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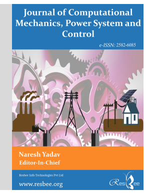

Enhanced Self Adaptive Bat Algorithm for Optimal Location of Unified Power Quality Conditioner

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Abstract: In the electrical, various researchers have worked on Unified Power Quality Conditioner (UPQC) is considered as an ultimate solution to enhance the power quality. Nevertheless, because of the maximum cost included; the position of UPQC in the Distributed System required to be determined with enormous concern and have to rather be resolved as the optimization issue. Moreover, the optimization of UPQC positioning issue in a competitive environment such as the reduction of Total Harmonic Distortion (THD), reduction of power losses, improvement of unbalance minimization and voltage profile in both voltage and normal sag circumstances. In this paper, a power quality enhancement method which is on the basis of a novel self-adaptive optimization method called enhanced Self-Adaptive Bat Algorithm. The proposed method discovers the optimal position for the UPQC device regarding the UPQC cost, power system losses, and Voltage Stability Index (VSI). The simulations are performed in IEEE 69 bus systems. The performance of the proposed technique is evaluated with the traditional methods such as Artificial Bee Colony (ABC), Firefly (FF), and Grey Wolf Optimization (GWO) to exhibit the advantage of the proposed algorithm.

Keywords: Power System; UPQC; Power Loss; VSI; Optimization Algorithm

Nomenclature

Abbreviations	Descriptions
THD	Total Harmonic Distortion
FF	Firefly
ABC	Artificial Bee Colony
UPQC	Unified Power Quality Conditioner
WOA	Whale Optimization Algorithm
APFs	Active Power Filters
PAC	Power Angle Control
SC	Super Capacitor
GWO	Grey Wolf Optimization
PER	Pulse Emission Rate
VSI	Voltage Stability Index
PEMFC	Proton Exchange Membrane Fuel Cell
MR	Multi-Resonant
PI	Proportional-Integral
FFT	Fast Fourier Transform
PER	Pulse Emission Rate
VSI	Voltage Stability Index
VCS	Virus Colony Search
DS	Distribution System

1. Introduction

Power quality is considered a significant problem in the smart grid. Power quality problems like harmonic distortions are rising quickly by rising employ of power electronic converters. Over passive filters, the APFs being rapid and dynamic are chosen as recompense for power quality problems. Series APF mostly recompenses to supply voltage interrelated power quality issues like voltage sag, harmonics and swell. Conversely, shunt APF mostly recompenses for load current interrelated power quality problems like reduced power factor, unbalance, and harmonics. UPQC is an amalgamation of series and

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shunt APFs distribution of a widespread DC link. UPQC, incorporating advantages of both series and shunt APF, recompenses for the majority of the power quality problems [1].

UPQC is a multitasking power conditioner which is exploited to compensate numerous voltage disturbances of the voltage fluctuations, power supply, in addition to avert harmonic load current from inflowing the power system. It is a tradition power device modeled to ease the disturbances which have an effect on the sensitive loads performance. UPQC comprise of 2 voltage-source inverters with a widespread dc-link modeled in 1-phase, 3-phase 3-wire, or 3 phase 4-wire configurations [2]. In the series APF, 1 inverter is regulated as a variable voltage source, an additional inverter is represented as a variable current source which is controlled in the shunt APF. Moreover, the series active filter compensates for voltage supply disturbances, for example, such as imbalances, harmonics, sag, flickers, swell, zero and sequence negative components. For load current distortions the shunt filter compensates for instance occurred by imbalances, harmonics, and reactive power and carry out the dc-link voltage regulation.

For UPQC, various topologies developed in [6]. Previously, several control algorithms were proposed for UPQC controller. A few researchers were presented dc-link voltage regulation algorithms which play a significant task in UPQC controlling. By the exploitation of the existing PI controller that is a common method for dc-link voltage control that was discussed in [7]. For dc-link voltage regulation, various control algorithms such as fuzzy logic, fractional PID, and fuzzy-PID was proposed in [8], correspondingly. Additionally, for dc-link voltage control, intelligent control algorithms namely neural network were exploited [9]. Various researchers on controlling UPQC were studied regarding the series and shunt inverter control approaches that were categorized into two kinds such as frequency and time domain-based approaches. Moreover, the Frequency domain techniques like a wavelet transform [11] and FFT [10] possess two disadvantages such as delay in computation and high computation time. Hence, these approaches were least exploited in the literature and investigational studies. For UPQC, the majority of time-domain control approaches were on the basis of the reference signal extraction. Amid time-domain approaches, immediate reactive and active power theory and synchronous reference frame technique [12] were the majority well-liked and extensively exploited ones in a lot of different examinations. In [13], for pqr reference frame, the pq theory with the alteration of stationary reference frame was exploited [23]. An easy control approach for UPQC on the basis of the unit vector template generation was proposed in [14]. A controller on the basis of the load power phase angle control was modeled in [15].

