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

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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,

$$V_{se} = |V_{se}|(\cos\varphi_{se} + j\sin\varphi_{se}) \quad (1)$$

$$V_{sh} = |V_{sh}|(\cos\varphi_{sh} + j\sin\varphi_{sh}) \quad (2)$$

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

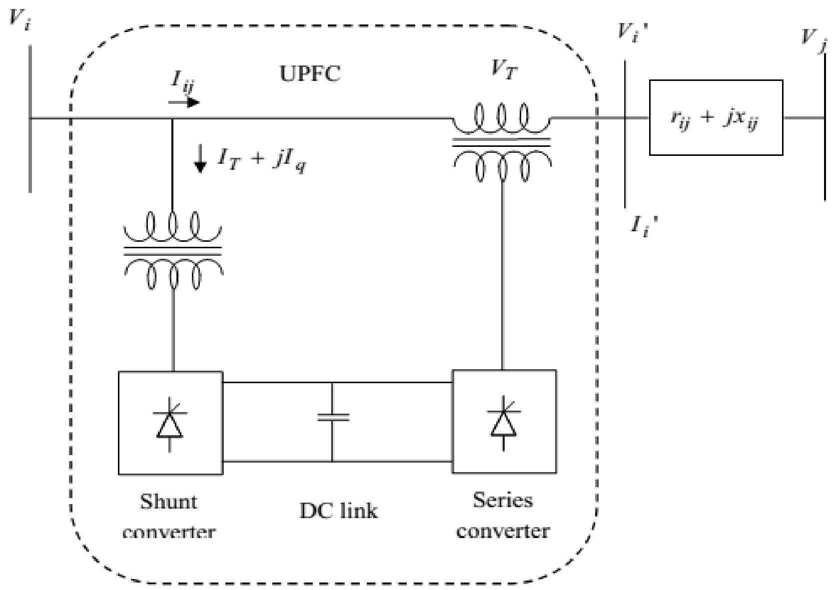

Figure.1: Basic schematic diagram of UPFC

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),

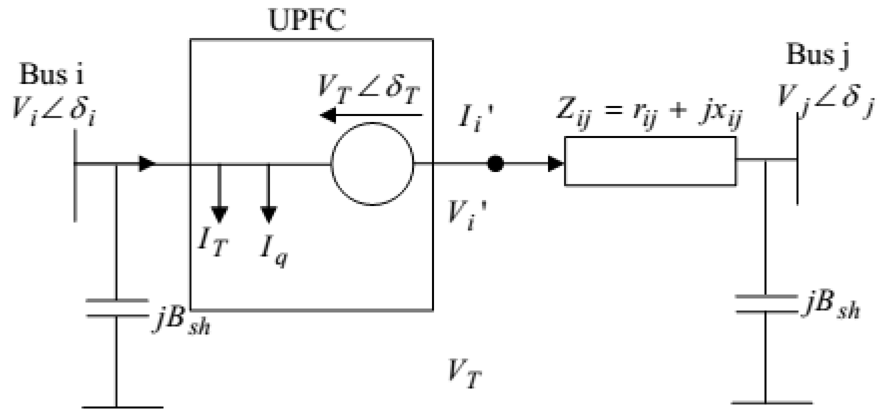

Figure 2: UPFC equivalent circuit

At bus k,

$$P_k = V_k^2 G_{kk} + V_k V_m (G_{km}\cos(\theta_k - \theta_m) + B_{km}\sin(\theta_k - \theta_m)) + V_k V_{se}(G_{km}\cos(\theta_k - \delta_{se}) + B_{km}\sin(\theta_k - \theta_{se})) + V_k V_{sh}(G_{sh}\cos(\theta_k - \delta_{vR}) + B_{sh}\sin(\theta_k - \theta_{sh})) \quad (3)$$

$$Q_k = -V_k^2 B_{kk} + V_k V_m (G_{km}\sin(\theta_k - \theta_m) - B_{km}\cos(\theta_k - \theta_m)) + V_k V_{se}(G_{km}\sin(\theta_k - \delta_{se}) - B_{km}\cos(\theta_k - \theta_{se})) + V_k V_{sh}(G_{sh}\sin(\theta_k - \delta_{vR}) - B_{sh}\cos(\theta_k - \theta_{sh})) \quad (4)$$

