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GENETIC-FIREFLY ALGORITHM TO CONTROL LOAD FLOW OF POWER SYSTEM BY OPTIMAL LOCATION AND CAPACITY OF UPFC

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ABSTRACT

An improved firefly algorithm is investigated with the aid of genetic algorithm (GA). The proposed algorithm improves the load ability of power system with unified power flow controller (UPFC). Random movement factor of firefly algorithm is improved by hybridizing the GA with classical firefly algorithm. In firefly algorithm, the next movement of firefly is depends on the movement factor which is determined by randomly so the best movement of firefly is possibility to fails by the distribution of random number. Thus, the best location of and capacity of UPFC can never able to recognize accurately. So in this paper, a GA based optimization algorithm is used to determine the optimal random movement factor of fireflies. Thus, the optimal location and capacity of UPFC is determined efficiently when compared to traditional fire fly algorithm. The proposed method implemented in MATALB and the optimal location and capacity of UPFC is examined as per the variation of voltage, power loss and power balance of the network. The load power control performance of proposed method is compared with classical firefly algorithm.

Keywords: *Improved Firefly, GA, Load Ability, UPFC, Location, Capacity, And Load Variation.*

1. INTRODUCTION

All round the world, due to the environmental and economic controls to erect novel generating plants and transmission lines, Electric power systems have been compelled to function to more or less their full capacities [2] [3]. By security and constancy controls, the amount of electric power that can be broadcasted between two positions through a transmission network is restricted [1]. Power flow in the lines and transformers should not be permitted to raise to a level where a random event could cause the network collapse as flowed outages [4] [5]. The system is said to be obstructed when such a limit accomplishes. Managing obstruction to diminish the constraints of the transmission network in the aggressive market has, consequently, turn into the central activity of systems operators [6]. It has been examined that the disappointing management of operations could raise the obstruction cost which is an unnecessary burden on customers [7].

For controlling the power transmission system, Flexible Alternating Current Transmission System (FACTS) is a fixed apparatus applied [8] [9]. FACTS is described as "a power electronic based system and other fixed apparatus that offer control of one or more AC transmission system parameters to improve controllability and raise power transfer capability" [10]. The different kinds of FACTS tools obtainable for this purpose comprises Static Var Compensator (SVC), Thyristor controlled series Capacitor (TCSC), Static Synchronous series compensator (SSSC), Static Synchronous Compensator (STATCOM), Unified Power Flow Controller (UPFC) and Interlink Power Flow Controller (IPFC) [12]. By inserting dynamic and reactive voltage component in series with the transmission line, UPFC is one of the FACTS tools that can manage the power flow in transmission line among them [11] [13].

Appearance of FACTS tools unlocks up novel opportunities for controlling power and improving the utilizable capacity of presented transmission lines [14]. An optimal site of UPFC tool permits to control its power flows for a interconnected network and as a result to raise the system load ability [15]. On the other hand, a limited number of tools, beyond which this load ability can

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never be enhanced, has been monitored [16]. The optimal location and optimal capacity of a specified number of FACTS in a power system is a problem of combinatorial study [18] [19]. Dissimilar kinds of optimization algorithm have been applied such as genetic algorithms, simulated annealing, tabu search and etc to work out this kind of problem [17] [20]. In the document, the GA base enhanced firefly algorithm is suggested for controlling the load deviation of power system by computing the optimal location and sizing of UPFC. The GA is employed and the movement factor is optimized as a substitute of random movement factor of firefly. The specified report of suggested algorithm is offered in section 3. The current research works are explained in section 2 before that. The conversation of results and ending of document is offered in section 4 and 5 correspondingly.

2. RECENT RESEARCH WORK: A BRIEF REVIEW

In literature, numbers of related works are available which based on improving the power transfer capability of power system. Some of them reviewed here. For improving the security of power systems under single line contingencies, the efficiency of the optimal location of UPFC has been explored by H.I. Shaheen *et al.* [21]. Based on the emergency selection and ranking process, determinations of the severest emergency scenarios were executed. One of the latest computational intelligence methods, namely: DE has been effectively employed to the problem under deliberation. Maximization of power system security was regarded as the optimization principle. The presentation of DE was compared with that of GA and PSO. Moreover, they were carried out two case studies by means of an IEEE 14-bus system and an IEEE 30-bus system.