Exploit of the fuzzy approach for series and shunt inverter controller design was developed in [16]. Another developed time-domain control approach for UPQC was on the basis of the mathematical model of UPQC and power systems. In [17], Predictive model control was developed and another control approach on the basis of the dynamic model was feedforward and feedback control, as stated in [18]. With an integral action control, a mixed linear quadratic regulator method exploited UPQC was developed in [19].

The main contribution of this paper is to develop a novel power quality enhancement method by taking into consideration of the equality and inequality constraints. This work proposed to discover the optimal UPQC sizing and location using the novel Enhanced Self-Adaptive Bat algorithm to improve the power quality. In addition, the optimal recognition of UPQC positioning fulfills the major aim of this paper such as reduction of cost, VSI, loss and that creates the method to improve the power quality.

2. Literature Review

In 2018, Ashish Patel et al [1] presented an enhanced control approach for UPQC with an unbalanced load. Shunt APF was overloaded while it only supplies total load reactive power in UPQC. PAC algorithm aspires at effectual use of shunt and series APFs by the distribution of reactive power load among the two. In attendance of unbalanced load, conventional PAC approaches can show the way to the circulation of reactive power among 2 APFs and thus consequence in UPQC overloading. Here, a novel PAC approach was developed that evades the reactive power circulation and redundant VA load on UPQC.

In 2018, Brahim Berbaoui [2] developed an optimal control approach for UPQC to enhance power quality and handle efficiently equal power-sharing amid series and shunt inverter of UPQC in electrical faults circumstance. From source-side voltage disturbances, the UPQC was modeled to defend sensitive load in nonlinear load circumstances. A hybrid power generator that combines PEMFC as the major energy source and as the secondary source was developed to provide for the FACT device. Here, a new control approach was proposed to consider the power factor, THD, and voltage sag, as multiobjective of the UPQC controller. Hence, a novel dominant method called VCS was exploited to determine the coefficients of the PI controller for UPQC.

In 2018, Gowtham N and Dr.Shobha Shankar [3], focused on UPQC that was an amalgamation of shunt and series APF. The series APF lessen voltage on the basis of the distortions when shunt APF alleviates present based distortions. UPQC eases the voltage and presents based distortions concomitantly and autonomously. UPQC enhances power quality using compensating both load current and harmonics so that it creates load voltage and source current sinusoidal at the necessary voltage level.

In 2018, Mojtaba Yavari et al [4], developed a novel method on the basis of the non-linear control method for UPQC. The amalgamation of sliding mode control and immediate reactive and active power theories was exploited to model this controller. UPQC comprised of a shunt and a series APF that was continuously associated with a widespread dc-link capacitor. Particular characteristics of the developed controller such as rapid dynamic response, total compensation of UPQC using the presented controller for the sag/swell in supply voltage, better performance in power system with great distortions, and for unbalance networks, the ideal performance in compensation.

In 2020, Guilherme Masquetti Pelz et al [5], developed a comprehensive assessment of the grid voltage disturbance denial ability by exploiting three types of controllers deployed into the current control loop of the series converter which creates a single-phase UPQC. The aforesaid controllers were estimated and evaluated with each other to provide subsidies to the designer in selecting the one which carries out superior, as static behavior of the UPQC was directly affected with the attendance of grid voltage disturbances. Initially, the traditional PI controller was explained. Subsequent to that, to enhance the traditional PI controller, MR phrase performances were augmented ensuing in the PI-MR controller.

3. Working model of UPQC to Improve the Power Quality

3.1 UPQC Model

The schematic diagram of the UPQC based on the 3-phase 4 wire voltage source converter is exhibited in Fig. 1. In reality, the UPQC is performed based on the shunt and series APF. Generally, the shunt APF is associated over the loads for compensating all current associated problems such as compensation of current harmonics, reactive power compensation, and compensation of load unbalance, dc-link voltage regulation and enhancement of power factor. The series APF is linked in series with a line via a 3-phase series transformer. This acts as the controlled voltage source, that might be controlled and compensate voltage source for all voltage associated issues like flicker voltage harmonics, and shortly. UPQC decreases the load disturbance region to a normal operating zone via fault protection. Moreover, it alleviates the voltage sag, voltage unbalance, and reduces the loss of real power. Two inverters which linked using a single dc storage capacitor are used. In this, 1 inverter is utilized for series voltage deployment and the after that is utilized for shunt current injection. The working standard of shunt inverter and series inverter is stated as below:

The magnitude of injected voltage through a series inverter, V_{se} merely based upon the maximum voltage sag which to be ease. The source voltage magnitude when normal and voltage sag circumstances are specified as $V_s = V_{SO}$ and $V_s = kV_{SO}$. Moreover, $k_{sag} = (1-k)$. At any circumstance load voltage, $V_L = V_{SO} = V_s$. The necessary series voltage injection for extenuating k_{sag} p.u of voltage sag is stated in eq. (1).

$$\begin{aligned} V_{se} &= \sqrt{V_L^2 + (kV_{SO})^2 - 2V_L(kV_{SO})\cos\delta} \\ &= V_s\sqrt{1+k^2-2k\cos\delta} \end{aligned} \tag{1}$$

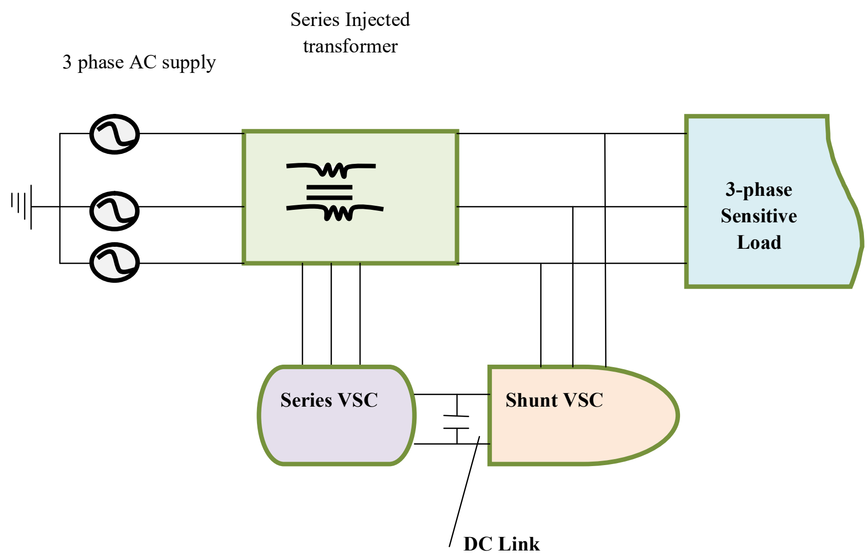

Fig. 1. *Block diagram of UPQC model*

During the supposition of UPQC lossless, the active power demanded by the load is indicated as active power drawn from the source. In the sense, $kV_sI_s = V_LI_L\cos\phi$, which shows the current source and it is stated in eq. (2), whereas I_s and I_L indicates the load current and compensated source-end current, correspondingly. From both eq. (1) and (2), VA rating of the series inverter is stated in eq. (3).

$$I_s = I_L\cos\phi / k \tag{2}$$

$$SE_{se} = V_{se}I_s = V_sI_L\cos\phi\sqrt{1+k^2-2k\cos\delta / k} \tag{3}$$

In eq. (4) and (5) indicates the active and reactive power showed using the series inverter was $\theta_{se} = 180^o - \tan^{-1}(\sin\delta/1-\cos\delta)$ [22].

$$P_{se} = SE_{se}\cos\theta_{se} \tag{4}$$

$$QU_{se} = SE_{se}\sin\theta_{se} \tag{5}$$

As in eq. (6) the expression of compensating current through shunt inverter I_{sh} is stated.

$$\begin{aligned} I_{sh} &= \sqrt{I_s^2 + I_L^2 - 2I_sI_L\cos(\phi-\delta)} \\ &= I_L\sqrt{1+\cos^2\phi/k^2 - 2\cos\phi\cos(\phi-\delta)/k} \end{aligned} \tag{6}$$

In addition, the shunt inverter performs the compensation of harmonic in attendance in load end (due to the non-linear load) that is stated in eq. (7) and (8).

$$I_L^{di} = I_{sh}^{di} \tag{7}$$

$$THD_L I_L^{fu} = THD_{sh} I_{sh}^{fu} \tag{8}$$

In Eq. (7) and (8), I_L^{di} denotes the distortion component, I_L^{fu} denotes the fundamental component, THD_L indicates the load current's THD I_{sh}^{di} denotes the distortion component, I_{sh}^{fu} denotes the fundamental component, THD_{sh} denotes the shunt inverter current's THD. Therefore the shunt compensating current's R.M.S value is decided using eq. (9).

$$\begin{aligned} I_{sh} &= I_{sh}^{fu}\sqrt{1+THD_{sh}^2} \\ &= I_L^{fu}\sqrt{1+\cos^2\phi/k^2 - 2\cos\phi\cos(\phi-\delta)/k + THD_L^2} \end{aligned} \tag{9}$$

From Eq. (9), the explanation of the shunt inverter's VA rating is stated, and it is stated in Eq. (10).

