MFFA Based Optimal Location and Capacity of UPFC for Improving the Loadability of Power System

1G.GOKULAKRISHNAN
Assistant Professor, School of Electrical Engineering (SELECT), VIT University, Vellore, Tamilnadu
gokulakrishnan0781@gmail.com

2Dr.V. RAMESH
Professor, School of Electrical Engineering(SELECT), VIT University, Vellore, Tamilnadu

Abstract:- In this article, a Modified Firefly Algorithm (MFFA) based optimal location and sizing of unified power flow controller (UPFC) to progress the dynamic stability is projected. At this point, the maximum power loss bus is acknowledged at the most auspicious location for fixing the UPFC, as the generator outage disturbs the power flow constraints like power loss, voltage and active and reactive power flow. An FFA (Firefly algorithm) is explored with the help of gravitational search algorithm (GSA). The projected algorithm progresses the loadability of power scheme with UPFC. Haphazard movement factor of firefly algorithm is enhanced by hybridizing the GSA with FFA. In outmoded firefly algorithm, the subsequent movement of firefly is hinge on the movement factor that is dogged by haphazardly so the best movement of firefly is prospect to fails by the dissemination of haphazard number. Therefore, the best location for placing and capability of UPFC can severable to identify precisely. In this article, a GSA based modified optimization algorithm is utilized to regulate the optimal haphazard movement factor of fireflies. Therefore, the optimal location and capability of UPFC is dogged competently if associated with traditional FFA. Lastly, the projected work is applied in MATLAB/Simulink and the optimal location and capacity of UPFC is scrutinized as per the variation of voltage, power loss and power balance of the network. To validate our anticipated method, we complete replications on an IEEE 30-bus power scheme. The solutions we have attained designate that installing UPFC in the location augmented by MFFA can meaningfully improve the loadability of power scheme by reducing the overloaded lines and the bus voltage edge violations.

Key-words:- MFFA, GSA, Power loss, Load Ability, UPFC, optimal Location, Capacity and Load Variation

1. Introduction
Universally, because of the ecological and economic controls to create new producing plants and transmission lines, Electric power schemes have been obliged to performance to more or less their full dimensions [1, 2]. The amount of electric power that can be disseminated within two positions via a transmission network is limited using security and constancy controls [3]. Power flow in the lines and transformers should not be endorsed to rise to a level where a random event could cause the network collapse as flowed outages [4, 5]. The scheme is said to be congested if such an edge achieves. Handling obstacle to decrease the constraints of the transmission network in the aggressive market has, therefore, turn into the central activity of schemes operators [6]. It has been inspected that the disappointing management of operations could increase the obstruction cost that is a needless encumbrance on users [7].

For scheming the power transmission scheme, Flexible Alternating Current Transmission System (FACTS) is a secure apparatus implemented [8, 9]. FACTS is designated as "a power electronic based scheme and other fixed apparatus that deal control of one or more AC transmission scheme parameters to progress controllability and raise power transmission capability" [10]. The dissimilar types of FACTS tools available for this drive encompasses Static VAR Compensator (SVC), Static Synchronous series compensator (SSSC), Thyristor controlled series Capacitor (TCSC), UPFC, Static Synchronous Compensator (STATCOM) and Interlink Power Flow Controller (IPFC) [11]. By introducing dynamic and reactive voltage component in sequences with the transmission line, UPFC is one among the FACTS tools that can accomplish the power flow in transmission line amongst them [12, 13].
Appearance of FACTS tools unlocks up new occasions for controlling power and enlightening the exploitable capacity of offered transmission lines [14]. An optimal site of UPFC tool badges to control its power flows for a unified network and as a solution to increase the system load capability [15]. On another aspect, a restricted number of tools, beyond that this load ability can never be enriched, have been scrutinized [16]. The optimal location and optimal capacity of a quantified number of FACTS in a power scheme is an issue of combinatorial analysis [17, 18]. Different types of optimization algorithm have been implemented like genetic algorithms, TABU search, simulated annealing and etc. to carry out this type of issue [19, 20]. In the document, the GSA based modified FFA is recommended for controlling the load deviation of power scheme by computing the optimal location and sizing of UPFC. The GSA is engaged and the crusade factor is augmented as a temporary of haphazard movement factor of firefly. The current research investigations are elucidated in segment 2 and the quantified report of recommended algorithm is presented in segment 3. The conversation of solutions and ending of document is presented in segment 4 and 5 consistently.

2. Recent Research Work: A Brief Review

In literature, quantities of associated works are accessible that is on the basis of enlightening the power transfer capability of power scheme. A few among them are appraised here. Mahdi Motalleb et al.[21] have designated a heuristic technique to detect the optimal location(s) and capacity of a multi-purpose BESS including transmission and distribution portions. In the transmission storage portion, a sensitive investigation was accomplished by Complex-Valued Neural Networks (CVNN) and Time Domain Power Flow (TDPF) for identifying the optimal BESS location(s). In addition to, running TDPF and Economic Dispatch (ED) tips to the optimal BESS size. In the distribution storage portion, the optimal BESS size is considered to perform distribution grid services like peak load shaving and load curve smoothing.