A strategy based on differential evolution method to find out the optimal position and parameter setting of UPFC for improving power system security under single line contingencies has been offered by Husam I. Shaheen *et al.* [22]. Initially, they carry out a contingency study and ranking process to find out the most severe line outage contingencies regarding line overloads and bus voltage limit violations as a presentation index. Secondly, they employ differential evolution method to determine the optimal location and parameter setting of UPFC under the determined emergency scenarios. They execute simulations on an IEEE 14-bus and an IEEE 30-bus power systems. They acquired results point out that installing UPFC in the location optimized by DE could considerably improved the security of power system by removing or minimizing the overloaded lines and the bus voltage limit violations.

Lashkar Ara *et al*. [29] have improved suitable models of flexible ac transmission systems (FACTS) shunt-series controllers for multiobjective optimization and furthermore offered a multiobjective optimization methodology to locate the optimal location of FACTS shunt series controllers. The intent functions were the total fuel cost, power losses, and system loadability with and without minimum cost of FACTS installation. The ε-constraint strategy was executed for the multiobjective mathematical programming (MMP) formulation, together with the FACTS shunt series controllers. For the IEEE 14-bus system, Simulation results were offered.

To find optimal location of UPFC to accomplish optimal power flow (OPF), the application of hybrid immune algorithm (HIA) such as immune genetic algorithm (IGA) and immune particle swarm algorithm (IPSO) has been offered by Seyed Abbas Taher *et al*. [30]. The overall cost function, the objective function in the OPF, comprises the total active and reactive production cost function of the generators and installation cost of UPFCs and therefore, should minimized. The OPF controls are generators, transmission lines and UPFCs limits. It may not all the time be feasible to send out the contracted power transactions totally in power system due to congestion of the consequent transmission corridors. The simulations were executed on IEEE 14-bus and IEEE 30-bus test systems for dissimilar techniques.

Ya-Chin Chang [31] has applied the modal analysis (MA) method to find out which buses require static var compensator (SVC) installation, and with maximum LM and minimum SVC installation cost composed into the multi-objective function the optimal LM improvement problem is created as a multi-objective optimization problem (MOP) and worked out by using the fitness sharing multi-objective particle swarm optimization (MOPSO) algorithm for a Pareto front set. The solution with the biggest presentation index value was found out for SVC installation in the Pareto front set for each reflected contingency. Lastly, an SVC installation plan derived from the union of the SVC installations for all regarded contingencies was proposed for LM improvement.

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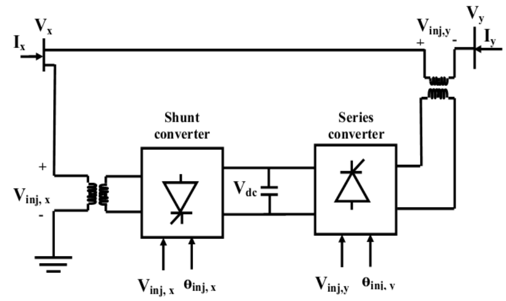
In large power systems, a graphical user interface (GUI) based on a genetic algorithm (GA) has been offered by Ghahremani, E. *et al*. [32] which was shown able to locate the optimal locations and sizing parameters of multi-type FACTS tools. This user friendly tool, called the FACTS Placement Toolbox, permits the user to pick a power system network, find out the GA settings and choose the number and kinds of FACTS tools distributed in the network. To get optimal locations, the GA-based optimization process was used and ratings of the chosen FACTS to maximize the system static loadability. Five dissimilar FACTS devices were executed: SVC, TCSC, TCVR, TCPST and UPFC.

Using particle swarm optimisation (PSO) technique, to improve the power system loadability with optimal placement of flexible AC transmission system (FACTS) controllers, multi objective–based method has been proposed by Made Wartana *et al*. [33]. The intent function was maximized the system loadability subjected to upholding the system security, integrity, and stability margins inside limits by attaining the optimal location, installation costs, and control settings of the FACTS controllers. The diverse FACTS controllers, i.e., static var compensator (SVC), thyristor controlled series compensator (TCSC), and unified power flow controller (UPFC), have been regarded.

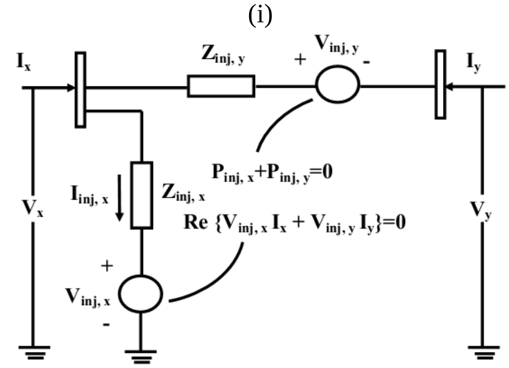
3. PROBLEM FORMULATION

UPFC power flow model

UPFC is one of the FACTS tools which competent to presenting true and reactive power flow control among its terminals [23]. The reactive power is reimbursed when attached UPFC. With one dc link capacitor, the series and shunt converters are attached. The inserting transformer applied to give the link of the converters and power transmission line. The UPFC is controlling the power flow among transmission lines by inserting the true and reactive power. The power flow injection copy and the corresponding circuit model of UPFC among transmission line x and y are specified in Fig.1. The functioning of UPFC can know simply from the power flow and corresponding circuit model.



