



Hybrid KHSO Based Optimal Location and Capacity of UPFC for Enhancing the Stability of Power System

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Abstract

Recently power losses and voltage volatility issues are the real issues in power system and production cost likewise goes high. Certainties idea made a revolution in power system which conquers every one of the issues. Numerous strategies are utilized to optimize the area of FACTS gadgets. Among the few FACTS controllers, the paper introduces the Unified Power Flow Controller (UPFC) to enhance the improvement of voltage stability and decreases the power loss. Here, the hybrid model (KHSO) i.e. Krill Herd Optimization (KHO) and Particle Swarm Optimization Techniques (PSO) are utilized for enhancing the voltage dependability of the power transmission systems. The hybrid model is connected in light of IEEE 30 BUS System. From the power stream examination, bus voltages, active power, reactive power, cost and power loss incurring in transmission systems are resolved. The voltages of the buses with and without UPFC are likewise revealed. It is evidently apparent from the outcomes that viable position of UPFC in appropriate areas can fundamentally enhance system execution. The outcome demonstrates that voltage profile is improved at buses and power losses are impressively diminished minimization of power losses and minimization of generation cost. Accordingly, it demonstrates that the productivity of KHSO is superior to the conventional technique (Firefly and GA).

1. INTRODUCTION

Present day power systems are inclined to extensive disappointments because of increment in power demand, so power system engineers are at present confronting difficulties to enhance control exchangeability of the current transmission system [1]. Flexible AC Transmission System (FACTS) controllers are acquainted with the power system to improve the security, capacity, and flexibility of energy transmission systems [2]. It is likewise utilized to reduce transmission loss and to enhance the voltage profile of the system [3]. A new prospect in the name of FACTS opens up for controlling the associated terms in power and improving the feasible limit of the transmission systems [4]. The prospects emerge through the capacity of FACTS controllers to control the interrelated parameters that represent the task of transmission systems [5], which incorporates the arrangement/shunt impedances, current angle, phase angle and damping of oscillations at different frequencies underneath the appraised recurrence [6]. This FACTs gadget joins the two highlights of two different FACTS gadgets STATCOM (static synchronous compensator) and SSSC (the static synchronous series compensator) [7]. Essentially, these gadgets are voltage source converters (VSC's). The Unified Power Flow Controller (UPFC) is a for the most part Synchronous Voltage Source (SVS) [8]. As of late FACTS controllers, such as UPFC and Interline Power Flow Controller (IPFC) have been connected for damping oscillations and enhancing the dynamic stability of power systems [9]. The utilized UPFC display is basic and supportive to comprehend the effect of UPFC on the power systems. In any case, amplitude modulation and phase-angle control signals of the Series Voltage Source Inverter (VSI) must be balanced physically so as to locate the desirable load-stream arrangement [10]. The DC interface control of the dynamic/receptive powers can be connected effortlessly to this strategy and it is appropriate for UPFC applications [11].

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Minimization of actual power losses in systems is taken as target capacity and simulation is completed with arrangement of UPFC is done in view of the less estimation of actual power loss [12]. Additionally, assurance of optimal region of UPFC for improving the security of an interconnected power system under single line possibility by utilizing evolutionary algorithmic approach is the fundamental saying of the proposed work [13]. Execution examination of various FACTS gadgets for the static voltage dependability upgrade is the principle subject and for minimization of actual power loss and also add up to fuel cost [14]. The results are gotten for adjusted IEEE 30 bus system without and with the nearness of UPFC [15]. Numerous examinations on the power flow control of transmission line can be completed with various optimization algorithms [16]. From the concise audit introduced above, it can be inferred that the [17] proposed algorithm is pertinent to control the power flow in the transmission line with more proficiency and stability.

2. LITERATURE REVIEW

In 2014 Gokulakrishnan et al. [18] proposed a Genetic Algorithm (GA) based optimization algorithm was utilized to decide the optimal arbitrary development factor of fireflies. The proposed algorithm enhances the load capacity of power system with Unified Power Flow Controller (UPFC). Consequently, the optimal solution and limit of UPFC are resolved productively when contrasted with conventional firefly calculation. The proposed technique actualized in MATLAB and the optimal location and limit of UPFC were inspected according to the variety of voltage, power loss and power balance of the system. The load control execution of the proposed technique was contrasted with traditional firefly calculation.

In 2014 Gokulakrishnan [19] had proposed a Modified Firefly Algorithm (MFFA) based optimal location and estimating of Unified Power Flow Controller (UPFC) to advance the dynamic strength is anticipated. Now, the highest power loss bus was recognized and no more capable location for settling the UPFC, as the generator blackout aggravates the power flow limitations like power loss, voltage, and dynamic and reactive power flow. An FFA (Firefly Algorithm) was investigated with the assistance of Gravitational Search Algorithm (GSA). The anticipated algorithm advances the loadability of power scheme with UPFC. The arrangements we have achieved assign that introducing UPFC in the location enlarged by MFFA can seriously enhance the loadability of power scheme by lessening the over-burden lines and the bus voltage edge violation.

In 2015 [20] to limit actual power losses in an power system by utilizing BAT optimization algorithm with and without the nearness of UPFC was proposed by Venkateswara Rao et al. Reduction of actual power losses was finished by looking into the power created by generator buses, voltage magnitudes at each generator buses and responsive power infusion from receptive power compensators. The proposed BAT Algorithm (BA) based Optimal Power Flow (OPF) has been tried on a 5 bus test system and adjusted IEEE 30 bus system without and with UPFC. The outcomes of the system with and without UPFC were contrasted as far as dynamic power losses in the transmission line utilizing BAT calculation. The acquired outcomes were additionally contrasted with the Genetic Algorithm (GA).