An enhanced evolutionary algorithm on the basis of oppositional krill herd algorithm (OKHA) for gaining optimal steady-state performance of power schemes was deliberated by Susanta Dutta et al.[22]. This article also offers the effect of UPFC location in steady-state investigation and to validate the competences of UPFC in regulating active and reactive power flow inside any electrical network. In power scheme, diminishing the power loss in the transmission lines and/or decreasing the voltage deviation at the load buses by regulating the reactive power is mentioned as optimal reactive power dispatch (ORPD).

Cuckoo Optimization Algorithm (COA) based Unified Power Quality Conditioner (UPQC) distribution in three phase unbalanced distribution network was exemplified by Jayanti Sarker et al.[23]. The function of UPQC was deliberate in the name of minimization of load disturbance at the time of fault ailment in the test schemes, percentage discount of entire harmonic distortion and separate harmonics, minimization of real power loss, reduction in voltage unbalance and upsurge in cost savings at the time of normal operating condition. The augmented usage of nonlinear loads in distribution scheme was accumulative the misrepresentation in the voltage and current waveforms. Furthermore, the distribution schemes were characteristically unbalanced.

A method for improving the FACTS devices, so as to preserve the voltage constancy in the power transmission schemes was given by Sai Ram Inkollu et al.[24]. At this time, the particle swarm optimization algorithm (PSO) and the adaptive GSA method are projected for refining the voltage solidity of the power transmission schemes. In the projected method, the PSO algorithm is utilized for enhancing the gravitational constant and to progress the searching function of the GSA. The projected algorithm is an actual technique for detecting the optimal location and the sizing of the FACTS controllers. The optimal locations and the power ratings of the FACTS devices are dogged on the basis of the voltage collapse rating and also the power loss of the scheme. At this time, two FACTS devices are utilized to evaluate the function of the anticipated algorithm, such as, the UPFC and the interline power flow controller (IPFC).

An optimal UPFC placement and load shedding coordination method for voltage collapse prevention in contingency condition by Hybrid Imperialist Competitive Algorithm-Pattern Search (HICA-PS) as explained by Majid Moazzami et al.[25]. ICA is the chief optimizer of the projected algorithm although pattern search is implemented to further fine tune the solution of the ICA. As power schemes become more multifaceted and heavily loaded, voltage collapse has become one among the most disparaging events in modern power schemes leading to blackouts in electric
utilities global. Voltage collapse is mostly instigated by operating power schemes at lower stability margins because of a surge in electric power demand.

A simple and consistent optimization tactic to optimally assign the TCSC and UPFC with wind generator under deregulated power scheme was given by Subhojit Dawn et al. [26]. The projected method is on the basis of stage by stage variation in control parameters of TCSC and UPFC devices. Solutions have been dogged for all conceivable locations, recompense level and reactance of TCSC and UPFC, maximization of social welfare, reactive power injection or absorption maximization of profit with minimization of objective performance. The double auction bidding model has been assimilated.

A GSA based optimization algorithm was implemented for the optimal distribution of FACTS devices in transmission scheme was deliberated by Biplab Bhattacharyya et al. [27]. Both active and reactive loading of the power scheme was measured and the effect of FACTS devices on the power transfer capacity of the individual generator was considered. The active power loss and operating cost also decreases by momentous margin with FACTS devices at each loading circumstance and GSA based planning method of reactive power sources with FACTS devices found to be the best amongst all the approaches deliberated in the name of dipping active power loss and whole operating cost of the scheme under all active and reactive loading circumstances.

The optimized position of placing FACT device in an industrial zone, the reactive power losses could be measured within a limit and could progress the real power flow in the power scheme network was described by M-Packiasudha et al. [28]. GSA on the basis of Newtonian law of gravity amongst masses was utilized to detect the minimum value precisely. In Opposition based GSA (OGSA) in its place in view of both active and passive masses, the passive mass alone is deliberated that was equivalent to reactive power force constituent. But in Cumulative Gravitational Search Algorithm (CGSA) active and passive mass communications are together measured so the resultant force attained within the masses will be efficiently considered. At this time, the two dissimilar mass inertias namely active mass and passive mass are implemented in CGSA and exact solutions could be found. The search agents were an assortment of masses that interacts with each other on the basis of Newtonian gravity and laws of motion in that algorithm.

