Power System Security Enhancement Using Optimal Placement and Parameter Setting of Multi-FACTS devices with BBO Algorithm

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Abstract: Power system maneuver known how to be alive the optimized by means of power electronics anchored in FACTS devices. The predicament of optimal location of Flexible AC Transmission System (FACTS) devices is deemed as a frightening optimization crisis. The Meta-heuristics is frequently worn solving FACTS locality problems. So, Biogeography Based Optimization (BBO) technique is a glowing recognized optimization algorithm which has been lucratively engaged in solving intricate optimization problem in dissimilar fields. The main contribution of this paper is to engage, BBO with conventional and non–conventional for solving FACTS devices locality problem in a technique to facilitate curtailed values of Over Load Index and Voltage Violation Index are resulted in during underline outage contingencies. Furthermore, via Newton-Raphson load flow routine, the transmission line loss of the IPFC as well as UPFC is connected to load bus system. The anticipated process is implemented on the IEEE 14 bus power system which is established throughout the MATLAB package. The results obtained designate that BBO algorithm and can drastically enhance the security the power system by curtailed Overload Index and improved bus voltage profile within the acceptable limit.

Index Terms: Biogeography Based Optimization; Unified Power Flow Controller; Interline Power Flow Controller; Line Overload Sensitivity Index; OverLoad Index; Voltage Violation Index.

I. INTRODUCTION

A power system has been a multifaceted network comprising of copious generators, transmission lines, assortment of loads, active or passive compensators as well as transformers. So in practice, such a network has been prone to disturbances. As a significance of escalating power stipulate, some transmission lines are supplementary loaded than was deliberate when they were built. As the volume of power transmitted and distributed escalating, so do the obligation for high superiority
and reliable supply. At the similar time, the production of new generating units and transmission circuits becomes extra tricky because of economic (rising cost) as well as growing ecological concerns. Consequently, the power utilities are compelled toward the maximize the use of their available resources. Furthermore, the sustained require the electric power system network has caused the system network toward being a great deal loaded foremost to enormous power losses and voltage instability. These and swarms of other factors compose the process of building innovative power transmission as well as distribution lines gradually more intricate as well as time intensive. These situations have therefore called for comprehensive analysis to estimate the present power system recital as well as investigate the effectiveness of innovative devices for improved system security as well as reliability.

Flexible Alternating Current Transmission Systems are a perception anticipated by [1] which is intended on the way to eliminate various limitations of transmission lines as well as convene to operator’s goals.

To achieve a certain objectives of a new methodology to analyze the system security under transmission line(s) and/or generator(s) outage conditions has been presented [2] a new optimization algorithm ITLBO has been anticipated. In paper present [3-6] Differential Evolution (DE) technique for optimal residency of UPFC device beneath this (i.e. Normal, moderate and critical) circumstances toward the power loss has been minimized as well as voltage profile enhancement of an interrelated power system. An exhaustive conversation on power flow along with voltage profile enhancement is accepted out which reveals that incorporate IPFC into power system network [7-11] using FACTS devices. Here, innovative to impress of the compensation and efficient power flow executive the multi-line transmission systems.

In [12-13], they anticipated Imperialistic competitive algorithm (ICA) for allocating the FACTS devices throughout the power systems. TCPST as well as TCSC units are second-hand to alleviate the overloads and voltage deviations throughout single line outages along with stipulate development. The PSO and GSA technique be investigated toward the recovering stability of the transmission system base on the voltage and the power loss. The consequences, successful and a realistic method for the allocation of FACTS controllers [14-15] of the SCOPF will be different from the OPF solution because the SCOPF meets additional inequality constraints associated with the contingency violations

The anticipated move toward [16] is compared with Non-Dominated Sorting Particle Swarm Optimization (NSPSO) algorithm is worth of the multi-objective anticipated technique that makes it capable for grit the combinatorial problems of FACTS device's location and setting in an enormous range of power systems. In [17-18] the paper, for the assortment of optimum location of SVC, determination of SVC's size and SVC's firing angle - three heuristic Optimization algorithms are proposed as evolutionary optimizing algorithms for the same objective function, namely, Genetic Algorithm, Particle Swarm Optimization and Dragonfly algorithm. Discussed in [19] work an objective
function comprising of cost, line loadings as well as load voltage deviations are anticipated to tap the
utmost profit out of their installation and the weights assigned to them decide their relative importance.