At bus m,

$$P_m = V_m^2 G_{mm} + V_m V_k (G_{mk}\cos(\theta_m - \theta_k) + B_{mk}\sin(\theta_m - \theta_k)) + V_m V_{se}(G_{mm}\cos(\theta_m - \delta_{se}) + B_{mm}\sin(\theta_m - \theta_{se})) \quad (5)$$

$$Q_m = -V_m^2 B_{mm} + V_m V_k (G_{mk}\sin(\theta_m - \theta_k) - B_{mk}\cos(\theta_m - \theta_k)) + V_m V_{sh}(G_{mm}\sin(\theta_m - \delta_{se}) - B_{mm}\cos(\theta_m - \theta_{se})) \quad (6)$$

At series converter,

$$P_{se} = V_{se}^2 G_{mm} + V_{se} V_k (G_{mk}\cos(\theta_{se} - \theta_k) + B_{mk}\sin(\theta_{se} - \theta_k)) + V_{se} V_m (G_{mm}\cos(\theta_{se} - \delta_k) + B_{mm}\sin(\theta_{se} - \theta_m)) \quad (7)$$

$$Q_{se} = -V_{se}^2 B_{mm} + V_{se} V_k (G_{km}\sin(\theta_{se} - \theta_k) - B_{mk}\cos(\theta_{se} - \theta_k)) + V_{se} V_m (G_{mm}\sin(\theta_{se} - \delta_m) - B_{mm}\cos(\theta_{se} - \theta_m)) \quad (8)$$

At shunt converter,

$$P_{sh} = -V_{sh}^2 G_{sh} + V_{sh} V_k (G_{sh}\cos(\theta_{sh} - \theta_k) + B_{sh}\sin(\theta_{sh} - \theta_k)) \quad (9)$$

$$Q_{sh} = V_{sh}^2 B_{sh} + V_{sh} V_k (G_{sh}\sin(\theta_{sh} - \theta_k) - B_{sh}\cos(\theta_{sh} - \theta_k)) \quad (10)$$

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

$$Y_{kk} = G_{kk} + jB_{kk} = Z_{se}^{-1} + Z_{sh}^{-1} \quad (11)$$

$$Y_{mm} = G_{mm} + jB_{mm} = Z_{se}^{-1} \quad (12)$$

$$Y_{km} = Y_{mk} = G_{km} + jB_{km} = -Z_{se}^{-1} \quad (13)$$

$$Y_{sh} = G_{sh} + jB_{sh} = -Z_{sh}^{-1} \quad (14)$$

Dismissing the converters misfortunes prompts dynamic influence parity as portrayed condition (15),

$$P_{se} + P_{sh} = 0 \qquad (15)$$

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

$$P_{sh} + P_{se} = P_k + P_m = 0 \qquad (16)$$

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),

$$F_t = \sum_{l=1}^{ntl} w_l \left(\frac{S_l}{S_l^{\max}} \right)^{2q} + \sum_{m=1}^{nb} W_m \left(\frac{V_m^{ref} - V_m}{V_m^{ref}} \right)^{2r} \qquad (17)$$

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:

$$P_k(V,\theta) + P_{dk} - P_{gk} = 0 \qquad (18)$$

$$Q_k(V,\theta) + Q_{dk} - Q_{gk} = 0 \qquad (19)$$

For bus m:

$$P_m(V,\theta) + P_{dm} - P_{gm} = 0 \qquad (20)$$

$$Q_m(V,\theta) + Q_{dm} - Q_{gm} = 0 \qquad (21)$$

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),

$$P_{gk}^{\min} \le P_{gk} \le P_{gk}^{\max}; k = 1,2,...,n_g \qquad (22)$$

$$Q_{gk}^{\min} \le Q_{gk} \le Q_{gk}^{\max}; k = 1,2,...,n_g \qquad (23)$$

$$V_k^{\min} \le V_k \le V_k^{\max}; k = 1,2,...,n_g \qquad (24)$$

$$\varphi_k^{\min} \le \varphi_k \le \varphi_k^{\max} \qquad (25)$$

$$V_{se}^{\min} \le V_{se} \le V_{se}^{\max} \qquad (26)$$

$$V_{sh}^{\min} \le V_{sh} \le V_{sh}^{\max} \qquad (27)$$

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 bio-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 (β). 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),

$$I(r) = I_0 e^{\varphi r} \quad (28)$$

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 β of a firefly is characterized as condition (29),

$$\beta = \beta_0 e^{-\varphi r^2} \quad (29)$$

Where, β_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),

$$r_{ij} = \left\| x_i - x_j \right\| = \sqrt{\sum_{k=1}^{n} \left(x_{ik} - x_{jk} \right)^2} \quad (30)$$