(i)



(ii)

Fig1: (I And Ii): Power Flow Model And Equivalent Circuit Of UPFC.

The DC link is assisted to balance the real power among the two voltage source converters so the real power loss is ignored. On the other hand, the voltage converters can produce or soak up the reactive power. To acquire the stable state system model, the above UPFC equivalent circuit model is applied. In the UPFC circuit copy, the two ideal voltage sources of UPFC signifying the fundamental Fourier series factor of the switched voltage waveforms at the AC converter terminals [24]. From the load flow studies technique, the power flow model of series and shunt converters are obtained [25]. The power flow of UPFC is computed according to the follow equation. The equation (1) and (2) are signify the true and reactive power injected to series and shunt converter.

$$\begin{aligned} P_{inj,se} &= V_{inj,se}^2 G_{yy} + V_{inj,sh} V_x \\ &\left(G_{xy}\cos\left(\theta_{inj,se}-\theta_x\right) + B_{xy}\sin\left(\theta_{inj,se}-\theta_x\right)\right) \\ &+ V_{inj,se} V_y \left(G_{yy}\cos\left(\theta_{inj,se}-\theta_y\right) + B_{yy}\sin\left(\theta_{inj,se}-\theta_y\right)\right) \end{aligned} \quad (1)$$

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$$Q_{inj,se}=-V_{inj,se}^2 G_{yy}+V_{inj,se}V_x \left(G_{xy}\sin\left(\theta_{inj,se}-\theta_x\right)-B_{xy}\cos\left(\theta_{inj,se}-\theta_x\right)\right) +V_{inj,se}V_y \left(G_{yy}\sin\left(\theta_{inj,se}-\theta_y\right)-B_{yy}\cos\left(\theta_{inj,se}-\theta_y\right)\right) \quad (2)$$

$$P_{inj,sh}=-V_{inj,sh}^2 G_{inj,sh}+ V_{inj,sh}V_x \left(G_{inj,sh}\cos\left(\theta_{inj,sh}-\theta_x\right)+B_{inj,sh}\sin\left(\theta_{inj,sh}-\theta_x\right)\right) \quad (3)$$

$$Q_{inj,sh}=V_{inj,sh}^2 G_{inj,sh}+V_{inj,sh} V_x\left(G_{inj,sh}\sin\left(\theta_{inj,sh}-\theta_x\right)-B_{inj,sh}\cos\left(\theta_{inj,sh}-\theta_x\right)\right) \quad (4)$$

Where, $P_{inj,se}$, $Q_{inj,se}$, $P_{inj,sh}$, and $Q_{inj,sh}$ are the real and reactive power injected to series and shunt converter. G_{yy}, $G_{inj,sh}$, and G_{xy} are the real part of the element of the admittance matrix of buses x, y and shunt converter respectively. B_{yy}, $B_{inj,sh}$, and B_{xy} are the imaginary part of the element of the admittance matrix of buses x, y and shunt converter respectively. $V_{inj,sh}$, $V_{inj,se}$, V_x, and V_y are the magnitude of injected voltage of series, shunt converter, and magnitude of bus voltage x and y. $\theta_{inj,se}$, $\theta_{inj,sh}$, θ_x, and θ_y are injected angle of series, shunt converter, and voltage angle of bus voltage x and y. Then, the constraints of voltage instability problem is described as following them,

Equality constraints:

The power flow equations are regarded as sameness constraints for upholding the load ability of power system by means of UPFC. The power flow equation of buses *x* and *y* are rely on the demand, voltage magnitude, and angle correspondingly. Moreover, the power balance condition is regarded as another equality constraint which explained in equation (9). The power balance equation depends on the generator power, demand, and loss of the whole system. The regarded power flow equation is set as following them,