$$\begin{aligned} SE_{sh} &= V_sI_{sh} \\ &= V_sI_L^{fu}\sqrt{1+\cos^2\phi/k^2 - 2\cos\phi\cos(\phi-\delta)/k + THD_L^2} \end{aligned} \tag{10}$$

Eq. (11) and (12) exhibits the active and reactive powers which are showed using the shunt inverter. $\theta_{sh} = \tan^{-1}\{\cos(\phi-\delta) - \cos\phi/\sin(\phi-\delta)\} + 90^o - \delta$. The UPQC's delivered total reactive power is shown in eq. (13).

$$P_{sh} = SE_{sh}\cos\theta_{sh} \tag{11}$$

$$QU_{sh} = SE_{sh}\sin\theta_{sh} \tag{12}$$

$$QU_{UPQC} = QU_{se} + QU_{sh} \tag{13}$$

3.2 Objective Function

The major feature following the proposed power quality enhancement is the positioning of UPQC. The UPQC positioning has to assure the objectives for improving power quality. Eq. (14) indicates the objective model of the proposed model and the Loss stated in Eq. (17). In this, O_k indicates the conductance of k^{th} line linked among i and j buses. Voltage angle of i and j buses is indicated using δ_i and δ_j. The UPQC cost is stated in Eq. (15). Here, R indicates the asset rate of return, O denotes the UPQC's operating range in MVAr, $UPQC_{Cost}$ denotes the investment cost, $UPQC_{Cost_{year}}$ denotes the annual cost of UPQC, $mUPQC$ denotes the UPQC's longevity. The voltage stability index measurement is stated in Eq. (16). In Eq. (16), μ denotes the small constant, the voltage magnitude for b^{th} bus. The voltage stability index must be in the range of 0.9 to 1.1, and if there occur any deviation in this range, the penalty is included.

$$OB = \min\left(UPQC_{\cos t} + Loss + VSI\right) \tag{14}$$

$$\begin{aligned} UPQC_{Cost}\left(US(\$/kVAr)\right) &= 0.0003O^2 - 0.2691O + 188.22 \\ UPQC_{Cost_{year}} &= UPQC_{Cost}\frac{(1-R)^{mUPQC} \times R}{(1+R)^{mUPQC} - 1} \end{aligned} \tag{15}$$

$$VSI = \begin{cases} 1 & \text{if} \quad V^{min} \le V^{b} \le V^{max} \\ \exp\left(\mu\,|1 - V^{b}|\right) & \text{otherwise} \end{cases} \tag{16}$$

$$Loss = \sum_{k=1}^{N_L} Loss_k = \sum_{k=1}^{N_L} O_k \left\{V_i^2 + V_j^2 - 2V_iV_j\cos\left(\delta_i - \delta_j\right)\right\} \tag{17}$$

Definite constraints (Equality and Inequality) should be satisfied in the proposed method and it is stated in the subsequent section.

3.3 Equality Constraints

Both reactive and active line power is indicated regarding bus phase angle and voltage magnitude. Eq. (18) indicates the active power balance in the distribution system. Eq. (19) decides the reactive power balance.

$$P_{H_i} - P_{E_i} - \sum_{k=1}^{N_L} o_{ik}\left\{V_i^2 + V_j^2 - 2V_iV_j\cos\left(\delta_i - \delta_j\right)\right\} = 0 \tag{18}$$

$$QU_{H_i} - QU_{E_i} - \sum_{k=1}^{N_L} p_{ik}\left\{V_i^2 + V_j^2 - 2V_iV_j\sin\left(\delta_i - \delta_j\right)\right\} = 0 \tag{19}$$

In this, P_{H_i} and P_{E_i} indicates the active power which injected at i^{th} bus, system active power demand, correspondingly. P_{loss} denotes the total active power loss. QU_{H_i} denotes the reactive power that injected at i^{th} bus, QU_{E_i} denotes the system reactive power demand and Q_{loss} denotes the reactive power loss. o_{i-j} and p_{i-j} are the conductance and susceptance, correspondingly linked between i and j. V_i and V_j denotes the voltage magnitude of both i and j buses.

3.4 Inequality Constraints

These constraints indicate the system's capacity and operational limits. Moreover, these constraints are categorized into main classes.