3. The Modeling Of UPFC

3.1. Configuration And Equivalent Circuit Of UPFC

The UPFC is a FACTS device that is accomplished of giving active and reactive load flow control within its terminals. It may also give reactive power recompense to the node at that it is associated. The device comprises of two converters associated together using a common DC link as illustrated in figure 1. These converters are associated to the power scheme through coupling transformers. One converter is linked in shunt to the sending end node at the time of the second converter is associated in series within the sending and receiving end nodes [29, 30]. The UPFC cannot produce or absorb active power and similar the active power in the two converters must be balanced if active power loss is deserted. This is attained through the DC link. The converters, though, may produce or absorb reactive power. The UPFC equivalent circuit revealed in figure 2 is utilized to originate the steady-state model. The corresponding circuit comprises of two ideal voltage sources demonstrating the basic Fourier series constituent of the switched voltage waveforms at the AC converter terminals. The UPFC voltage resources are declared as equations 1 and 2,

\[ V_{se} = |V_{se}| \left( \cos \varphi_{se} + j \sin \varphi_{se} \right) \]  
\[ V_{sh} = |V_{sh}| \left( \cos \varphi_{sh} + j \sin \varphi_{sh} \right) \]

Where, \( V_{se} \) and \( V_{sh} \) are the manageable magnitude \( V_{se}^{\min} \leq |V_{se}| \leq V_{se}^{\max} \) and \( 0 \leq \varphi_{se} \leq 2\pi \) phase angle of the voltage source demonstrating the shunt converter. The magnitude \( V_{sh} \) and phase angle \( \varphi_{sh} \) of the voltage source demonstrating the series converter are controlled within these limits:

\( V_{sh}^{\min} \leq |V_{sh}| \leq V_{sh}^{\max} \) and \( 0 \leq \varphi_{sh} \leq 2\pi \).
3.2. Power Flow Calculation With UPFC

This area clarifies the force stream estimation with UPFC gadgets. Taking into account the proportional circuit appeared in figure 2, the dynamic and receptive force conditions (3-10),

At bus $k$,

$$
P_k = V_k^2 G_{kk} + V_k V_k (G_{km} \cos(\theta_k - \theta_m) + B_{km} \sin(\theta_k - \theta_m)) + V_k V_{sc} (G_{km} \cos(\theta_k - \delta_{sc}) + B_{km} \sin(\theta_k - \delta_{sc})) + V_k V_{sh} (G_{sh} \cos(\theta_k - \delta_{sh}) + B_{sh} \sin(\theta_k - \delta_{sh}))
$$

$$
Q_k = -V_k^2 B_{kk} + V_k V_k (G_{km} \sin(\theta_k - \theta_m) - B_{km} \cos(\theta_k - \theta_m)) + V_k V_{sc} (G_{km} \sin(\theta_k - \delta_{sc}) - B_{km} \cos(\theta_k - \delta_{sc})) + V_k V_{sh} (G_{sh} \sin(\theta_k - \delta_{sh}) - B_{sh} \cos(\theta_k - \delta_{sh}))
$$

At bus $m$,

$$
P_m = V_m^2 G_{mm} + V_m V_m (G_{km} \cos(\theta_m - \theta_k) + B_{km} \sin(\theta_m - \theta_k))
$$

$$
Q_m = -V_m^2 B_{mm} + V_m V_m (G_{km} \sin(\theta_m - \theta_k) - B_{km} \cos(\theta_m - \theta_k))
$$

At series converter,

$$
P_{sc} = V_{sc}^2 G_{sc} + V_{sc} V_{sc} (G_{sc} \cos(\theta_{sc} - \theta_k) + B_{sc} \sin(\theta_{sc} - \theta_k))
$$

$$
Q_{sc} = -V_{sc}^2 B_{sc} + V_{sc} V_{sc} (G_{sc} \sin(\theta_{sc} - \theta_k) - B_{sc} \cos(\theta_{sc} - \theta_k))
$$

At shunt converter,

$$
P_{sh} = V_{sh}^2 G_{sh} + V_{sh} V_{sh} (G_{sh} \cos(\theta_{sh} - \theta_k) + B_{sh} \sin(\theta_{sh} - \theta_k))
$$

$$
Q_{sh} = -V_{sh}^2 B_{sh} + V_{sh} V_{sh} (G_{sh} \sin(\theta_{sh} - \theta_k) - B_{sh} \cos(\theta_{sh} - \theta_k))
$$

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

$$
Y_{kk} = G_{kk} + jB_{kk} = Z^{-1}_{sc} + Z^{-1}_{sh}
$$

$$
Y_{mm} = G_{mm} + jB_{mm} = Z^{-1}_{sc}
$$

$$
Y_{km} = Y_{mk} = G_{km} + jB_{km} = -Z^{-1}_{sc}
$$

$$
Y_{sh} = G_{sh} + jB_{sh} = -Z^{-1}_{sh}
$$
Dismissing the converters misfortunes prompts dynamic influence parity as portrayed condition (15),

\[ P_{se} + P_{sh} = 0 \]  

(15)

The coupling transformer resistance is additionally ignored bringing about equivalent dynamic force in transports and that is depicted as condition (16),

\[ P_{sh} + P_{se} = P_{k} + P_{m} = 0 \]  

(16)

Henceforth the UPFC gadget controls the extent of the voltage of the parallel converter terminal, the dynamic force amongst transport and the responsive force infused to bus. Along these lines, UPFC controls transport as a PQ bus.