At bus *x*:

$$P_{gx}=P_x(V,\theta)+P_{dx} \quad (5)$$

$$Q_{gx}=Q_x(V,\theta)+Q_{dx} \quad (6)$$

At bus *y*:

$$P_{gy}=P_y(V,\theta)+P_{dy} \quad (7)$$

$$Q_{gy}=Q_y(V,\theta)+Q_{dy} \quad (8)$$

$$\sum_{i=1}^{N_g} P_{gi}=\sum_{i=1}^{N_G} P_{Li}+P_{loss}(i) \quad (9)$$

Where, P_{gx}, Q_{gx}, P_{gy}, and Q_{gy} are the real and reactive power of generator to bus *x* and *y*. $P_x(V,\theta)$, $Q_x(V,\theta)$, $P_y(V,\theta)$, and $Q_y(V,\theta)$ are the real, reactive power, voltage magnitude, and angle of bus *x* and *y*. P_{dx}, Q_{dx}, P_{dy}, and Q_{dy} are the real and reactive power demand of bus *x* and *y*. P_{gi} is the real power of i^{th} generator, P_{Li} is the real power of i^{th} load bus and $P_{loss}(i)$ is the power loss of i^{th} bus.

Inequality constraints

The inequalities constraints are defined which parameters are depending on the stability of the system and the limits are selected as inequality constraints. Usually, the real P_{gi}, reactive Q_{gi} power of generator, voltage magnitude V_i, and angle θ_i are selected as the inequality constraints. In the case of stability by UPFC is depending on the injected voltage magnitude and angle of shunt and series active converter respectively. The maximum and minimum limits of the inequality constraints are represented as following them,

$$P_{gi}^{\min}\le P_{gi}\le P_{gi}^{\max} \qquad i=1,2,..n_g \quad (10)$$

$$Q_{gi}^{\min}\le Q_{gi}\le Q_{gi}^{\max} \qquad i=1,2,..n_g \quad (11)$$

$$V_i^{\min}\le V_i\le V_i^{\max} \qquad i=1,2,..n_g \quad (12)$$

$$\theta_i^{\min}\le \theta_i\le \theta_i^{\max} \quad (13)$$

$$V_{inj,sh}^{\min}\le V_{inj,sh}\le V_{inj,sh}^{\max} \quad (14)$$

$$\theta_{inj,sh}^{\min}\le \theta_{inj,sh}\le \theta_{inj,sh}^{\max} \quad (15)$$

$$V_{inj,se}^{\min}\le V_{inj,se}\le V_{inj,se}^{\max} \quad (16)$$

$$\theta_{inj,se}^{\min}\le \theta_{inj,se}\le \theta_{inj,se}^{\max} \quad (17)$$

For maintaining the stability of system, the location and capacity of UPFC is determined. So,

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the optimization algorithm is used to determine the optimal location and capacity of UPFC. To perform the optimization algorithm, the parameters are optimized to decide the power flow of the system. In the paper, the GA based firefly algorithm is proposed to perform the optimization process. The following parameters are considered in the optimization process:

(i) The optimal location of UPFC in the network is considered as the first step of optimization process. Here, the network variables such as voltage changes, power loss and system balance condition are incorporate with the optimization algorithm.
(ii) Then, the capacity of UPFC is determined according to the working range of network.
For that, the series and shunt voltage source converter injected voltage ranges are determined.
(iii) From that, the real and reactive power flow model of UPFC is examined. Also the stability of the system is evaluated. These are the steps used to analyze the stability and control the power flow of the system.

3.2. Proposed GA based Firefly Algorithm

Firefly Algorithm is one of the optimization algorithm which progressed based on the blinking performance of fireflies [26]. In the document, an enhanced fire fly algorithm is suggested to develop the load ability of power system. The firefly algorithm is enhanced by hybridize the GA with classical algorithm to verified the random movement factor. In firefly algorithm, the subsequent movement of firefly is depends on the progress factor. But the movement factor is determined by arbitrarily so the most excellent movement of firefly is possibility to miss by the sharing of random number. Therefore, the top position of and capacity of UPFC is can never able to recognized precisely. Hence, a GA based optimization algorithm is suggested to find out the optimal random movement factor of fireflies in this paper. Therefore, when compared to traditional fire fly algorithm, the optimal location and capacity of UPFC is found out competently. According to the suggested fire fly algorithm, the optimal location and capacity of UPFC is found out. Now, the position of UPFC is determined as per the deviation of voltage, power loss and power balance of the network. The ability of UPFC is found out as per the real power of the load buses. The flowchart of suggested algorithm is explained as following them,

