POWER QUALITY IMPROVEMENT IN POWER SYSTEM WITH FACTS DEVICES

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ABSTRACT

In this paper FACTS controller models have been developed for Power Quality improvement with power flow algorithm and models have been linearised by Newton's algorithm method. The comprehensive power flow algorithm is a very powerful tool competent of solving FACTS-upgraded power networks very reliably, using a least iterative step.

This paper describes the implementation of the Flexible AC Transmission Systems (FACTS) devices manually at each bus in power flow of IEEE 30 bus test system to reduce the losses and improve the voltage profile for Power Quality Improvement. The simulations are performed on two types of FACTS controllers such as SVC and STATCOM.

***Key words*: FACTS, Power flow, Power Quality**

I. INTRODUCTION

Power quality problems play a very important role in power system and its monitoring is the essential to make power supply in high-quality working order. Due to large inductive load power quality problem may take place that causes the damage of electrical equipments; these also cause reduction in power factor. On the way to transmit and allocate permanent quantity of power at fixed voltage of the conductor to carry additional current at little power factor requires a bulky conductor size. The heavy current at low power factor increases copper loss as well as enlarge KVA rating of equipments. The low power factor root poor voltage regulation and decrease power handling capability of power system [1,2].

The Power Quality is a combination of Voltage and frequency profile. It can be defined as degree to which the power supply approaches for the ideal case of stable, distortion and disturbance free supply. The standard that ensures amenable power quality is EN 50160 and IEC 61000-4-30 [13].

1.1 FACTS Technology

The developments in power electronics by FACTS technology which emerges as fast active response new concept which replaces old low speed electronics equipments. 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 [3-4].

FACTS devices are playing an important role in the area of extra high-voltage power transmission system to enhance the control of power flows of the network during stable and unstable conditions. The exchanged powers transfer through lines by changing angle, magnitude of bus voltage and lines reactance to avoid the congestion problem, enhancement in transmission capability, security and stability of transmission system are the ability of FACTS devices [5-6].

The flexible ac transmission system categorized in to series controller, shunt controller and series-shunt controller. The most popular FACTS controller are static var compensator (SVC), static compensators (STATCOM), thyristor series controller (TCSC) and unified power flow controller (UPFC) [13].

For operation of power system in right way, there is small voltage drops in lines and voltage at all buses will then be smooth voltage profile. Real power will be effectively transmitted by the transmission line not the reactive power. Reactive power flow will strongly affected the transmission voltage and by reactive power control, the transmission voltage can be controlled at its preferred value. Therefore it is necessary to study devices and research in the right way to control the reactive power in the transmission system [6-7].

1.2 PROBLEM IDENTIFICATION:

For cost-effective process of power system there is a need to balance power supply and demand. 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. There will be an opportunity and challenge to electrical engineers and researchers to examine and development of FACTS that:

Which kind of FACTS devices must be used for Power Quality Improvement?

What is there best location?

What should be there parameter setting?

How many FACTS devices should be used at minimum cost?

In previous from last few years many authors have worked on optimization technique for solve the problem of optimal power flow such as PSO [1], GSA [2], multiobjective [3,10], sparse optimization [4], ANN [7,19], GA [11], bacteria forging [15] and fuzzy [22] but in this paper FACTS devices are placed manually at each bus and results obtained shows proposed method give good response for placement of FACTS devices.

II. POWER FLOWS

Power flow is the solution of network under steady state conditions some inequality constraints such as load nodal voltages, reactive power generations, tap settings. It gives nodal voltages phase angle that power injection at all buses and interconnected power lines.