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 α and the irregular created number ε_i from interim [0, 1]. The development is communicated as condition (31),

$$x_i = x_i + \beta_0 e^{-\varphi r_{ij}^2} (x_i - x_j) + \alpha \varepsilon_i \quad (31)$$

Where, α is the randomization parameter and is the vector of irregular numbers taken from Gaussian appropriation. Here α controls the progression size. The quality α 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 nearby ideal. By looking at the best arrangements among all these optima, the worldwide optima are accomplished. By modifying parameters φ and α, 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*

$$t = 0; s^* = \Phi; \varphi = 1.0;$$

Step 2: *initialize a population*

$$P^{(0)} = initializeFA();$$

Step 3: $while(t < MAX\_FES)$ ***do***

Step 4: *Determine a new value of* α

$$\alpha^{(t)} = AlphaNew();$$

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 while 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 α. 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).

$$X_i = (x^1{}_i, x^2{}_i, ..., x^d{}_i, ..., x^N{}_i);\ for, i = 1,2,..., N \quad (32)$$

Where, N is the dimension of agent and $x^d{}_i$ 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).

$$F_i{}^d(t) = \sum_{j=1, j\neq 1}^{N} rand_j F_{ij}{}^d(t) \quad (33)$$

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),

$$F_{ij}{}^d(t) = G(t)\frac{M_{pi}(t) * M_{aj}(t)}{R_{ij}(t) + \varepsilon}\left(x^d{}_j(t) - x^d{}_i(t)\right) \quad (34)$$

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

$$R_{ij}(t) = \left\| X_i(t), X_j(t) \right\|_2 \quad (35)$$

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}, $a_i{}^d(t)$ is assumed as followed equation (36),

$$a_i{}^d(t) = \frac{F_i{}^d(t)}{M_{ii}(t)} \quad (36)$$

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 t time 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),

$$v_i^d(t+1) = rand_i \times v_i^d(t) + a_i^d(t) \qquad (37)$$

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

Step 4: Update the Position of the Agents

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

$$x_i^d(t+1) = x_i^d(t) + v_i^d(t+1) \qquad (38)$$

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),

$$M_{ai} = M_{pi} = M_{ii} = M_i; i = 1,2,...N \qquad (39)$$

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

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

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),

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

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

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).

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

Where, G_0 is the initial gravitational constant, a is the coefficient of decrease, $iter$ is the current iteration and $iter_{\max}$ 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.