Line flow limit: This limit states the utmost power transmission via the exact transmission line in a few stated conditions. The limits are based upon stability or thermal consideration. The power flow limit constraint is stated in Eq. (20), whereas $SE_{k_{max}}$ denotes the power flow's utmost value through-line.

$$SE_k \le SE_{k_{max}} \tag{20}$$

Bus voltage limit: The consideration of bus voltage limit is regarding voltage unbalance limit node and voltage magnitude limit, correspondingly. Eq. (21) states the 3-phase node voltage magnitude limit constraint.

$$V^{min} < V < V^{max} \tag{21}$$

4. Proposed methodology for the Optimal Positioning and Sizing of UPQC

4.1 Conventional Bat Algorithm (BA)

The conventional Bat Algorithm was enthused using the echolocation behavior which is shown using bats when exploring the food [20]. Bats produce ultrasonic pulses into their surroundings and pay attention to the echoes to aid with navigation and hunting [21]. The optimization technique for the conventional BA is on the basis of the loudness A , frequency f , and PER R of foraging bats. Its iteration procedure mostly includes local and global search stages, and the parameters of every individual bat i are updated as below:

The solutions for the location vector in the global search stage.

$$f_i = f^{min} + \left(f^{max} - f^{min}\right)\alpha \tag{22}$$

$$u_i^t = u_i^{t-1} + \left(y_i^{t-1} - y_{\bullet}\right)f_i \tag{23}$$

$$y_i^t = y_i^{t-1} + u_i^t \tag{24}$$

In eq. (23), t indicates the current iteration number, $\alpha \in [0, 1]$ indicates an arbitrary number attained from the uniform distribution and $y_{\bullet}$ indicates the current global optimum solution. Moreover, f^{min} and f^{max} indicates the least and maximum frequencies, correspondingly, which can be produced by the bats. In the local search stage, a new solution y_i^t indicates produced for a bat i if definite circumstances are fulfilled as below:

$$y_i^t = y_{\bullet}^{'} + \varepsilon A^t \tag{25}$$

In eq. (25), $y_{\bullet}^{'}$ indicates chosen from amid the current optimal solutions, $\varepsilon \in [-1, 1]$ indicates a uniformly arbitrary number, and A^t indicates the current average loudness of all the bats. In addition, the current loudness A_i^t and PER R_i^t of bat i can update as below:

$$A_i^{t+1} = \beta_b A_i^t \tag{26}$$

$$R_i^{t+1} = R_{max}\left[1 - e^{-\delta_b t}\right] \tag{27}$$

In eq. (27) R_{max} indicates the utmost probable PER and β_b and δ_b denotes the constants which are usually set to 0.9. As the iteration number leads to infinity, these acquiesce

$$A_i^{t+1} \to 0,\ R_i^t \to R_{max} \tag{28}$$

4.2 Proposed Enhanced Self-adaptive BA

When close to the prey, a bat maximizes it's PER R when minimizing its loudness A hence it have the ability to observe the prey's movement when residual ignored. Consequently, these alter in PER and loudness considerably affects the search procedure for optimization. In the previous phases of BA, the value of A shows an important power; additional, utmost probable count of global search operations has to be done. Hence, the global search probability of the method must be modified based on the loudness A . In the later on phases of the method, the PER R shows a significantly important influence; the additional, utmost probable count of global search operations must be done. Hence, the local search procedure must be altered based on the PER R . Enthused by these characteristics, this paper develops SABA by exploiting the mutation and step-control model.

a) Step-control scheme:

During each iteration, self adaptive at algorithm step-control method controls the step sizes which are exploited in both the local and global searches. The conventional BA exploits the frequency f to indicate the result of alters in the optimal solutions on the velocities of the bat group, as stated in eq. (23). Nevertheless, the proposed method exploits two frequencies f_1 and f_2 , that indicate the effects of modifications in optimal solutions for bat group and the individual bats, correspondingly, on the velocities. In addition, the 2 frequencies adjust to modifications in both the iteration procedure and the bat group's fitness.

Initially, in the global search stage of the proposed method, the new solutions for a bat i in the D-dimensional space have to be updated exploiting eq. (29) to (32).

$$u_i^t = \omega u_i^{t-1} + f_1 r_1 \left(h_{i\bullet} - y_i^{t-1}\right) + f_2 r_2 \left(y_{i\bullet} - y_i^{t-1}\right) \tag{29}$$

$$f_1 = \beta\left(1 - e^{-\left|F_{avg} - F_{best}\right|}\right) + \delta(1-k) + f_{min} \tag{30}$$

$$C_w = f_1 + f_2 \tag{31}$$

$$y_i^t = y_i^{t-1} + \mu u_i^t \tag{32}$$

In Eq. (29), ω is represented to be a minimizing weight coefficient. This is exploited to provide the method with sturdy global search capabilities in the previous phases when lesser ω values in the afterward phases to assure the method as well show strong local search capability. Moreover, $h_{i\bullet}$ indicates the optimal solution for bat i, $y_{i\bullet}$ represents the current global optimum f_1 and f_2 represents the frequencies, and r_1 and r_2 represents the uniformly arbitrary numbers obtained from (0.5, 1.5). In Eq. (30), F_{best} represents the fitness of the current global optimum and F_{avg} represents the average fitness of the current optimal solutions for individual bats. Moreover, $k = t/t_{max}$ represents the estimate index, where t_{max} represents the utmost number of iterations; therefore, $k \in (0, 1]$. At last, f^{min} it represents a constant that states the least value of f_1. Hence, f_1 represents updated based on the bat group fitness and the current iteration number by exploiting the weights β and χ, correspondingly.

