Optimal Placement and Capacity of UPFC Using JMFALO Technique to Upgrade Power System Dynamic Stability

Tarasi Madhuranthaka, T. Gowri Manohar

Abstract*: *This paper proposes an optimal placement and capacitance of UPFC for enhancing the dynamic stability of a power system using a new hybrid optimization technique. The hybrid optimization technique is the joined execution of both the moth flame optimization (MFO) and ant lion optimization (ALO) and hence it is named as Joined moth flame ant lion optimization (JMFALO) technique. Here, the MFO technique optimizes the maximum power loss line as the suitable location of the UPFC by considering the variation available in the bus system power flow parameters like voltage, angle, real power and reactive power. Dependent on the ALO technique the influenced location parameters and dynamic stability constraints are restored into secure limits utilizing the optimum capacity of the UPFC with least voltage deviation, loss of power, and reduced installation cost. Subsequently, to restore the dynamic stability constraints at a secure limit the optimized UPFC capacity is utilized. The dynamic stability constraint of the system is power balance constraint, active and reactive power loss, and UPFC installation cost and bus voltage constraints. The proposed technique is implemented in MATLAB/Simulink working platform. The performance of the proposed technique is assessed by utilizing the comparison analysis with the existing techniques.

Keywords*: *Optimal Placement, UPFC, Power System's Dynamic Stability, MFO, ALO

I. INTRODUCTION

Because of the ecological and economic constraints for new power plants and power lines, electrical power systems were compelled to procure full-scale capacities over the globe [1, 2]. Here, amount of power and stable controls of power can be transmitted through the transmission network between the two positions [3]. Since the network may have tumbled down as cascaded outages because of an arbitrary event, ought not to permit the stream of power in the lines and transformers [4, 5]. When such a limit accomplishes the system is believed to be blocked. So as to diminish the limitations of the transmission network in the compelling market, by the focal development of system administrators the checks are directed.[6]. It is examined that the congestion cost could be expanded by the inadequate management of dealings which is additional weight on clients [7].

The fixed device named as flexible alternating current transmission system (FACTS) which is connected for dealing with the power transmission system [8, 9]. So as to build up the controllability and amplify power transferability, the power electronic based FACTS device is utilized [10]. The Static Synchronous Series Compensator (SSSC), Thyristor Controlled Series Capacitor (TCSC), Static VAR Compensator (SVC), Static Synchronous Compensator (STATCOM), Unified Power Flow Controller (UPFC) and Interline Power Flow Controller (IPFC) are the different kinds of FACTS devices accessible for the reason [11]. Among all the devices UPFC is also one of the FACTS devices that can regulate the flow of power in a transmission line by including active and reactive voltage segment in the chain with the transmission line [12, 13]. New open doors for control power and upgrade of the capacity to have survival capacity are discharged by the presence of FACTS [14]. For an interconnected network, the power streams can control by an optimum location of the UPFC device which can expand the capacity of the system load [15]. On the other hand, a limit number of devices, far from which this load capacity cannot the slightest bit be enhanced, has been investigated [16]. The optimal location and optimal capacity of a specific number of FACTS in a power system avoids nonlinear reconsideration [17, 18]. Diverse sorts of optimization algorithm has been utilized to exertion out this sort of issue, for example, genetic algorithms (GA), reproduced annealing, Tabu search and so on [19, 20].

This paper employed an efficient hybrid approach for the optimal placement and UPFC sizing to improve the dynamic stability of the power system. Here, the greatest power loss bus is distinguished at the most positive area for locating the UPFC, in light of the fact that the generator blackout influences the influence power flow constraints, for example, loss of power, voltage, real and reactive power flow. Here, the MFO algorithm is used to distinguish the optimal location of UPFC and the required capacity of the UPFC is optimized by the ALO algorithm to recover the initial operating condition subject to the violated power flow quantities. The remaining section of the paper is organized as follows. Section 2 includes the recent research works about the optimal location and sizing of UPFC. Section 3 delineates the detailed explanation about the proposed approach. Section 4 includes the result and discussion, section 5 delineates the conclusions of the research.

II. RECENT RESEARCH WORKS: A BRIEF REVIEW

Numerous research works have previously existed in the literature which was based on the optimal location and UPFC capacity to improve the power

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stability system utilizing different methods and different features. A portion of the works is examined here.

For optimal placement and parameters setting of a Unified Power Flow Controller (UPFC), a multi-objective framework was illustrated by S. Galvani *et al.* [21]. The loss of active power and the system predictability was handled by the well-known multi-objective non-dominated sorting genetic algorithm (NSGA-II) in the presence of operational constraints and uncertainties. The probabilistic nature of the wind power was modelled by the Point estimate method (PEM). In order to damp frequency and power oscillations in the power system, a hybrid method was implemented by M. Khaksar *et al.* [22]. In their approach, the power system equipped with Unified Power Flow Controller (UPFC) and Power System Stabilizer (PSS) controllers. The offline and online stages are the two important stages in the hybrid method. In the offline stage, the PSO algorithm was used to found the coefficients of PSS and UPFC controllers for different operating points. In the online stage, the best PSS and UPFC coefficients according to the operating point were selected by a new fuzzy controller.

In the power system, an improved nonlinear (IN) H∞ control of UPFC was investigated and designed by B. Lei *et al.* [23] by the Hamiltonian function method. By means of variable transformation, the author has established the dissipative Hamiltonian structure of the UPFC system. After that, an IN H∞ control was put forward subject to the obtained dissipative Hamiltonian structure. For two inter-connected areas of a power system, an adaptive-supplementary UPFC was actualized by N. Zeb*et al.* [24]. With the above-mentioned control scheme, the stability of the power system was enhanced in terms of (1) effective LFO damping; (2) power transfer; (3) improvement in the dynamic parameters of the system; (4) active and reactive power support; (5) loss minimization; and (6) demand–supply management.