The motivation of [20] locality of SVC is finalized throughout feeble bus detection methods. Voltage stability indices, specifically Fast Voltage Stability Index (FVSI) are utilized to recognize the feeble buses in the systems. For calculation of the Size of SVC, an optimization routine Gravitational Search Algorithm (GSA) is established.

II. PROBLEM FORMULATION

The foremost aspire of this paper is to locate away the optimal locations of FACTS devices to curtail the cost of installation of FACTS devices, Overload index as well as a Voltage Violation Index deviation to enhance the power system security. By combination all these functions an objective function is formed.

A. CONTINGENCY ANALYSIS

A contingency is considered towards the outage of a generator and transmission line. The system might turn into unstable and enters an insecure state when a contingency occasion is taking place. Contingency analysis is one of the mainly significant functions performed on power system to establish appropriate preventive and corrective actions for each contingency. In this work, it is focused only on the single line outage contingency (N-1 contingency) and to identify an optimal location of UPFC and IPFC in this paper, a methodology based on Line Overload Sensitivity Index (LOSI) is developed in equation (1).

For each simulated line outage contingency, the overall the Overload Index and Voltage Violation Index are determined, and then the lines in the system are ranked according to the severity of the contingency, when the line outage contingency scenarios, the proposed method technique is applied to find out the optimal location and parameter setting of FACTS devices. Installing FACTS devices in the optimized location with the optimized parameter setting will minimize the overloaded lines and the bus voltage limit violations under these critical contingencies according to the objective function described in the next subsection. Two types of contingencies are considered in [21] transmission line (N – 1) contingency and generator outage contingency. The proposed work is tested in IEEE 14 bus test system.

\[ \text{LOSI} = \sum_{m=1}^{n_l} \left( \frac{P_{lm}}{P_{lmax}} \right)^{2n} \]

B. COST  \( (C_{UPFC})&(C_{IPFC}) \)

The cost function for UPFC can be obtained from the database, which is given by,
Assuming that there is not much difference in the construction of UPFC and IPFC (both having two inverters and two transformers along with the control circuit), the same cost function can be used for deriving the cost function for IPFC. The cost function of UPFC can be modified as,

\[ C_{UPFC} = 0.0003S_{UPFC}^2 - 0.2691S_{UPFC} + 188.22 \frac{US\$}{KVAr} \]  \hspace{1cm} (2)

Where,

\[ S = |Q_2| - |Q_1| \]

\[ Q_2 = \text{Reactive Power flow in the line after installing Facts device in Mvar}, \]

\[ Q_1 = \text{Reactive Power flow in the line before installing Facts device in Mvar}. \]

In this paper, the main objective is to determine the optimal parameter setting and location of the FACTS devices in the network for enhancing the system security level. This enhancement can be achieved through eliminating or minimizing overloaded lines and bus voltage limit violations under the most several single line contingencies. It provides, simultaneously, the active and reactive power flow control setting with minimum overloading and the best voltage security [22].

The objective function is formulated as

\[ \text{Min} \ F = \ w_1 \left[ (C_{UPFC} * s) + (C_{IPFC} * s) \right] + w_2 \left[ LVD = \sum_{i=1}^{nb} \left( \frac{V_i - V_{ref}}{V_{ref}} \right)^{2n} \right] + w_3 \left[ LL = \sum_{l=1}^{nl} \left( \frac{S_{lm}}{S_{lmax}} \right)^{2n} \right] \]  \hspace{1cm} (4)

Where, \( W_1 = 0.5, W_2 = 0.25, W_3 = 0.25; \)

\( S_l \) and \( S_{lmax} \) represent the current apparent power in line \( l \) and the maximum apparent power of line \( l \), respectively; \( V_i \) represents the voltage magnitude at bus \( i \); \( V_{ref} \) represents the nominal voltage at bus \( i \); \( nl \) and \( nb \) represent the number of line and number of buses in the system. \( W_1, W_2, W_3 \) are the weight factors.

