Smart Inverter-Based PV-STATCOM Power Compensation using BaPhin Optimization Algorithm

Bharat Dubey*‡, Seema Agrawal**, Ashok Kumar Sharma**

*‡PhD Scholar
**Faculty
Department of Electrical Engineering, Rajasthan Technical University, Rawatbhata Road, Kota – 324010
(bharatdubey8888@gmail.com,seema10dec@gmail.com, aksharma_eck@hotmail.com)

‡Corresponding Author; Bharat Dubey, Rajasthan Technical University, Rawatbhata Road, Kota – 324010.
Tel: +91 9425742824, bharatdubey425@gmail.com

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Abstract: In the Photovoltaic (PV) Solar farms the whole expensive resources are kept unused, while the PV-STATCOM one of the FACTS device is still be active at all time to provide voltage control even at the critical system needs, on a 24/7 basis. For the functioning of STATCOM at the night time the inverter capacity is used. This research developed a smart optimized inverter for reactive power compensation in the distributed grid systems, and a new optimized controller for current regulation, voltage regulation, reactive power control, and power factor regulation. The PV-STATCOM controller is optimized using the BaPhin algorithm, which compensates for the voltage, current, real, and reactive power in the distribution system and also it effectively tunes the parameters included in the controller. The static synchronous compensator (STATCOM), controls the voltage-current components and balances the reactive power in the power system. The current, power factor, voltage, and reactive power in the grid-connected PVsystem as well as in the inverter is regulated by the BaPhin optimization algorithm, which optimally adjusts the proportional controller in the regulators. The performance of the BaPhin method is more effective in reactive power compensation than the existing methods. The attained results of the BaPhin method in the reactive power compensation that achieved the values of 500V at 0.49 sec, 0.0097 at 0.49 sec, and 1.0093A concerning DC link voltage, DC, and Quadrature current. The active, reactive, and power factor of the BaPhin algorithm is measured that achieved 98.73kW, -0.329KVAR,1 concerning grid 90.7944kw, -13.3753 kVAR, 0.9998 in 0.5 sec concerning inverter, 84.369kw, -5.1345KVAR,1 concerning load.

Keywords PV-STATCOM, optimization, converters, damping control, and power compensation.

Nomenclature

Abbreviations	Description
PV	Photovoltaic
STATCOM	Static Synchronous Compensator
FACTS	Flexible Alternating Current Transmission System
PSO	Particle Swarm Optimization
BFOA	Bacterial Foraging Optimization Algorithm
CSO	Chicken Swarm Optimization
VSI	Voltage Source Inverter
THD	Total Harmonic Distortion
VSM	Virtual Synchronous Machine
MW	Mega Watt
KW	Kilo Watt
IGBT	Insulated-Gate Bipolar Transistor
PCC	Point Of Common Coupling
WOA	Whale Optimization Algorithm
WECS	Wind Energy Conversion Systems
RES	Renewable Energy Sources

1. Introduction

Renewable resources are becoming increasingly popular around the world in the power source industry. Among the most preferable static power sources, the PV system is considered as most popular because of the easy installation of small-scale PV which depends on the status of the consumer[1]. Concerning a recent research report for Solar Farm, the night time utilization (usually when idle) shows that the STATCOM - a flexible alternating current transmission system (FACT) device is commonly preferred in PV solar farms for enhancing the performance of the system and improving the grid structure which is done by the complete voltage regulation [2]. The capacity of power distribution is need to be improved for that the newly developed voltage regulation be incorporated into the PV farm which has the same characteristic as STATCOM [3][4][5] reveal the regulation of voltage on PV systems even though they were never taken into account for improving the limitation of transferring power. During the occurrence of faults, there is a lack of capability in generating responses which can be overcome by integrating the full converter-dependent wind turbine generator with the FACTS devices [6]. The enhancement of transient steadiness and the limitation in power distribution with the improvement in regulation of voltage in which the grid-connected inverter consistently acts as FACTS device [7]. In the utilized technology, Solar farm is considered as the PV STATCOM to carry out the capacity of the inverter during nighttime and day the remaining energy be utilized after the generation of real power [8].

The limitation in transferring the power from the power station and distribution systems PV STATCOM is utilized [9] [10]. The capacity of the inverter helps to regulate the function of STATCOM during nightfall. The active power produced by the inverter is stopped for a short term during the occurrence of a fault during daytime when the STATCOM starts its function by the capacity of the inverter [11][12]-[17]. In most research cases, PV STATCOM and grid are synchronized in which the current regulating loop is involved in the d-q reference frame of the Phase locked loop for managing the PV STATCOM [18]. Thus, the solar farm generates 24/7 performance on the STATCOM which is enabled by the PV-STATCOM methods. Before the field description, the regulation of PVSTATCOM for day and night is estimated in constant loads with the laboratory surroundings and the results were introduced in [19]. It has been shown that the solar field automatically converts to PVSTATCOM during major disturbances occurring day and night, ensuring the continuous operation of a critical asynchronous motor, otherwise, it lacks stability [20].Within a short cycle 1-2, the delay-free compensation of reactive power is provided which in turn results in the limited current reaction as 0.2 p.u. for the low voltage. To improve day and night power transmission efficiency and the interconnection of the nearest wind turbines PV STATCOM is utilized [9] [11]. The transfer of the modulated reaction power can be continued until the phase is required [19].

The incorporation of PV-STATCOM and Wind model in the hybridized Wind-PV model which is involved with the intelligent control unit dependent Particle swarm optimization (PSO)-Bacterial foraging optimization algorithm (BFOA). Solar farms generate electricity using forenoon sunlight. Therefore, their reverse capability could not be used effectively during that period for other purposes such as mitigating the oscillations of the electrical system. Due to the alternating speed of the wind, windmills have interruptions in power generation, so often, its reverse capability is free, i.e., unused, so other subsidiary supports in the power system are available. At nighttime, when the production of PV is not applicable there is the availability of both the sun and wind in reverse capabilities which is completely free. The reverse capacity of PV STATCOM is used to mitigate the oscillations and supporting voltage in the electrical systems [21][22][23]. The output obtained by the PV STATCOM is reactive power which is regulated by controlling the reactive power with the use of various controllers. The error deviations are calculated by the reference and actual reactive power which is reduced by the utilization of the controller. The controlling schemes are obtained by the hybridization of Chicken swarm optimization (CSO) and PSO techniques. The error obtained in the current, voltage, reactive, and real power is minimized by the CSO algorithm with tuning purposes. The CSO optimization operation is enhanced using the PSO algorithm. In the CSO algorithm, the worst and best value of fitness is allocated for the chick and rooster swarm, whereas the remaining values are allocated for the hen swarm [24].

The research contribution of this paper follows,

- The smart inverter performance is enhanced during the night time using the STATCOM controller, which significantly compensates power deviation in the distribution system
- The power compensation by the STATCOM controller is further enhanced by the BaPhin optimization, effectively tunes the parameters. The low and high frequencies are taken into consideration for the BaPhin optimization from the characteristics of Bats and mammals. When the bats produce high frequency, the wavelength will be considerably low, which tends to search the food over shorter distances and is enhanced using the low frequency of the mammals. This results in providing the better-optimized output of the STATCOM controller that is used in the power system network which increases the transmission line power transfer ability.

Section 2 reveals the review of the various existing methods and the challenges for power compensation. Section 3 reveals theBaPhin optimization with the mathematical modeling and the developed method for power compensation. Section 4 includes the discussion and results of the BaPhin optimization as well as the other comparative methods. The last section 5 includes the conclusion part.

2. Motivation

The ideal selection of compensating reactive power area on the requirement of demand in the grid, inverter, and load by regulating the voltage using the hybridized optimization strategy in the smart inverter is the motivation for developing this research. Depending on this, the various methods existing for reactive power compensation are reviewed in this section with various benefits and drawbacks, in addition, the complications faced by the researchers in the area of power compensation are also discussed.