To improve the dynamic stability of the power system, the Firefly Algorithm (FA) and Cuckoo Search (CS) algorithm were invented by B. Vijay Kumar *et al.* [25] for identifying the optimal location and the capacity of UPFC. The maximum power loss was optimized by the FA technique. By utilizing the optimum capacity of the UPFC, the influenced location parameters and dynamic stability limitations are restored into secure limits by utilizing the CS technique. In order to manage the adaptable power flow control through transmission lines, a UPFC control strategy was developed by F. Albatsh*et al.* [26]. In order to optimize the parameters of power system stabilizer (PSS) of power network incorporating UPFC, M. S. Shahriar*et al.* [27] have presented the support vector regression (SVR) in real time to damp out the small signal oscillations hence to improve the transient stability.

A.Background of the Research Work

The review of the ongoing research work demonstrates that the minimization of working expense and for the position a loss of active power and capacity of FACTS devices is a significant part of the influence power system. The UPFC is one of the most competent FACTS devices among all the FACTS devices, for the load flow control considering as it can either at the same time handle the active and reactive power flow close to the lines in nodal voltage. To rectify the optimal location and capacity of UPFCs various examines have endeavoured as for various aims and strategies like non-dominated sorting genetic algorithm (NSGA-II), Firefly Algorithm (FA), Particle swarm algorithm (PSO), Cuckoo Search (CS) algorithm, and so on. In any case, for solving the optimization issues GA has raised one of the significant techniques but unfortunately, it neglects to solve of some variation in optimization issues. Because of the ineffectually known fitness capacities this issue happens chiefly, it delivers terrible chromosome blocks despite the fact that solitary great chromosome blocks traverse. There is no finished verification that GA will get the global optimum. Also, from the disadvantages of weak local search and slow convergence issue the PSO procedure experiences. Although the above-said techniques are used for optimal placement and capacity of UPFC, due to the increased number of samples required the complexity of the algorithm is very high. To overcome these challenges, optimal location and capacity of UPFC using advanced hybrid technology are required. The greater part of the works is displayed to deal with this issue in the literature, and the works are not giving the proficient outcomes. These issues and impediments have inspired to do this literature work.

III. MODELING OF UPFC FOR DYNAMIC STABILITY ENHANCEMENT OF POWER SYSTEM

In this section, the modelling of UPFC is employed to enhance the dynamic stability of the power system which is otherwise known as the FACTS device. The flows of the active power, flows of the reactive power, and voltage magnitude at the terminals of the UPFC are simultaneously controlled by this FACTS device.

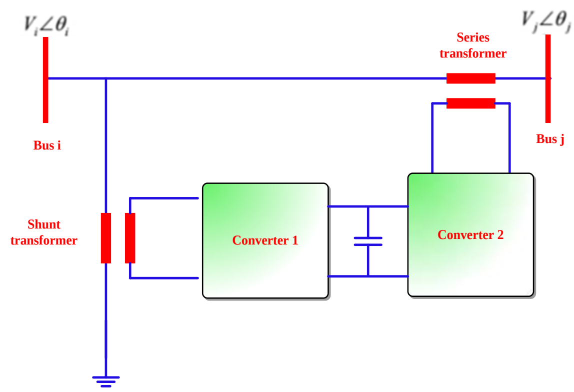

Fig. 1 Basic arrangements of the UPFC model

Here, Converter 1 and converter 2 are two voltage source converters that are consolidated by the UPFC; moreover, the DC storage capacitor provides the common DC link which is used to associates the voltage source converters back to back. Here, the controllable reactive power and shunt reactive compensation for the line are generated or absorbed by the converter 1 which is a shunt connected voltage source converter. Likewise, the converter 2 plays out the fundamental capacity of UPFC by acquiring an AC voltage with a magnitude that can be controlled and the phase angle is in series with the transmission line through a series transformer. Moreover, the converter 2 is also used to supply or absorbed the necessary reactive power and the active power is supplanted as an outcome of the series injection voltage. The basic arrangement of the UPFC structure model is illustrated in Figure 1 which describes the basic arrangements between i and j bus of the UPFC model.

A. Power Flow Equations of the UPFC Model

The equivalent circuit of the UPFC model is illustrated in Figure 2.

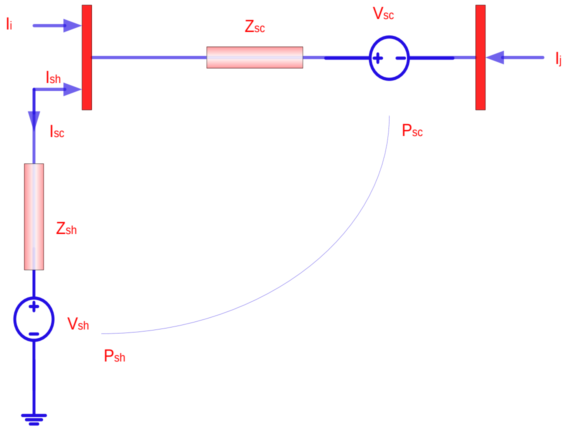

Fig. 2 Equivalent circuit of the UPFC model

Here, the UPFC is located between *i* and *j* bus likewise figure 1. In this section, the load flow solution is used to compute the real and reactive power at i and j buses. At every bus, the real and reactive power injections and the power flow equations of the UPFC model have illustrated as takes after. The power flow from i to j is given as follows,

$$P_{ij}(t) = (V_i^{2(t)} + V_{kl}^{2(t)})C_{ij}^{(t)} + 2V_i^{(t)}V_{kl}^{(t)}C_{ij}^{(t)}\cos(a_{kl}-\delta_j) - V_j^{(t)}V_{kl}^{(t)}\left[C_{ij}^{(t)}\cos(a_{kl}-\delta_j) + b_{ij}^{(t)}(\sin a_{kl}-\delta_j)\right] - V_i^{(t)}V_j^{(t)}\left[C_{ij}^{(t)}\cos\delta_{ij} + b_{ij}^{(t)}\sin\delta_{ij}\right] \quad (1)$$

$$Q_{ij}(t) = V_i^{(t)}I^{(t)} - V_i^{2(t)}\left(b_{ij}^{(t)} + B/2\right) - V_i^{(t)}V_{kl}^{(t)}\left[C_{ij}^{(t)}\sin\left(a_{kl}-\delta_i\right) + b_{ij}^{(t)}\left(\cos\ a_{kl}-\delta_i\right)\right] - V_i^{(t)}V_j^{(t)}\left[C_{ij}^{(t)}\sin\delta_{ij} - b_{ij}^{(t)}\cos\delta_{ij}\right] \quad (2)$$

