OPTIMAL PLACEMENT OF UNIFIED POWER FLOW CONTROLLER (UPFC) TO MAXIMIZE POWER TRANSFER CAPABILITY

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Abstract—Flexible Alternating current transmission system i.e FACTS device have come into account for the major use for the controllability in the power system. With the increase in the load of the transmission line the power system may face voltage drop in the busses which may also result in the overloading of some transmission line in the system. FACTS device open ups a new opportunity for the controllability to maximizing power system capability of the system for this Unified Power Flow Controller is considered as a powerful FACTS device which helps in controlling both active and reactive power in the system. This paper mainly deals with the optimal placement of UPFC to maximize power transfer capability. Real power sensitivity performance index have been used to find optimal location of UPFC on IEEE-5 and IEEE-14 bus system.

Index Terms—Unified Power Flow Controller(UPFC), Flexible AC Transmission SystemFACTS), sensitivity performance index PI, GUI(Graphical User Interface).

I. INTRODUCTION

Different types of load increasing have been found out in the system. Load increase in the system up to particular limit is tolerable but if it is increased further it may lead to the voltage drop which may result instability of the system and overloading of the line. FACTS devices helps to maintain system stability as well as help to maintain the system to the normal required condition. There are various types of FACTS devices are available such as UPFC, IPFC, TCSC, STATCOM, SVC, etc. UPFC is proved to be a powerful device in controlling of both active and reactive power in the transmission line. Optimal location of UPFC can be calculated using genetic algorithm (GA) method which is mainly based on the natural and random selection as well as easy for implementation. Graphical user interface(GUI) have been used along with GA.

II. PRINCIPAL OF OPERATION OF UPFC

The unified power flow controller UPFC combines the feature of static synchronous compensator (STATCOM) and static synchronous series compensator (SSSC). This two converters allow a bidirectional flow of real power between the SSSC and STATCOM.

First converter(CONVERTER 1) is connected in shunt and second one(CONVERTER 2) is series with the line. The shunt converter is commonly used to provide active power demand of the series converter through a common DC link. converter1 can also produce and absorb reactive power and by this means provide independent shunt reactive compensation for the line. Secondly Converter2 provide the main function of the UPFC by injecting a voltage with controllable magnitude and phase angle in series with the line through a voltage source.

![Fig 1. UPFC functional model](image)

![Fig 2. Power injection model](image)

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**III. SENSITIVITY TECHNIQUES**

Optimal location of UPFC can be found out by using sensitivity method. It mainly depends on the objective of the device where it should be placement. By using this method sensitivity of device are to be calculated. The various objectives for device placement may be one of the following method given below:

i. Reduction in the real power loss of a particular line.
ii. Reduction in total system real power loss.
iii. Reduction in the real power flow performance index.

From the above three methods for sensitivity analysis approach methods, the real power flow performance index is calculated to find FACTS device i.e UPFC placement for maximum power transfer capability of the system given.

**Real power flow sensitivity index (PI)**

The real power flow performance index is given by the formula described below:

$$PI = \sum_{m=1}^{NL} W_m \left( \frac{P_{LM}}{P_{LM}} \right)^{2n}$$

Where,

- $P_{LM}$ is the rated capacity of line $m$.
- $P_{LM}^{max}$ is the real power flow in a line.
- $W_m$ is a real non-negative weighting coefficient which may be used to reflect the importance of lines.
- The real power flow performance index (PI) sensitivity factors are controlled by using various parameters of UPFC which can be given as follows:

$$\frac{\partial PI}{\partial \text{VT}} = \sum_{m=1}^{NL} \frac{W_m}{2n} \left( \frac{P_{LM}}{P_{LM}} \right)^{2n} \left( \frac{1}{P_{LM}} \right)^{2n}$$

Performance index (PI) will have minor value when lines are inside their limits and have high values when lines are overloaded.

Using the above equation the real power flow in line-$m$ ($P_{lm}$) with respect to UPFC parameters in $x^k$ line is given by the formula described below:

$$\frac{\partial P_{lm}}{\partial \text{VT}} = \sum_{m=1}^{NL} W_m P_{lm}^3 \left( \frac{1}{P_{LM}} \right)^{2n} \frac{\partial P_{lm}}{\partial x_{vt}}$$

The real power flow performance index sensitivity factors with respect to parameter of UPFC can be well-defined by this general formula

$$\frac{\partial PI}{\partial \text{VT}} \bigg|_{x_{vt}=0} = PI$$

**Table no. 1 Voltage magnitude and voltage angle comparison for IEEE-5 Bus system**

<table>
<thead>
<tr>
<th>Bus no.</th>
<th>VM(without UPFC)</th>
<th>VM(with UPFC)</th>
<th>VA(without UPFC)</th>
<th>VA(with UPFC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.0600</td>
<td>1.0600</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>1.0000</td>
<td>1.0000</td>
<td>-2.06</td>
<td>-1.77</td>
</tr>
<tr>
<td>3</td>
<td>0.987</td>
<td>1.0000</td>
<td>-4.64</td>
<td>-6.02</td>
</tr>
<tr>
<td>4</td>
<td>0.984</td>
<td>0.992</td>
<td>-4.96</td>
<td>-3.19</td>
</tr>
<tr>
<td>5</td>
<td>0.972</td>
<td>0.975</td>
<td>-5.77</td>
<td>-4.97</td>
</tr>
</tbody>
</table>

In this paper we have calculated sensitivity performance index with respect to VT i.e $C^k_{vt}$ is calculated.