2.1 Review of the literature

The investigation on the conventional methods is briefly deliberated here. Rajiv K. Varma *et al*. [8] utilized a novel damping and voltage regulation with the PV system works as a STATCOM by the connection of the grid for enhancing performance during both forenoon and nightfall time. The transmission of power in the system is increased whereas the regulation of damping and voltage is less effective when compared with the conventional methods. Rajeev Kumar *et al*. [21] developed a Hybridized PSO-BFOA intelligent inverter control scheme for controlling and tuning the measures involved in the parameters. The oscillations encountered in the power system are to be repressed and minimized even though the condition of damping is worse than the existing methods. Fida Hasan Md Rafi *et al.* [1] introduced an improved version of smart PV VSI for maintaining both active and reactive power. This method helps to overcome the stability issues due to the external distraction nevertheless it is not well suited for high-power applications. Rajiv K. Varma and Sibin Mohan [7] employed the enhancement of PV-STATCOM control using the improvisation of reactive and real power during night and day where the use improvement of reactive power is used at nightfall. The stability of the motor and recovery of voltage be available at nighttime still the regulation of voltage is slightly disabled. Luis F. N. Lourenco *et al.* [10] utilized an Electromagnetic Transient simulation for analyzing the support for compensating the power and also the related technical cost. It is mostly utilized due to the nature of less amount of reactive power transmitted at nightfall whereas the expenses are greatly increased. M. P. Thakre and N. Kumar [18] utilized a Virtual Synchronous Machine controller for concatenating and coordinating renewable energy sources with electric power. The utilized controller can maintain the transients in voltage within the specified limit. On measuring the Total Harmonic Distortion with the three-level converter which is slightly higher than the Total harmonic distortion (THD) in Phase locked loop controller. Rajiv K. Varma *et al*. [20] expanded the PV STATCOM as the smart inverter for regulating the voltage within a few seconds and the relative expense is reduced to 50%. It tends to control the voltage effectively during nightfall, where the losses not be prevented in the charging circuit. Rajiv K. Varma and Ehsan M. Siavashi [19] employed a new enhanced smart inverter for the improvement in voltage regulation. The requirement of voltage regulation in common coupling is strongly attained within the limit. Instead of exceeding the solar panel voltage, it is lower when compared to the voltage in the open circuit. Rajiv K. Varma and Ehsan M. Siavashi [25] introduced an improvised smart inverter for reducing the rise in steady-state voltage and the occurrence of a short-term overvoltage by the high perforation of the solar system. The appearance of short-term overvoltage due to the various faults is successfully overcome within the specified acceptable limit. The capacity of the system is low when compared with the existing solar systems. Lizi Luo *et al*. [26] utilized a method of Second-order cone Programming for reducing the complication and non-convexity of the developed model named mixed integer nonlinear programming. The actual recovery time of the voltage is reduced and mitigates the depth in voltage sag. It is not fair to place too much emphasis on voltage support capacity. [27] introduced a Chi-mo optimization technique that effectively optimized the values of the proportional-integral controller was controlled at the STATCOM operation. [28] designed a combined hybrid system of Wind energy conversion systems (WECS) and PV against the fault occurrence of wind gusts and continuous operation of Renewable energy sources (RESs) to the grid. The parameters such as reactive power flow, and regulating the voltage at PCC were regulated by stimulating PI controllers with STATCOM and the PI worked on the Whale optimization algorithm (WAO). Wind guest as a disturbance affects the performance.

2.2 Challenges

- Current sophistication uses the reverse proficiencies of wind or solar farms as STATCOM. Many advanced controllers are custom-controllers (not smart). The reverse capabilities of wind or solar farms are used to solve only electromechanical or electrical or torque methods [21].
- During the forenoon, solar farms have the capability in generating electricity utilizing sunlight. Therefore, their reverse capability could not be used effectively during that period for other purposes such as mitigating the oscillations of the electrical system [21].
- Due to the enormous profit obtained by the controllers, it may be considered as strongly related to the gain. The parameter and random disturbances are influencing the system to some extent [21].
- The PCC voltage decreases by about 0.5 p. u during nightfall and forenoon due to the changes occurring in large induction load. In both times, the condition of the motor is unstable and will stop [20].
- The system may be affected by short-term and steady-state overvoltage and imbalanced voltage with various issues related to power quality. Due to the occurrence of high voltages in PCC, reverse flow of current takes place in the high perforation of PV farms, which will restrict subsequent DG initiation [19].

The power compensation's performance is laterally improved using the STATCOM controller with the combination of BaPhin optimization where the low and high frequencies are considered at high frequency travels a short distance and low frequency travels a long distance to find the correct resolution at less time. The BaPhin algorithm compensates the voltage, current, real, and reactive power in the distribution system that reduces the power loss. The LC filter present neglects the high-frequency noise that provides the best voltage regulation that is highly suitable for high-power applications.

3. Power Compensation Method Using the BaPhin Optimization Algorithm

The ultimate aim of the research will be to design and develop a smart optimized inverter for reactive power compensation in distributed grid systems. In the case of distributed-generator systems, current regulation, voltage regulation, reactive power control, and power factor regulation are considered the major challenges. Hence, this research aims to develop a new optimized controller for current regulation, reactive power control, voltage regulation, and power factor regulation. During the day, the PV source is connected to the load for solving the load demands, while the inverter as the PV-STATCOM with the power factor control will be used during the night to meet the load demands. The inverter as a PV-STATCOM will be engaged in compensating the power demands on any load dynamics and under fault conditions. Moreover, the PV-STATCOM controller is optimized using the BaPhin algorithm, which will compensate the voltage, current, real, and reactive power in the distribution system. The BaPhin optimization inherits the hunting features of bats and sea mammals. Hence, the hybrid predator optimization is nature-inspired optimization, which will optimally tune the controller toward attaining the research objectives. The implementation analysis is done with respect to the existing models on Power transfer limits in Mega watt (MW) on voltage control, damping control, and using the damping and voltage controls, the output power in kilo watt (KW), and reactive voltage compensation.

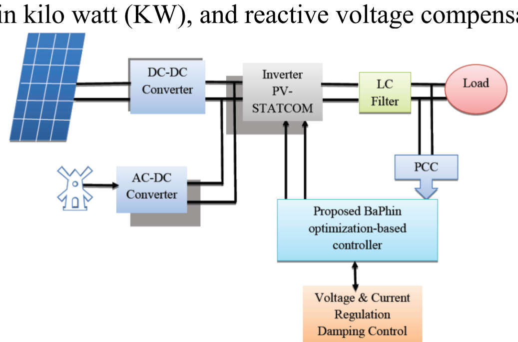


Fig. 1. Block Diagram for the power compensation method

3.1 PV panel modelling:

In photovoltaic cells, there is the presence of P-N junction semiconductor material mainly silicon which generates current through the photovoltaic effect. The solar cell carries electrons that are energized and move freely away from the atom during the process of striking the sunlight in the semiconductor material. The electrical circuit is in the form of connecting electrical conductors on both the positive and negative terminals and the generation of electric current takes place by capturing electrons. The generated power is then utilized to provide power to the load. Numerous PV cells are connected in series and parallel to form a PV module for obtaining high voltage and current at the desired output, where the individual cell in the PV panel generates power only around 0.5V.

i) Characteristics of PV cell

The equivalent circuit of PV cell is represented in figure 2. The schematic of the PV cell is represented by connecting the current source in parallel with the diode because it generates current during glowing and in the absence of glow it acts as diode. The shunt and series internal resistance is provided in the model of the equivalent circuit. Where R_S the value is very small which denotes the intrinsic series resistance and the equivalent shunt resistance is denoted as R_P which holds extremely high value.