Where,

$$C_{ij} = \left[\frac{1}{R_{ij} + jX_{ij}}\right] - jb_{ij} \quad (3)$$

In the above equations, the voltages of the buses i and *j* are represented as V_i and V_j respectively, the voltage of the compensating device is denoted as V_{kl}. Likewise, the real and reactive power flow from the buses *j* to *i* is given as follows,

$$P_{ji}(t) = (V_j^{2(t)}C_{ij}^{(t)} - \begin{bmatrix} V_j^{(t)}V_{kl}^{(t)}C_{ij}^{(t)}\cos(a_{kl}-\delta_j) \\ -b_{ij}^{(t)}C^{(t)}\sin(a_{kl}-\delta_j) \end{bmatrix} - V_i^{(t)}V_j^{(t)}\left[C_{ij}^{(t)}\cos\delta_{ij} - b_{ij}^{(t)}\sin\delta_{ij}\right] \quad (4)$$

$$Q_{ji}(t) = -V_j^{(t)}\left(b_{ij}^{(t)} + B/2\right) - V_j^{(t)}V_{kl}^{(t)}\begin{bmatrix} C_{ij}^{(t)}\sin\left(a_{kl}-\delta_j\right) \\ -b_{ij}^{(t)}\left(\cos\ a_{kl}-\delta_j\right) \end{bmatrix} + V_i^{(t)}V_j^{(t)}\left[C_{ij}^{(t)}\sin\delta_{ij} - b_{ij}^{(t)}\cos\delta_{ij}\right] \quad (5)$$

The capacity of the UPFC is determined by the above-estimated power flow equations. Here, the dynamic stability constraints are used to decide the capacity of UPFC. Typically the system is infixed condition and constraints are observed by the system if the generator fault occurs. Here, the dynamic stability constraints ought to 739 eight by ideal location and UPFC capacity which is also solved the situation of generator faults. The accompanying section 3.2 delineates the objective of the dynamic stability and constraints.

B. Enhancement of Dynamic Stability Using Dynamic Stability Constraints

In this section, the control variables or dynamic stability constraints are kept up at safety limits to accomplish the dynamic stability of the power system. Here the maximum power loss and minimum voltage deviation are optimized by the objective function which is chosen subject to the power balance condition, loss of power, stability of the voltage, UPFC cost, real and reactive power flow.

1) Equation of power balance: The system demand is just as the power loss must 739eight by the generation of the power from the system of the power. The generators exhibited in the system may get blackout that implies the loss of power in buses is expanded, that damages the condition of power balance. The following equations expressed the power balance condition.

$$\sum_{i=0}^{N_C} P_C^i = P_D + \sum_{i=0}^{N_C}(P_L + jQ) \quad (6)$$

In the i^{th} bus, the power generation are expressed as P_C^i. In the j^{th} bus, the actual and reactive power is denoted as P_L^j and Q_L^j. The demand of the system is represented as P_D. The accompanying expressions delineate the generation limits of the generators and demand of the system.

$$P_C^{i(\min)} \le P_C^i \le P_G^{i(\max)} \quad (7)$$

$$P_D^{(\min)} \le P_D \le P_D^{(\max)} \quad (8)$$

Where the minimum-maximum range of the generators limits are expressed as $P_C^{i(\min)}$ and $P_G^{i(\max)}$. The load demand's minimum-maximum range of the limits is denoted as $P_D^{(\min)}$ and $P_D^{(\max)}$. The following section explained the constraints of power loss.

2) Power Loss Equation: In this

section, the accompanying equations obviously delineate the losses of the real and reactive powers.

$$P_L^j = |V_i||V_j||Y_{ij}|\sum_{n=1}^{N}\cos\left(a_{ij} - \phi_i - \phi_j\right) \tag{9}$$

$$Q_L^j = |V_i||V_j||Y_{ij}|\sum_{n=1}^{N}\sin\left(a_{ij} - \phi_i - \phi_j\right) \tag{10}$$

Where i and j are the buses of voltage that are represented as V_i and V_j, the bus admittance matrix is indicated as Y_{ij}, then the i and $j$are the angle betwixt the buses that is expressed as a_{ij}, the load angle of i and j are represented as ϕ_i and ϕ_i. Likewise, the actual and reactive power constraints are described in the following section.

3) Flow of Real and Reactive Power: The real and reactive power constraints of i-th bus are expressed in the following equations.

$$P_i = |V_i||V_j|\sum_{n=1}^{N_B}\left(C_{ij}\cos\phi_{ij} + B_{ij}\sin\phi_{ij}\right) \tag{11}$$

$$Q_i = |V_i||V_j|\sum_{n=1}^{N_B}\left(C_{ij}\sin\phi_{ij} - B_{ij}\cos\phi_{ij}\right) \tag{12}$$

Where the total number of buses is represented as N_B, the conductance and susceptance values are denoted as C_{ij} and B_{ij}.