In 2017 Ravindra et al. [21], a novel severity work was detailed utilizing transmission line loadings and bus voltage magnitude deviations. The proposed severity facility and generation fuel cost targets were examined under transmission line(s) or potentially generator(s) possibility conditions. The system security under possibility conditions was analyzed utilizing optimal power flow issue. A new type of hybrid Improved Teaching Learning Optimization (ITLBO) algorithm has been looked into. To increase the system security under possibility conditions within the presence of UPFC. The whole proposed procedure was tried on standard IEEE-30 bus test system with its supporting data and graphical outcomes. In 2013 Thirumalaivasan et al. [22] announced the investigation and analysis of Subsynchronous Resonance (SSR) qualities of compensated hybrid system with Generalized Unified Power Flow Controller (GUPFC). The different working mode combined series converted and shunt converter were considered to research their effect on SSR qualities. The strategies for examination of SSR with GUPFC depended on the assessment of damping torque, eigenvalue of the system and transient reenactment. The calculation of damping torque considers D– Q model of GUPFC to decide the torsional mode strength.

The examination was performed on a framework adjusted from benchmarked IEEE Second Model (SBM). The outcomes showed that the adequacy of series actual infused voltage in moderating the SSR. In 2014 Vyakaranamet al. [23] had introduced a combined solution to control power quality in the Unified Power Flow Controller (GUPFC) during unflinching and transient conditions utilizing a dynamic consonant space strategy. This procedure enables the client to dissect music created in the GUPFC more absolutely than utilizing time domain strategies. The induction of a model was introduced and after that reenacted within the sight of voltage unsettling influences to exhibit its utilization in power quality evaluation. The consequences of the proposed model were approved against time domain reproductions. In 2011 Baskar et al. [24] had proposed a novel setup utilizing multistage two-leg three stage converters for UPFC. The exchanging level displaying of UPFC was done utilizing IGBT based shunt and series converters. The proposed converter has the capacity of conveying sinusoidal input current with unity power factor and bidirectional power flow. The working execution of UPFC was shown on Single Machine Infinite Bus (SMIB) system and IEEE 30 Bus system for various load conditions. The actual and responsive power tracings through the transmission lines in the system were acquired. The reenactment considers was done in a MATLAB/SIMULINK condition.

In 2015 Khadanga et al. [25] displayed an appropriate tuning technique for enhancing the damping controller parameters by utilizing a novel hybrid Genetic based– Gravitational Search Algorithm (GA-GSA). This FACTS based damping controller parameter plays a role in advanced utilizing the proposed technique. The focal research objective should end in enhancing the optimal settings of the factors for the damping controller acquired by utilizing the above-proposed algorithm. The broad test comes about on various benchmarks demonstrated that the hybrid technique based algorithm performs superior to standard Gravitational Search Algorithm (GSA) and Genetic Algorithm (GA).

In 2016 Susanta Dutta et al. [26] had displayed an enhanced evolutionary algorithm in view of Oppositional Krill Herd Algorithm (OKHA) for amassing steady-state execution of power systems. This work likewise proposed the impact of locating UPFC in the steady-state examination and to show the capacities of UPFC in governing the power stream inside any electrical system. To confirm the viability of Krill Herd Algorithm (KHA) and OKHA, two distinctive single target capacities, such as reduction of actual power losses and change of voltage profile and a multi-target work that at the same time limits transmission losses and voltage deviation have been considered through standard IEEE 57-transport and 118-transport test systems and their outcomes have been accounted for.

3. PROBLEM IDENTIFICATION

A few issues identified with the power flow controller and in the optimization approach is depicted as underneath:

- The designed parameters of PI controller can be changed when the elements of energy system change quickly, (such as line current, connected loads, and so forth.). In this circumstance, a dynamic controller, this does not have to compute parameters [16].
- The genetic algorithm needs more opportunity to merge to achieving an optimum solution of location and limit of UPFC contrasting with alternate algorithms [24].
- Issues like the bus voltage variety in presence of the Interline Power Flow, the impact of the transmission angle variation upon the controlled locale of the series voltages infused.
- The multi-objective issue of a power system is solved by legitimate designation of arrangement and shunt FACTS controller [15, 21].
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In the existing papers, some UPFC with FFA is utilized to control the power flow of the transmission line and enhance the system stability [18, 19]. The particular issues identified with control systems are lost power, voltage variances, system stability, and so forth. With a specific end goal to defeat these issues paid the way to the proposed strategy.

4. METHODOLOGY

The paper centers to enhance the load-ability and stability of the power transmission system. UPFC is a standout amongst the most encouraging FACTS strategies for the load flow control. In this investigation, UPFC with IEEE 30 bus system is considered to control the dynamic and responsive power flows in the transmission line. The DC link capacity capacitor in UPFC adjusts the actual power between the two voltage source converters with the goal that the actual power loss and power disturbance are disregarded. Besides, with the expectation of keeping up the stability of the power system, the optimal estimation of location and limit of UPFC system is analyzed by the hybrid KHSO Optimization. From the execution parameters, it is clear that the UPFC controller with hybrid optimization executes better power stability with least power loss than the conventional strategy.

4.1. Unified Power Flow Controller (UPFC)

The UPFC comprises a combination of a series device and a shunt device, the dc terminals of which are associated with a typical dc- link capacitor. Voltage of the DC link capacitor is maintained at its reference value using the current drawn by shunt controller. Power flow over the line is controlled by the series converter below the receiving-end voltage.