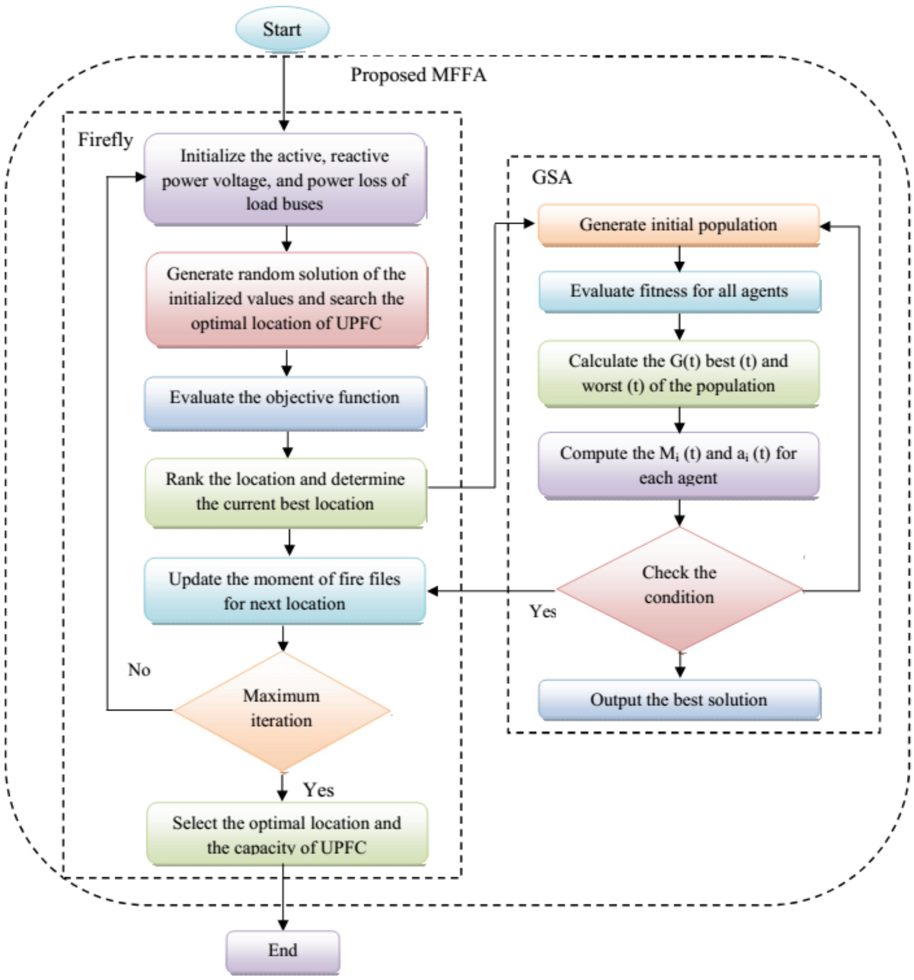

Figure.3: The flow chart for the proposed MFFA

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.

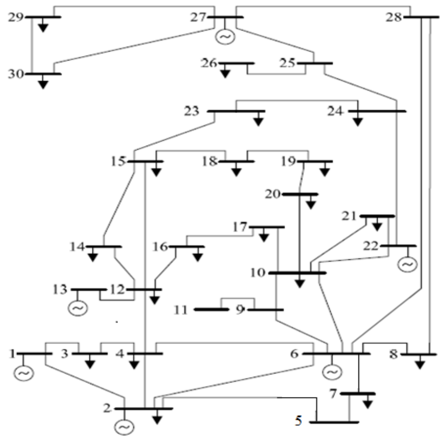

Figure.4: Proposed IEEE 30 bus system test structure

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 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 1: Measured load line active and reactive power

Line no	From bus	To bus	From bus power		To bus power		Power losses	
			Active (P)	Reactive (Q)	Active (P)	Reactive (Q)	Normal loss	With UPFC
16	12	13	4.75985	19.9333	2.3092	5.9498	21.6965	10.5349
4	3	4	3.3837	5.6816	7.8808	8.4593	15.6443	10.5138
28	10	22	20.4577	23.0708	20.4577	12.8815	13.4396	10.4985
30	15	23	12.4095	14.3751	4.1365	2.5035	19.0255	11.3014
20	14	15	3.0287	2.3926	1.5143	4.5918	17.3181	10.868
3	2	4	13.509	18.4805	10.8072	16.0391	18.1707	10.5647
6	2	6	8.7423	6.0862	8.7423	17.2517	16.8464	10.3659
8	5	7	1.0611	4.6765	4.2443	18.8689	22.0038	10.8353
22	15	18	8.7572	2.6382	13.1358	6.1524	15.7365	11.0124
33	24	25	12.0566	12.0445	7.234	12.5727	12.1376	11.1836
40	8	28	2.22	18.9032	2.775	24.0156	19.6163	10.8624
36	28	27	9.5673	8.6996	14.3509	2.1101	18.4824	10.3957

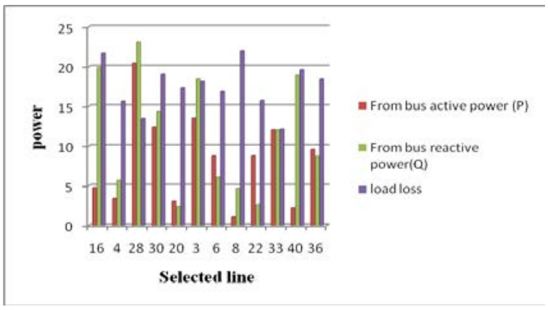

Figure.5: Comparison chart of load active and reactive power of selected from bus