4) Voltage Stability: In order to achieve the stability of dynamic, voltage stability of each and every bus is act as the foremost factor. The stability of dynamic system is delineated in the following equations.

$$\Delta V_i = \frac{1}{l}\sqrt{\sum_{i=1}^{l}\left(V_i^k\right)^2} \tag{13}$$

In the above equation, V_i^k is expressed as follows,

$$V_i^k = V_{slack} - \sum_{i=1}^{n} H_i\left(\frac{P_i - jQ_i}{V_i}\right) \tag{14}$$

In the above equation, the slack bus voltage is denoted as V_{slack}, the voltage stability bus index i is represented as ΔV_i, the impedance of the bus i is denoted as H_i, the real and reactive power of bus i and j are expressed as P_i and Q_i. The cost constraint of the UPFC is delineated as follows.

5) UPFC Cost: The cost of the UPFC can be expressed in the following equation.

$$Cost(UPFC) = 0.0003S^2 - 0.269S + 188.22(\$/KVAR) \tag{15}$$

In MVAR, the operating range of the facts devices is represented as S. In this research, an efficient hybrid JMFALO approach is proposed to achieve the target. The explanation of the MFO and ALO to get the optimal location and capacity of UPFC are briefly described in the following section.

IV. OPTIMUM LOCATION AND CAPACITY DETERMINATION USING HYBRID JMFALO APPROACH

The approach which is proposed is the connected implementation of MFO and ALO algorithm named as JMFALO. Here, the UPFC's optimal capacity is determined by the MFO algorithm; likewise, the optimum capacity of the UPFC is determined by the ALO algorithm to reduce the cost. The MFO is a nature enlivened optimization algorithm, that works in perspective of the moth fly that conduct in around night time by keeping a settled point concerning the moon [28]. To improve the concealed sporadic courses of action and joining to a predominant point the MFO has the capacity. Likewise, In 2015 Mirjalili introduced an Ant Lion Optimizer (ALO) is a novel nature-inspired algorithm [33]. The ALO imitates the hunting mechanism of antlions in nature. Hatchlings phase and adult phases are two essential stages in the life cycle of ALO. The step by step process of MFO and ALO algorithm is depicted in follows.

A. Step by Step Process of MFO for Location Optimization of UPFC

Step 1: Initialization

In the first step, the voltage of each and every bus and the line power losses is initialized and randomly generated that are given as follows;

$$D_i = \begin{bmatrix} (V_1, P_{L1})^{B1}, (V_2, P_{L2})^{B2}, \\ (V_3, P_{L3})^{B3}, \cdots, (V_n, P_{Ln})^{Bn} \end{bmatrix} \tag{16}$$

where V_1, V_2, V_3 and V_n are the voltages of the buses B_1, B_2, B_3 and B_n.

Step 2: Evaluation

Apply the fitness function and assess the fitness values of the random starting populace for each and every particle [29]. By utilizing the following relation the fitness function is determined.

$$Fit_{obj} = \psi = Max\left\{|V_i||V_j||Y_{ij}|\sum_{n=1}^{N}\cos\left(a_{ij} - \phi_i - \phi_j\right)\right\} \tag{17}$$

where ψ is the value of the objective function which is added to the actual objective function.

Step 3: Updating

The position of the moth is updated based on the fitness function with respect to the flame using the following equation [18] and 19],

$$V_{ij} = D_{i,j} + \psi_{ij}\left(D_{i,j} - D_{k,j}\right) \quad (18)$$

$$D_i^j = D_{\min}^j + rand\ [0,1]\left(D_{\max}^j - D_{\min}^j\right) \quad (19)$$

where k denotes the solution of the neighbourhood of i, ψ denotes the fitness a random number uniformly distributed in [-1, 1], k = (1, 2, 3…n) and j = (1, 2, 3…n), the neighbourhood solution is denoted as $D_{i,j}$ and the randomly selected index is expressed as V_{ij} .

Step 4: Crossover

At that point, another chromosome is created when the operation of chromosomes is performed between the chromosomes of fitness value. Consequent a fitness function is applied to the new chromosome to create a new chromosome [30]. The equation for computing the crossover rate is portrayed as follows.

$$CO_{rate} = \frac{No.of\ gene\ crossovered}{Length of\ Chromosome} \quad (20)$$

where CO_{rate} represent the crossover rate which is given as the proportion between the number of crossover genes and the chromosome length

Step 5: Mutation

The genes are muted randomly in the mutation operation which is dependent on the given mutation rate [31]. By the given formula the rate of mutation is determined.

$$M_{rate} = \frac{Mutation\ po\,\text{int}}{Length of\ Chromosome} \quad (21)$$

where M_{rate} represent the mutation rate which is given as the proportion between the point of mutation and the chromosome length

Step 6: Iteration

Test the iteration limit, in the event that it arrives at the most extreme range, go to or else increment the iteration number and return to stage 2.

Step 7: Termination

After completing the process of the MFO technique, the optimal location is determined. Based on the above process, the location of UPFC is optimally tuned [32]. Once the location of UPFC determination is finished, the optimal capacity of UPFC is determined in the second stage by the ALO algorithm. The step by step process of ALOtechnique is depicted in the following section.

B. Step by Step Process of ALO for the Capacity of UPFC Prediction

The second process of the proposed approach is delineated in this section which predicts the capacity of UPFC. Here, flow of power quantity of the UPFC is optimized to get the optimum capacity which is liable to the distinction between the reductions of the typical voltage of the bus system and the generator fault time voltage. In the proposed methodology, the dynamic steadiness of the system is improved by the optimum capacity of UPFC. The accompanying section involves the steps to predict the capacity of UPFC

Step 1: Initialization

In the initial step, the voltage limits and power flow equations of UPFC are initialized which are assumed as the agents. It is randomly generated using the following equation.

$$Y = \left(y_i^1, \cdots, y_i^d, \cdots y_i^n\right) \text{ Where, } i = 1, 2 \ldots n \quad (22)$$

Step 2: Fitness Evaluation

The fitness function of agents is assessed as for their minimal objective function [34]. The fitness function of ant-lion and ants is figured as takes after:

$$ObjF_i = \varphi = \min \sum_{i=1}^{N_B}\left(V_{Normal} - V_i^F\right) \quad (23)$$

Step 3: Evaluation of ant-lion solutions and selection

At that point find the finest ant-lions solutions and accept it as Elite [35]. Also, here the selection procedure of the Ant-Lion is done by utilizing the roulette wheel.