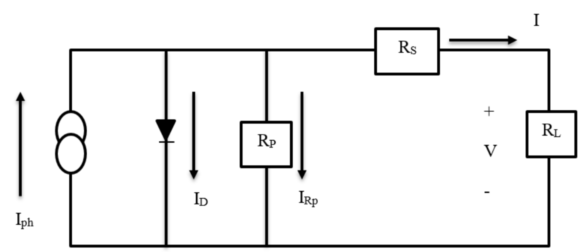


Fig. 2. Equivalent circuit of PV cell

The PV cell characteristic equation of current-voltage is given as:

$$\mathrm{I} = n_p \mathrm{I}_{ph} - n_p \mathrm{I}_{rs}\left(\exp\left(\frac{qV}{\mathrm{KTA}n_s}\right) - 1\right) \tag{8}$$

$$\mathrm{I}_{rs} = \mathrm{I}_{rr}\left(\frac{\mathrm{T}}{\mathrm{T}_r}\right)^3\left(\exp\left[\frac{q\mathrm{E}_G}{\mathrm{KA}}\left(\frac{1}{\mathrm{T}_r} - \frac{1}{\mathrm{T}}\right)\right]\right) \tag{9}$$

$$\mathrm{E}_G = \mathrm{E}_G(0) - \frac{\alpha \mathrm{T}^2}{\mathrm{T} + \beta} \tag{10}$$

$$\mathrm{I}_{ph} = \left(\mathrm{I}_{scr} + k_i\left(\mathrm{T} - \mathrm{T}_r\right)\right)\frac{S}{100} \tag{11}$$

where, the radiation current is denoted as I_{ph}, the current flowing through the cell is I, reverse saturation current is I_{rs}, the voltage available in the cell is V, the number of parallel connected cells is n_p, the number of series connected cells is

n_s, output current I_o, series, and parallel resistance is denoted as R_s and R_p, thermal voltage is as V_T, Boltzmann constant is K, ideality factor is denoted as A, the temperature in kelvin and the charge of an electron is represented as T and q, reference temperature of the cell is T_r, the reverse saturation current of the cell at I_r is I_{rr}, semiconductor bandgap energy is denoted as E_G, Short circuit current of the cell at the reference temperature is I_{scr}, the temperature coefficient of short circuit current is k_i and the solar radiation is denoted as S in mW/sq.cm.

The PV module output voltage is obtained using equation (8) as,

$$V = \frac{n_s KTA}{q} \ln\left[\frac{n_p I_{ph} - I}{n_p I_{rs}} + 1\right] \quad (12)$$

With the help of equation (12), the PV panel can be modeled and it is shown in figure 3.

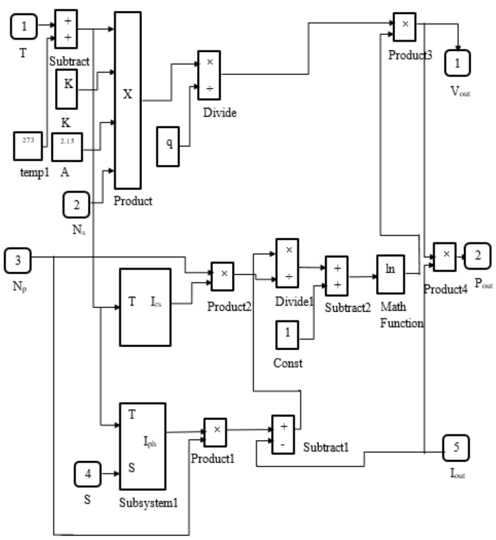


Fig. 3. PV array Simulink model

3.2 Wind turbine modelling

In the wind power system, the wind turbine is the prime and most important component. When the wind blows, the blades tend to rotate thus the wind turbine collects the power from the rotating wind energy of the aerodynamically modeled blades and covert it into the form of mechanical energy. Manually, the wind turbine holds three blades, and the obtained mechanical energy is supplied to the electric generator rotor for converting it into electrical power. The utilized electrical generator may be a synchronous generator or an induction generator.

The generated mechanical power by the wind turbine is given as,

$$P_m = 0.5\rho A C_p(\lambda,\beta) v_w^3 \quad (13)$$

where: ρ be the density of air, swept area of rotor be A, the Coefficient function of power is denoted as $C_p(\lambda,\beta)$, tip speed ratio is as λ, pitch angle and the speed of wind is considered as β and v_w.

Depending on the characteristics of the steady-state power wind turbine can be modeled, then equation (13) can be written as per unit of the system by using equation (14).

$$P_{m\,pu} = k_p C_{p\,pu} V_{w\,pu}^3 \quad (14)$$

where the certain value of ρ and A nominal power in per unit is denoted as $P_{m\,pu}$, the power gain is expressed as K_p which is equal to 1 per unit, the maximum value of C_p performance coefficient is expressed as $C_{p\,pu}$, the base of wind speed in per unit is expressed as V_w.

The nonlinear function C_p is on both the pitch angle and tip speed ratio further it can be described as,

$$C_p(\lambda,\beta) = C_1\left(\frac{C_2}{\lambda_1} - C_3\beta - C_4\right)\exp\left(\frac{-C_5}{\lambda_i}\right) + C_6\lambda \quad (15)$$

$$\frac{1}{\lambda_i} = \frac{1}{\lambda + 0.08\beta} - \frac{0.035}{\beta^3 + 1} \quad (16)$$

The C_p maximum value is assumed as 0.48 at $\lambda = 0.16$, $\beta = 0$.

The wind turbine in the wind power system is connected to the squirrel cage asynchronous generator, and the obtained mechanical energy of the wind turbine is fed to the generator and converted into electrical energy. The wind turbine simulation model is revealed in figure 4,

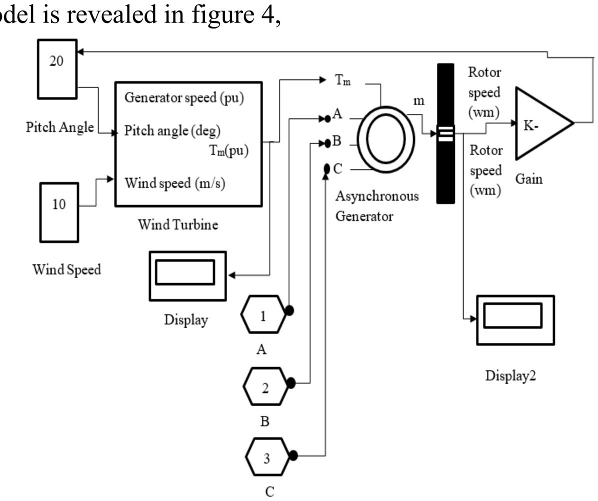


Fig. 4. Wind turbine Simulink model

3.3 Mathematical model for the BaPhin algorithm

The newly developed BaPhin algorithm combines the behavior of Bats (BA)[29] and the sea mammal [30] for various prey-searching attitudes. BA has the benefit of intelligibility and modifiable for easy implementation, thus the corresponding algorithm is adaptable to provide a solution to critical problems. The three main features involved in BA is tuning the frequency, spontaneous zooming, and controlling the parameters. The frequency is slightly adjusted to find out the real function though the echo function is not used directly. The presence of spontaneous tuning may increase the advantage of BA over conventional algorithms. This spontaneous zooming focuses on the regions where the possible solutions are determined. With this zoom, the probe automatically shifts the phases, compared to existing algorithms, BA has a rapid integration rate, in the premature stage of reiteration. Some of the metaheuristic algorithms use standard parameters using pre-tuned algorithmic parameters. Instead of that, BA uses controlling the parameters, which changes the value of the parameter as the repetitions continue. When obtaining the optimal solution, the phase shifts from exploration to exploitation phase is the additional advantage of the BA algorithm.