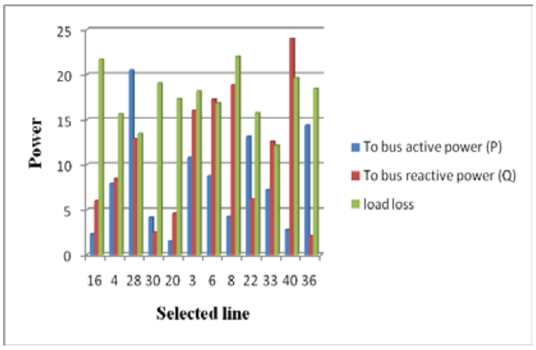

Figure.6: Comparison chart of load active and reactive power of selected to bus

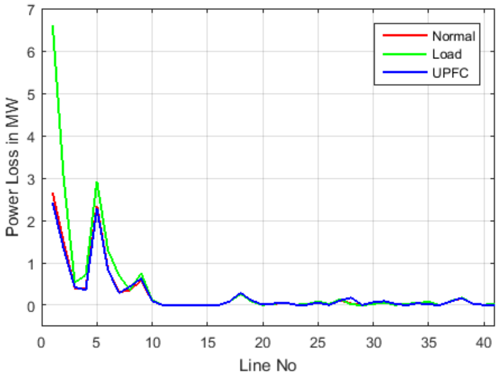

Figure.7: Performance of power losses in UPFC connected system

Throughout load variation, the usual load of the system is departed from the real load condition. So, the load ability of the analogous load buses is moved. To utilize the load variation of the suggested technique uses combination of UPFC.

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

Line no	From Bus	To Bus	Actual voltage		Load voltage		Connect with UPFC	
16	12	13	1.0572	1.071	1.8431	1.862	1.0356	1.0765
4	3	4	1.0228	1.0136	1.7709	1.773	1.0138	1.0069
28	10	22	1.0367	1.03	1.8431	1.8431	1.0356	1.03
30	15	23	1.0355	1.0229	1.8434	1.8371	1.0341	1.0219
20	14	15	1.0414	1.0355	1.8466	1.8434	1.0403	1.0341
3	2	4	1.033	1.0136	1.7657	1.773	1.043	1.0069
6	2	6	1.033	1.01	1.7657	1.7872	1.233	1.01
8	5	7	1.0044	0.9999	1.7736	1.7786	1.0043	0.9999
22	15	18	1.0355	1.0236	1.8434	1.8365	1.0341	1.0224
33	24	25	1.0158	1.0069	1.8386	1.8465	1.0154	1.0068
40	8	28	1.0103	1.0094	1.7898	1.7947	1.0103	1.0094
36	28	27	1.0094	1.01	1.7947	1.856	1.0094	1.001

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 $1p.u$ 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.