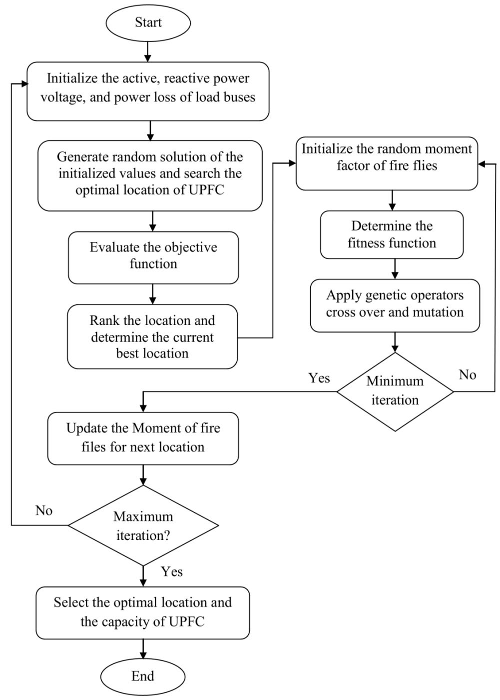

Fig 2: Flow Chart For Proposed Technique.

According to the searching concept of traditional firefly algorithm, the proposed algorithm is improved. The steps of the proposed improve firefly algorithm can be summarized as the following them,

Steps of GA based firefly algorithm

Step 1: First the network dates are initialized. Here, the voltage, real and reactive power of the load bus of the power system is initialized. The initialized system parameters considered as a function which denoted as $f(x)$. Also, the algorithm parameters are predetermined such as maximum attractiveness β_0, absorption coefficient γ, initial distance of fireflies d_j and random factor α_n respectively.

Step 2: From the initialized values, the random number of solution is generated. To control the system when load varies, the UPFC location is determined as per the power loss and voltage deviation of load bus. So the $f(x)$ is to be varied according to the number of optimal variable. For example, the $f(x)$ is the function of power loss of the system, then the random number of solution is described as following them,

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$$f(x) = [x_1, x_2, ... x_{n-1}, x_n] \tag{18}$$

The $f(x)$ is depends on the power loss of the system which depends on the constraints that is denoted as J . The location of UPFC is depends on which load bus affect high power loss while the real power is varied. The output function is described as follow,

$$f(x)_{output} = \max(x_n) \tag{19}$$

Step 3: Start the iteration count and determine the optimal location of UPFC. At the end of iteration, ranking the solution by using equation (19) and determine the current best solution as per the rank.

Step 4: In this step, the optimal random movement factor is optimized by GA. Initialize, the random movement factor $\alpha_n(0,1)$ for counting the iteration level. The range of random movement factor is described as follow,

$$\alpha_{n,\min} \le \alpha_n \le \alpha_{n,\max} \tag{20}$$

From the initialized random movement factor, the fitness is evaluated. The fitness depends on the distance updating formula of the fireflies. Apply genetic operators [27] cross over, mutation and selection. The best selection i.e. optimal random movement factor depends on the distance of the fireflies. If the distance is low select minimum level random factor $\alpha_{n,\min}$. If the distance of the fireflies is high select maximum level random factor $\alpha_{n,\max}$. According to the optimal output $\alpha_{n(optimal)}$ of GA, the next location of fireflies is rearranged.

Step 5: The location of fireflies rearranged by equation (21) and the equation is represented as follow,

$$x_n^{k+1} = x_n^k + \beta_0 e^{-\gamma d_j}\left(x_m^k - x_n^k\right) + \alpha_{n(optimal)}^k \tag{21}$$

Where, $\alpha_{n(optimal)}^k$ is the optimal random movement factor.

Step 6: Check the optimal location of UPFC is at the end of the maximum iteration. If, it not reaches the optimal location go to step 3 and increase the iteration.

Then, the capacity of UPFC is determined as per the voltage level of magnitude and angle of load buses. According to this approaches, the steps to determine the optimal location and capacity of UPFC by proposed firefly approach can be summarized as the pseudo code which described as follow,

Pseudo code of proposed firefly algorithm to determined the optimal location and capacity of UPFC

Input:
$f(x) = [x_1, x_2, ... x_{n-1}, x_n]$
{location of UPFC}
Output:
$f(x)_{output} = \max(x_n)$ {optimal location of UPFC}
begin
for n=1 to t
$x_n \leftarrow$ generate load bus voltages as initial solution
end
repeat
$n^{\min} \leftarrow \arg\min_n f(x_n)$
$x_{n^{\min}} \leftarrow \arg\min_{x_n} f(x_n)$
for n=1 to t do
for m=1 to t do
if $f(x_m) < f(x_n)$ then {move firefly n towards m}
$\alpha_n \leftarrow$ optimize the random movement factor by GA
for k=1 to n do
$x_n^{k+1} = x_n^k + \beta_0 e^{-\gamma d_j}\left(x_m^k - x_n^k\right) + \alpha_{n(optimal)}^k$
end
end
end
end
$\alpha_{n(optimal)}^k \leftarrow (\min \alpha_n, \max \alpha_n)$
until stop condition true
end