3.4.1 Inspiration

It is inspired by the specific echolocation behavior of the Microchiroptera suborder, with its different noise and emission pulse range. The velocity and location of individual bats carrying different frequencies and sound with random movement of flies. When they found the prey, it slowly reduces the frequency, sound, and rate of emission. Foraging prey is in the way of the unplanned walk until choosing the suitable position. This random behavior of BA is conquered by the interesting behavior of one type of sea mammal which generate echo for searching the prey. It has the capability to cover large distance objects or its prey by their sound wave traveling. It creates clicks that have the most abundant frequency than the sound evolved for communication and it varies from other species. The own echo has reflected the mammal, without deliberation it tends to generate the next click. Utilizing the time interval between the produced and reflected echoes, the mammal easily finds the distance between the prey and the initial position. The characteristics of covering a large distance for searching the prey is the advantage over the BA algorithm which is coagulated to improve the BaPhin algorithm.

i) Frequency of pulse

The velocity V_m and position p_m obtained in the analyzing search space in dimensional D be decided for individual bats (m). p_m and V_m values are renovated during each iteration. The updated solutions at time T for p_m^{T} and V_m^{T} is estimated by,

$$h_m = h_{\min} + \left(h_{\max} - h_{\min}\right)\alpha \tag{1}$$

$$V_m^{\mathrm{T}} = V_m^{\mathrm{T}-1} + \left(p_m^{\mathrm{T}-1} - p*\right)h_m \tag{2}$$

$$p_m^{\mathrm{T}} = p_m^{\mathrm{T}-1} + V_m^{\mathrm{T}} \tag{3}$$

where α be the random vector from the normal distribution within the range of $[0,1]$. $p*$ is placed after the comparison of all the i bats solutions, which is described as present a suitable solution. The problem of interest, ε_m or h_m is utilized to adjust the changes involved in the velocity.

ii)Objective function:

The determination of the optimal solution is obtained by minimizing or maximizing the parameters $Acc\,F_{(\mathrm{M}+l)i}$ and P_{new}

iii) Random phase:

The solution is obtained once from the present suitable solutions for the localized searching area, the renovated solution is introduced locally for an individual bat utilizing the random walk manner.

$$p_{new} = p_{old} + \omega \mathrm{B}^{\mathrm{T}} \tag{4}$$

Where ω be the random number which is in the range of $[-1,1]$, the bat's average capacity of its loudness at the time step T is $\mathrm{B}^{\mathrm{T}} =< \mathrm{B}_m^{\mathrm{T}}$.

iv) Updating phase:

The Bat optimization contains the combination of intensive local analyzing and PS optimization by its renovating characters in position and velocity, where the h_m has the ability in controlling the range and pace of the maneuver particles. Depending on the pulse rate and loudness, it is able to analyze whether the bat found its food or not. Where the loudness depends on the convenience value, $\mathrm{B}^0 = 1$ and $\mathrm{B}_{\min} = 0$ be utilized for simplicity. If the bat reaches its food it stops the emission of sound temporarily and then $\mathrm{B}_{\min} = 0$.

$$\mathrm{B}_m^{\mathrm{T}+1} = \beta \mathrm{B}_m, s_m^{\mathrm{T}+1} = s_m^0\left[1 - \exp\left(-\nu\mathrm{T}\right)\right] \tag{5}$$

The constants are represented as β and ν, for $0 < \beta, \nu > 1$:

$$\mathrm{B}_m^{\mathrm{T}} \to 0, s_m^{\mathrm{T}} \to s_m^0, as\,\mathrm{T} \to \infty \tag{6}$$

The advantages involved in bat optimization are dynamic control and tuning the frequency belonging to the exploitation and exploration phase. The convergence is better, and the implementation is manageable when compared with the conventional algorithms. The alternate emission of pulse rates and its sound effectively regulate the utilization of exploration and exploitation which is similar to the auto-homing behavior of bats related to its food.

v) Emplacement phase

Finding the prey using echolocation is the characteristic of BA and one type of sea mammal, in which the sea mammal has the tendency to locate the prey over a long distance by producing the sound. The loudness of the produced sound frequency is high when compared to the ranges involved in communication. Some waves are reflected backward facing the sea mammal, depending on the variation in time for the received echoes the echo producer may reduce the loudness or increase the frequency. The Bat lacks the ability in tracking the location of prey over long distances which is covered by coagulating the sea mammal character for accurate detection of its prey location. Now, the BaPhin algorithm can found out its prey over a longer distance by increasing the clicking rates of a sea mammal.

$$p_{new} = p_{old} + \omega\left(Acc\,F_{(\mathrm{M}+l)i}\right) \tag{7}$$

$$Acc\,F_{(\mathrm{M}+l)i} = \frac{1}{\mathrm{K}_g} * \left(\mathrm{K}_g - |l|\right) Fit(j) + Acc\,F_{(\mathrm{M}+l)i},$$

where $Acc\,F_{(\mathrm{M}+l)i}$ is the Accumulative fitness for the $(\mathrm{M}+l)th$ different numbering which is similar to the ordering of the possible matrix. The fitness is evaluated by using the characteristic of reflection, where the space between possible location and edge is lower than K_g.

vi) Termination:

The stages involved in the BaPhin algorithm are used frequently until the reach of the best solution p_{best} is specified. The pseudocode prepared for the developed BaPhin algorithm is explained in algorithm 1 and systematically shown in figure 5.

S. No	Algorithm 1. BaPhin algorithm pseudocode
1.	Input: $p^m(\mathrm{T}); (1 < m < \mathrm{N}_n)$
2.	Output: p_{best}
3.	Initialize: Population of bat $p_i\,(i = 1, 2, 3, ...n)$
4.	Determine the objective function
5.	Updating phase
6.	Emplacement phase
7.	Initial position: $p_m^{\mathrm{T}} = p_m^{\mathrm{T}-1} + V_m^{\mathrm{T}}$
8.	Random walk search #Random phase
9.	if $\left(\mathrm{B}^{\mathrm{T}} =< \mathrm{B}_m^{\mathrm{T}}\right)$
10.	Enable random walk (4)
11.	Else if $\left(\mathrm{B}_{\min} = 0\right)$
12.	Update the position (5)
13.	End if
14.	Exploring the distance # emplacement phase
15.	$p_{new} = p_{old} + \omega\left(Acc\,F_{(\mathrm{M}+l)i}\right)$
16.	Reduce the iteration
17.	Choose finest position
18.	End while

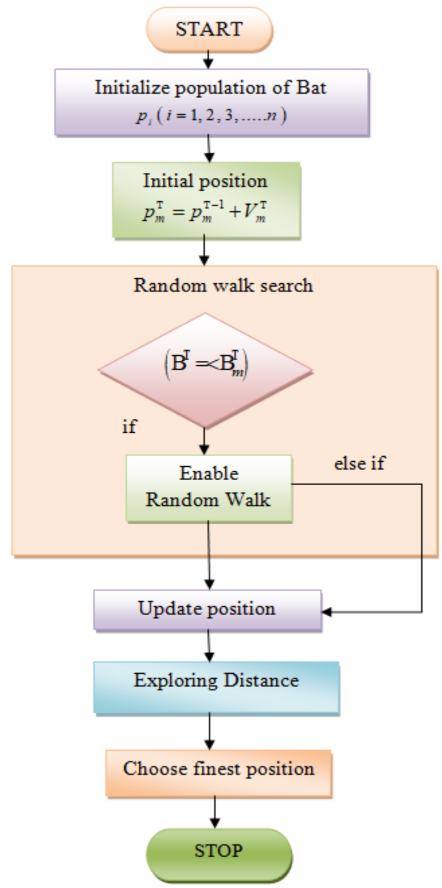


Fig. 5. Flow chart of the BaPhim algorithm

3.5Modelling of PV STATCOM and its operation as a Smart inverter

The PV STATCOM contains VSC, which acts as the smart inverter for providing or absorbing reactive and real power from the system. The power generated from the system is regulated by the utilization of phase angle and amplitude of the voltage. In this grid-connected PV system, both the real and reactive power is regulated by the $dq-axis$ reference frame current components. The smart inverter emulates the function of STATCOM which includes absorbing or injecting actual and reactive power. Thus, the smart inverter operation is considered as the two modes of operation partial STATCOM in full PV mode and full STATCOM mode. In mode 1, the inverter potential under the actual power generation is required for the smart inverter to function as a STATCOM. In mode 2, the PV inverter operates in full STATCOM mode by cutting-off actual power generation for a short term in the smart inverter where the demand for reactive power is higher than the residual capacity of the inverter. Consequently, the $q-axis$ reference value is determined by the Point of Common coupling voltage regulator or the regulation module of power factor, and at the same time, current variation in $d-axis$ mainly depends on the PV system operating modules.