Algorithm for N-R method:

1. Assume initial values of bus voltage and phase angle. $|V_x|$ and δ_x for i=2,3….n
2. Calculate P_x and Q_y for each load bus

$$P_x = \sum_{k=1}^{n}(VxVk\ Yxk\ Cos(\delta x - \delta k - \theta xk)$$

$$Q_y = \sum_{k=1}^{n}(VxVk\ Yxk\ Sin(\delta x - \delta k - \theta xk)$$

Calculate schedule errors

$$\Delta P^{(r)}_x = P_{xsp} - P^{(r)}_{x(cal)} \qquad i = 2,3,\ldots.n$$

$$\Delta Q^{(r)}_y = Q_{xsp} - Q^{(r)}_{y(cal)}$$

Obtain δ and Δ|V| by Jacobian matrix

$$\begin{bmatrix} \Delta Px \\ \Delta Q \end{bmatrix} = \begin{bmatrix} H & N \\ M & L \end{bmatrix} \begin{bmatrix} \Delta\delta \\ \frac{\Delta V}{V} \end{bmatrix}$$

Modify δ and $\Delta|V_x|$

$$|V_x^{(r+1)}| = |V_x^{(r)}| + \Delta|V_x^{(r)}|$$

$$|\delta_x^{(r+1)}| = \delta_x^{(r)} + \Delta\, \delta_x^{(r)}$$

3. Continue until schedule errors for all load buses are within a tolerance ΔP and $\Delta Q < \varepsilon$.
4. Calculate the power flows.

2.1 POWER FLOW WITH FLEXIBLE ALTERNATING CURRENT TRANSMISSION SYSTEMS (FACTS) CONTROLLER:

FACTS controllers are used to improve power system performance. These controllers be able to reduce electrical disturbances, modified the flow of power and absorb or provide reactive power support [14-16].

(i) STATIC VAR COMPENSATORS (SVC)

It is a shunt-connected variable reactance, which moreover generates or absorbs reactive power in order to adjust voltage magnitude at point of link to the AC network. Static VAR Compensator (SVC) is a static var producer or absorber whose output is adjusted to substitute capacitive or inductive current so as to maintain or control specific parameters of the electric power system [8-11]. The model of SVC is shown below in Fig.1.0 below.

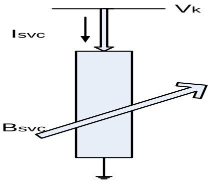

Figure 1.0. Model of S.V.C.

At every one iteration the variable shunt susceptance B_{svc} restructured by

$$B^{k+1}_{svc} = B^{k}_{svc} + \Delta\, B^{k}_{svc}$$

The susceptance changing represents whole SVC susceptance essential to preserve the nodal voltage magnitude at the specified value.

(ii)STATIC SYNCHRONOUS COMPENSATOR (STATCOM)

The shunt operated voltage source converter (VSC) is known as STATCOM which converts the dc voltage in to a three set of desired output voltages, amplitude, frequency and phase. Like SVC, a STATCOM provides voltage regulation and dynamic reactive power support throughout the purpose of power electronics and output current is adjusted to control either the nodal voltage magnitude or the reactive power injected at the bus. It absorbs or generates reactive power at a quicker rate because moving parts are not involved during operation. The primary goal of STATCOM are to counterbalance the effect of unbalanced load so as to current drawn from source is balanced, elimination of dc offset in loads, to cancel cause of poor load power factor such that current drawn from the source has a close to unity power factor and to cancel outcome of harmonic contents in the load so as to the current drawn from the source is nearly sinusoidal [17-23]. The model of STATCOM is Fig1.1 shown below.

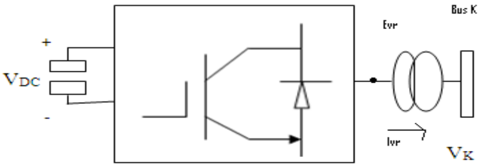

Figure 1.1. STATCOM system

The active and reactive power flow is obtained at bus k and with these equations linearized STATCOM replica can be obtained as:

$P_{vR} = V^2_{vR}G_{vR} + V_{vR}V_k\ [\ G_{vR}\ \mathrm{Cos}\ (\ \delta_{vR} - \theta_k) + BvR\ \mathrm{Sin}\ (\ \delta_{vR} - \theta_k)\ ]$