Optimal Placement Of Unified Power Flow Controller(UPFC) To Maximize Power Transfer Capability
IV. PROGRAMMING RESULTS

Table no.2 Voltage magnitude and voltage angle comparison for IEEE-14 Bus system

<table>
<thead>
<tr>
<th>Bus no.</th>
<th>VM(without UPFC)</th>
<th>VM(with UPFC)</th>
<th>VA(without UPFC)</th>
<th>VA(with UPFC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.06</td>
<td>0</td>
<td>1.06</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>1.04</td>
<td>-9.8</td>
<td>1.00</td>
<td>-4.42</td>
</tr>
<tr>
<td>3</td>
<td>1.01</td>
<td>-12.73</td>
<td>1.02</td>
<td>-12.93</td>
</tr>
<tr>
<td>4</td>
<td>1.01</td>
<td>-10.31</td>
<td>1.06</td>
<td>-10.39</td>
</tr>
<tr>
<td>5</td>
<td>1.02</td>
<td>-8.77</td>
<td>1.07</td>
<td>-8.63</td>
</tr>
<tr>
<td>6</td>
<td>1.07</td>
<td>-14.22</td>
<td>1.05</td>
<td>-14.68</td>
</tr>
<tr>
<td>7</td>
<td>1.06</td>
<td>-13.36</td>
<td>1.09</td>
<td>-13.51</td>
</tr>
<tr>
<td>8</td>
<td>1.09</td>
<td>-13.36</td>
<td>1.05</td>
<td>-13.5</td>
</tr>
<tr>
<td>9</td>
<td>1.05</td>
<td>-14.94</td>
<td>1.04</td>
<td>-15.15</td>
</tr>
<tr>
<td>10</td>
<td>1.05</td>
<td>-15.09</td>
<td>1.04</td>
<td>-15.35</td>
</tr>
<tr>
<td>11</td>
<td>1.06</td>
<td>-14.08</td>
<td>1.05</td>
<td>-15.14</td>
</tr>
<tr>
<td>12</td>
<td>1.06</td>
<td>-15.08</td>
<td>1.05</td>
<td>-15.52</td>
</tr>
<tr>
<td>13</td>
<td>1.05</td>
<td>-15.16</td>
<td>1.05</td>
<td>-15.57</td>
</tr>
<tr>
<td>14</td>
<td>1.04</td>
<td>-16.03</td>
<td>1.02</td>
<td>-16.35</td>
</tr>
</tbody>
</table>

Sensitivity performance index based on real power flow (PI) is determine on several line by employing UPFC separately on each line and sensitivity factor is calculated as shown in table given below

Table no.3 PI SENSITIVITY FACTOR (5 BUS SYSTEM)

<table>
<thead>
<tr>
<th>Line</th>
<th>From bus-i to bus-j</th>
<th>Sensitivity factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>2-3</td>
<td>-9.57</td>
</tr>
<tr>
<td>1</td>
<td>1-2</td>
<td>1.88</td>
</tr>
<tr>
<td>4</td>
<td>2-4</td>
<td>5.55</td>
</tr>
<tr>
<td>2</td>
<td>1-5</td>
<td>28.22</td>
</tr>
</tbody>
</table>

Table no.4 PI SENSITIVITY FACTOR (14 BUS SYSTEM)

<table>
<thead>
<tr>
<th>Line</th>
<th>From bus-i to bus-j</th>
<th>Sensitivity factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>2-3</td>
<td>-45.11</td>
</tr>
<tr>
<td>7</td>
<td>1-2</td>
<td>-41.25</td>
</tr>
<tr>
<td>4</td>
<td>2-4</td>
<td>-39.56</td>
</tr>
<tr>
<td>2</td>
<td>1-5</td>
<td>-38.22</td>
</tr>
</tbody>
</table>

VI. GRAPHICAL USER INTERFACE (GUI)

A graphical user interface (GUI) is a graphical display in one or more windows comprising of controls, called components. This permit a user to achieve interactive task accordingly. GUI users doesn’t have to create any scripts of program they are automatically generated.m-file.

GUI components mainly includes include menus, toolbars, push buttons, list boxes, sliders, radio buttons etc. GUIs created by means of MATLAB tools can also accomplish any type of computation, read and write data files, communicate with other GUIs, and display data as tables or as plots as per requirement. The figure and the code file or either one also opens the other to run the GUI.

V. GENETIC ALGORITHM

Genetic algorithm show that it mainly depends upon the control parameter comprising of population size, crossover, generation, objective function, etc GA randomly generates initial population, selection, crossover, etc. The value are proceeded till the maximum generation value to reach.

Therefore it is necessary to have selection process to be precise for GA parameter to have high effect to give finest solution and optimal results.

The advantage of GA as an optimal placement method is ability to solve multi-objective, multi-variable function.

CONCLUSION

Real powerflow performance index for the optimal placement of UPFC have been studied as FACTS devices are used to maximize power transfer capability of the system. Genetic algorithm is used which is based on the mechanisms of natural/random selection. It gives high quality solutions because they are self-governing of the
choice of the initial configurations. As compared to other methods it is simple and easy to implement. In this paper we have calculated sensitivity performance index so as to obtain optimal location for FACTS device placement i.e. UPFC to Maximize power transfer capability of the system.

REFERENCES