### III. OVERVIEW OF BBO TECHNIQUE

Biogeography is the study of the geographic distribution of biological organisms. BBO is the optimization technique which was developed on the basis of this biogeography, concept was given by Dan Simon in the year 2008 [23]. The different terms associated with this algorithm are explained as follows. A population or island is geographically isolated from one another and this is termed as a habitat. The habitat where the species thrive well is said to have a high HSI, that is, Habitat Suitability Index, which means, some islands are more suitable for habitation than others. Habitability is related to features such as rainfall, topography, diversity of vegetation, temperature, etc. And these factors are...
collectively known as Suitability Index Variables (SIVs). In BBO, we can also see how species migrate from one population to another population. Suppose in a particular location A, people have a tendency to settle in a developed location B. This is termed as immigration. There also exists a case where the economically backward settle in location A itself. And this is known as emigration. Say in location B attractive salary is one of the factors besides several luxuries. That is here cost is the objective function and the above explanation implies the if the objective function is higher people move towards that particular location. On location A immigration rate is higher and in location B emigration rate is higher, i.e., In overall, the total exchange will be the same. In short, population will be higher where the objective function is higher. Say, if there are three locations, we have to see where the objective function is higher, that means we have to choose the best location. We will be getting the feedback or information from those who are well settled in location B. This is known as mutation and correspondingly we have mutation factor (i.e., From where the knowledge comes). HSI, that is, the suitability means the environment. The environment includes different factors like climate, etc. And these factors are collectively known as SIVs.

Table 1: Characteristics for BBO

<table>
<thead>
<tr>
<th>Population-based</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Habitat</td>
<td></td>
</tr>
<tr>
<td>SIV</td>
<td></td>
</tr>
<tr>
<td>HIS</td>
<td></td>
</tr>
<tr>
<td>Migration operator</td>
<td></td>
</tr>
<tr>
<td>Mutation operator</td>
<td></td>
</tr>
</tbody>
</table>

From Fig. 1. the following conclusions are drawn: As habitat suitability improves:

- The species count increases
Emigration increases (more species leave the habitat)

Immigration decreases (fewer species enter the habitat)

Mathematical modeling of BBO is given as follows equation (5). If \( P_s(t) \) denote the probability that a habitat contains exactly \( S \) species at time \( t \), at time \( t+\Delta t \) the probability is:

\[
P_s(t + \Delta t) = P_s(t) (1 - \lambda_S \Delta t - \mu_S \Delta t) + P_s - 1 \lambda_S \Delta t + P_s + 1 \mu_S \Delta t
\]

(5)

Where \( \lambda_S \) and \( \mu_S \) are the immigration and emigration rates. If there are \( S \) species in the habitat. If time \( \Delta t \) is small enough so that the probability of more than one immigration or emigration can be ignored, then taking the limit of equation (5) as \( \Delta t = 0 \) gives the following equation

\[
P_s = \begin{cases} 
-(\lambda_S + \mu_S)P_s^s + P_s^{s+1}\mu_{s+1} & s = 0 \\
-(\lambda_S + \mu_S)P_s^s + P_s^{s+1}\mu_{s+1} + P_s^{s-1}\lambda_{s-1} & 1 \leq s \leq s_{\text{max}} \\
-(\lambda_S + \mu_S)P_s^s + P_s^{s-1}\lambda_{s-1} & s = s_{\text{max}} 
\end{cases}
\]

(6)

According to the biogeography, the SIVs of a good habitat (with low HSI) tend to emigrate to a poor habitat (with high HSI). Therefore, a good habitat has relatively high \( \mu_k \) and low \( \lambda_k \), while a poor solution has relatively low \( \mu_k \) and high \( \lambda_k \).

The immigration rate \( \lambda_k \) and the emigration rates \( \mu_k \) are calculated with the following equations, respectively Fig.1.

\[
\mu_k = E_k / n
\]

(7)

\[
\lambda_k = I_k (1 - k / n)
\]

(8)

Where, \( E \) and \( I \) are the maximum emigration rate and maximum immigration rate respectively “n” is the total number of species in the habitat. Wan, \( E = I \)

\[
\lambda_k + \mu_k = E
\]

(9)

**B. Migration**

For the modification of a particular solution we use its immigration rate \( \lambda_i \) to probabilistically decide whether or not to modify each Suitability Index Variable (SIV) in that solution. If a given SIV in a given solution \( S_i \) is selected to be modified, then we use the emigration rates \( \mu_j \) of the other solutions to probabilistically decide which of the solutions should migrate a randomly selected SIV to solution \( S_i \).
C. Mutation

In BBO, each habitat has an associated probability for them to exist as a solution to the given problem. The probability that whether the mutation occurs in a habitat is called the mutation rate. To determine the mutation rate for each habitat, we must first evaluate the species count probability with the following equation:

\[
m(s) = m_{\text{max}} \left( 1 - P_{\text{max}}^s \right)
\]

where \( m_{\text{max}} \) is the maximum mutation rate and \( P_{\text{max}} \) the largest species count probability.