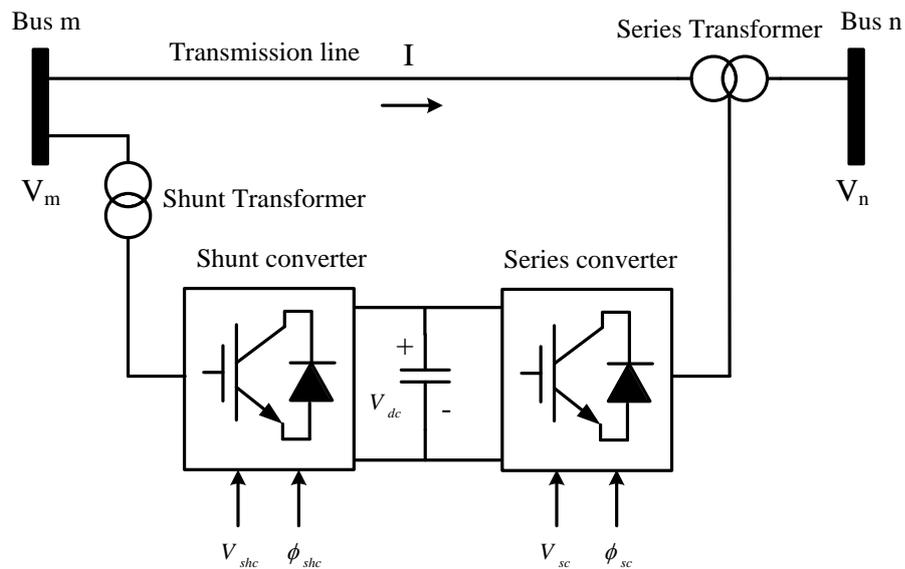


Figure 1. UPFC circuit diagram

The relating circuit includes two ideal voltage sources showing the fundamental Fourier series constituent of the switched voltage waveforms at the AC converter terminals. The UPFC voltage assets are announced as equations 1 and 2,

$$V_{sc} = |V_{sc}|(\cos\varphi_{sc} + j\sin\varphi_{sc}) \dots\dots\dots (1)$$

$$V_{shc} = |V_{shc}|(\cos\varphi_{shc} + j\sin\varphi_{shc}) \dots\dots\dots (2)$$

Where, V_{sc} and V_{sh} are the manageable magnitude ($V_{sc}^{min} \leq |V_{sc}| \leq V_{sc}^{max}$) and $(0 \leq \varphi_{sc} \leq 2\pi)$ phase angle of the voltage source demonstrating the shunt converter. The magnitude V_{shc} and phase angle φ_{shc}

of the voltage source demonstrating the series converter are controlled within these limits: $(V_{shc}^{min} \leq |V_{shc}| \leq V_{shc}^{max})$ and $(0 \leq \varphi_{shc} \leq 2\pi)$.

4.1.1. Power flow calculations in UPFC

UPFC is associated with two buses m and n in the power system. Applying the Kirchhoff's current and voltage laws for the network in Fig. 2 gives:

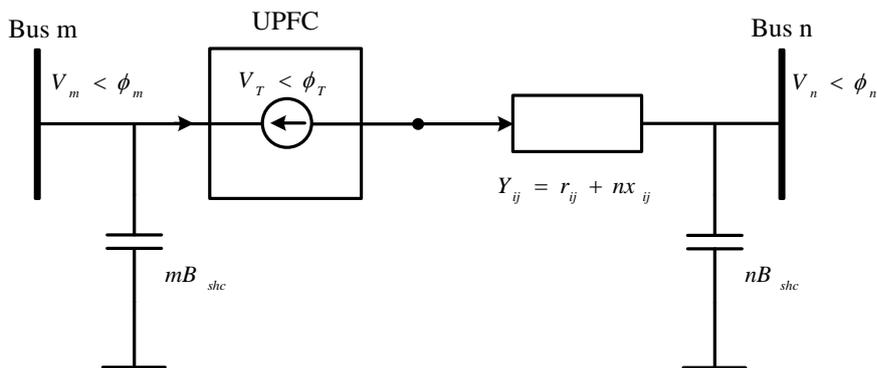


Figure 2. Equivalent circuit diagram

$$\begin{bmatrix} I_m \\ I_n \end{bmatrix} = \begin{bmatrix} Z_{sc} + Z_{shc} & -Z_{sc} & -Z_{sc} & -Z_{shc} \\ -Z_{sc} & Z_{sc} & Z_{se} & 0 \end{bmatrix} \begin{bmatrix} V_m \\ V_n \\ V_{sc} \\ V_{shc} \end{bmatrix} \dots\dots\dots (3)$$

Where, $Z_{sc} = \frac{1}{Y_{sc}}$ and $Z_{shc} = \frac{1}{Y_{shc}}$

The UPFC converters are expected lossless in this voltage sources model. The DC link capacitor voltage V_{dc} stays consistent. Consequently, the active power provided to the shunt converter P_{shc} must be equivalent to the active power requested by the series converter P_{sc} at the DC link. At that point, the accompanying equality constraint must be ensured.

$$P_{sc} + P_{shc} = 0 \dots\dots\dots (4)$$

In view of the voltage source model of UPFC the active and reactive power conditions are:

At series converter,

$$\begin{aligned} P_{sc} &= V_{sc} G_{mn} + V_{sc} V_m (G_{mn} \cos(\varphi_{sc} - \varphi_m) + B_{nm} \sin(\varphi_{sc} - \varphi_n)) + V_{sc} V_n (G_{nm} \cos(\varphi_{sc} - \varphi_m)) + B_{nm} \sin(\varphi_{shc} - \varphi_m) \\ Q_{sc} &= -V_{sc}^2 B_{nm} + V_{sc} V_m (G_{mn} \sin(\varphi_{sc} - \varphi_m) - B_{nm} \cos(\varphi_{sc} - \varphi_m)) + V_{sc} V_n (G_{nm} \sin(\varphi_{sc} - \varphi_n) - B_{nm} \cos(\varphi_{sc} - \varphi_n)) \end{aligned}$$

At shunt converter,

$$P_{shc} = -V_{shc}^2 G_{shc} + V_{shc} V_m (G_{shc} \cos(\varphi_{shc} - \varphi_m) + B_{shc} \sin(\varphi_{shc} - \varphi_n)) \dots\dots\dots (7)$$

$$Q_{shc} = V_{shc}^2 B_{shc} + V_{shc} V_m (G_{shc} \sin(\varphi_{shc} - \varphi_n) - B_{shc} \cos(\varphi_{shc} - \varphi_m)) \dots\dots\dots (8)$$

Where, Y_{kk}, Y_{mn}, Y_{km} and Y_{sh} are calculated as followed equations (11-14),

$$Z_{nm} = G_{mn} + jB_{mn} = Y_{sc}^{-1} + Y_{shc}^{-1} \dots\dots\dots (9)$$

$$Z_{nn} = G_{nn} + jB_{nn} = Y_{sc}^{-1} \dots\dots\dots (10)$$

$$Z_{mm} = Z_{nm} = G_{mn} + jB_{mn} = -Y_{sc}^{-1} \dots\dots\dots (11)$$

$$Z_{shc} = G_{shc} + jB_{shc} = -Y_{shc}^{-1} \dots\dots\dots (12)$$

In addition, when the coupling transformers are assumed to have no resistance, there exists a match of active power at bus m and bus n, then:

$$P_{shc} + P_{sc} = P_m + P_n = 0$$

Where, $P_{sc}, Q_{sc}, P_{shc}, Q_{shc}$ are the real and reactive power injected into series and shunt converter. G_{nm}, G_{nn}, G_{shc} are the real part of the element of the admittance matrix of buses m, n and shunt converter respectively. B_{nm}, B_{nn}, B_{shc} are the imaginary part of the element of admittance matrix of buses y x, and shunt converter respectively.