i) Active and Reactive power control:

During the daytime, the full PV mode of operation is exhibited for the smart inverter in which the real power is generated by the execution of controlling the $d-axis$ higher value. At the same time during nightfall, the DC capacitor is being charged by maintaining the $d-axis$ component reference value as low. Therefore, the smart inverter acts as partial STATCOM of full PV mode during day hours and acts as full STATCOM during nightfall time. Eventually, the switching pulses get generated by the PWM generator which is then fed forward to IGBT switches for managing VSC, here the Phase Locked Loop is utilized for evaluating the phase angle via the abc/dq conversion and vice versa.

ii) Designing of PV STATCOM:

DC-AC conversion takes place in the STATCOM and the voltage is generated during the lack of external capacitor banks. The reactive power absorption generates source voltage by assuming the point as a common coupling. Over the equilibrium condition, the balanced three-phase voltages are generated as output by the STATCOM with the regulated phase angle and amplitude. Generally, the process of transferring power between the generator and AC system is obvious and the transferred power is mostly in reactive capacity. The output voltage of the transformer phase angle and magnitude is controlled for the effective way of transferring power in-between the AC system and generator in which the phase angle and magnitude-controlled value is determined. The STATCOM inverter magnitude and frequency are fixed for satisfying the above-mentioned conditions. When the output voltage of PV STATCOM is higher than the voltage of AC system $\left(V_{STATCOM} > V_{AC}\right)$, the current flows in the direction of STATCOM to the AC system via the reactance in the transformer. With the utilization of the STATCOM device, the reactive power is distributed to the transmission line.

The device is need to be operated in capacitive mode if the output voltage is greater than the voltage in the transmission line in the STATCOM controllers. The capacitor plays a major role in the inverter as the DC voltage supply unit where the capacitor function depends on discharging or charging rate, the inverter and AC system voltage phase difference is also taken into account. The generated real power from the AC power system to the STATCOM is considered by rejecting the resistance in the transformer whereas, only the reactive power is generated as an input. The real power mathematical equation is expressed as,

$$\mathrm{P} = \frac{V_{AC} \cdot V_{STATCOM} \cdot \sin\alpha}{\mathrm{X}} \tag{17}$$

The output voltage of the inverter and the system reactive power or the voltage is in the same phase when $\alpha > 0$. The flow of reactive power is from the AC system to the STATCOM or vice versa if $\alpha < 0$. The capacitor is in charging mode if $\mathrm{P} > 0$ and the capacitor starts discharging when the controller terminates the condition as $\mathrm{P} < 0$. The flow of reactive power in the STATCOM is evaluated as,

$$Q = \frac{V_{AC} \cdot V_{STATCOM} \cdot \mathrm{Cos}\,\alpha - V_{AC}^2}{\mathrm{X}} \tag{18}$$

where the voltage in AC system is denoted as V_{AC} and the output voltage of the inverter is represented as $V_{STATCOM}$, the transformer equivalent resistance is denoted as X, and the voltage phase difference is represented as α . The AC output amplitude is calculated by maintaining the voltage V_{dc} at constant with varying modulation index $\left(m_a\right)$.

Conditions for computing AC output voltage with respect to $\left(m_a\right)$*:* The modulation index value varies between $0 < m_a < 1$. Depending on the modulation index, the performance of the STATCOM varies, if $m_a = 0.75$ the STATCOM controller has no exchange of power and the STATCOM voltage is equal to the AC voltage which is given as $V_{AC} = V_{STATCOM}$. If the modulation index $m_a = 0.65$ then $V_{STATCOM} < V_{AC}$, the voltage of the STATCOM is lesser than that of the AC System voltage and the STATCOM behaves as an inductor. When the modulation index m_a is equal to 0.85 then $V_{AC} < V_{STATCOM}$, the voltage of the AC system is lesser than that of the STATCOM voltage, here the STATCOM behaves as the capacitor. The inverter output voltage in STATCOM is evaluated by,

$$V_{STATCOM} = V_{ef} \cdot \frac{\sqrt{3}}{2} \tag{19}$$

$$V_{ef} = V_{dc} \cdot \frac{m_a}{2} \tag{20}$$

The STATCOM output is modified by assuming the value of V_{dc} as constant and vary the value of m_a by using the equations (19) and (20). The reactive power is limited in the grid which is compensated by the varying mode of the STATCOM controller as inductive or capacitive mode and it regulates the transmission loss. The insulated-gate bipolar transistor (IGBT) power electronics switching elements in the inverter aids in regulating the STATCOM with the Pulse Width Modulation method. PI controller is utilized for regulating the STATCOM controller and with the aid of PLL and PI controller, the circuit is simulated in MATLAB/Simulink.

iii) Active and reactive power control circuit:

To ensure uniform and transient performance, the synchronously rotating reference frame dq is utilized for modeling the smart inverter. The real and reactive power control circuit is illustrated in figure 2. The acquired grid current I_{abc}, phase angle and grid voltage V_{abc} components in $d-axis$ and $q-axis$ are taken into account for obtaining the active and reactive power which is fed to the generation of the magnitude of voltage and dq components from which the voltage and current regulation is extinct. PLL is mainly utilized by the smart inverter in grid-connected PV systems for synchronizing the frequency with the grid and the PV system is in phase. The DC connection voltage provides active power to the inverters, thus compensating for the power shortage of the switches due to the lack of optimal performance of the switches in the inverter, which completely discharges the DC connection capacitor. In order to maintain the charge in the capacitor, the accessible real power is provided by the inverter. During the availability of sunlight, the smart inverter utilizes less amount of sunlight for charging the capacitor, and large amount is distributed to the grid for charging the diode. The inverter working in dq frames for obtaining the real power is evaluated using the equation (21),

$$P_s(t)=\frac{3}{2}\left(V_{pcc-d}(t)I_{sd}(t)+V_{pcc-q}(t)I_{sq}(t)\right) \tag{21}$$

The inverter working in dq frames for obtaining the reactive power is evaluated using equation (22),

$$Q_s(t)=\frac{3}{2}\left(-V_{pcc-d}(t)I_{sq}(t)+V_{pcc-q}(t)I_{sd}(t)\right) \tag{22}$$

The PCC voltages are represented as $V_{pcc-d}(t)$ and $V_{pcc-q}(t)$, the inverter output current is denoted as I_{sq} and I_{sd} in the dq frame. $V_{pcc-d}=V$ and $V_{pcc-q}=0$, it shows that at certain Point of common coupling (PCC) voltage the output real and reactive power of the inverter is moderated by $I_{sq}(t)$ and $I_{sd}(t)$ output currents. Thus, PLL plays an important role in both real and active power decoupling control.

iv) Improving power factor:

Power factor is the major component for compensating the reactive power, thus the improvement in power factor is involved in the PV systems for maintaining the required reactive power supplied to the load. When the grid power factor is increased, the phase angle between the PCC voltage and the grid current is reduced. Assume the grid current i_g is in the leading phase angle concerning the PCC voltage V_{pcc}. PLL holds the phase angle to maintain the PCC voltage in $d-axis$, where $V_{pcc-q}=0$, and $V_{pcc-d}=V$. The phase difference δ that is between voltage and current is decreased for improving the power factor and it is expressed as $PF=\cos\delta$.

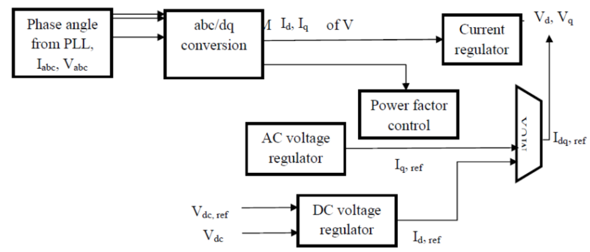


Fig. 6. PV STATCOM control circuit

iv) System design on grid distribution:

The AC electrical signal is transmitted through the transmission line for the related loads inside the bus bar. The appearance of voltage fluctuations is regulated in the STATCOM by inserting the PCC. Initially, the voltage, current and reactive power is computed in the absence of STATCOM. The voltage, current, power factor, and reactive power is regulated and the time domain is estimated by the optimized PI controller in the STATCOM controller. In figure 6, maintaining the current, voltage, reactive power, and power factor is shown. Therefore, the system with an uninterrupted power supply is maintained by employing the enhanced optimization in the PV system. The controller's prime function is to accurately predict the parameters for tuning and optimal regulation which is enhanced by the developed optimization.