By using mutation factor, we need to develop the random values. This mutation has a probability and based on this we have to do the modifications. If this mutation probability is greater than the random value, we have to modify the mutated value. And consequently we arrive at the best solution. We have the migration as well as the mutation updating in order to avoid the pre-convergence problem.

D. Classical BBO Algorithm

1. Initialize the BBO parameters
2. Initialize a random set of habitats, corresponding to the potential solutions.
3. Associate each habitat with immigration and emigration rate based on their HSI.
4. Probabilistically perform the migration to modify each one-elite habitat. Then, recompute each HSI.
5. Associate each habitat with mutation rate based on their species count.
6. Probabilistically perform mutation to modify each non-elite habitat. Then, recompute each HSI.
7. Go to step (3) for the next iteration. Repeat until a predefined number of generations are reached, or after an acceptable solution is found.

E. Certain features of BBO

- BBO has a way of sharing information between solutions.
- BBO solutions survive forever.
- BBO does not require a priori knowledge of the number of partitions in the image.

The [24] results have been compared between both the techniques in terms of minimization of active power loss and operating cost.
IV. MODELLING OF FACTS DEVICES

The simulation results demonstrate the performance of the system with the inclusion of the above (IPFC and UPFC) FACTS devices in improving the voltage stability and power profile. All simulations have been carried out in the MATLAB/SIMULINK environment [25].

A. MODELLING OF UPFC DEVICES

A schematic representation of UPFC is shown in Figure.2. The output voltage of the series converter is added to the AC terminal voltage $V_0$ via the series connected coupling transformer. The injected voltage $V_{CR}$ acts as a series voltage source, changing the effective sending-end voltage as seen from node m. The products of the transmission line current $I_m$ and the series voltage source $V_{CR}$ determines the active and reactive power exchanged between the series converter and the AC system.

Fig.2. Structure of UPFC

Fig.3 shows the equivalent circuit of a UPFC power flow model, this circuit consists of two coordinated synchronous voltage sources represent the UPFC adequately for the purpose of fundamental steady-state analysis, the UPFC voltage sources are:

$$E_{vR} = v_{vR}(\cos\delta_{vR} + jsin\delta_{vR})$$  \hspace{1cm} (11)

$$E_{cR} = v_{cR}(\cos\delta_{cR} + jsin\delta_{cR})$$  \hspace{1cm} (12)

Fig.3. Equivalent circuit of Unified Power Flow Controller.
Where, $V_{vR}$ is the shunt voltage source magnitude; $\delta_{vR}$ is the shunt voltage source angle; $V_{cR}$ is the series voltage source magnitude; and $\delta_{cR}$ is the series voltage source angle.

The active power demanded by the series converter is drawn by the shunt converter from the AC network and supplied to bus m through the DC link. The output voltage of the series voltage source (series converter) is added to the nodal voltage, let say at bus k, to boost the nodal voltage at bus m. The voltage magnitude of the output voltage $V_{cR}$ provides voltage regulation, and the phase angle $\delta_{cR}$ determines the mode of power flow control. In addition to providing a supporting role in the active power exchange that takes place between the series converter and the AC system, the shunt converter may also generate or absorb reactive power in order to provide independent voltage magnitude regulation at its point of connection with the AC system. Based on the equivalent circuit and on (11) and (12) the active and reactive power equations.