Step 4: Updating

To show this deductively following condition are proposed in such a way, the reviving limit of I using the following conditions [36],

$$V_i^d(t+1) = rand_i\left\lfloor V_i^d\right\rfloor + \partial_i^d(t) \quad (24)$$

To develop a new operators the above velocity function is utilized, which is portrayed in the accompanying equation,

$$Y_i^d(t+1) = Y_i^d(t) + V_i^d(t+1) \quad (25)$$

From the above equations, the velocity and position of an agent are denoted as $V_i^d(t)$ and $Y_i^d(t)$ at time t and dimension d, the random number is represented as $rand_i$ in the interval [0, 1].

Step 5: Save the optimal results

The fitness of the new operators is tested and spares the best solutions. Exactly when the above procedure is completed, the optimal capacity of UPFC is distinguished by utilizing the objective Function. The above procedure is repeated until the point that the maximum iteration is reached.

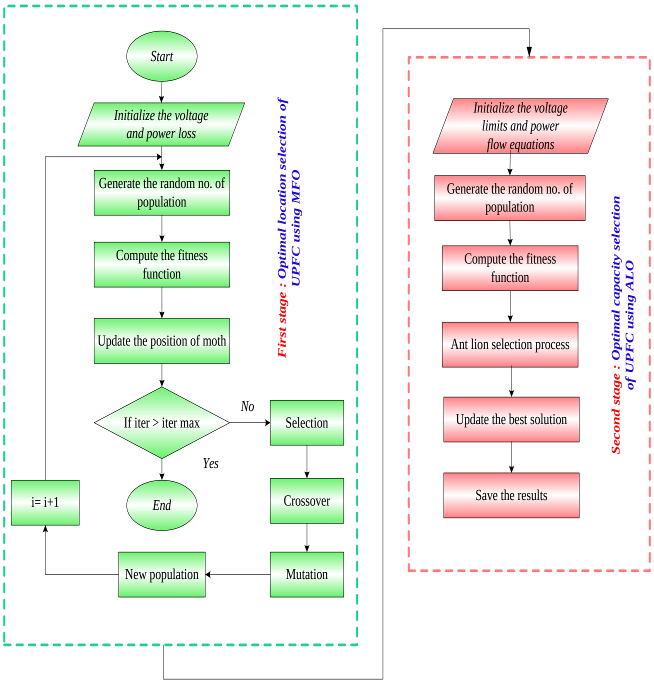

Fig. 3. Flowchart of the proposed JMFALO technique

V. RESULTS AND DISCUSSIONS

This section delineates the performance of the proposed JMFALO approach which is implemented in MATLAB 7.10.0(R2010a) platform. In this section, the brief explanation and discussions of the numerical results are presented. Here, the experimental results are validated by the IEEE standard benchmark system named as (i) IEEE 30 bus system and (ii) IEEE 14 bus system. The proposed JMFALO approach is compared with the existing approaches named as Artificial Bee Colony technique with Gravitational Search technique (ABC-GSA) [3], Firefly algorithm with a cuckoo search algorithm (FF-CS) [10], normal and fault conditions. The clarification of two bus systems is portrayed in the bellowed area.

A. Testing of IEEE 30 Bus System

The performance of the proposed JMFALO technique is depicted in this area. The JMFALO approach is validated by the IEEE 30 bus system that incorporates six generator bus, twenty one load bus, and forty two transmission lines. Here, figure 4 illustrates the voltage profile problem during single generator outage at 2nd, 6th, 13^{h}, 22^{nd,} and 27th bus system. In that figure, the subplot (a) represents the voltage profile of the 2ndbussystem, the subplot (b) represents the voltage profile of 6th bussystem, the subplot (c) represents the voltage profile of 13th bussystem, the subplot (d) represents the voltage profile of 22nd bussystem and the subplot (e) represents the voltage profile of 27th bussystem. That subplot includes the maximum voltage during generation outage, maximum voltage during a normal condition and the voltage profile of the JMFALO approach. In all the plots, the voltage during the generator outage is high when compared with the other two voltage profiles. During the generation shutdown time, the voltage profile of every bus is collapsed which is analyzed from the analysis of voltage profile. At this situation, the voltage profile of the UPFC is enhanced by the proposed method. In that instant, the power flow analysis of the single generators at various environments is illustrated in table 1, which includes the flow of power during normal condition, flow of power during generator outage and flow of power using proposed JMFALO approach.