$Q_{vR} = -\ V^2_{vR}B_{vR} + V_{vR}V_k\ [\ G_{vR}\ \mathrm{Sin}\ (\delta_{vR} - \theta_k)\ -\ BvR\ \mathrm{Cos}\ (\delta_{vR} - \theta_k)\ ]$

$P_k = V^2_{vR}G_{vR} + V_{vR}V_k\ [\ G_{vR}\ \mathrm{Cos}\ (\ \theta_k - \delta_{vR}\ ) + BvR\ \mathrm{Sin}\ (\theta_k - \delta_{vR})\ ]$

SVC:

susceptance value in p.u.: B = 0.02

Limitation of variable susceptance in p.u.: BLo = -0.25; BHi=0.25

SVC controlled Target nodal voltage magnitude (p.u.) : TarVol =1.0

Control status for nodal voltage magnitude: VSta =1

STATCOM:

Converter's reactance (p.u.): Xvr =10

Initial condition for the voltage source magnitude (p.u.) : Vvr =1.0

Higher and lower limit voltage source magnitude (p.u.) VvrHi =1.1; VvrLo =0.9

target nodal magnitude of voltage (p.u.): TarVol =1.0

Initial condition value for voltage source angle (deg): Tvr =0.0

III. SIMULATION OF IEEE 30 BUS SYSTEMS:

The IEEE 30 bus analysis system has six generators connected on buses 1, 2, 5,8,11 along with 13. The scheduled active and reactive powers contributed by generators are 40 MW and 151.1 MVAR respectively. The buses are interconnected with 41 transmission line branches and 24 load buses with a total load of 137.6 MW and 64.5 MVAR. In this work SVC and STATCOM are placed manually at each load bus in IEEE 30 bus test system without FACTS devices then after with FACTS devices.

3.1. Simulation Results:

Case 1: Without any FACTS device

Simulation of power flow data for IEEE 30 bus test system without FACTS devices the result obtained are shown in Table I.

Table I. Simulation results for variation of Power loss and Voltage deviation at IEEE 30 bus system without FACTS devices

System	P_{loss} (p.u.)	Q_{loss} (p.u.)	Voltage Deviation
IEEE 30 Bus	0.0731	0.10581	0.1851

The simulation results of voltage profile without FACTS devices is shown in figure 2.0 below**.**

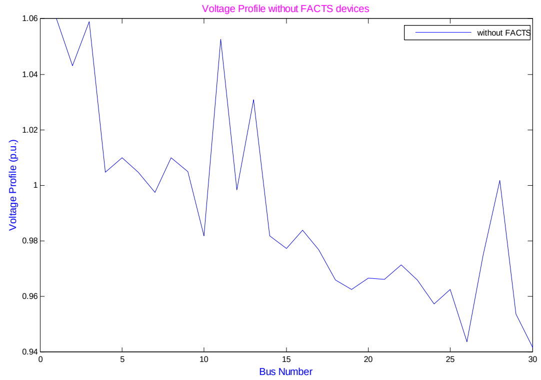

Figure 2.0 Voltage profile without FACTS devices

Case 2. With FACTS Devices

Simulation of power flow for IEEE 30 bus test system with various FACTS devices placement.

1. SVC Placement

In this case the purpose is to minimize real power losses, reduce reactive power flow and to improve the voltage profile. The SVC is placed at various load buses at favorable location to satisfy the objective. The result after placing SVC in power flow analysis at each load buses manually, some of them are shown in table II.

Table II. Simulation results of variation of Power loss and Voltage deviation in support of IEEE 30 bus test method power flow after SVC placement

Devices	**Load Bus**	**P_{loss} (pu)**	**Q_{loss} (pu)**	**V.D.**
SVC	20	0.05131	0.0470	0.1630
	22	0.05092	0.0443	0.1611
	24	0.05012	0.0395	0.1548
	25	0.05086	0.0446	0.1509
	28	0.05264	0.0573	0.1719
STATCOM	22	0.0512	0.0472	0.1610
	24	0.0508	0.0404	0.1546
	25	0.0506	0.044	0.1506
	26	0.05109	0.045	0.1508
	28	0.0525	0.0573	0.1712