4.2. Objective Function

The main aim of this work is to choose the optimal parameter setting and zone of the UPFC in the framework for updating the framework security level. Along these lines, the objective function can be communicated based on equality and inequality constraints. It is given as,

$$F_t = \sum_{l=1}^{nl} w_l \left(\frac{S_l}{S_l^{max}} \right)^{2q} + \sum_{n=1}^{nb} W_m \left(\frac{V_n^{ref} - V_n}{V_n^{ref}} \right)^{2r} \dots\dots\dots (13)$$

These variables are at the same time updated to enhance the security of power framework under single line potential outcomes. Through single line conceivable outcomes, the region and parameter setting of UPFC by and large effect the power stream in the flow. Thusly, any change in one, two or these parameters will yield a modification in the power flow (line loading and transport voltages which are the guideline factors of the goal work). In this way, expanding the load capacity however much as possible should be the objective function.

4.3. Optimization Techniques

The aim of the optimization is to exploit the accessible system sufficiently as per the optimal location and parameters of UPFCs. Along these lines, the optimization algorithm is utilized to decide the optimal location and capacity of UPFC. In the paper, hybrid (KHSO) algorithm is proposed to execute the optimization process. Here, the system factors, for example, voltage variation, power loss and system imbalance condition are consolidated with the optimization technique.

4.3.1. Krill Herd Optimization (KHO)

Krill Herd optimization (KHO) algorithm is a type of nature-roused algorithm, which recreates the crowding attitude of krill individual. In KH algorithm, the objective function for the movement of krill is estimated by the shortest distance of every individual krill from food and highest density of the herd. Every individual in KH algorithm changes its position in view of three operational procedures:

- (1) Motion-induced by other individuals
- (2) Foraging movement
- (3) Random physical diffusion

Updating procedure

It is realized that an optimization algorithm should be capable of searching spaces of subjective dimensionality. Accordingly, the accompanying Lagrangian model is summed up in an n-dimensional decision space.

$$\frac{dF_i}{dt} = P_i + Q_i + R_i \dots\dots\dots (14)$$

Here P_i → motion induced by other krill individuals; Q_i → foraging motion, and R_i → physical diffusion of the i^{th} krill individuals.

Steps for KHO

Step1: Define the size of population and iteration (I_{max}). Initialize foraging speed, maximum induced speed, also maximum iteration number. Here, the actual(real) and reactive power of the load bus along with voltage profile of the power system is initialized.

Step 2: Do the fitness evaluation that calculates the present position of all krill’s.

Step 3: Estimate the movement of krill with respect to the mentioned operational factors.

a) Movement induced by other krill individuals: In the process, the direction of motion of a krill individual is settled by the objective thickness of swarm (target), nearby swarm dense nature (localized impact) and repulsive density of swarm (repulsive impact). The krill advancement can be described as

$$P_i^{new} = P^{max} \alpha_i + \omega_n P_i^{old} \dots\dots\dots (15)$$

Where $\alpha_i = \alpha_i^{local} + \alpha_i^{target}$

Here, P^{max} is the induce speed, P_i^{old} is the last motion induced and ω_n is the inertia weight of the motion induced in the range of (0, 1). α_i^{local} is the local effect provided by the neighbors and α_i^{target} represents the target direction effect provided by the best krill individual.

b) Foraging motion: The foraging motion is defined as far as two primary powerful criterions. First one being the food location and the second one the observed experience about the food location. This movement can be communicated to the i^{th} krill individual as takes after:

$$Q_i = F_s \beta_i + \omega_m Q_i^{old} \dots\dots\dots (16)$$

Where $\beta_i = \beta_i^{food} + \beta_i^{best}$

Here, F_s represents the foraging speed; ω_m is the inertia weight of the foraging motion in the range (0, 1), Y_{old}^i is the last foraging motion. β_i^{food} gives the food attraction, β_i^{best} shows the effect of best fitness of the i^{th} krill so far.

c) Physical Diffusion: Krill individual’s physical diffusion is assumed to be arbitrary in nature. This motion can be in terms of a maximum diffusion speed with a random directional vector, which can be expressed as follows:

$$R_i = R^{max} \lambda \dots\dots\dots (17)$$

Here R^{max} is the maximum diffusion speed, and λ is the random directional vector and its arrays are random values between -1 and 1.

Step 4: If constraints are not satisfied to go to step 2.

Step 5: The new position of krill in the population search space is amended according to the new krill individual position.

Step 6: Optimal location of UPFC is verified at the end of the ultimate iteration. If termination criterion is not met, then go to step 3 otherwise find the best result in the search space.

4.3.2. Particle Swarm Optimization (PSO)

PSO is an evolutionary computation method and was enlivened by the social conduct of bird flocking and fish schooling. It uses a populace of people, called particles, which fly through the problem hyperspace with some given initial velocities. In every cycle, the briskness of the particles are speculatively balanced by keeping the authentic prime position of the particles and their parish prime position; where these positions are resolved by some listed fitness work. At that point, the development of every particle normally advances to an optimal or near-optimal solution.