Eq. (31) sets the summation of f_1 and f_2 to be a constant (C_w), showing that $f_2 = C_w - f_1$. As the iteration procedure carries on, f_1 minimizes from C_w to f^{min}, when f_2 maximizes from 0 to $C_w - f^{min}$. In the previous phases, the high f_1 values maximize the bat group's diversity and enhance the methods of global search capability, when the high f_2 values in the last phase assurance the method convergence. In Eq. (32), μ indicates the step weight coefficient that is exploited to limit the iteration step size. In this paper, μ is in the range (0, 1].

Next, the algorithm local search stages exploit a scheme that involves the PER R in the iteration procedure. If the uniformly arbitrary number $\alpha_0 \in [0, R_{max}]$ is minimum than R, bat i carries out a local search by exploiting Eq. (33) and (34). Due to the R maximization, as the iteration goes on, the local search probability is seen to maximize in the subsequent phases of the method. This search can be performed as below: if the estimate index $k < 0.4$, subsequently

$$y_i^t = y_\bullet + A^t s\chi \times h(k) \tag{33}$$

else, if the evaluation index $k \geq 0.4$, subsequently

$$y_i^t = y_\bullet + A^t s\chi \times 0.1^{h(k)} \tag{34}$$

Moreover, A^t indicates the bat group's current average loudness, $\chi \in [-1, 1]$ indicates the uniformly arbitrary number, and s indicates the ratio of the distance among the lower and upper boundaries of the possible solution domain and the number of bats in the group, that alters the local search step size to the scale of the issue which is being resolved. The model $h(k)$ is used to assure which the large local search steps aid to expand the search domain of the method during its previous phases when the small local search steps in the short phase aid to enhance the search accuracy.

b) Mutation scheme

The aforesaid step-control model can efficiently develop the global search capability of the method although this capability is still restricted by minimizing f_1 in the forthcoming phases. To promote enhancement the method capability to evade local optima, the proposed method, in addition, involves a mutation model that integrates the loudness A. If the uniformly arbitrary number $\alpha_1 \in [0, 1]$ is lesser than A and the bat i has not done a local search, a second arbitrary number $\alpha_2 \in [0, 1]$ is produced. If this is higher than the mutation threshold $\rho \in (0, 1)$ after that bat i is rearranged to arbitrary values.

Additionally, as shown in Eq. (28), the loudness A in the conventional BA minimizes to zero in the afterward phases, where the PER R minimizes to R_{max}. If the aforesaid values were taken, the proposed model would do numerous local search operations with insignificant step sizes in the afterward phases, whereas hardly doing mutation. To advance enhance the competence of the method, the proposed method updates A and R as below:

$$A_i^{t+1} = \frac{f_1}{f_{max}}, R_i^{t+1} = \frac{f_2}{f_{max}} \tag{35}$$

In eq. (22), f_{max} indicates the upper-frequency restrict. Due to the f_1 and f_2 are adaptively updated on the basis of the bat group's fitness and the iteration procedure, also the proposed algorithm R and A parameters are adaptively modified in the search procedure.

To recapitulate, this paper presents the step-control and mutation model. By altering the R and A parameters in the search procedure, the proposed method economically evades falling into local optima in the previous phases and posses enhanced accurateness in the afterward phases. Fig 2 demonstrates the flow chart of the proposed enhanced self adaptive bat algorithm.