4. RESULTS AND DISCUSSION

The proposed GA based firefly algorithm was implemented in MATLAB working platform and the load ability performance is evaluated. The load variation control capability of proposed technique with UPFC is evaluated with IEEE 30 bus bench mark system. The system data is referring from [28]. The structure IEEE 30 bus system is illustrated in Fig 3. Here, the load bus real power is varied randomly as per the allowable limits. Using the proposed method, the load power variation is controlled by connecting UPFC. Then, the voltage magnitude, load power and power loss are evaluated after and before connecting UPFC. Also, the performance of proposed firefly algorithm is

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compared with traditional firefly algorithm and the outcomes are analyzed.

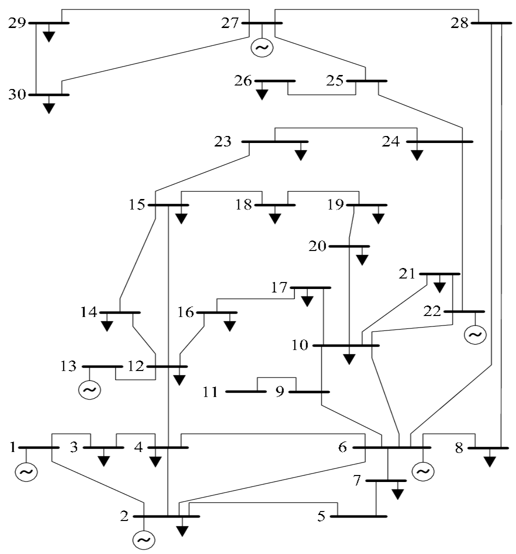

Fig 3: Structure Of IEEE 30 Bus Bench Mark System.

From the testing bus system, the load bus details active power, voltage magnitude, and angle are defined. Then, the load power of load bus is varied arbitrary from the actual value. Initialize the load variation in the proposed method. By the initialized values, the optimal location and capacity of UPFC is determined. Then, the UPFC is located between two buses and the active load variation controllability performance is examined. Also, the magnitude of load voltage and the system power loss are evaluated by proposed firefly algorithm and classical algorithm. The normal load power, during load variation and the load power after connecting UPFC by proposed method and classical firefly algorithm are examined. The examined load power data's are tabulated as in table I.

In table I, the load power is examined while normal load, load variation, and after connecting UPFC. The optimal location and capacity of UPFC is determined by two methods. One is proposed method and another firefly algorithm. As per the optimal location, the UPFC is installed between from and to load buses which are listed in the corresponding table I. During load variation, the normal load of the system is deviated from the actual load condition. So, the load ability of the corresponding load buses is affected. To control the load variation, proposed method uses incorporation of UPFC. The comparison chart of load power of buses is presented in Fig 4 and 5.

Table I: Load Bus Power: Normal Load, Load Variation, And After Connecting UPFC.

Load buses		Normal load in MW		Load variation power in MW		After connecting UPFC load power in MW			
From bus	To bus					Firefly algorithm		Proposed method	
10	22	5.80	0	10.7700	4.9700	2.1907	4.8729	0.8997	4.2047
22	24	0	8.70	4.890	13.590	3.61	8.7000	1.8424	7.4566
9	10	0	5.800	4.950	10.750	1.8972	5.0258	2.6857	4.277
23	24	3.20	8.70	8.180	13.680	5.3268	2.3658	5.2163	2.2941
12	13	11.2	0	16.15	4.950	14.6271	1.7371	7.7912	3.2094
16	17	3.500	9.000	8.440	13.940	3.500	9.0000	2.3215	4.9066
7	8	22.8	30.00	27.56	34.76	18.9804	25.9534	18.1447	25.4364
15	16	8.20	3.50	13.04	8.3400	4.9991	0.2516	4.1828	0.0920
3	4	2.40	7.60	7.350	12.550	0.2645	5.7929	0.9161	5.2568
29	30	2.40	10.60	7.300	15.500	3.5294	6.0373	1.2759	8.2328
19	20	9.500	2.200	14.450	7.1500	2.6403	6.7724	7.2457	0.6370

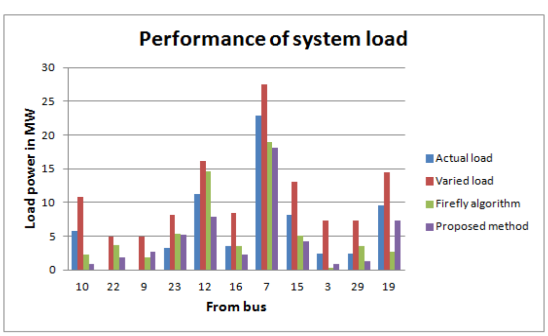

Fig 4: Comparison Chart Of From Bus Load.