Find the velocity U_p and position of the particles W_p

Now in PSO, the best velocity is equally initiated by all particles and the finest positions are established by every particle in the search method.

$$U_p^{y+1} = w.U_p^y + h_1 * r_1 * (Pbest_p - W_p^y) + h_2 * r_2 * (Gbest_p - W_p^y) \dots\dots\dots (18)$$

$$U_p^{y+1} = W_p^y + U_p^{y+1} \dots\dots\dots (19)$$

Where, U_p is the particle velocity, W_p is the current particle, h_1 and h_2 are the learning factor, r_1 and r_2 are the random value within the [0, 1].

After finding the velocity and position estimation of the particles, the fitness value is again found out for the assessed velocity of the particles. If the most extraordinary fitness is uncovered, thusly the novel result is optimal or else the system is repeated by upgrading the velocity and positions.

4.4. Our Proposed Hybrid Approach (KHSO)

The Hybrid global optimization approach is framed from the pros of the two algorithms which are most renowned in the field of global optimization algorithms. In the proposed technique the algorithms are the Krill herd optimization and particle swarm optimization. In order to overcome, the poor abuse of the Krill Herd (KH) algorithm, a hybrid KHSO strategy has been produced for function optimization. The improvement of exploitation involves updating the position of the swarm in view of their food distance that can directly utilize the worldwide best solution at iteration. A Hybrid (KHSO) algorithm graph shows up in figure 2. The recently updated equation is made based on condition (17) and (19) is given as takes after:

$$R_i^{new} = W_p^y + U_p^{y+1}$$

Where R_i^{new} indicates the new solution after updating the solution, this is the hybrid definition of krill herd and particle swarm optimization. At that point, the capacity of UPFC is resolved according to the voltage level of magnitude and angle of load buses. As indicated by this methodology, the flow to get the optimal placement and size of UPFC by proposed hybrid technique can be visualized as the flowchart which portrayed as take after,

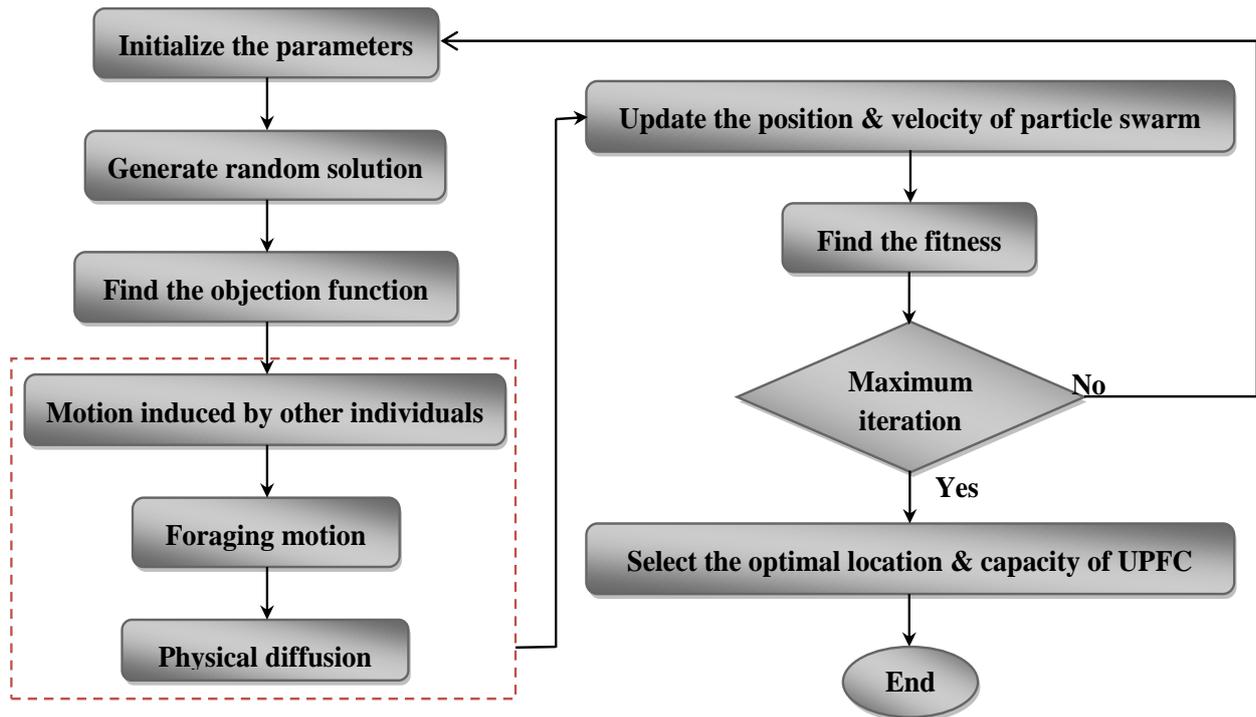


Figure 3. Flowchart for hybrid model

The flowchart (figure 3) viable shows the hybrid strategy for the procedure initialization and fitness calculation. Based on the above strategy the new solution sets are achieved. At that point, the fitness value is discovered for another updated solution. The ability of UPFC is discovered according to the real power of the load buses. From that, the real and reactive power flow model of UPFC is inspected. Likewise, the stability of the framework is assessed.

5. IEEE BUS STRUCTURE

The structure IEEE 30 bus framework is represented in figure 4. Here, the load bus real power is differed haphazardly according to as far as possible. Utilizing the proposed strategy, the load power variation is controlled by interfacing UPFC. At that point, the voltage size, load power, and power loss are assessed after and before associating UPFC.