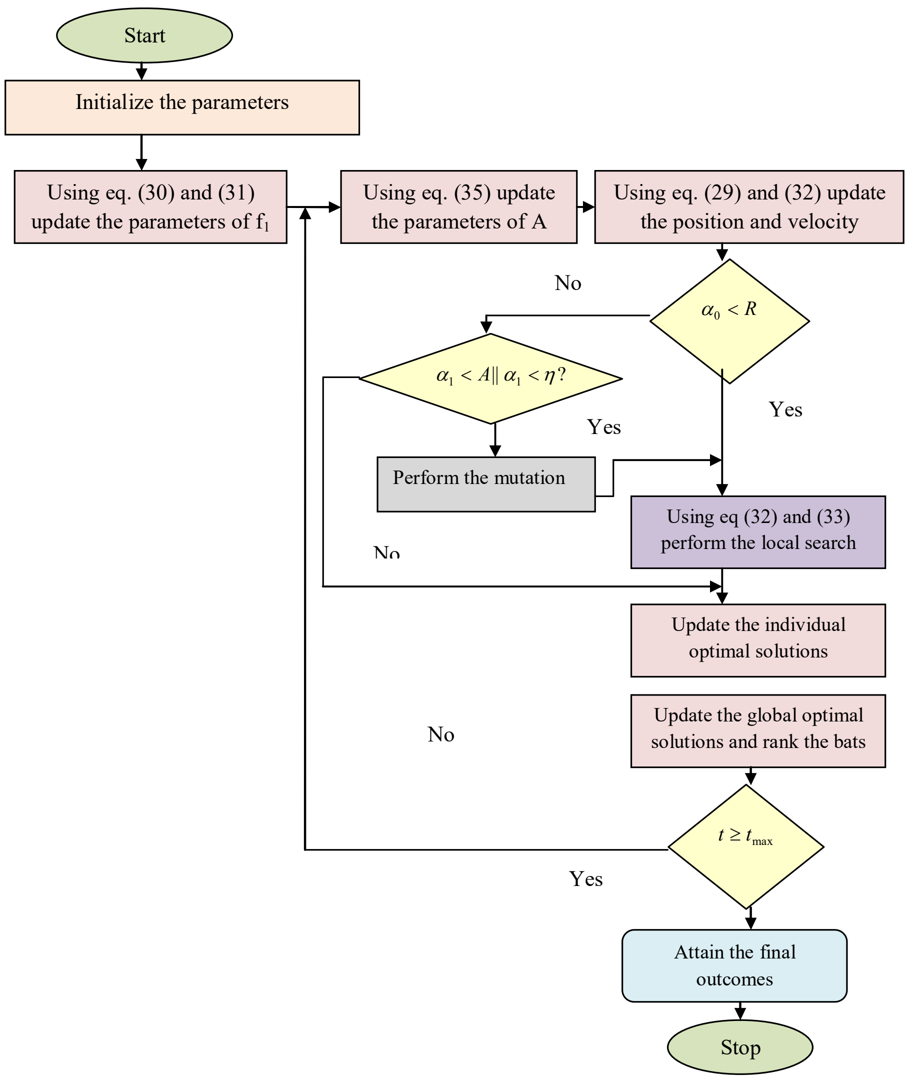

Fig. 2. *Flow chart of the proposed enhanced self adaptive bat algorithm*

5. Results and Discussions

5.1 Experimentation Set-up

The proposed model was simulated in MATLAB. Moreover, two different bus systems were used namely IEEE 69 bus system. Here, three experimentations were performed on the basis of the UPQC placement one location, two locations, and three locations. Moreover, the analysis of proposed work was carried out by varying the load conditions. The comparison was done with other conventional methods such as WOA, GWO, FF and ABC for the bus systems.

5.2 Performance Analysis in IEEE 69 Bus System

In this section, the performance analysis of proposed method over other methods for IEEE 69 bus system is shown. The analysis under location counts (1, 2 and 3) is done by varying the loading conditions to 0%, 50%, 100%, 150%, 200% and 250% and it is shown in Fig 3, 4 and 5. The analysis exhibits that the proposed model obtains less fitness value when compared to other conventional models such as ABC, GWO and FF.

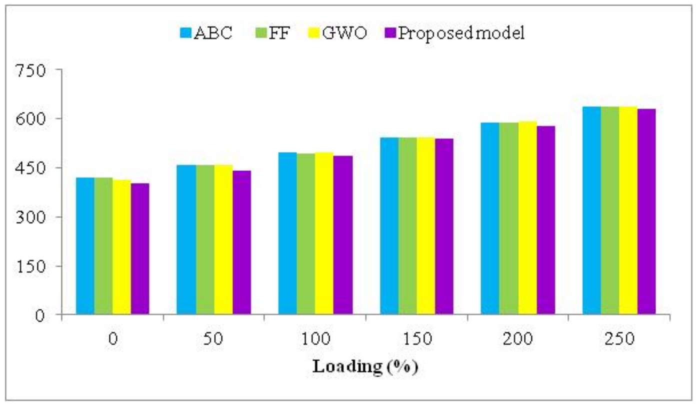

Fig. 3. *Performance analysis of the proposed model by varying the load conditions: no of location 1 in the IEEE 69 bus system*

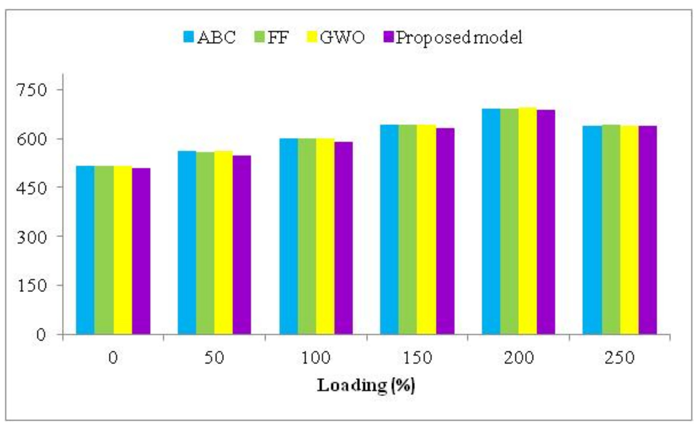

Fig. 4. *Performance analysis of the proposed model by varying the load conditions: no of location 2 in IEEE 69 bus system*