### 3.3. Objective Function

The principle goal of this work is to decide the ideal parameter setting and area of the UPFC in the system for upgrading the framework security level [31, 32]. This improvement can be accomplished through dispensing with or minimizing over-burden lines and transport voltage limit infringement under the most serious single line possibilities. Subsequently, we consider the accompanying specialized target capacity is portrayed as equation (17),

\[ F_{z} = \sum_{i=1}^{m} w_{i} \left( \frac{S_{i}}{S_{\max}} \right)^{2z} + \sum_{n=1}^{n} W_{n} \left( \frac{V_{n}^{\max} - V_{n}}{V_{n}^{\max}} \right)^{2z} \]  

(17)

The optimization is Subject to:

(A) Equality Constraints

In this advancement the correspondence requirements are the force stream conditions, which are given all in all structure as took after equations (18-21),

For bus k:

\[ P_{k} (V_{k}, \theta) + P_{dk} - P_{gk} = 0 \]  

(18)

\[ Q_{k} (V_{k}, \theta) + Q_{dk} - Q_{gk} = 0 \]  

(19)

For bus m:

\[ P_{m} (V_{m}, \theta) + P_{dm} - P_{gm} = 0 \]  

(20)

\[ Q_{m} (V_{m}, \theta) + Q_{dm} - Q_{gm} = 0 \]  

(21)

For the line where the UPFC is introduced, While for alternate lines \( P_{k}, Q_{k}, P_{m}, \) and \( Q_{m} \) can be computed utilizing the traditional force stream conditions.

(B) Inequality Constraints:

This area portrays the imbalance requirements like voltage, and genuine and responsive force streams, which are influenced because of the dissent of the era unit [33, 34]. The force framework dynamic steadiness for the most part considers the voltage soundness of each hub. The steady power stream needs the voltage at every transport at the scope of 0.95 – 1.05 \( p.u \), which is depicted as equations (22-27),

\[ P_{gk}^{\min} \leq P_{gk} \leq P_{gk}^{\max} ; k = 1,2,\ldots,n_{g} \]  

(22)

\[ Q_{gk}^{\min} \leq Q_{gk} \leq Q_{gk}^{\max} ; k = 1,2,\ldots,n_{g} \]  

(23)

\[ V_{k}^{\min} \leq V_{k} \leq V_{k}^{\max} ; k = 1,2,\ldots,n_{g} \]  

(24)

\[ \varphi_{k}^{\min} \leq \varphi_{k} \leq \varphi_{k}^{\max} \]  

(25)

\[ V_{se}^{\min} \leq V_{se} \leq V_{se}^{\max} \]  

(26)

\[ V_{sh}^{\min} \leq V_{sh} \leq V_{sh}^{\max} \]  

(27)

These variables are at the same time upgraded to improve the security of force framework under single line possibilities. Amid single line possibilities, the area and parameter setting of UPFC altogether impact the force stream in the system [35-38]. Consequently, any adjustment in one, two or these parameters will yield an adjustment in the force stream (line stacking and transport voltages which are the principle variables of the goal capacity).

### 3.4. Proposed Modified Firefly Algorithm

Fireflies use streak signs to draw in different fireflies for potential mates. Taking into account this conduct, a metaheuristic calculation was produced by Xin-She Yang [39, 40]. Every one of the fireflies is viewed as unisexual and their fascination is straightforwardly corresponding to the power of their glimmer. Consequently, if a firefly molecule had the decision of moving toward both of two fireflies, it will be more pulled in toward the firefly with higher splendor and moves in that course. On the off chance that there are no fireflies adjacent, the firefly will move in an arbitrary heading. The shine of glimmer is connected with the wellness capacity. In firefly calculation, there are three admired tenets:

i. A firefly will be pulled in by different fireflies paying little mind to their sex.

ii. Attractiveness is corresponding to their shine and declines as the separation among them increments.

iii. The scene of the target capacity decides the splendor of a firefly.

Fireflies or lightning bugs have a place with a group of creepy crawlies that are fit to create normal light to draw in a mate or prey. There are around two thousand firefly species which create short and cadenced flashes. These flashes regularly...
have all the earmarks of being in an interesting example and produce an astounding sight in the tropical territories amid summer. In the usage of the calculation, the glimmering light is figured in a manner that it gets connected with the target capacity to be advanced.