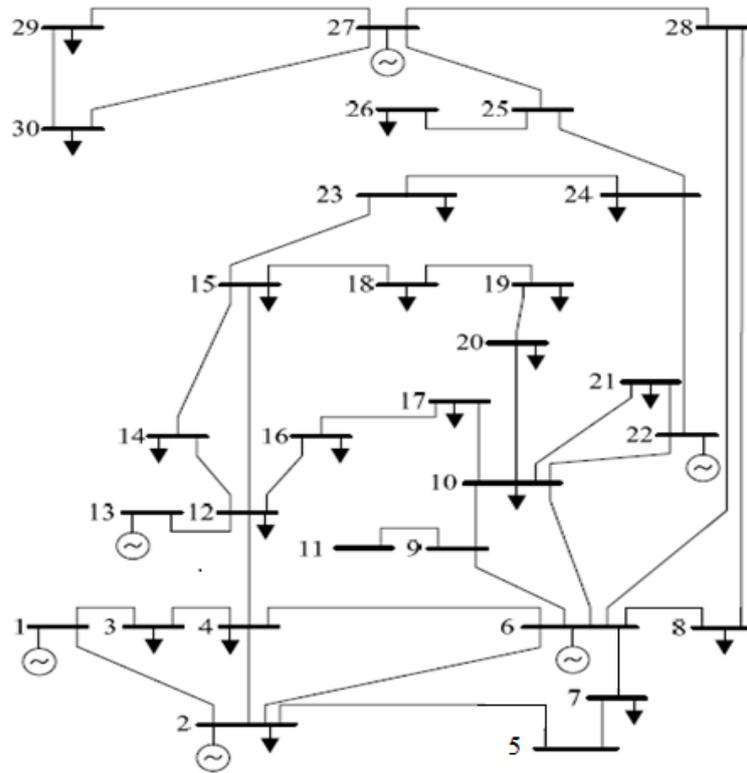


Figure 4. IEEE 30 bus system test structure

From the testing bus framework, the load bus details active power, voltage magnitude, and angle are characterized. In this paper, a KHSO based strategy is examined for the IEEE 30 bus framework by setting a UPFC to accomplish optimal location in improving voltage stability of the interconnected transmission framework.

6. RESULT AND DISCUSSION

The proposed technique actualized in MATLAB rendition 2015a with an i5 processor and 4GB RAM and the optimal location and limit of UPFC is analyzed according to the variety of voltage, power loss and power balance of the system. Likewise, the performance of proposed hybrid KHSO algorithm is contrasted with the separate algorithm and the results are analyzed.

Table 1. Power flow and loss profiles for proposed (UPFC-KHSO) Approach

Generator Bus Number	Load (KN)	Best Bus Location		P(MW)	Q(MVAR)	P(MW)	Q(MVAR)	Loss(MW)		Cost(\$)
		From	To	From		To		Normal	UPFC connected	
3	40	3	4	22.06	-9.45	22.06	16.18	10.81	6.46	189.47
5	40	25	27	13.18	-10.59	65.89	16.36		6.73	187.35
10	20	5	7	21.82	-33.73	5.45	6.72		6.89	184.89
12	60	4	6	30.57	0.69	7.64	1.26		6.73	186.14
15	80	15	18	9.96	22.43	9.96	-25.54		6.46	187.67
20	60	6	7	12.36	17.14	9.27	24.42		6.50	187.59
21	40	10	20	13.26	-26.07	22.10	-40.03		6.89	189.47
24	40	10	22	1.95	-12.38	2.44	45.96		6.81	187.96
30	80	24	25	16.84	6.89	5.61	-6.80		6.66	189.46

Table 1 demonstrates the power flow and loss profiles for proposed (UPFC-KHSO) approach. The simulation yields the power flow for lines and bus active and reactive powers which are organized. The UPFC is situated between two buses so from location and to optimal location are distinguished. In the proposed modeling, the loss of the active and reactive power is figured based on best bus location and varying loads. At long last, the loss of power is contrasted with a normal device. For each computation, the cost is analyzed and the optimal values are noted.

Table 2. Voltage Profile of Load bus for different Technique

Generator Bus Number	Normal	With-Load	UPFC connected		
			KHSO	Firefly	GA
3	1.01	1.01	1.01	1.01	1.01
5	1.05	1.05	1.05	1.05	1.05
10	1.04	1.04	1.04	1.04	1.04
12	1.08	1.08	1.08	1.08	1.08
15	1.06	1.06	1.06	1.06	1.06
20	1.07	1.07	1.07	1.07	1.07
21	1.04	1.04	1.04	1.04	1.04
24	1.04	1.04	1.04	1.04	1.04
30	1.03	1.03	1.03	1.03	1.04

Table 2 delineates the voltage profile of load bus for various methods. The optimal location and capacity of UPFC are figured based on KHSO, Firefly, and GA. For the examination of all the three procedures, KHSO achieves the optimal value. In addition, to controlling the load variation, proposed strategy utilizes joining of UPFC.