A.1 Advantages of UPFC

The UPFC is an advantageous power system device capable of providing simultaneous control of voltage magnitude, active and reactive power flows. Also, it has

- Instantaneous speed of response
- Extended functionality
- Capability to control voltage, line impedance and phase angle in the power system network
- Enhanced power transfer capability
- The ability to decrease generation cost
- Ability to improve security and stability

B. Power Injection Model of IPFC

The IPFC addresses the problem of compensating a number of transmission lines at a given substation. Conventionally series capacitors are used to improve the real power transfer in a given line. However, it cannot control the reactive flow in the line, thus resulting in improper compensation. This problem occurs when the ratio of reactance to resistance of transmission line (X/R) is relatively low. By using capacitive combination, the resistance of the line decreases, which in turn reduces the (X/R) ratio of the line, resulting in improper compensation and improper load balancing in transmission lines. Series reactive compensation reduces only the effective reactive impedance X and, thus, significantly decreases the effective X/R ratio and thereby increases the reactive power flow and losses in the line. The IPFC scheme, together with independently controllable reactive series compensation of each individual line enables the transfer of real power between the compensated lines. IPFC can be employed to transfer power between multiple lines in a substation, where as the other available FACTS devices can control the power flow through a single line only. The power flow through a line can be regulated by controlling both magnitude and angles of the series voltage
injections. The converters have the capability of independently generating or absorbing the reactive power.

Fig.4. Schematic diagram of IPFC

The converters have the capability of independently generating or absorbing the reactive power.

The converters have the capability of independently generating or absorbing the reactive power.

Fig.5. Equivalent Circuit of the IPFC

The mathematical model for IPFC, which will be referred to as a power injection model, is helpful in understanding the impact of the IPFC on the power system in the steady state. Furthermore, this IPFC model can easily be incorporated in the power flow analysis. Usually, in the steady state analysis of power system, the Voltage Source Converters (VSC) may be represented as a synchronous voltage source injecting an almost sinusoidal voltage with controllable magnitude and angle. The power injection model of IPFC is useful for calculating the injecting active power, voltage and voltage angle in each bus. The power calculation is based on the NR load flow algorithm. It is used to check the loss variation before and after connecting IPFC. The equivalent circuit for the power injection model of IPFC is shown in Fig.5. The Mathematical model for IPFC, which will be referred to as a power injection model, is helpful in understanding the impact of the IPFC on the power system in the steady state.

In Fig.5. $V_i$, $V_j$ and $V_k$ are the complex bus voltages at the buses i, j and k respectively, $V_{sein}$ is the complex controllable series injected voltage source, and $Z_{sein} (n = j, k)$ is the series coupling trans-
former impedance. The complex power injected by series converter connected in between bus i and bus j as shown in Fig.5. can be written as

\[
g_{ii} = -g_{ij} = \text{Re}\left(\frac{1}{Z_{sel}}\right) \\
b_{ii} = -b_{ij} = \text{Im}\left(\frac{1}{Z_{sel}}\right)
\]

(13)

(14)

\[
P_{mn} = \sum_{j=1, j \neq i}^{n} \text{Re}\left(V_{selj} \ast I_{ij} \ast \right)
\]

(15)

B.1. Advantages of IPFC

Interline Power Flow controller (IPFC) FACTS controller has the following Advantages.

- Low stability margin
- Good dynamic performances
- Cycling repeatability
- Continuous and smooth control
- Negligible failures

Power electronics based solutions of FACTS controllers are the solutions for the present and future problems of the transmission system.

V. IMPLEMENTATIONS OF ALGORITHM

**Step 1:** Read the line data, bus data& tolerance of convergence

**Step 2:** Choose the BBO parameters like no of habitats, Habitat modification probability ‘\(P_{mod}\)’, mutation probability ‘\(P_{mut}\)’, the maximum immigration rate I, maximum emigration rate E& set maximum number of iterations.

**Step 3:** Run Newton –Raphson load flow and obtain bus voltages and line flows.

**Step 4:** Simulate contingency in Kth line, where K=1to nl and calculate the line loading and load voltage deviations.

**Step 5:** Calculate Line Overload Severity Index - LOSI value of the system using the equation (1).

**Step 6:** Randomly generate SIV that represents number, type, location and rating of the device to form a habitat.

**Step 7:** Run Newton-Raphson load flow using these SIV

**Step 8:** Calculate the HSI for each habitat set of the total habitat as per the objective function in the equation. (4) For the given emigration rate \(\mu\), immigration rate \(\lambda\), & based on the HSI value identify the elite habitat, habitats (here elite term is used to indicate those habitat sets, which give best HSI value) elite habitats are kept as it is without making any modification on them.

**Step 9:** Migration operation is performed probabilistically on those SIVs on non-elite habitats selected for migration using \(P_{mod}\).
**Step 10:** Species count probability of each habitat is updated using $P_s$ and mutation operation is performed probabilistically on non-elite habitats selected for mutation using $P_{mut}$.