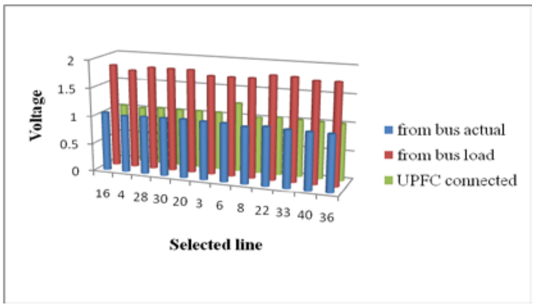

Figure.8: Voltage variation chart of selected from bus

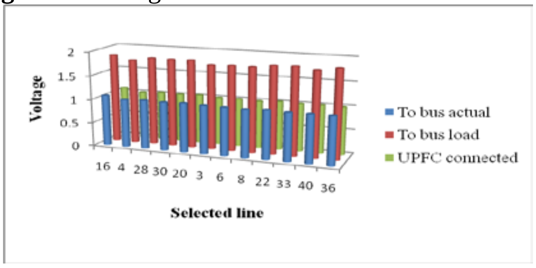

Figure.9: Voltage variation chart of selected to bus

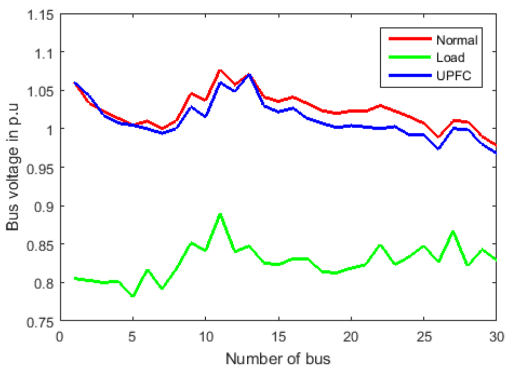

Figure.10: Performance of voltage variations in UPFC connected system

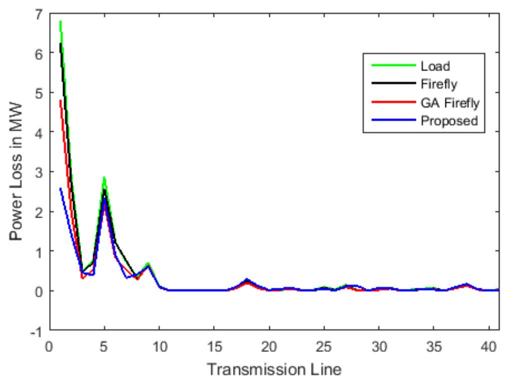

Figure.11: The comparison graph of power loss with classical methods

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

[1] P.Ramasubramanian, G.Uma Prasana and K. Sumathi, "Optimal Location of FACTS Devices by Evolutionary Programming Based OPF in Deregulated Power Systems", British Journal of Mathematics and Computer Science, Vol.2, No.1, pp.21-30, 2012

[2] Rakhmad Syafutra Lubis, Sasongko Pramono Hadi, and Tumiran, "Selection of Suitable Location of the FACTS Devices for Optimal Power Flow", International Journal of Electrical and Computer Sciences, Vol.12, No.3, pp.38-49, 2012

[3] S.Durairaj and B.Fox, "Optimal Placement of Facts Devices", International Conference on Energy and Environment, 2008

[4] D.Devaraj and J. Preetha Roselyn, "Genetic algorithm based reactive power dispatch for voltage stability improvement", International Journal of Electrical Power and Energy Systems, Vol.32, No.10, pp.1151–1156, 2010

[5] Chaohua Dai, Weirong Chen, Yunfang Zhu and Xuexia Zhang, "Reactive power dispatch considering voltage stability with seeker optimization algorithm", International Journal of Electric Power