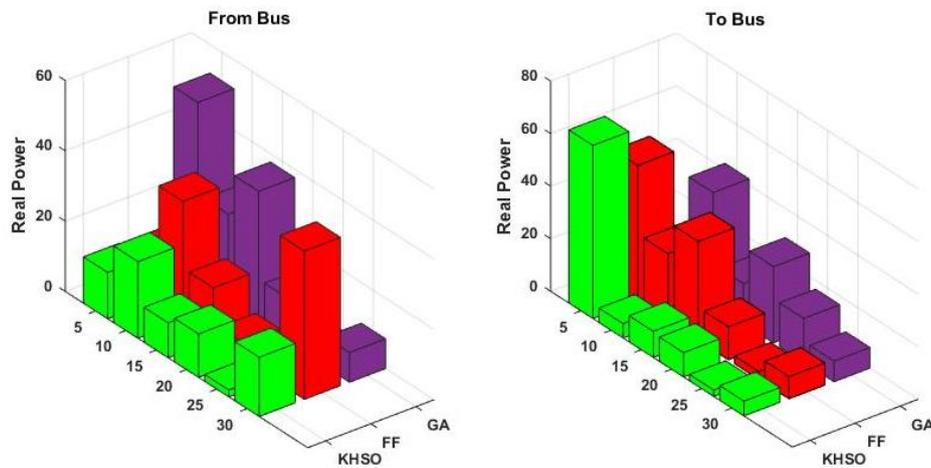


Figure 5 (a). Comparison graph for real Power

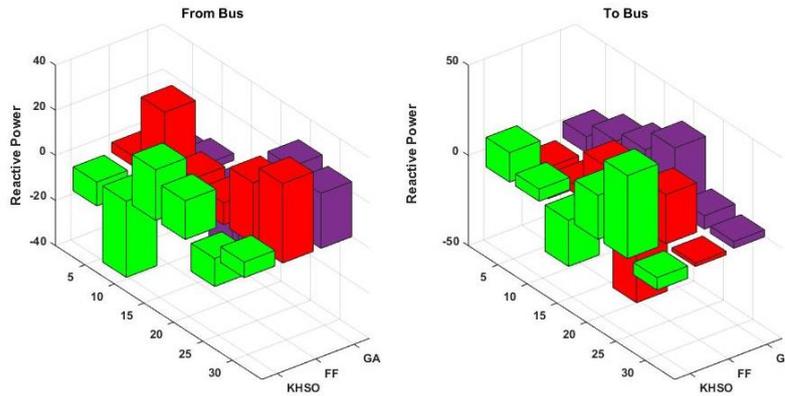


Figure 5 (b). Comparison Graph for Reactive Power

Figure 5 (a) and (b) demonstrates the comparison graph for active and real power in view of optimization algorithms. The optimization algorithms maintain the stability of the framework by interfacing UPFC in an ideal location. Here, in both the charts KHSO accomplishes the better stability when contrasted with other two methodologies.

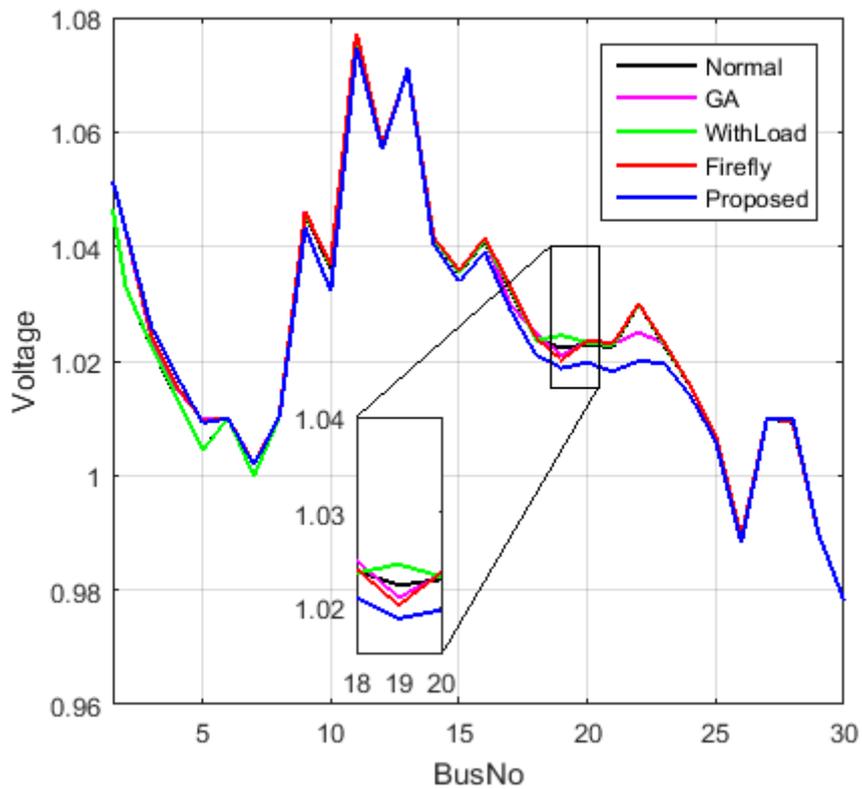


Figure 6 (a). Comparative analysis for Voltage Vs Bus Number

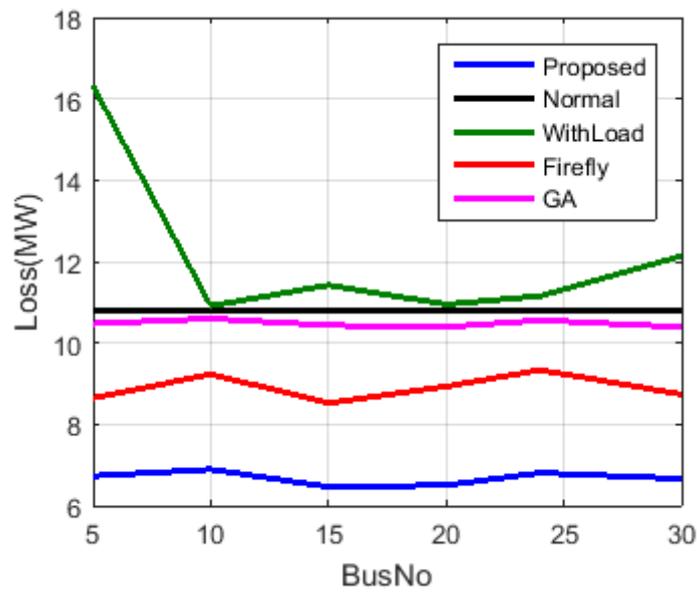


Figure 6 (b). Comparative analysis Loss Vs Bus Number

Figure 6 (a) and (b) illustrates the loss and voltage investigation based on the bus number. The examination is given for bus 5 to 30 and the loss and voltage are given for proposed, ordinary, with load, Firefly, and GA approaches. The overall losses have been lessened because of its placing UPFC in the bus network accomplished in proposed strategy. Thus, the size of the bus voltages has been increased due to the setting of UPFC in the bus network.