3.4.1. Characteristics Of The FFA

Fireflies are described by their glimmering light delivered by biochemical procedure bi-iridescence. The glimmering light may serve as the principle romance signs for mating [41]. For legitimate configuration of FA, two essential issues should be characterized: the variety of light intensity \( I \) and the formulation of attractiveness \( \beta \). The appeal of a firefly is dictated by its light power or shine and the brilliance is connected with the goal capacity. The light intensity \( I(r) \) with the separation monotonically and exponentially as condition (28),

\[
I(r) = I_0 e^{\alpha r}
\]

Where, \( I_0 \) is the first light power and is the light retention coefficient. As a firefly's engaging quality is relative to the light force seen by adjoining fireflies, the allure \( \beta \) of a firefly is characterized as condition (29),

\[
\beta = \beta_0 e^{-\alpha r^2}
\]

Where, \( \beta_0 \) is the engaging quality at \( r = 0 \). The separation between any two fireflies \( x_i \) and \( x_j \) is communicated as Euclidean separation by the base firefly calculation as condition (30),

\[
r_{ij} = |x_i - x_j| = \sqrt{\sum_{k=1}^{n}(x_{ik} - x_{jk})^2}
\]

Where, \( n \) represents the dimensionality of the issue. The development of the \( i \)th firefly is pulled in to another more appealing firefly \( j \). The developments of fireflies comprise of three terms: the present position of \( i \)th firefly, appreciation for another more appealing firefly, and an arbitrary walk that comprises of a randomization parameter \( \alpha \) and the irregular created number \( \xi_i \) from interim [0, 1]. The development is communicated as condition (31),

\[
x_i = x_i + \beta_0 e^{-\alpha \xi_i} (x_i - x_j) + \alpha \xi_i
\]

Where, \( \alpha \) is the randomization parameter and is the vector of irregular numbers taken from Gaussian appropriation. Here \( \alpha \) controls the progression size. The quality \( \alpha \) is been 0.3, which controls haphazardly. Development of the fireflies toward the end of every era, the fireflies is positioned taking into account their shine, and the best firefly in every era is found. The fireflies are made to move in ensuing eras and in every era; the light intensities of every firefly is upgraded regarding the wellness capacity [42, 43]. Toward the end of the considerable number of eras, the firefly with the most astounding shine, i.e., the best wellness worth is finished up as the ideal answer for the issue.

For any vast number of fireflies \( n \), if \( n >> m \), then the merging of the calculation can be accomplished, where \( m \) is the quantity of nearby optima of an improvement issue. Here, the underlying area of \( n \) fireflies is circulated consistently in the whole hunt space, and as the emphases of the calculation proceed with fireflies meet into the entire ideal. By looking at the best arrangements among all these optima, the worldwide optima are accomplished. By modifying parameters \( \phi \) and \( \alpha \), the FFA can beat both the calculations Harmony Search calculation and PSO. It can locate the worldwide optima and also the nearby optima all the while and adequately. So the FFA is adjusted utilizing the GSA calculation so it is named as altered FFA calculation.

3.4.2. Structure Of The Firefly Algorithm

As said in an above segment, this paper concentrates on execution of the firefly calculation. This calculation depends on a physical recipe of light power those reductions with the expansion in the square of the separation. Notwithstanding, as the separation from the light source builds, the light retention causes that light gets to be weaker and weaker. These marvels can be connected with the target capacity to be improved. Therefore, the base FA can be detailed as represented in took after Algorithm1. Some blazing attributes of the fireflies are romanticized keeping in mind the end goal to detail the FA, as takes after:

Algorithm 1: Pseudo-code of the base Firefly algorithm.

Step 1: initialize generation counter, best solution, attractiveness

\[
t = 0; s^* = \Phi; \phi = 1.0;
\]

Step 2: initialize a population

\[
P^{(0)} = \text{initializeFA}();
\]

Step 3: while\( (t < \text{MAX}_\text{FES}) \) do

Step 4: Determine a new value of \( \alpha \)

\[
\alpha^{(t)} = \text{AlphaNew}();
\]

Step 5: Evaluates according to \( f(s) \)
EvaluateFA(P(t), f(s));

**Step 6:** Sorts according to f(s)

OrderFA(P(t), f(s));

**Step 7:** Determine the best solution

s* = FindTheBestFA(P(t), f(s));

**Step 8:** Vary the attractiveness accordingly

\[ P^{(t+1)} = MoveFA(P(t)) \]