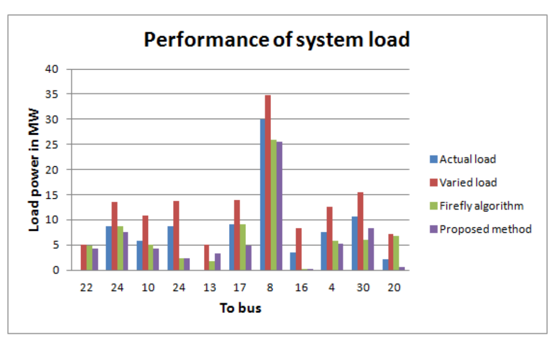

Fig 5: Comparison Chart Of To Bus Load Power.

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From fig.4 and 5, the load ability performance of proposed method is analyzed with actual load of the system and during load variation. When load varied suddenly, it changed from the actual value so the stability of the system gets affected. Here, firefly and proposed algorithm working towards maintain the stability of the system by connecting UPFC. The UPFC is injecting the power both connected buses and the load flow power is balanced. When evaluate the balance power, the proposed method control the load power variation effectively compared to firefly algorithm. Hence the stability of the system towards maintains the normal system.

The power loss of the system is analyzed while normal load, load variation, and after connecting UPFC. As per the optimal location, the UPFC is installed between from and to load buses and the power loss are illustrated in table II. For the duration of load variation, the power loss of the system is deviated from the actual system power loss i.e. 10.805 MW. When power loss increased, the load buses are affected because of insufficient power to balance the load. Therefore, the load ability of the consequent load buses is to be exaggerated. After connecting UPFC, the power loss of the system gets reduced. The power loss comparison chart of load buses is presented in Fig 6.

Table II: Power Loss Of System: Normal Load, Load Variation, And After Connecting UPFC.

Load buses		Power loss when load power change in MW	Power loss after connecting UPFC in MW	
From bus	To bus		Firefly algorithm	Proposed method
10	22	15.9402	10.6852	10.5651
22	24	16.08	10.4832	10.2572
9	10	17.9414	10.5569	10.4711
23	24	15.84	10.2354	8.0549
12	13	13.9983	9.9562	9.7594
16	17	10.466	10.0889	9.1101
7	8	11.4334	10.1589	10.0816
15	16	13.138	10.0986	9.3967
3	4	10.8137	10.3587	8.32
29	30	14.3298	9.3889	9.2373
19	20	11.3256	10.0874	9.3645

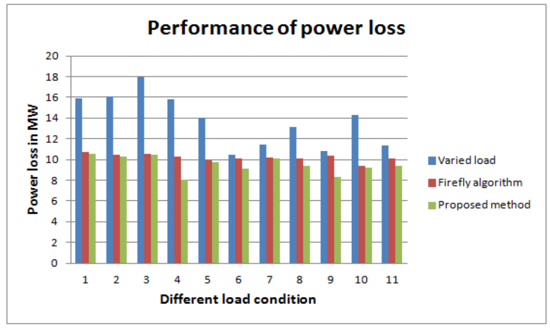

Fig 6: Power Loss Comparison Chart Of Varied Load, UPFC With Firefly And UPFC With Proposed Method.

In fig.6, the power loss of the system is compared with firefly algorithm and proposed method. The comparison is examined with the power loss of system load at abnormal condition. The examination is evaluated with 11 different loading levels. When load changed, the power loss of the system is increased maximum level as 17.9414 MW. But, the power loss of the system is reduced as 9.3889 MW by UPFC with firefly algorithm. However, the proposed method with UPFC is reducing the power loss as 8.0549 MW. This power loss is the minimum power loss among all the loading levels. As per the comparison, the proposed method gives as less power loss to compare with firefly algorithm.

The voltage magnitude of the system is depends on the injecting voltage of UPFC. When control the load variation by UPFC, the voltage variation of the system is also improved. The per unit voltage of load bus is evaluated at different loading levels which are tabulated in table III. From the voltage levels, the load variation control performance of control is evaluated. When loading level changed, the actual value bus voltage 1 p.u is deviated so the stability of the system is varied. While connecting UPFC with firefly algorithm, the deviated voltage is improved towards actual voltage level. In the case of proposed method with UPFC, the voltage level of the system gets increased as much considered level that are described in Fig 7 and 8 respectively.

