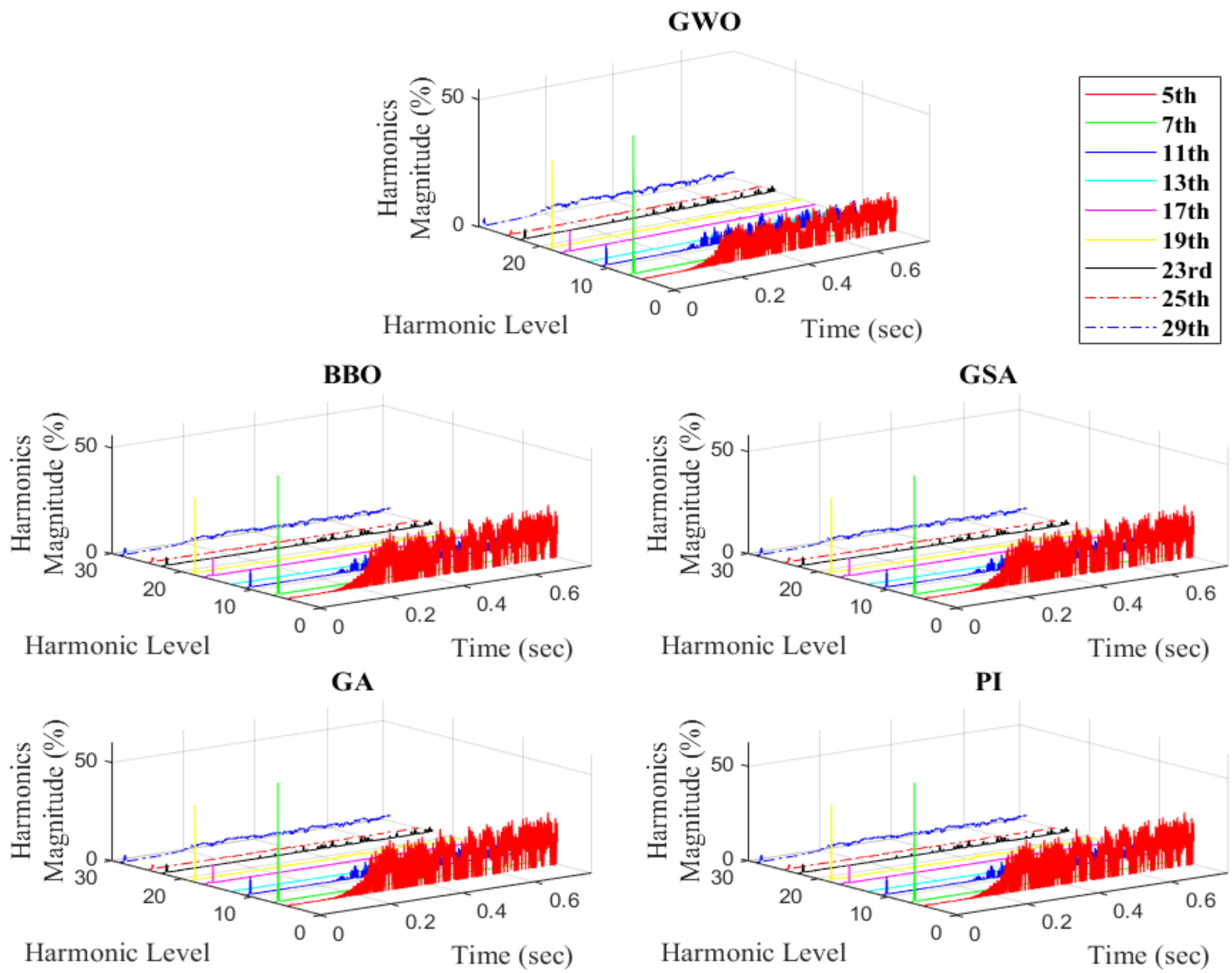

Fig. 13: Comparison Analysis of THD

6. Conclusion

A GW optimization is implemented as a controller for the distributed power system to improve the power quality in a grid-connected hybrid system with battery storage without causing any effects its normal operation of real power transfer. By using the GWO, the perfect combination of parameters is generated and the optimal control signals are predicted using the PI technique. The obtained results show that the implemented method improves the control performance of the UPQC and maintains the best real and reactive power in the system without any disturbances. The harmonics levels in the system are reduced with the utilization of GWO-FOPID controller and shown the best results in terms of THD's when compared with various techniques. The proposed system is designed in MATLAB/ Simulink platform. The results obtained of the proposed system are compared with various existing techniques like GA, GSA, BBO with PI controller and concluded that GWO has produced the best results.

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