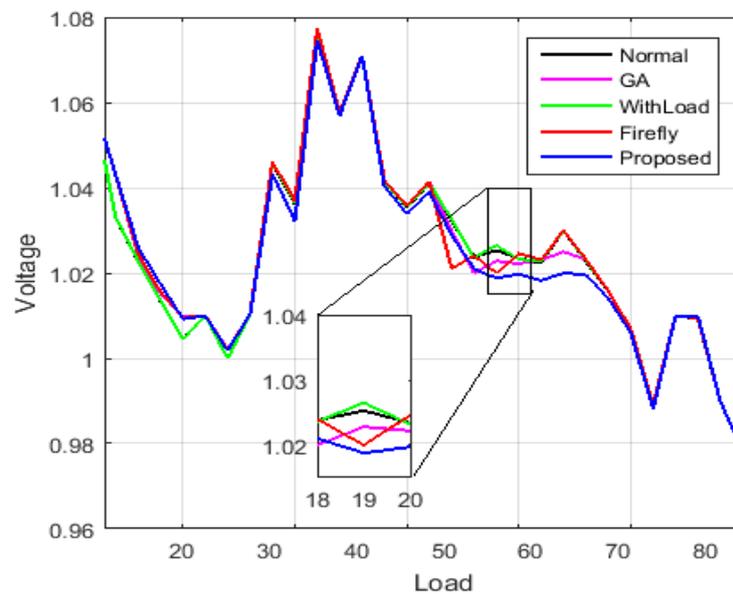


Figure 7 (a). Voltage profile under 12th bus generator

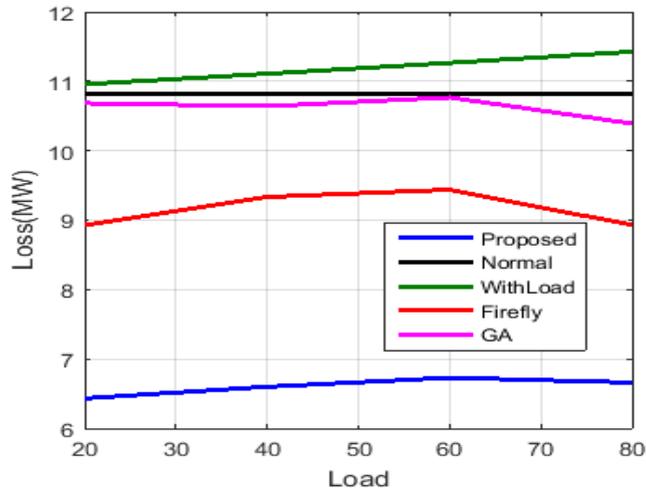


Figure 7 (b). Loss profile under 12th bus generator

Figure 7 (a) and (b) demonstrates the voltage and loss profile under twelfth bus generator. For instance, in voltage investigation of twelfth bus generator, proposed technique achieves 1.02, yet alternate strategies accomplish more than 1.02. Also, in loss analysis proposed strategy accomplishes minimum loss. The proposed technique diminishes the loss of the voltage got expanded in each bus because of its placing of UPFC.

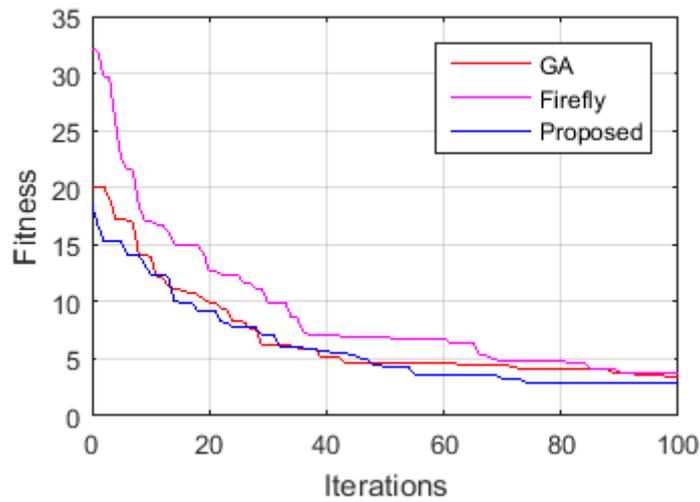


Figure 8. Convergence Graph

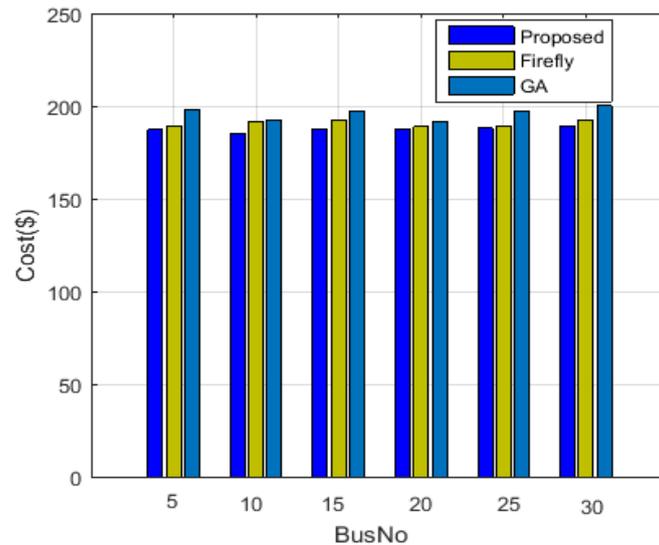


Figure 9. Cost analysis for UPFC with Different Techniques

The most favorable position of the proposed UPFC is, at the same time it controls the real and reactive power of the line and voltage of the buses at which it is associated with the framework. Figure 8 demonstrates the convergence graph for differing iterations. The optimal fitness value reaches KHSO for increasing iterations. The outcomes show that the optimal placement of UPFC at bus there is voltage stability upgrade. At that point, the cost is lessened in the modeling of proposed technique delineated in figure 9.

7. CONCLUSION

In the proposed UPFC is utilized with the series and shunt FACTS controllers as specified along with the current power framework factors in minimizing active power loss and system working cost. The UPFC idea gives a powerful apparatus to the cost-effective use of individual transmission lines by encouraging the free control of both the real and reactive power flow. It is observed that utilization of UPFC along with series and shunt FACTS controller gives preferred outcome over without UPFC. Active power loss and working cost lessened fundamentally and huge economic gain is accomplished with the situation of UPFC with different FACTS controller by hybrid based optimization (KHSO) strategies. The correlation of results demonstrates the adequacy of the proposed algorithm as far as improved loadability. The results demonstrate that voltage profile is improved at buses and power losses are extensively diminished minimization of power losses and minimization of generation cost. Therefore it demonstrates that the proficiency of KHSO is better and maintains the stability of the framework than the ordinary strategy (GA, Firefly). Further studies can explore if there is an optimal configuration of the hybrid algorithm to the issues of placement and estimate of UPFC unit as well as of other power system's equipment.

CONFLICT OF INTEREST

No conflict of interest was declared by the authors

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