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Placement of UPFC in power system to improve the power system performance

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ABSTRACT

The FACTS known as flexible AC transmission systems devices are solid state converters designed on voltage source converter and now the approach of engineers towards planning and operations of power systems by the implementation of FACTS devices. In this thesis work, UPFC FACTS controller models have been developed to reduce transmission losses and to improve voltage profile with power flow algorithm and models have been linearized by Newton's method using a minimum of iterative steps. This paper describes the implementation of the UPFC Flexible AC Transmission Systems (FACTS) devices optimally locate in IEEE 14 bus system for power flow analysis to reduce the transmission losses and improve the voltage profile. In this thesis, UPFC is placed at every load bus at every transmission line to obtain the result of minimum power losses and minimum voltage deviation.

Keywords*— FACTS, UPFC, IEEE 14 bus*

1. INTRODUCTION

With the increase in load demand, we have to increase the generation & require proper channel to transfer electrical power from generating end to receiving end which is highly efficient in nature (that is transmission line). But when we try to add one or more number of generators to the existing transmission network then system suffers from large number of problems such as a reduction in power, voltage dip, interruption, over voltage etc. which can cause the ill effect to the power system quality [1-9]. It is necessary to maintain or enhance the quality of the network in order to get efficient power flow. Adding a large number of generating to the existing transmission makes it more and more complex. Hence designing of such a system is really a hectic job or we have to redesign the whole system by selecting the proper filter rating, power system stabilizer etc. We can use the traditional controller also for controlling power flow of these lines but frequent tuning is again a problem. Hence to overcome from above mention problem, we can use the fast acting power electronics controllers called FACTS devices. In the late 1980s, Electric power research institute introduce the new technology called Flexible AC Transmission Technology (FACTS devices) acts as controller used for controlling power flow. The deregulated environment is again one of the major causes of making line network more and bulkier. In power system, AC system cannot be preferable for long transmission of power because of high transmission losses but by using this technology we can able to transfer the AC power for long distance [26-31].

2. FACTS TECHNOLOGY

Flexible ac transmission system refers to FACTS, an integrated new technology consists of power electronics controlled devices playing a very important role in power systems. It will be flexible to enhance the flow of power control and power transfer capacity. FACTS device improves the voltage stability profile, reduces power losses and also increase the load ability [10-14].

The flexible ac transmission system categorized in to the series controller, shunt controller and series-shunt controller. The most popular FACTS controller is Static Var Compensator (SVC), static compensators (STATCOM), thyristor series controller (TCSC) and Unified Power Flow Controller (UPFC) [Hingorani N.G, IEEE press 2000 et *al*] [9, 15-26]. In this work by Matlab (version 2013) is used for programming for placement of FACTS devices in IEEE 14 bus system.

3. PROBLEM IDENTIFICATION

The Flexible AC Transmission System (FACTS) is attractive as the control expertise which replaces the low–rapidity control electronics by a novel production of control devices. The FACTS devices can manage power flows in the network by varying transmission line parameters. The problem of which kind of FACTS devices must be used for Power Quality Improvement by reducing transmission losses, and what is there best location?

4. METHODOLOGY

UPFCs have deserved a lot of attention in the last few years [11-14]. UPFCs are able to control, simultaneously or selectively, all the parameters affecting power flow in the transmission line. Alternatively, they can independently control both the real and reactive power flow in the line, unlike any of the other controllers. Figure 1 shows the general arrangement of UPFC which is consists of an advanced Shunt Static Synchronous Compensator (STATCOM)) and series (Series Static Synchronous Compensator (SSSC)) compensators connected through a common DC link. Each converter can independently generate or absorb reactive power.

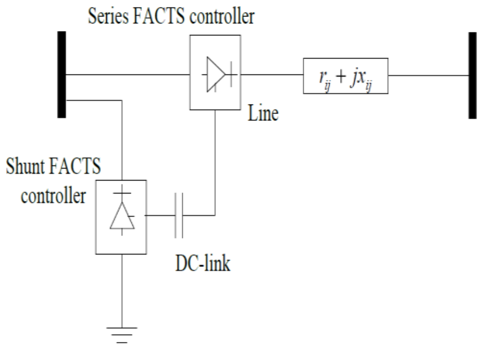

Fig. 1: Combined series-shunt FACTS controller

This configuration enables the free flow of active power in either direction between the AC terminals of the two converters. The main function of the shunt converter (STATCOM) is to supply or absorb the active power ordered by the series (SSSC) branch. STATCOM shunt converter is connected to the AC terminal through a shunt connected transformer.