4. Results and Discussion

The performance of the BaPhin optimization in terms of the DC, dc voltage, grid, as well as the inverter current, voltage, reactive power, active power, power factor, Quadrature current, load active, reactive, and power factor, are evaluated in this section with the other existing methods for the reactive power compensation.

4.1 Comparative methods

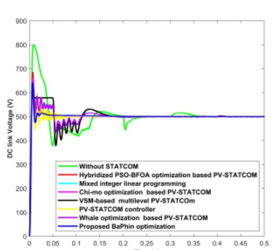
The existing methods considered for evaluating the performance of the BaPhin optimization are without STATCOM [31], Hybridized PSO-BFOA optimization- PV-STATCOM [21], Mixed integer linear programming [26], Virtual synchronous machine (VSM)-multilevel PV-STATCOM [18], and PV-STATCOM controller [20]Whale Optimization PV-STATCOM [27], Chi-mooptimization PV-STATCOM[28].

4.1.1 Comparisonon the DC link voltage, direct currentand Quadrature current

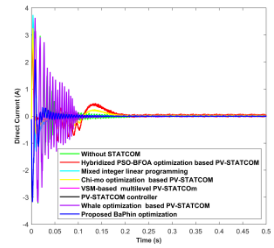
Figure 7 reveals the comparative performance of the BaPhin optimization along with the existing methods for the dc link voltage and direct current. The dc link voltage highly oscillates initially around 0 to 0.2 s than the BaPhin optimization-controller for compensating the reactive power, which is revealed in figure 7 a). The dc link voltage of the BaPhin optimization-controller is 500 Vwith the reference voltage as 500 V at the instant of 0.4989 s, in which the other existing methods still oscillating between the voltages of 498 V and 499 V.

Figure7b) reveals the direct current of the BaPhin optimization-controller with the other existing methods. The BaPhin optimization-controller attains the direct current as 0.0097 A with the reference current as 0 A at the instant of 0.4997 s. The other existing methods generally vary between 0.02 A to 0.4 A at the same instant.

Figure 7 c) reveals the quadrature current of the BaPhinand the other existing methods. The quadrature current for the without STATCOM is 1.0188 A, the hybridized PSO-BFOA optimization-PV-STATCOM is 1.0188 A, mixed integer linear programming is -0.0114 A, the VSM- multilevel PV-STATCOM is -0.03662 A, the PV-STATCOM controller is -0.3662A,Whale Optimization PV-STATCOM-0.246A, Chi-mo optimization PV-STATCOM0.273A and the BaPhin optimization attains the quadrature current as 1.0093 A.



a)



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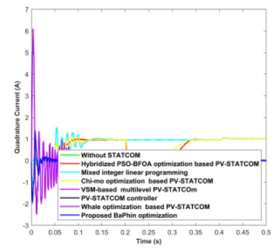


c)

Fig. 7. Comparisionof a) DC link voltage b) Direct current c) quadrature current

4.1.2 Comparison based on the grid

Figure 7 reveals the comparative performance of theBaPhin optimization for the power compensation in the grid.The active power of the grid without STATCOM, Hybridized PSO-BFOA optimization-PV-STATCOM, Mixed integer linear programming, VSM-multilevel PV-STATCOM, PV-STATCOM controller,Whale Optimization PV-STATCOM, Chi-mo optimization PV-STATCOMand BaPhin optimization-controllerat 0.5 sec is 66.9529kW, 68.0433kW, 68.3103kW, 87.6381kW, 88.8923kW, 78.177kW, 90.765kW and 98.7387kW, respectively, which is revealed in figure 8a).

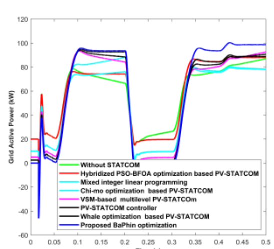
Figure 8b) shows the reactive power of the methods across the grid. The reactive power of the grid without STATCOM, Hybridized PSO-BFOA optimization-PV-STATCOM, Mixed integer linear programming, VSM- multilevel PV-STATCOM, PV-STATCOM controller, Whale Optimization PV-STATCOM, Chi-mo optimization PV-STATCOMand BaPhin optimization- controller at 0.5 sec is -0.3326kVAR, -0.3110kVAR, -0.3181kVAR, -0.3193kVAR, -0.7464kVAR, -0.315kVAR, -0.214kVAR and -0.3297kVAR, respectively

.

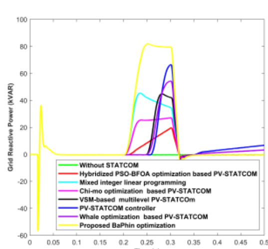
Figure 8c) shows the power factor of the methods across the grid. The power factor of the grid without STATCOM, Hybridized PSO-BFOA optimization-PV-STATCOM, Mixed integer linear programming, VSM- multilevel PV-STATCOM, PV-STATCOM controller, Whale Optimization PV-STATCOM, Chi-mo optimization PV-STATCOM and BaPhin optimization-controller at 0.5 sec is 0.9893, 0.9939, 0.9938, 0.994, 0.9893,1.006,1.004, and 1, respectively.

Figure 8 d) indicates the current response of the comparative methods. The current through the grid without STATCOM in a,b,c phase-1.9978A, -1.2586A, and 3.2564A, respectively. The current through the grid for the system with Hybridized PSO-BFOA optimization-PV-STATCOMin a-phase, b-phase, and c-phase are -2.003A, -1.2484A, and 3.2514A, respectively. The current through the grid for the system with mixed integer linear programming in a-phase, b-phase, and c-phase are -1.9981A, -1.2588A, and 3.2569A, respectively. The current through the grid for the system with VSM- multilevel PV-STATCOM in a-phase, b-phase, and c-phase are -1.9978A, -1.2571A, and 3.2549A, respectively. The current through the grid for the system with PV-STATCOM controller in a-phase, b-phase, and c-phase are -2.0005A, -1.2501A, and 3.2506A, respectively. The current through the grid for the system with the BaPhin optimization- controller in a,b,c phase are -2.0615A, -1.2292A, and 3.2907A, respectively.

Figure 8e) indicates the voltage response of the comparative methods. The voltage through the grid without STATCOM in a,b,c phase are -110.8513V, -68.3073V, and 179.1586V, respectively. The voltage through the grid for the system with Hybridized PSO-BFOA optimization-PV-STATCOMin a-phase, b-phase, and c-phase are -121.9401V, -75.1357V, and 197.0758V, respectively. The voltage through the grid for the system with mixed integer linear programming a,b,c phase are -121.9364V, -75.1380V, and 197.0745V, respectively. The voltage through the grid for the system with VSM-multilevel PV-STATCOMin a-phase, b-phase, and c-phase are -152.4228V, -93.9240V, and 246.3468V, respectively. The voltage through the grid for the system with PV-STATCOM controller in a-phase, b-phase, and c-phase are -203.2277V, -125.2228V, and 328.4505V, respectively. The voltage through the grid for the system with the BaPhin optimization-controller in a,b,c phasea re -270.9658V, -166.9676V, and 437.9334V, respectively.



a)