Systems Research, Vol.79, No.10, pp.1462–1471, 2009
[6] A.H.Khazali and M.Kalantar, "Optimal reactive power dispatch based on harmony search algorithm", International Journal of Electrical Power and Energy Systems, Vol.33, No.3, pp.684–692, 2011
[7] Habibollah Raoufi and Mohsen Kalantar, "Reactive power rescheduling with generator ranking for voltage stability improvement", International Journal of Energy Conversion and Management, Vol.50, No.4, pp.1129–1135, 2009
[8] Rahul J.Shimpi, Rajendra P.Desale, Kunal S.Patil, Jaswantsing L.Rajput and Shailesh B.Chavan, "Flexible AC Transmission Systems", International Journal of Computer Applications, Vol.1, No.15, pp.54-57, 2010
[9] P.K.Dash, S.R.Samantaray and Ganapati Panda, "Fault Classification and Section Identification of an Advanced Series Compensated Transmission Line Using Support Vector Machine", IEEE Transaction on Power Delivery, Vol.22, No.1, pp.67-73, 2007
[10] H.O.Bansal, H.P.Agrawal, S.Tiwana, A.R.Singal and L.Shrivastava, "Optimal Location of FACT Devices to Control Reactive Power", International Journal of Engineering Science and Technology, Vol.2, No.6, pp.1556-1560, 2010
[11] D.Murali, and M.Rajaram, "Active and Reactive Power Flow Control using FACTS Devices", International Journal of Computer Applications, Vol.9, No.8, pp.45-50, 2010
[12] Xuan Wei, Joe H.Chow, Behruz Fardanesh and Abdel-Aty Edris, "A Common Modeling Framework of Voltage-Sourced Converters for Load Flow, Sensitivity, and Dispatch Analysis", IEEE Transactions On Power Systems, Vol.19, No.2, pp.934-941, 2004
[13] S.V.Ravi Kumar and S.Siva Nagaraju, "Functionality of UPFC in Stability Improvement", International Journal of Electrical and Power Engineering, Vol.1, No.3, pp.339-348, 2007
[14] Jigar S.Sarda, Vibha N.Parmar, Dhaval G.Patel,and Lalit K.Patel, "Genetic Algorithm Approach for Optimal location of FACTS devices to improve system loadability and minimization of losses", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol.1, No.3, pp.114-125, 2012
[15] Gerbex.S, Cherkaoui.R and Germond.A.J, "Optimal location of FACTS devices to enhance power system security", IEEE Bologna Power Tech Conference Proceedings, 2003
[16] Cai.L.J, Erlich.I and Stamtsis.G, "Optimal choice and allocation of FACTS devices in deregulated electricity market using genetic algorithms", IEEE PES Power Systems Conference and Exposition, 2004
[17] Mori.H and Goto.Y, "A parallel tabu search based method for determining optimal allocation of FACTS in power systems", International Conference on Power System Technology, 2000
[18] Wang Feng and Shrestha.G.B., "Allocation of TCSC devices to optimize total transmission capacity in a competitive power market", IEEE Power Engineering Society Winter Meeting, 2001
[19] Vaidya.P.S. and Rajderkar.V.P., "Optimal Location of Series FACTS Devices for Enhancing Power System Security", 4th International Conference on Emerging Trends in Engineering and Technology, 2011
[20] Belkacem Mahdad, Tarek Bouktir and Kamel Srairi, "GA Coordinated with Practical Fuzzy Rules with Multi Shunt FACTS Devices to Enhance the Optimal Power Flow", The International Conference on Computer and Tool, 2007
[21] Mahdi Motalleb, Ehsan Reihani and Reza Ghorbani, "Optimal placement and sizing of the storage supporting transmission and distribution networks", International Journal of Renewable Energy, Vol.94, pp.651-659, 2016
[22] Susanta Dutta, Pranabesh Mukhopadhyay, Provas Kumar Roy and Debashis Nandi, "Unified power flow controller based reactive power dispatch using oppositional krill herd algorithm", International Journal of Electrical Power and Energy Systems, Vol.80, pp.10–25, 2016
[23] Jayanti Sarker and S.K.Goswami, "Optimal Location of Unified Power Quality Conditioner in Distribution System for Power Quality Improvement", International Journal of Electrical Power and Energy Systems, Vol.83, pp.309–324, 2016

[24] Sai Ram Inkollu and Venkata Reddy Kota, "Optimal setting of FACTS devices for voltage stability improvement using PSO adaptive GSA hybrid algorithm", International Journal of Engineering Science and Technology, 2016

[25] Majid Moazzami, Mohammad Javad Morshed and Afef Fekih, "A new optimal unified power flow controller placement and load shedding coordination approach using the Hybrid Imperialist Competitive Algorithm-Pattern Search method for voltage collapse prevention in power system", International Journal of Electrical Power and Energy Systems, Vol.79, pp.263–274, 2016

[26] Subhojit Dawn and Prashant Kumar Tiwari, "Improvement of economic profit by optimal allocation of TCSC & UPFC with wind power generators in double auction competitive power market", International Journal of Electrical Power and Energy Systems, Vol.80, pp.190–201, 2016

[27] Biplab Bhattacharyya and Sanjay Kumar, "Loadability enhancement with FACTS devices using gravitational search algorithm", International Journal of Electrical Power and Energy Systems, Vol.78, pp.470–479, 2016

[28] M.Packiasudha, S.Suja and Jovitha Jerome, "A new Cumulative Gravitational Search algorithm for optimal placement of FACT device to minimize system loss in the deregulated electrical power environment", International Journal of Electrical Power and Energy Systems, Vol.84, pp.34–46, 2017

[29] Susanta Dutta, Provas Kumar Roy and Debashis Nandi, "Optimal location of UPFC controller in transmission network using hybrid chemical reaction optimization algorithm",Electrical Power and Energy Systems, Vol.64, pp.194–211, 2015

[30] N.Mohandas, R.Balamurugan and L.Lakshminarasimman, "Optimal location and sizing of real power DG units to improve the voltage stability in the distribution system using ABC algorithm united with chaos", Electrical Power and Energy Systems, Vol.66, pp.41–52, 2015

[31] R.Srinivasa Rao and V.Srinivasa Rao, "A generalized approach for determination of optimal location and performance analysis of FACTs devices", Electrical Power and Energy Systems, Vol.73, pp.711–724, 2015