Fig. 5. *Performance analysis of the proposed model by varying the load conditions: no of location 3 in the IEEE 69 bus system*

In Fig 6, 7 and 8, the performance analysis of proposed method with respect to the loss, VSI and UPQC system is exhibited. Here, the evaluation is done under location 1, 2 and 3. The overall analysis shows that the proposed method attains better performance when compared to conventional models such as ABC, GWO and FF.

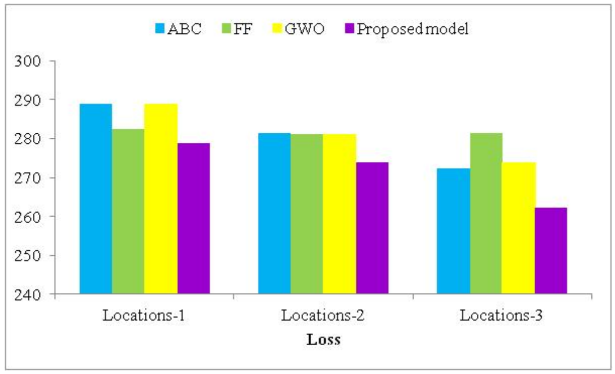

Fig. 6. *Analysis of the proposed model regarding the loss: no of location 1,2 and 3 in IEEE 69 bus system*

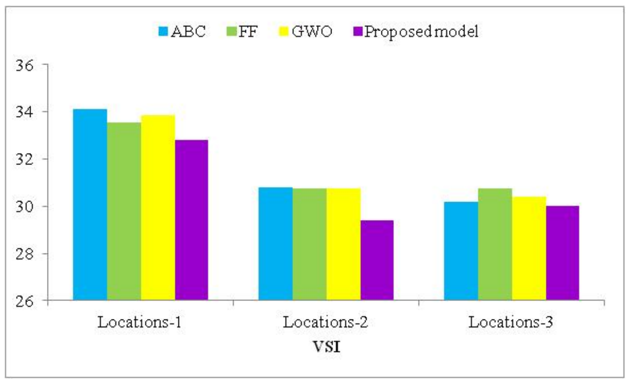

Fig. 7. *Analysis of the proposed model regarding the VSI: no of location 1,2 and 3 in IEEE 69 bus system*

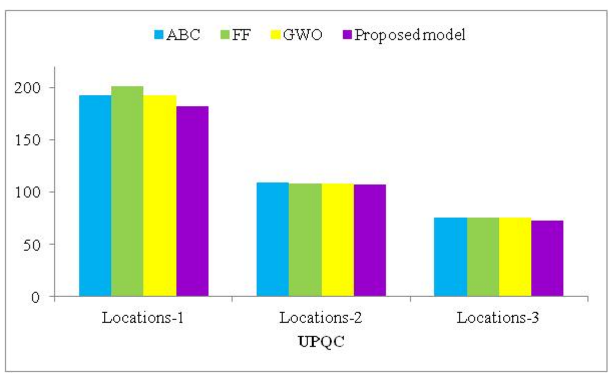

Fig. 8. *Analysis of the proposed model regarding the UPQC: no of location 1,2 and 3 in IEEE 69 bus system*

6. Conclusion

In power systems, compensation is necessary to minimize the power loss and maintain the voltage profile. Reactive power compensation and voltage compensation are the different compensation methods present in power systems. Series compensators help to maintain the voltage profile by providing voltage compensation. Shunt compensators help to minimize the power losses happening in the network by providing reactive power compensation. The functioning of series and shunt compensators are combined in a device called as UPQC. In this paper, a novel power quality enhancement method, which was on the basis of a novel optimization algorithm. To improve the power quality, the method was experimented on to recognize the optimal UPQC positioning and sizing. So as to recognize the optimal positioning and UPQC sizing, this work has presented a novel enhanced self-adaptive Bat method that has regarded as the objective of reduction of UPQC cost, power system losses, and Voltage Stability Index. The experimentation was performed in IEEE 69 bus systems. The performance of the proposed algorithm was evaluated with the existing algorithms namely ABC, GWO, and FF. Hence, the proposed method shows its performance with the existing algorithms regarding power quality improvement.

Compliance with Ethical Standards

Conflicts of interest: Authors declared that they have no conflict of interest.

Human participants: The conducted research follows the ethical standards and the authors ensured that they have not conducted any studies with human participants or animals.

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