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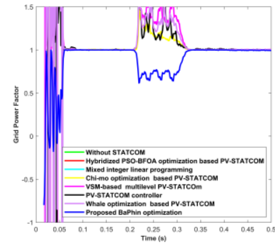
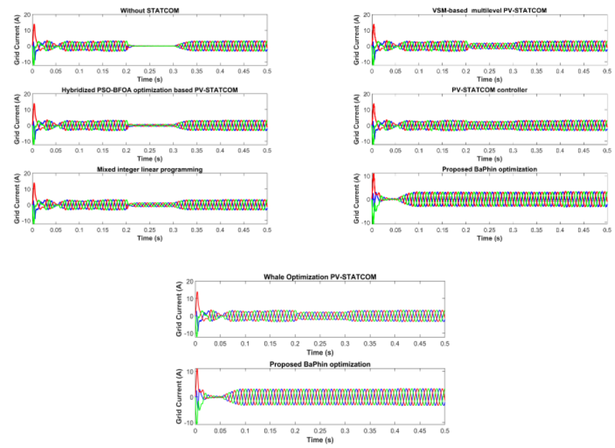
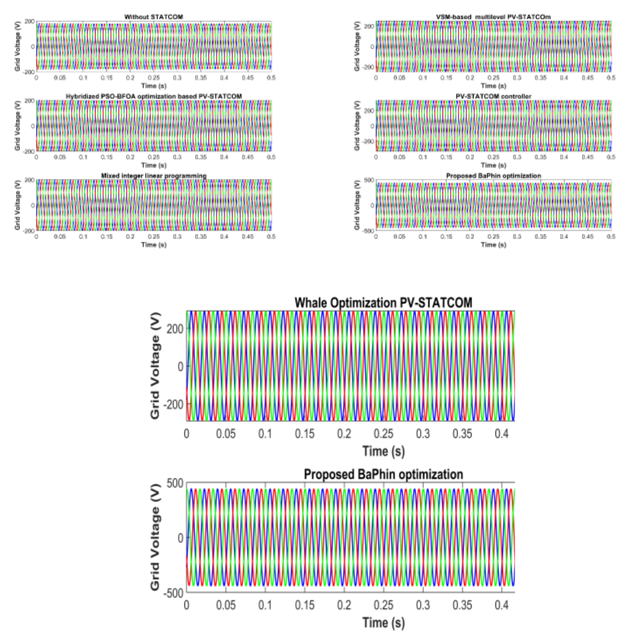


c)



d)



e)

Fig. 8. Comparision of grid factor performance a) Grid Active power b) Grid reactive power c) Grid power factor d) Grid current e) Grid voltage

4.1.3 Comparison based on the inverter

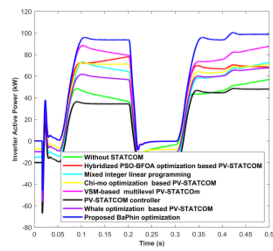
Figure 9 reveals the comparative performance of the BaPhin optimization for the power compensation in the inverter. The active power of the inverter without STATCOM, Hybridized PSO-BFOA optimization-PV-STATCOM, Mixed integer linear programming, VSM-multilevel PV-STATCOM, PV-STATCOM controller, Whale Optimization PV-STATCOM, Chi-mo optimization V-STATCOM and BaPhin optimization controller at 0.5 sec is 90.7944kW, 87.9607kW, 89.7374kW, 88.6455kW, 88.6519kW, 70.474kW, 67.841kW and 90.7944kW, respectively, which is revealed in figure 8 a).

Figure 9b) shows the reactive power of the methods across the inverter. The reactive power of the inverter without STATCOM, Hybridized PSO-BFOA optimization PV-STATCOM, Mixed integer linear programming, VSM multilevel PV-STATCOM, PV-STATCOM controller, Whale Optimization PV-STATCOM, Chi-mo optimization PV-STATCOM and BaPhin optimization- controller at 0.5 sec is -13.3753kVAR, -9.7576kVAR, -9.9993kVAR, -9.7336kVAR, -9.7274kVAR, -17.815kVAR, -0.286 kVARand -13.3753kVAR, respectively.

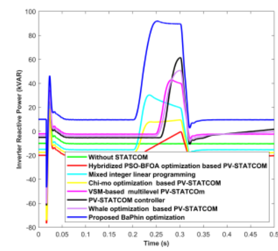
Figure 9 c) shows the power factor of the methods across the inverter. The power factor of the inverter without STATCOM, Hybridized PSO-BFOA optimization-PV-STATCOM, Mixed integer linear programming, VSM-multilevel PV-STATCOM, PV-STATCOM controller, Whale Optimization PV-STATCOM, Chi-mo optimization PV-STATCOM and BaPhin optimization- controller at 0.5 sec is 0.7854, 0.7651, 0.8008, 0.687, 0.6879, 0.469 , 0.340 and 0.9998, respectively.

Figure 9 d) indicates the current response of the comparative methods. The current through the inverter without STATCOM in a,b,c phase are -262.8307A, -17.1166A, and 279.9473A, respectively. The current through the inverterfor the system with Hybridized PSO-BFOA optimization- PV-STATCOM in a,b,c phaseare -262.7129A, -17.1082A, and 279.8211A, respectively. The current through the inverter for the system with mixed integer linear programming in a,b,cphaseare-262.7396A, -17.2352A, and 279.9749A, respectively. The current through the inverter for the system with VSM-multilevel PV-STATCOM in a,b,c phase are 262.8550A, -17.1276A, and 279.9826A, respectively. The current through the inverterfor the system with PV-STATCOM controller in a,b,c phasephase are -255.2123A, -12.7025A, and 267.9148A,respectively. The current through the inverter for the system with the BaPhin optimization- controller in a,b,c phase are -262.6986A, -16.7234A, and 279.4220A, respectively.

Figure 9 e) indicates the voltage response of the comparative methods. The voltage through the inverter without STATCOM in a,b,cphasephase are-338.8770V, 329.392V, and 9.485V, respectively. The voltage through the inverterfor the system with Hybridized PSO-BFOA optimization-PV-STATCOM in a,b,c phaseare-336.6995V, 332.0476V, and 4.652V, respectively. The voltage through the inverterfor the system with mixed integer linear programming in a,b,c phaseare7.1744V, 384.5548V, and -391.7291V,respectively. The voltage through the grid for the system with VSM-multilevel PV-STATCOM in a,b,c phaseare -249.2413V, -2.8752V, and 252.1165Vrespectively. The voltage through the inverterfor the system with PV-STATCOM controller in a,b,cphasephase are-249.3624V, -2.8559V, and 252.2182V, respectively. The voltage through the inverterfor the system with the BaPhin optimization-controller in a,b,c phaseare-248.039V, -3.9801V, and 252.0191V, respectively.



a)



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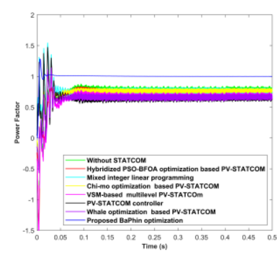

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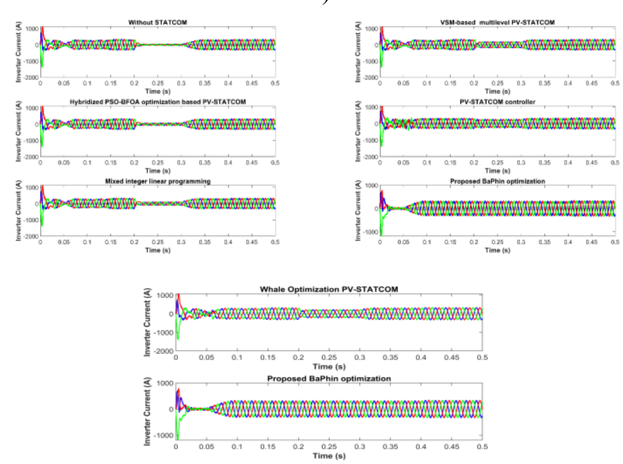

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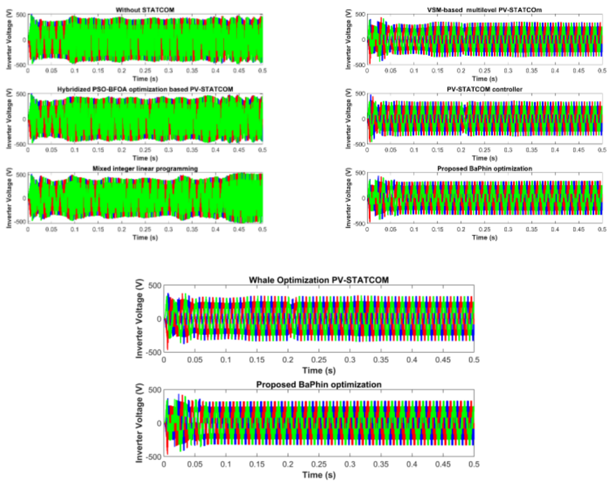


e)