**Step 11:** If stopping criteria are satisfied, then optimum is reached otherwise go to step 7 for the next iteration.

**Step 12:** Run the load flow after optimally placing the FACTS devices as per the BBO algorithm to determine the line loading and load voltage deviations.

**Step 13:** The same procedure is repeated from step 4 for different line contingencies.

**VI. SIMULATION AND RESULTS**

**A. Simulation tool and power systems**

Matlab programming codes for BBO and the modified power flow algorithm to include UPFC and IPFC are developed and incorporated together for the simulation purposes in this research. To look interested in the validation and performance of the applied techniques, BBO has been tested on the subsequent IEEE 14-bus system.

**B. Simulation results**

BBO techniques are implemented to find the best possible ideals of the aforesaid variables. These ideals are adopted according to the ideals report in the open literature, for BBO Since these techniques are probabilistic and stochastic search techniques and the adopted values were found to give the best routine in most cases as it is stated in the literature.

This system consists of five generators, 14 buses, 20 transmission lines along with 11 loads. Contingency analysis as well as ranking route is performed on this system, there are 20 possible single line contingencies. For each single line outage contingency:

The value of the anticipated, algorithm has been experienced on IEEE 14 bus systems. (N-1) contingencies are simulated on the system and for each contingency the optimal device location and ratings are identified. The optimal placement of FACTS devices is done by minimizing an objective function consisting of Cost of the devices, load voltage deviations and line loadings. Device placement is carried out by fixing the location and ratings by applying BBO technique. The simulated results are shown in Table 2, 3, 4.

Lines over Sensitivity Index, Overload Index and Voltage Violation Index under single line contingency conditions are shown in Fig.6-8 for IEEE 14 bus system. When this system is operated without UPFC and IPFC devices are carried out through BBO techniques. It has been observed that Overload Index and Voltage Violation Index are reduced when the system is operated with FACTS devices at optimum locations. There is a significant improvement in the performance of the system when the device placement is done through the algorithm.
From Table 1, we can find that the impact of single line contingency scenarios on this system can be completely eliminated by using FACTS devices in the optimized locations with the optimized parameter setting obtained by the applied techniques. For single line contingency scenarios, although with the help of using UPFC and IPFC in the optimized locations with the optimized parameter setting did not result in eliminating all of the overloaded lines in these cases, most of overloaded lines are eliminated and the power flow distributions in the rest are significantly reduced. Also, all bus voltage limit violations are eliminated; these results are achieved by BBO.

Table 2: Line Overload Sensitivity Index, Over Load Index and Voltage Violation Index before and after using UPFC and IPFC in the optimal locations obtained by BBO

<table>
<thead>
<tr>
<th>Contingencies</th>
<th>Line overload sensitivity Index (LOSI)</th>
<th>Over Load Index (OLI)</th>
<th>Voltage Violation Index (VVI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Branch</td>
<td>Line No</td>
<td>Before Placing FACTS Devices</td>
</tr>
<tr>
<td>2-3</td>
<td>2</td>
<td>36.57</td>
<td>32.36</td>
</tr>
<tr>
<td>2-4</td>
<td>3</td>
<td>22.34</td>
<td>20.65</td>
</tr>
<tr>
<td>2-4</td>
<td>4</td>
<td>35.09</td>
<td>25.10</td>
</tr>
<tr>
<td>2-5</td>
<td>5</td>
<td>21.78</td>
<td>20.38</td>
</tr>
<tr>
<td>4-7</td>
<td>7</td>
<td>23.33</td>
<td>20.02</td>
</tr>
<tr>
<td>4-9</td>
<td>8</td>
<td>20.98</td>
<td>18.16</td>
</tr>
<tr>
<td>5-6</td>
<td>9</td>
<td>291.41</td>
<td>120.21</td>
</tr>
<tr>
<td>6-11</td>
<td>10</td>
<td>29.61</td>
<td>21.17</td>
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<tr>
<td>6-12</td>
<td>11</td>
<td>25.35</td>
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<td>6-13</td>
<td>12</td>
<td>218.97</td>
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<td>7-9</td>
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<td>12-13</td>
<td>18</td>
<td>20.28</td>
<td>16.92</td>
</tr>
<tr>
<td>13-14</td>
<td>19</td>
<td>21.87</td>
<td>17.49</td>
</tr>
</tbody>
</table>
Fig.6: Minimization of the Line Overload Sensitivity Index by BBO technique for IEEE 14 bus system under contingency line Outage

From the table 2 shows, lines 10 & 12 are critical lines contingencies. After analyzing the tabulation 3, it is observed that by modeling a UPFC and IPFC between line no. 17 and bus no. 14 can enhance the overall security of the system at network contingencies.