5. SIMULATION AND RESULTS

The applicability of the proposed method has been tested on IEEE 14 bus system shown in figure 2. The branches data of IEEE 14 bus network of the proposed method are shown in Table 1 and power flow data are shown in Table 2. The first simulation was carried out without UPFC and in the second simulation carried out with UPFC in Matlab (version 2013) software by programming.

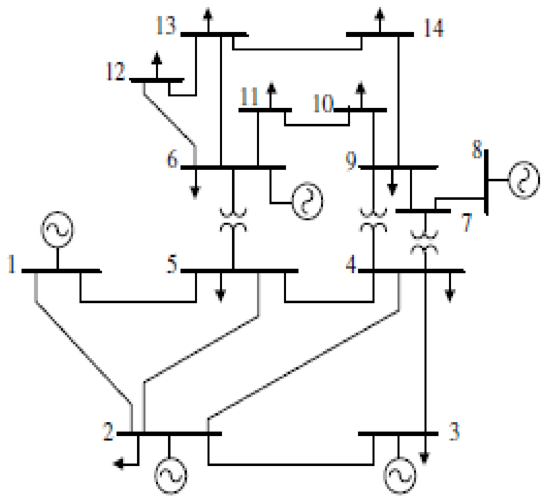

Fig. 2: Standard IEEE 14 bus system

Table 1: Branches data of IEEE 14 bus network

Initial Bus	Final Bus	R (pu)	X (pu)	B (pu)
1	2	0.01938	0.0591	0.0264
1	5	0.05403	0.2230	0.0219
2	3	0.04699	0.1979	0.0187
2	4	0.05811	0.1763	0.0246
2	5	0.05695	0.1738	0.0170
3	4	0.06701	0.1710	0.0173
4	5	0.01355	0.0421	0.0064
4	7	0	0.209	0
4	9	0	0.556	0
5	6	0	0.252	0
6	11	0.09498	0.198	0
6	12	0.12291	0.255	0
6	13	0.06615	0.130	0
7	8	0	0.176	0
7	9	0	0.110	0
9	10	0.0318	0.0845	0
9	14	0.1271	0.2703	0
10	11	0.0820	0.1920	0
12	13	0.2209	0.1998	0
13	14	0.1709	0.3480	0

Table 2: Schedule active power and reactive power contributed by generator for Power Flow Analysis

Gen.bus no.	Gen. Power		Load Data		
	P (pu)	Q (pu)	Bus no.	P	Q
1	0	0	4	0.478	-0.039
2	0.40	0.424	5	0.076	0.016
3	0	0.234	7	0.0	0.0
6	0	0.122	9	0.295	0.166
8	0	0.174	10	0.09	0.058
1	0	0	11	0.035	0.18
			12	0.06	0.016
			13	0.135	0.058
			14	0.149	0.05

5.1 For the IEEE 14 bus test system

Case 1: Simulate the power flow data of the IEEE 14 bus test system without FACTS devices.
Case 2: Simulate the power flow data of the IEEE 14 bus test system with UPFC FACTS devices.

6. SIMULATION RESULTS

6.1 Case 1: Without any FACTS device

Simulation of power flow data for IEEE 14 bus test system without FACTS devices the result obtained is shown in table 3.

Table 3: Results for variation of power loss and voltage deviation at the IEEE 14 bus system without FACTS devices

System	P_{loss} (p.u.)	Q_{loss} (p.u.)	Voltage Deviation
IEEE 14 Bus	0.07310	0.1193	0.6540

The simulation results of voltage profile without FACTS devices is shown in figure 3 below**.**

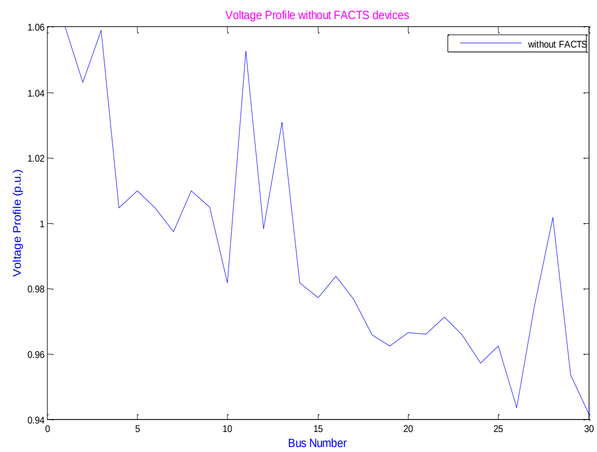

Fig. 3: Voltage profile without FACTS devices

6.2 Case 2. With FACTS Devices

Simulation of power flow for the IEEE 14 bus test system with UPFC FACTS device placement.