**Step 9:** \( t = t + 1 \);

**Step 10:** end while

The number of inhabitants in fireflies is introduced by the "initializeFA()" capacity. Ordinarily, this introduction is performed haphazardly. The firefly seek process includes within the white circle (lines 3–10 in Algorithm 1) and is made out of the accompanying strides: Firstly, the "AlphaNew" capacity is committed to adjust the underlying estimation of parameter \( \alpha \). Note that this progression is discretionary in the firefly calculation [44]. Also, the "EvaluateFA" capacity assesses the nature of the arrangement. The execution of a wellness capacity is performed inside this. Thirdly, the "OrderFA" capacity sorts the number of inhabitants in fireflies as per their wellness values. Fourthly, the "FindTheBestFA" capacity chooses the best individual in populace. At long last, the "MoveFA" capacity plays out a move of the firefly positions in the hunt space. Note that the fireflies are moved towards the more appealing people. The firefly seek procedure is controlled by the greatest number of wellness capacity assessments \( MAX_{FES} \). At that point the GSA is utilized for decide the ideal irregular development element of fireflies. Therefore, the ideal area and limit of UPFC is resolved effectively when contrasted with customary FFA. The development element changes are portrayed in the following segment.

### 3.4.3. Gravitational Search Algorithm

Gravitational search algorithm (GSA) is an unconventional method, in favor of discovering an ideal clarification. This procedure is related with the former process and appears to be a hopeful technique and provides a well-functioning that can be observed from the several replicated outcomes. The system is largely based on the Newtonian law, which expresses: there is a power of magnetism force between each subdivision of the world. The power of magnetism can be assessed by openly multiplying the amounts and by dividing the result to their square of the space between the particles. \( R \) is used in place of \( R^2 \) because simulation results shows that \( R \) is presenting much better result as related to \( R^2 \) [45, 46]. The following defines the necessary stages of GSA for the difficulty to be resolved. The algorithm for GSA can be specified as:

**Step 1:** Initialization

Understood that there are \( N \) agents, the position of the \( i^{th} \) agent is described as followed equation (32).

\[ X_i = (x_i^1, x_i^2, ..., x_i^d, ..., x_i^N); \text{ for } i = 1, 2, ..., N \ (32) \]

Where, \( N \) is the dimension of agent and \( x_i^d \) is the position of the \( i^{th} \) agent in the \( d^{th} \) dimension. The GSA twitches by casually hiring all agents in a quest space [42].

**Step 2:** Calculate the Total Force

To offer a stochastic distinctive to our algorithm, we assume that the entire power that turns on agent \( i \) in a dimension \( d \) be a aimlessly weighted sum of \( d^{th} \) mechanisms of the powers applied from other agents, which is proposed as equation (33).

\[ F_{i}^{d}(t) = \sum_{j \neq i}^{N} F_{ij}^{d}(t) \]

Where, \( rand_j \) is a random number in the interval \([0, 1]\). As said by Newton’s law of gravitation, the gravitational force \( F_{ij}^{d}(t) \) from the \( i^{th} \) mass due to \( j^{th} \) mass at a specific time period is described as equation (34),

\[ F_{ij}^{d}(t) = G(t) \frac{M_{pj}(t) \cdot M_{ij}(t)}{R_{ij}(t)^2} \]

Where, \( M_{pj}(t) \) is the dynamic gravitational mass associated to agent \( j \), \( M_{ij}(t) \) is the passive gravitational mass associated to agent \( i \), \( G(t) \) is gravitational constant at time \( t \), \( \varepsilon \) is a small constant, and \( R_{ij}(t) \) is the Euclidian distance between two agents \( i \) and \( j \), which is described in equation (35),

\[ R_{ij}(t) = \|X_i(t), X_j(t)\|_2 \ (35) \]

**Step 3:** Calculate the Acceleration and Velocity

Therefore, through the law of motion, the acceleration of the agent \( i \) at time \( t \), and in direction \( d^{th} \), \( a_{id}^{d}(t) \) is assumed as followed equation (36),

\[ a_{id}^{d}(t) = \frac{F_{i}^{d}(t)}{M_i(t)} \]

[Note: The equations and symbols used in the text are not properly rendered in this response.]
Where, $M_{ii}(t)$ is the inertial mass of $i$th agent. Moreover, the next velocity of an agent is measured as a fraction of its current velocity in addition its acceleration [43]. In this stage, the acceleration $a_i^d(t)$ and velocity $v_i^d(t+1)$ of the $i$th agent at time $t$ in $d$th dimension are measured over law of gravity and law of motion as follows. Hence, its velocity could be computed as followed equation (37),

$$v_i^d(t+1) = rand_i \times v_i^d(t) + a_i^d(t) \tag{37}$$

Where, $rand_i$ is a uniform random variable in the interval $[0, 1]$.

**Step 4: Update the Position of the Agents**

In this stage, the following position of the $i$th agents in $d$th, $x_i^d(t+1)$ dimension are modernized as following equation (38),

$$x_i^d(t+1) = x_i^d(t) + v_i^d(t+1) \tag{38}$$

We use this random number to give a randomized distinctive to the search.