Table 3: BBO based on UPFC and IPFC Placement and their rating

<table>
<thead>
<tr>
<th>Contingencies</th>
<th>IPFC</th>
<th>UPFC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Branch</td>
<td>Line No</td>
<td>X (IPFC)</td>
</tr>
<tr>
<td>2-3</td>
<td>17</td>
<td>0.106</td>
</tr>
<tr>
<td>2-4</td>
<td>17</td>
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<td>0.087</td>
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<td>4-9</td>
<td>15</td>
<td>0.438</td>
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<tr>
<td>5-6</td>
<td>13</td>
<td>0.348</td>
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<tr>
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<tr>
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<tr>
<td>6-13</td>
<td>14</td>
<td>0.005</td>
</tr>
<tr>
<td>7-9</td>
<td>17</td>
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<tr>
<td>9-10</td>
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</tr>
<tr>
<td>9-14</td>
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<tr>
<td>10-11</td>
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<tr>
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<tr>
<td>13-14</td>
<td>18</td>
<td>0.708</td>
</tr>
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</table>
Table.3 shows that the UPFC and IPFC placement line number and bus number with their corresponding values. It has been observed that there is a considerable reduction in line loadings and improvement in bus voltage profile after the placement of FACTS devices using BBO technique.

Fig.7: Minimization of the Over Load Index by BBO technique for IEEE 14 bus system under contingency line outage

Fig.8: Improvement of the Voltage Violation Index by BBO technique for IEEE 14 bus system under contingency line outage
Fig. 9: Minimization of the Bus voltage by BBO technique for IEEE 14 bus system under contingency line outage.

Fig. 9 shows the minimization of Bus Voltage before and after placing FACTS devices achieved by BBO techniques when contingencies line. Fig. 10. Minimization of the Voltage Angle by BBO technique for IEEE 14 bus system under the contingency line outage. Fig. 11. shows the convergence characteristics of the objective function by BBO techniques when single line contingency.

Table 4: Total Bus Voltage and Voltage angle before and after using UPFC and IPFC in single line Contingency

<table>
<thead>
<tr>
<th>Contingencies</th>
<th>Bus voltage (p.u)</th>
<th>Voltage Angle (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Branch</td>
<td>Without FACTS</td>
<td>With FACTS</td>
</tr>
<tr>
<td>2-3</td>
<td>13.279</td>
<td>13.3298</td>
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<td>2-4</td>
<td>13.1939</td>
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<td>2-4</td>
<td>13.0255</td>
<td>13.1486</td>
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<tr>
<td>2-5</td>
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</tr>
<tr>
<td>6-11</td>
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<td>13-14</td>
<td>13.3401</td>
<td>13.880</td>
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</table>
Table 4 clearly shows the importance of problem formulation used in this paper to combine the conflicting objectives and to maintain the minimum bus voltage and voltage degree of satisfaction among the objectives. Therefore, to investigate the effectiveness of FACTS devices on the system under such case, we apply BBO techniques under single line contingency.

Fig. 10: Minimization of the Voltage Angle by BBO technique for IEEE 14 bus system under contingency line outage

Fig. 11: Objective function values after Placement of FACTS devices using BBO techniques

VII. CONCLUSION

This paper puts forward BBO for locating FACTS devices in a power system UPFC as well as IPFC units are used to relive the overloads and voltage deviations throughout single line contingency. The results illustrate that BBO capably solves together UPFC as well as IPFC locality predicament for IEEE14 bus system. The obtained result illustrate the anticipated technique has superior features and so as to the anticipated, algorithm is an effective and practical routine for the location of UPFC as well as
IPFC in power system. Finally, our results illustrate, so as to via FACTS devices in the optimal location with the optimal parameter settings know how to be alive the drastically improve the security of the power system under single line contingencies. The optimal clarification is achieved by BBO during line outage contingency can be utilized in power system.

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REFERENCES


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