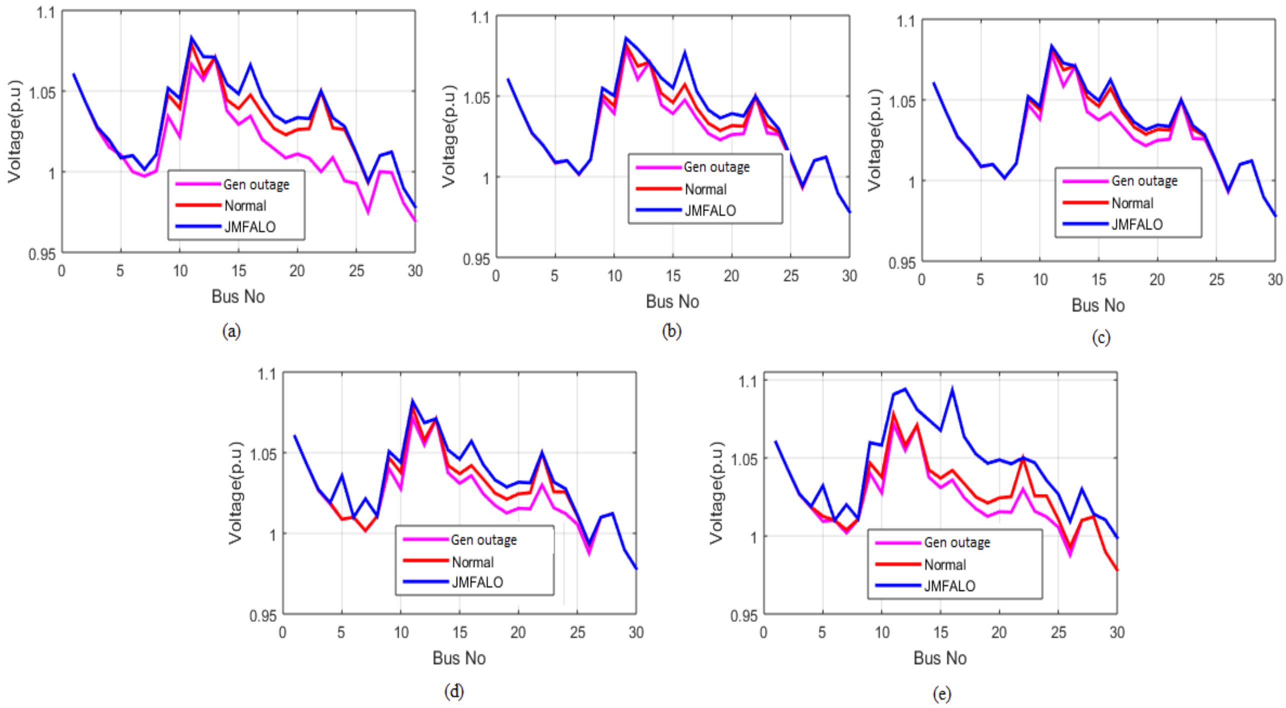

Fig. 4. Voltage profile during single generator outage at (a) 2nd bus (b) 6th bus (c) 13th bus (d) 22nd bus (e) 27th bus

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Table- I: Analysis of power flow at a single generator problem using the proposed technique

Generator bus no.	Best location		Power flow					
	From bus	*To bus*	*Normal*		*Generator outage*		*Proposed method*	
			P (MW)	*Q (MVAR)*	*P (MW)*	*Q (MVAR)*	*P (MW)*	*Q (MVAR)*
2	27	30	7.118	1.711	7.078	1.637	7.090	1.659
6	12	15	17.963	6.803	17.782	7.635	19.484	5.430
13	2	5	67.878	1.245	67.764	0.868	68.508	1.275
22	15	23	3.031	4.313	2.986	4.313	3.034	4.920
27	10	22	3.706	24.741	1.981	15.903	3.581	23.102

Table- II: Analysis of power loss at a single generator problem using the proposed technique

Generator bus no.	Best location		Power loss in MW			
	From bus	*To bus*	*Normal*	*Generator outage*	*Proposed method*	*UPFC cost ($/KVAR)*
2	27	30		12.419	6.434	175.704
6	12	15		12.061	6.449	185.003
13	2	5	10.5653	12.268	6.471	187.301
22	15	23		11.4231	6.433	175.196
27	10	22		11.526	6.418	180.049

Similarly, the power loss analysis of the single generators at various environments is illustrated in Table 2, which includes the flow of power during normal condition, generator outage and using the proposed JMFALO approach. At last, the proposed JMFALO approach is compared with the existing FFCS and ABCGSA approach and the results are illustrated in table 3.

Table- III: Power loss comparison during single generator outage at 6^{th} bus

Methods	Power loss in MW	UPFC cost
JMALO	6.449	185.003
FFCS	6.845	186.147
ABCGSA	7.275	187.248