[32] B.Vijay Kumar and N.V.Srikanth, "Optimal location and sizing of Unified Power Flow Controller (UPFC) to improve dynamic stability: A hybrid technique", Electrical Power and Energy Systems, Vol.64, pp.429–438, 2015

[33] B.Venkateswara Rao and G.V.Nagesh Kumar, "Optimal power flow by BAT search algorithm for generation reallocation with unified power flow controller", Electrical Power and Energy Systems, Vol.68, pp.81–88, 2015

[34] H.I.Shaheen, G.I.Rashed and S.J.Cheng, "Application and comparison of computational intelligence techniques for optimal location and parameter setting of UPFC", Engineering Applications of Artificial Intelligence, Vol.23, pp.203–216, 2010

[35] Somasundaram Alamelu, S.Baskar, C.K.Babulal and S.Jeyadevi, "Optimal siting and sizing of UPFC using evolutionary algorithms", Electrical Power and Energy Systems, Vol.69, pp.222–231, 2015

[36] Husam I.Shaheen, Ghamgeen I.Rashed and S.J.Cheng, "Optimal location and parameter setting of UPFC for enhancing power system security based on Differential Evolution algorithm", Electrical Power and Energy Systems, Vol.33, pp.94–105, 2011

[37] Seyed Abbas Taher and Muhammad Karim Amooshahi, "Optimal placement of UPFC in power systems using immune algorithm", Simulation Modelling Practice and Theory, Vol.19, pp.1399–1412, 2011

[38] Majid Moazzami, Mohammad Javad Morshed and Afef Fekih, "A new optimal unified power flow controller placement and load shedding coordination approach using the Hybrid Imperialist Competitive Algorithm-Pattern Search method for voltage collapse prevention in power system", Electrical Power and Energy Systems, Vol.79, pp.263–274, 2016

[39] P.Balachennaiah, M.Suryakalavathi and P.Nagendra, "Firefly algorithm based solution to minimize the real power loss in a power system", Ain Shams Engineering Journal, 2015

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

of firefly algorithms", International Journal of Swarm and Evolutionary Computation, Vol.13, pp.34–46, 2013
[41] M.M.Othman, Walid El-Khattam, Y.G.Hegazy and Almoataz Y.Abdelaziz, "Optimal placement and sizing of voltage controlled distributed generators in unbalanced distribution networks using supervised firefly algorithm", International Journal of Electrical Power and Energy Systems, Vol.82, pp.105–113, 2016
[42] Pratap Chandra Pradhan, Rabindra Kumar Sahu and Sidhartha Panda, "Firefly algorithm optimized fuzzy PID controller for AGC of multi-area multi-source power systems with UPFC and SMES", International Journal of Engineering Science and Technology, Vol.19, No.1, pp.338–354, 2016
[43] Adil Hashmi, Nishant Goel, Shruti Goel and Divya Gupta, "Firefly Algorithm for Unconstrained Optimization", IOSR Journal of Computer Engineering, Vol.11, No.1, PP.75-78, 2013
[44] P.Balachennaiah, M.Suryakalavathi and Palukuru Nagendra, "Optimizing real power loss and voltage stability limit of a large transmission network using firefly algorithm", International Journal of Engineering Science and Technology, Vol.19, No.2, pp.800–810, 2016
[45] Rajendra Ku Khadanga and Jitendriya Ku Satapathy, "A new hybrid GA–GSA algorithm for tuning damping controller parameters for a unified power flow controller", International Journal of Electrical Power and Energy Systems, Vol.73, pp.1060–1069, 2015
[46] S.M.Abd Elazim and E.S.Ali, "Optimal SSSC design for damping power systems oscillations via Gravitational Search Algorithm", International Journal of Electrical Power and Energy Systems, Vol.82, pp.161–168, 2016
[47] Biplab Bhattacharyya and Sanjay Kumar, "Reactive power planning with FACTS devices using gravitational search algorithm", Ain Shams Engineering Journal, Vol.6, No.3, pp.865–871, 2015
[48] Jayanti Sarker and S.K.Goswami, "Solution of multiple UPFC placement problems using Gravitational Search Algorithm", International Journal of Electrical Power and Energy Systems, Vol.55, pp.531–541, 2014