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Table III: Voltage Magnitude Of Load Buses: Normal Load, Load Variation, And After Connecting UPFC.

Load buses		Actual voltage of load bus in p.u		Voltage variation of load bus in p.u		Voltage variation of load bus after connecting UPFC in p.u			
From bus	To bus					Firefly algorithm		Proposed method	
10	22	1.0367	1.0300	0.9607	0.9686	1.0385	1.0900	1.0224	1.0100
22	24	1.0300	1.0158	0.9529	0.9404	1.0158	0.9991	1.0100	0.9991
9	10	1.0458	1.0367	0.9435	0.9373	1.0658	1.0315	1.0270	1.0217
23	24	1.0229	1.0158	0.9599	0.9650	1.0258	0.9913	0.9990	1.008
12	13	1.0572	1.0610	1.0380	1.0458	1.0255	1.0310	1.0198	1.0210
16	17	1.0411	1.0326	1.1588	1.1574	1.0324	1.0203	1.0300	1.0242
7	8	0.9999	1.0103	1.0698	1.0864	1.0158	1.0096	0.9983	1.0091
15	16	1.0355	1.0411	1.0534	1.0585	1.0106	0.9940	1.0217	1.0361
3	4	1.0228	1.0136	1.2331	1.2324	1.0387	1.0136	1.0192	1.0108
29	30	0.9899	0.9782	1.0143	1.0012	0.8599	0.8537	0.9583	0.9453
19	20	1.0198	1.0232	1.4990	1.2020	0.9664	0.9707	0.9939	0.9977

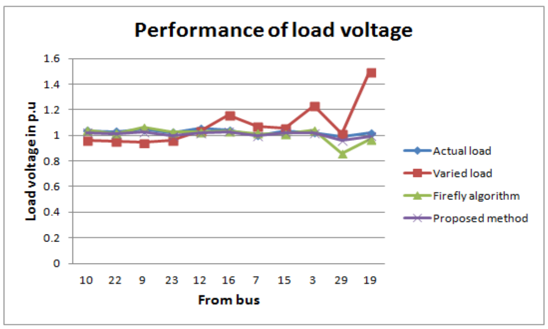

Fig 7: From Bus Load Voltage Comparison Chart Of Varied Load, UPFC With Firefly And UPFC With Proposed Method.

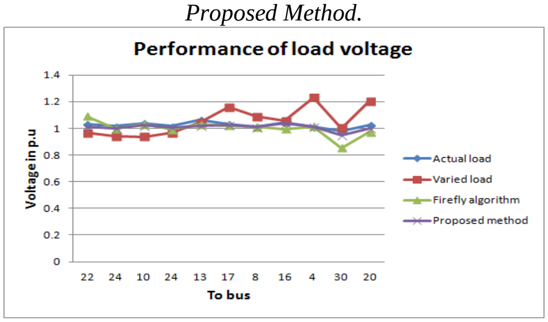

Fig 8: To Bus Load Voltage Comparison Chart Of Varied Load, UPFC With Firefly And UPFC With Proposed Method.

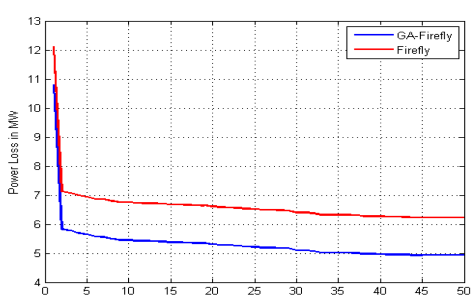

Fig 9: Performance Of Generation For Reducing The System Power Loss.

Fig. 7 and 8, the load voltage stability of the IEEE 30 bus system is evaluated for series and shunt injecting buses. From the examined results, the load voltage stability improvement of proposed method with UPFC is revealed. In shunt and series injecting cases, the voltage stability of the proposed method is improved as better level when compared to UPFC with firefly algorithm. Also, the iteration cure is described for proposed algorithm (GA-firefly) and firefly is illustrated in Fig 9. From the iteration curve, the proposed method gives up minimum power loss as compared with firefly algorithm. Therefore, the load power variation is controlled effectively by proposed method.

5. CONCLUSION

The proposed load power control method by UPFC was implemented in MATLAB and the performance is evaluated. The performance of load bus power, voltage magnitude, and power loss were examined and compared with classical algorithm. From evaluating the effectiveness, different loading level are used. The comparative analysis shows that, the proposed method give better control performance when compared to classical firefly algorithm. Also, the comparison charts of control load power and the power loss are analyzed. The characteristics of power loss, voltage, and power loss iteration are studied.

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