**Step 5: Update the Gravitational and Inertial Masses**

Supposing the parity of the gravitational and inertia mass, the assessments of figures is analyzed using the map of fitness [47]. We modernize the gravitational and inertial masses by the following equations (39), (40) and (41),

$$M_{ai} = M_{pi} = M_i; i = 1,2,...,N \tag{39}$$

$$m_i(t) = \frac{fit_i(t) - worst(t)}{best(t) - worst(t)} \tag{40}$$

$$M_i(t) = \frac{m_i(t)}{\sum_{j=1} m_j(t)} \tag{41}$$

Where, $fit_i(t)$ signify the fitness value of the agent $i$ at time $t$, and worst ($t$) and best ($t$) are described.

**Step 6: Fitness Evaluation of All Agents**

In this pace, for all agents, best and worst fitness are calculated at each period designated as followed (for a minimization problem) equations (42) and (43),

$$best(t) = \min_{j \in \{1,2,...,N\}} fit_j(t) \tag{42}$$

$$worst(t) = \max_{j \in \{1,2,...,N\}} fit_j(t) \tag{43}$$

The gravitational constant, $G$, is modified at the opening and will be decreased with time to switch the quest precision [44].

**Step 7: Compute the Gravitational Constant ($G(t)$)**

In other words, $G$ is a function of the initial value ($G_0$) and time ($t$), which is estimated in equation (44).

$$G(t) = G_0 \times \exp\left(-a \times \frac{iter}{iter_{\text{max}}}\right) \tag{44}$$

Where, $G_0$ is the initial gravitational constant, $a$ is the coefficient of decrease, iter is the current iteration and $iter_{\text{max}}$ is the maximum number of iterations. Gravitational and inertia masses are merely analyzed by the fitness evaluation.

**Step 8: Repeat**

In this stage, phases from 2 to 7 are reiterated until the iterations extent the criteria. In the final iteration, the algorithm yields the assessment of locations of the consistent agent at detailed measurements and also this assessment is the universal resolution of the optimization problem [48]. Figure 3 signifies the flow chart for the GSA.
Once the procedure departs, the system is prepared to improve active constancy. Lastly the method of ideal position discovering and the UPFC is associated the position then it will assesses the limitations for showing the efficacy and the loadability of the system. Then, the suggested scheme is employed in the MATLAB platform and its concert is tested with numerous functioning situations. It is assumed in the subsequent unit.

4. Result And Analysis
The projected GSA based FFA algorithm was executed in MATLAB employed podium and the load ability functioning is appraised. Now, the suggested copy is mixture of FFA and GSA algorithms that are labeled for the differences of load ability in the power system. The offered procedure is used for examining the ideal setting to fix the UPFC for declining the power loss of the system. The load disparity resistor ability of projected method with UPFC is assessed with IEEE 30 bus bench mark system. The test structure IEEE 30 bus system is demonstrated in figure 4. At this time, the load bus real power is contrasted randomly as per the tolerable restrictions. By means of the suggested technique, the load power difference is skilful by connecting UPFC. Then, the voltage magnitude, load power and power loss are assessed after and before connecting UPFC. Also, the functioning of proposed algorithm is compared with conventional algorithm and the results are examined. From the examining bus system, the load bus particulars active power and voltage magnitude are defined. Then, the load power of load bus is modified arbitrary from the real assessment.
Through the modified values, the ideal location and capacity of UPFC is regulated. Then, the UPFC is positioned among two buses and the dynamic load difference controllability functioning is observed. Also, the magnitude of load voltage and the system power loss are assessed by anticipated technique and traditional approaches. The active power and reactive power is dignified from the selected bus and to bus after linking UPFC by the projected technique is observed. The ideal location and capacity of UPFC is defined by the planned technique. According to the ideal location, the UPFC is mounted between from and to load buses which are registered in the equivalent table 1. The load active, reactive power and power losses also observed while the selected bus and to bus after connecting UPFC. The power loss of the system is analyzed while normal load, load variation, and after linking UPFC. Following the ideal location, the UPFC is mounted between from and to load buses and the power loss are demonstrated.

<table>
<thead>
<tr>
<th>Line no</th>
<th>From bus</th>
<th>To bus</th>
<th>From bus power</th>
<th>To bus power</th>
<th>Power losses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Active (P)</td>
<td>Reactive (Q)</td>
<td>Active (P)</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>4</td>
<td>3.3837</td>
<td>5.6816</td>
<td>7.8808</td>
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<tr>
<td>20</td>
<td>14</td>
<td>15</td>
<td>3.0287</td>
<td>2.3926</td>
<td>1.5143</td>
</tr>
<tr>
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<td>2</td>
<td>6</td>
<td>8.7423</td>
<td>6.0862</td>
<td>8.7423</td>
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<tr>
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<td>7</td>
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<td>4.6765</td>
<td>4.2443</td>
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<td>18</td>
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<td>2.6382</td>
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<td>8</td>
<td>28</td>
<td>2.22</td>
<td>18.9032</td>
<td>2.775</td>
</tr>
</tbody>
</table>