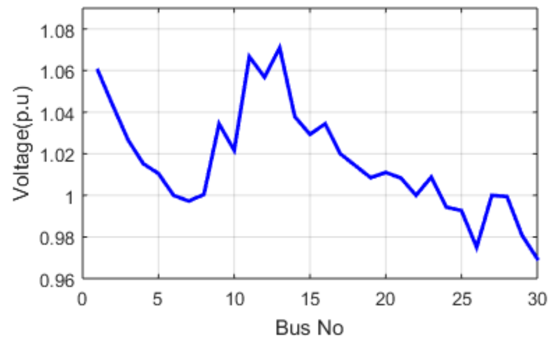

Fig. 5. Normal voltage profile through double generator bus

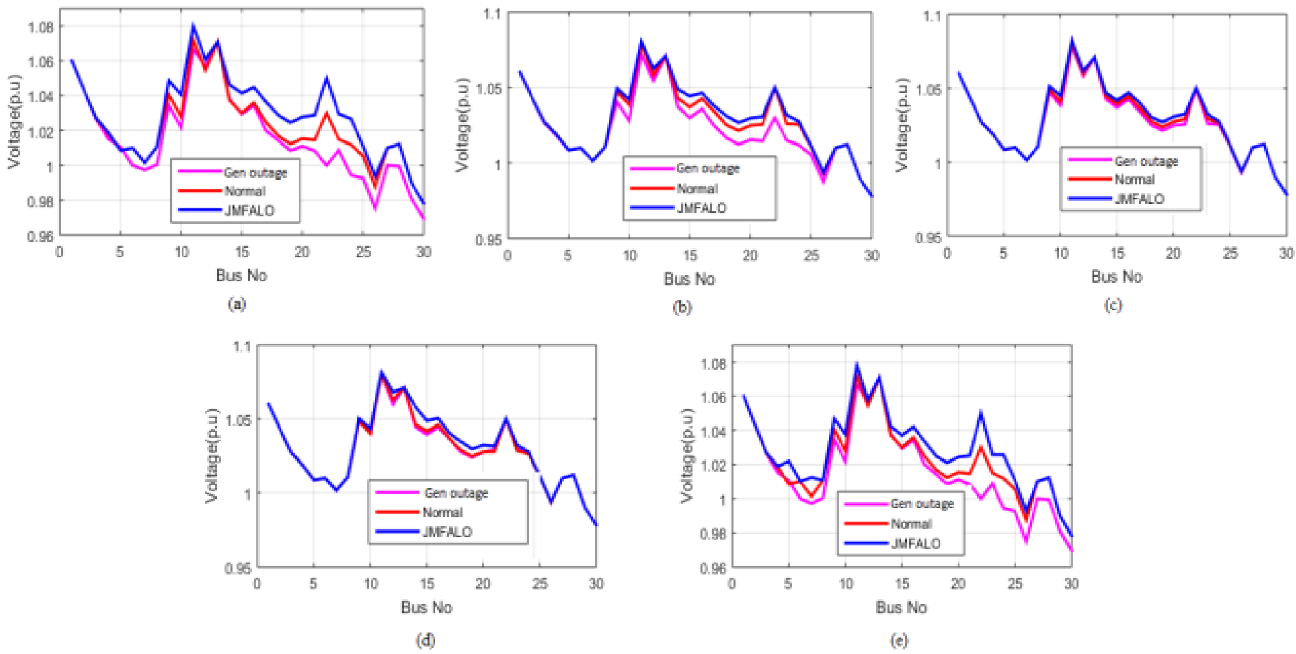

Fig. 6. Voltage profile during double generator outage at (a) 2^{nd} and 6^{th} bus (b) 2^{nd} and 13^{th} bus (c) 6^{th} and 13^{th} bus (d) 13^{th} and 27^{th} bus (e) 22^{nd} and 27^{th} bus

Figure 5 represents the normal voltage profile problem during the outage of double generator. Figure 6 outlines the voltage profile problem through the outage of double generator at 2^{nd} and 6^{th}, 2^{nd} and 13^{h}, 6^{th} and 13^{th}, 13 th and 27^{th} , 22^{nd} and 27^{th} bus system. In that figure, the subplot (a) delineates the voltage profile of the 2^{nd} and 6^{th} bussystem, the subplot (b) shows the voltage profile of the 2^{nd} and 13^{th} bussystem, the subplot (c) outlines the voltage profile of the 6^{th} and 13^{th} bussystem, the subplot (d) represents the voltage profile of the 13^{th} and 27^{th} bussystem and the subplot (e) outlines the voltage profile of the 22^{nd} and 27^{th} bussystem. In every one of the plots, the voltage during the generator outage is practically equivalent when compared with other two voltage profiles. In that instant, the power flow analysis of the double generators at various environments is illustrated in Table 4, which includes the flow of power during normal condition, flow of power during generator outage and flow of power using proposed JMFALO approach. Similarly, the power loss analysis of the double generators at various environments is illustrated in Table 5, which incorporates the power flow during normal condition, generator outage and using the proposed JMFALO approach. At long last, the proposed JMFALO approach is contrasted with the existing FFCS and ABCGSA approach and the outcomes are outlined in Table 6.

Table- IV: Analysis of power flow at a double generator problem using the proposed method

Generator bus no.	Best location		Power flow					
	From bus	*To bus*	*Normal*		*Generator outage*		*Proposed method*	
			P (MW)	*Q (MVAR)*	*P (MW)*	*Q (MVAR)*	*P (MW)*	*Q (MVAR)*
2 and 6	15	23	2.769	7.404	1.703	6.278	2.382	6.386
2 and 13	12	16	19.998	-7.539	18.578	-5.764	19.750	-4.785
6 and 13	4	6	24.150	13.871	16.659	14.945	21.122	14.547
22 and 27	12	15	28.625	0.598	19.618	0.082	28.053	0.026
13 and 27	12	14	29.259	-8.454	24.800	-8.455	28.980	-8.772

Table- V: Analysis of power loss at a double generator problem using the proposed method

Generator bus no.	Best location		Power loss in MW			
	From bus	*To bus*	*Normal*	*Generator outage*	*Proposed method*	*UPFC cost ($/KVAR)*
2 and 6	15	23	10.5653	14.1067	6.544	184.312
2 and 13	12	16		14.3518	6.447	187.664
6 and 13	4	6		14.0103	5.990	178.652
22 and 27	12	15		12.4465	6.427	188.106
13 and 27	12	14		13.3187	6.424	189.562

Table- VI: Power loss comparison during double generator outage at 22 nd and 27th bus

Methods	Power loss in MW	UPFC cost($/KVAR)
JMALO	6.427	188.106
FFCS	6.895	189.571
ABCGSA	7.548	190.257

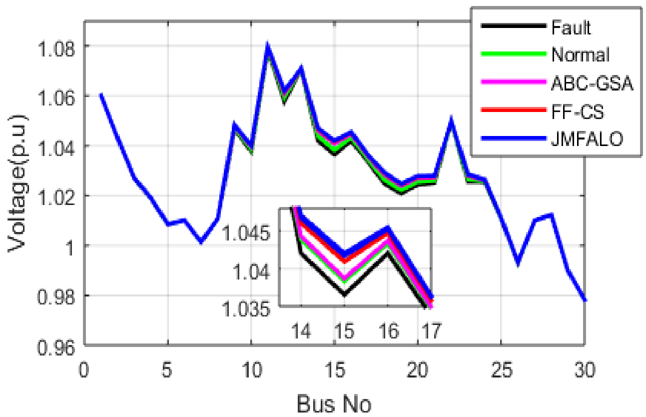

Fig. 7. Voltage profile comparison at double generator outage

The voltage profile comparison at outage of double generator is illustrated in figure 7, which includes the comparison results of the proposed JMFALO approach and the existing approaches such as ABSGSA, FFCS, and the voltage during fault and normal condition. Here, the proposed JMFALO approach has a high voltage between the 14th and 17th bus system.