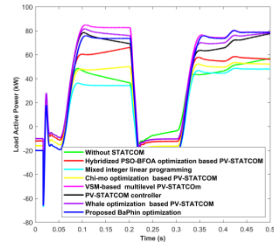
Fig. 9. Comparison of inverter-factor performance a) active power b) inverterreactive power c) inverterpower factor d) invertercurrent e) invertervoltage

4.1.4 Comparison based on the load

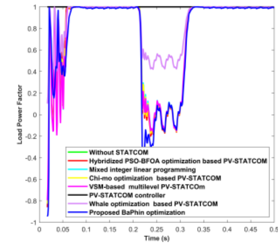
Figure 10 reveals the comparative performance of the BaPhin optimization for the power compensation in the load. The active power of the load without STATCOM, Hybridized PSO-BFOA optimization-PV-STATCOM, Mixed integer linear programming, VSM-multilevel PV-STATCOM, PV-STATCOM controller, Whale Optimization PV-STATCOM, Chi-mo optimization PV-STATCOM and BaPhin optimization controller at 0.5 sec is 84.3698kW, 88.5988kW, 88.5988kW, 88.6519kW, 88.125kW, 52.177kW, 78.265 and 84.3698kW, respectively, which is revealed in figure 10a).

Figure 10b) shows the reactive power of the methods across the load. The reactive power of the loadwithout STATCOM, Hybridized PSO-BFOA optimization-PV-STATCOM, Mixed integer linear programming, VSM- multilevel PV-STATCOM, PV-STATCOM controller, Whale Optimization PV-STATCOM, Chi-mo optimization PV-STATCOM and BaPhin optimization- controller at 0.5 sec is -5.1345kVAR, -9.721kVAR, -9.721kVAR, -9.7274kVAR, -9.6426kVAR,-6.315kVAR, -4.286kVAR and -5.1345kVAR, respectively.

Figure 10c) shows the power factor of the methods across the load. The power factor of the load without STATCOM, Hybridized PSO-BFOA optimization-PV-STATCOM, Mixed integer linear programming, VSM-multilevel PV-STATCOM, PV-STATCOM controller, Whale Optimization PV-STATCOM, Chi-mo optimization PV-STATCOM and BaPhin optimization-controller at 0.5 sec is 0.7843, 0.7692, 0.8102, 0.6849, 0.7013,0.994, 0.997 and 1, respectively.



a)



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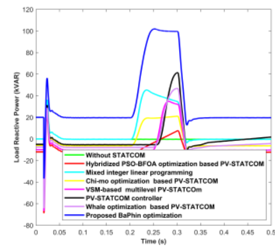

c)

Fig.10. Comparison of performance for the load a) load Active power b) load reactive power c) load power factor

4.2 Comparative Discussion*:* The power compensation's performance is laterally improved using the STATCOM controller with the combination of BaPhin optimization where the low and high frequencies are considered at high frequency travels a short distance and low frequency travels a long distance to find the correct resolution at less time.

The BaPhin algorithm compensates the voltage, current, real, and reactive power in thedistribution system that reduces the power loss. The LC filter present neglects the high-frequency noise that provides the best voltage regulation that is highly suitable for high-power applications. Table 1 discusses the comparison of BaPhin optimization with various existing methods on DC link voltage, direct current, and quadrature current that provides an optimal result while table 2 discusses on grid, inverter, and load.

Table 1. Comparative discussion of BaPhinconcerning D.C link voltage and D.C current

Method	**D.C link Voltage (0.5 sec)**	**Direct current (0.5 sec)**	**Quadrature current (0.5 sec)**
Without STATCOM	501.576	-0.026	1.0188
Hybridized PSO-BFOA optimization PV-STATCOM	499.881	-0.022	1.0188
Mixed integer linear programming	500.064	-0.018	-0.0114
VSM- multilevel PV-STATCOM	501.874	-0.025	-0.0366
PV-STATCOM controller	500.438	-0.025	-0.0366
Chi-mooptimization PV-STATCOM	499.97	-0.296	-0.246
Whale Optimization PV-STATCOM	501.16	0.619	0.273
BaPhin optimization	**499.915**	**0.006**	**1.0093**

Table 2. Comparative discussion of BaPhin optimization on grid, inverter, and load

Method	Grid			Inverter			Load		
	Active power	Reactive power	Power factor	Active power	Reactive power	Power factor	Active power	Reactive power	Power factor
Without STATCOM	66.953	-0.333	1.002	66.953	-10.333	0.785	66.953	-0.333	0.989
Hybridized PSO-BFOA optimization-PV-STATCOM	68.043	-0.311	1.006	68.310	-20.311	0.765	68.043	-12.311	0.994
Mixed integer linear programming	68.310	-0.318	1.006	87.638	-15.318	0.801	68.310	-0.318	0.994
VSM-multilevel PV-STATCOM	87.638	-0.319	1.006	87.638	-2.319	0.687	87.638	-10.319	0.994
PV-STATCOM controller	88.892	-0.746	0.994	68.043	1.746	0.688	88.892	1.746	0.995
Chi-mooptimization PV-STATCOM	78.177	-0.315	1.001	70.474	-17.815	0.469	52.177	-6.315	0.994
Whale Optimization PV-STATCOM	90.765	-0.214	1.000	67.841	-0.286	0.340	78.265	-4.286	0.997
BaPhin optimization	**98.739**	**-0.330**	**1.002**	**98.739**	**9.670**	**1.000**	**98.739**	**19.670**	**0.989**

4.3 Convergence Analysis

The graphical display of various existing methods such as without STATCOM, Hybridized PSO-BFOA optimization- PV-STATCOM, Mixed integer linear programming, VSM-multilevel PV-STATCOM, PV-STATCOM controller,Whale Optimization PV-STATCOM, Chi-mo optimization PV-STATCOMand BaPhin optimization- controller along with the BaPhin optimization on the basis of cost estimation and iteration provides the value of 0.42997, 0.441246, 0.579006, 0.406673, 0.402504, 0.696927, 0.473971, and 0.540029is given in figure 11.

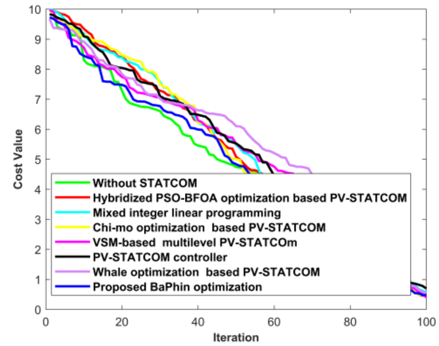

Fig. 11. Convergence Analysis

5. Conclusion

In this research, a smart optimized inverter for distributed grid systems' reactive power compensation as well as a novel optimized controller for controlling current, reactive power, voltage and power factor is developed. The BaPhin algorithm is used to optimize the PV-STATCOM controller, which will adjustthe voltage, current, real, and reactive power in the distribution system. The STATCOM, one of the FACTS components, regulates the voltage-current elements and balances the reactive power in the power system. The suggested BaPhin optimization algorithm regulates the grid-connected PV system's voltage, current, power factor, and reactive power while optimally adjusting the proportional controller in the regulators. The performance of the BaPhin optimization attains better performance in all the considered measures on the grid as well as the inverter in the distributed system and that are applied in the power system network.The optimization technique is significant for well-tuning the hyperparameters of the PI controller in the reactive power compensation of the smart inverter. In the future, the reactive power compensation is enhanced by using different optimization strategies.In future, the research can be carried out on the damping level of oscillations for analyzing the fast restoration capabilities of the PVSTATCOM.

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