**Table 1:** Measured load line active and reactive power

**Figure 4:** Proposed IEEE 30 bus system test structure

**Figure 5:** Comparison chart of load active and reactive power of selected from bus

**Figure 6:** Comparison chart of load active and reactive power of selected to bus
The assessment chart of load active and reactive power of designated from bus is accessible in figure 5 and the selected to bus is exemplified in figure 6. The load ability operative of projected technique is examined with actual load of the system and during load variation is demonstrated in figure 7. When load varied unexpectedly, it altered from the real value so the constancy of the system gets disturbed. Now, the projected technique is functioning in the direction of preserve the constancy of the system by relating UPFC. The UPFC is injecting the power both associated buses and the load flow power is composed. When assess the balance power, the planned technique restrain the load power difference efficiently associated to conventional algorithm. Therefore the constancy of the system near upholds the regular scheme.

Table 2: The voltage variation of load bus at different loading levels

<table>
<thead>
<tr>
<th>Line no</th>
<th>From Bus</th>
<th>To Bus</th>
<th>Actual voltage</th>
<th>Load voltage</th>
<th>Connect with UPFC</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>12</td>
<td>13</td>
<td>1.0572</td>
<td>1.071</td>
<td>1.8431</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>4</td>
<td>1.0228</td>
<td>1.0136</td>
<td>1.7709</td>
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<tr>
<td>28</td>
<td>10</td>
<td>22</td>
<td>1.0367</td>
<td>1.03</td>
<td>1.8431</td>
</tr>
<tr>
<td>30</td>
<td>15</td>
<td>23</td>
<td>1.0355</td>
<td>1.0229</td>
<td>1.8434</td>
</tr>
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<td>14</td>
<td>15</td>
<td>1.0414</td>
<td>1.0355</td>
<td>1.8466</td>
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<tr>
<td>3</td>
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<td>1.01</td>
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<td>5</td>
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<td>1.0236</td>
<td>1.8434</td>
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<td>1.0069</td>
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<td>1.0094</td>
<td>1.7898</td>
</tr>
<tr>
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<td>28</td>
<td>27</td>
<td>1.0094</td>
<td>1.01</td>
<td>1.7947</td>
</tr>
</tbody>
</table>

The voltage magnitude of the system is rest on the injecting voltage of UPFC. When switch the load variation by UPFC, the voltage variation of the system is also enhanced. The per unit voltage of load bus is assessed at altered loading levels which are charted in table 2. From the voltage levels, the load difference control working of control is estimated. When loading level improved, the real value bus voltage \(1 \ p.u\) is departed so the constancy of the system is speckled. While joining UPFC with projected algorithm, the deviated voltage is enhanced near actual voltage level. In the case of projected technique with UPFC, the voltage level of the system gets improved as much measured level that are designated in figure 8, 9 and 10 correspondingly. The load voltage stability of the IEEE 30 bus system is assessed for sequences and shunt injecting buses.
For the period of load difference, the power loss of the system is departed from the real system power loss i.e. 10.53 MW. When power loss rise, the load buses are disturbed because of inadequate power to compare the load. Hence, the load ability of the resultant load buses is to be extravagant. After linking UPFC, the power loss of the system gets decreased. The power loss evaluation chart of load buses is presented in figure 11. This power loss is the least power loss between all the loading levels. According to the assessment, the projected technique gives as less power loss to associate with firefly algorithm. From the observed outcomes, the load voltage stability development of suggested technique with UPFC is exposed. In shunt and series injecting cases, the voltage stability of the suggested technique is developed as improved level when related to UPFC with traditional algorithm. Thus, the load power difference is measured efficiently by projected technique.

5. Conclusion
The projected a MFFA centered best location and sizing by UPFC was employed in MATLAB and the operational is assessed. The working of load bus power, voltage magnitude, and power loss were observed and related with conventional algorithm. From assessing the efficiency, diverse loading level are used. The UPFC can offer control of voltage magnitude, voltage phase angle and impedance. Hence, it can be operated efficiently to raise power transference ability of the current power transmission lines and decrease functioning. Imitations were achieved on IEEE 30-bus test systems. The active constancy of IEEE 30 bus benchmark system, which comprises of six generator bus, 21 load bus and 42 diffusion lines, is examined in this segment. Primarily, the method load flow examination is prepared by the normal Newton–Raphson (N–R) method. Here, the IEEE 30 bus system normal essentials are used. Optimizations were executed on the control limitations containing the position of the UPFCs and their locations in the line. The relative study displays that, the projected technique give better switch effective when associated to conventional firefly algorithm. Also, the assessment graphs of control load power and the power loss are examined. The features of power loss, voltage, and power loss iteration are calculated.

References


[40] Iztok Fister, Iztok Fister, Xin-She Yang and Janez Brest, "A comprehensive review