Table 4: Simulation results for variation of power loss and voltage deviation at the IEEE 14 bus system without FACTS devices

System	T. L. bus	P_{loss} (p.u.)	Q_{loss} (p.u.)	Voltage Deviation
IEEE 14 Bus	4-5	0.0587	0.1329	0.3790
	4-7	0.0511	0.0825	0.3557
	4-9	0.0512	0.0554	0.3325
	9-10	0.0508	0.1005	0.1544
	9-14	0.0522	0.0996	0.0623
	10-11	0.0628	0.1362	0.1945
	12-13	0.0707	0.1557	0.4366

Table 4 shows variation of power loss and voltage deviation at IEEE 14 bus system after placement of UPFC and it is found that power losses and voltage deviation are minimum at all buses as compared to Table 3, but the most suitable & favorable location after checking all possible locations in the vicinity of nodes to place UPFC in transmission line between 9-14 where active power loss, reactive power loss as well as voltage deviations are minimum. On comparison of result obtained in table 3 and table 4 with and without UPFC placement, it can be seen that the, when UPFC is connected in transmission line bus, 9-14 the real power loss is reduced from 7.310 MW to 5.22 MW and reactive power flow is reduced from 11.93 MVAR to 9.96 MVAR, voltage deviations are also minimum beginning 0.6540 to 0.0623 (p.u.).

The UPFC gives better improvement result when connected to bus no 9 and bus no.14 so it improves the voltage profile and power losses are minimum. The voltage profile magnitude and phase angle with UPFC placement in IEEE bus system are shown in figure 2 and 3 respectively. Figure 4 shows that with the placement of UPFC in IEEE 14 bus system the voltage profile is improved and phase angle is also improved as a comparison to without UPFC placement as shown in figure 3 After placement of UPFC in IEEE 14 bus system power losses are also minimum as a comparison to without its placement as shown in figure 4 below.

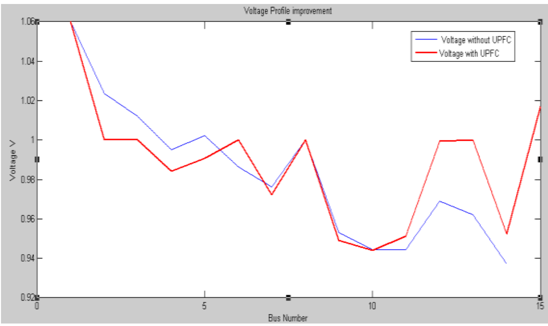

Fig. 4: Voltage magnitude comparisons without placement of UPFC and with UPFC in IEEE 14 bus system

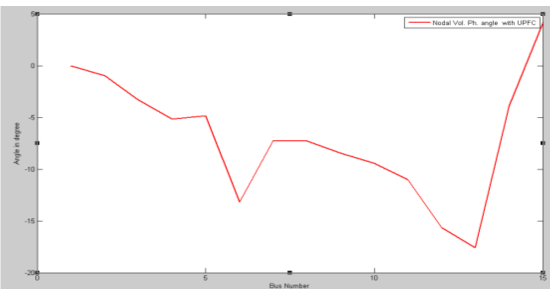

Fig. 5: Nodal Voltage Phase angle with UPFC

6. CONCLUSION

The effectiveness of the UPFC (Unified Power Flow Controller) FACTS devices for reducing the real power loss, reactive power loss in the power system is investigated. Towards the success of the proposed methods, standard test system IEEE 14 bus is used for simulation study work. Moreover, it can be inferred from the simulation results that putting of UPFC FACTS devices in the proposed bus system can decrease the transmission power loss and improve the power flow by improving the voltage profile. In this thesis work classical method are used to optimally locate the various UPFC, FACTS devices to the IEEE 14 bus test scheme to minimize active power loss, reactive power loss and least voltage deviation.

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