B. Testing of IEEE 14 Bus System

The performance of the proposed JMFALO technique is depicted in this area. The JMFALO approach is validated by the IEEE 30 bus system which includes 2nd generator bus. Initially, the normal voltage profile of the bus system is illustrated in figure 8. The maximum normal voltage is greater than 1.08 p.u during the 8th bus generator outage.

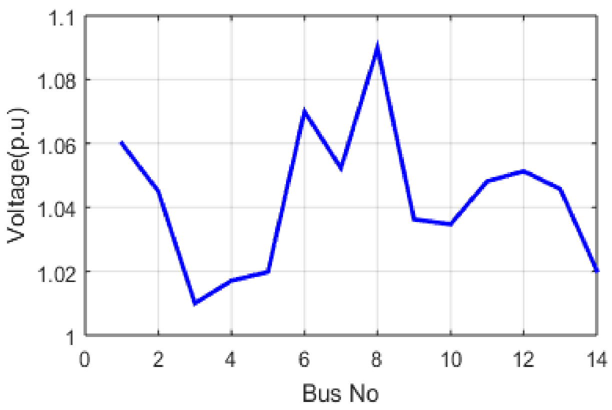

Fig. 8. Normal bus voltage profile

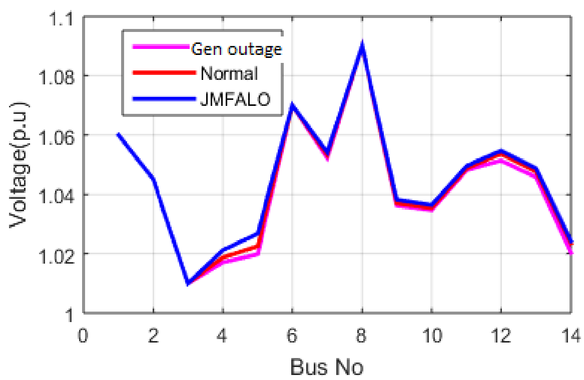

Fig. 9. Voltage profile during 2nd bus generator outage

The voltage profile during the 2nd bus generator outage is represented in figure 9 which delineates the voltage during the normal condition, generator outage and voltage using the proposed JMFALO approach. The voltage maximum voltage range id almost equal (i.e) greater than 1.08 p.u during the above mentioned three conditions. The voltage profile comparison at the outage of single generator is illustrated in figure 10, which incorporates the comparison results of the proposed JMFALO approach and the existing approaches such as ABSGSA, FFCS, and the voltage during fault and normal condition. Here, the proposed JMFALO approach has a high voltage during the 2nd bus generation outage. The power flow analysis of the 2nd generators outage at various environment is illustrated in table 7, which includes the power flow during normal condition, generator outage and power flow using the proposed JMFALO approach. Similarly, the power loss analysis of the 2nd generators outage at various environment is illustrated in Table VIII, which incorporates the power flow during normal condition, generator outage and using the proposed JMFALO approach. At last, the proposed JMFALO approach is contrasted with the FFCS and ABCGSA approach and the outcomes are depicted in Table IX.

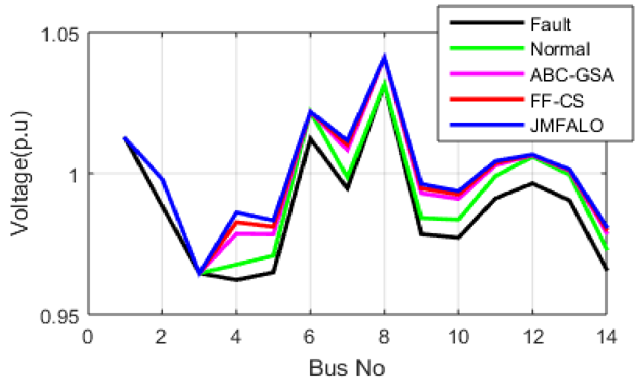

Fig. 10. Voltage profile during 2nd bus generator outage

Table- VII: Analysis of power flow at a single generator problem using the proposed method

Generator bus no.	Best location		Power flow					
	From bus	To bus	Normal		Generator outage		Proposed method	
			P (MW)	Q (MVAR)	P (MW)	Q (MVAR)	P (MW)	Q (MVAR)
2	9	14	22.626	-7.020	21.724	-2.132	22.484	-6.931

Table- VIII: Analysis of power loss at a single generator problem using the proposed method

Generator bus no.	Best location		Power loss in MW			UPFC cost ($/KVAR)
	From bus	To bus	Normal	Generator outage	Proposed method	
2	9	14	12.718	14.9957	5.519	179.802

Table- IX: Power loss comparison during single generator outage at 6th bus

Methods	Power loss in MW	UPFC cost
JMALO	5.519	179.802
FFCS	5.947	186.147
ABCGSA	6.425	187.248

VI. CONCLUSIONS

This paper proposes an efficient hybrid approach for the improvement of dynamic stability of the power system utilizing UPFC. The main goal of presented work is the determination of optimal locality and the UPFC capacity for the stability enhancement which is done by the proposed joined execution technique JMFALO. Here, the proposed JMFALO methods performance is tried by two bus system. The two bus system is IEEE 14 bus system and IEEE 30 bus system. To identify the UPFCs affected location and the system fault the MFO methodology is utilized in the bus system. From that point onward, the optimal capacity of UPFC is recognized subject to the affected dynamic stability limitation, for example, voltage, loss of power, real power and reactive power which are optimized by the ALO approach. The performance of the proposed method is identified under the normal condition, generator outage condition and using the proposed approaches. The experimental results are implemented in MATLAB 7.10.0 (R2010a) platform.

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