Table I shows that when power flow in support of IEEE 30 bus scheme is running without FACTS devices the real power losses is 7.31MW, reactive power loss is 10.581 MVAR and voltage deviation is 0.1851. The table II shows variation of power loss and voltage deviation at IEEE 30 bus system after placement of SVC and it is found that power losses and voltage deviation is minimum at all buses, but the most suitable & favorable location subsequent to checking all possible locations in the vicinity of nodes to place the SVC at load bus 25 where active power loss, reactive power loss and voltage deviation are minimum. On comparison of result obtained in Table I and Table II for power flow of test system with and without SVC, it can be seen that the when SVC is connected at bus 25 the real power loss is reduced from 7.31 MW to 5.08 MW and reactive power flow is reduced from 10.581 MVAR to 4.462 MVAR, voltage deviation is also minimum beginning 0.1851 to 0.15098 (p.u.). The Voltage profile after SVC placement at bus 25 is shown in Fig. 2.1 below.

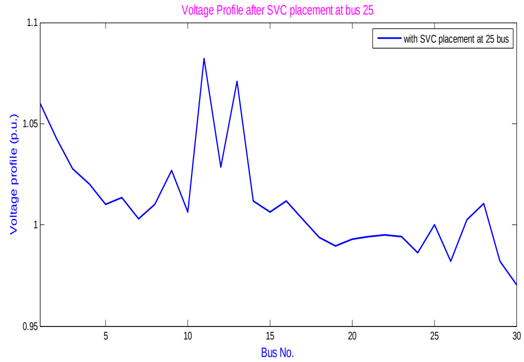

Figure 2.1. Voltage profile after SVC placement at bus 25

On comparison of result obtained in Table I and Table II for power flow of test system with and without STATCOM, it can be seen to facilitate the when STATCOM is attached at bus 25 the real power loss is reduced from 7.31 MW to 5.06 MW and reactive power flow is reduced from 10.581 MVAR to 4.4 MVAR, the voltage deviation is also minimum from 0.1851 to 0.1546 p.u. The Voltage profile after STATCOM placement at bus 25 is shown in Fig.2.2 and the comparison of real power loss savings is shown in Fig.2.3.

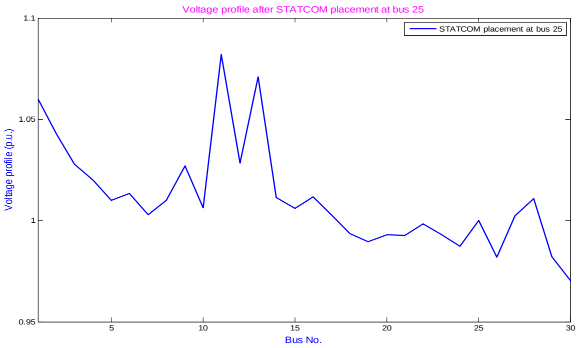

Figure 2.2. Voltage profile after STATCOM placement at bus 25

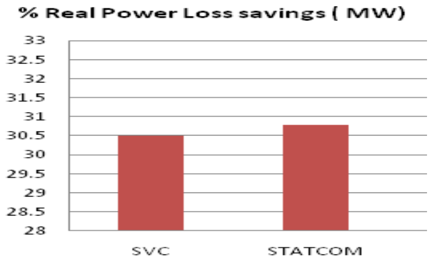

Figure 2.3. Comparison of % Real Power Loss Savings for IEEE 30 Bus system

IV. CONCLUSIONS

In this paper, the effectiveness of the FACTS devices for reducing the real power loss, reactive power loss in power system is investigated. Toward the success of the proposed methods, standard test system IEEE 30 bus is used for simulation study work. Simulation results disclose that the proposed works are acceptable for the test system. Moreover, it can be inferred from the simulation results that after putting FACTS devices in 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 FACTS devices to the IEEE 30 bus test scheme to minimize active power loss, reactive power loss and least voltage deviation. The following are the conclusion drawn on the strategy proposed for FACTS placement problem in this work.

The proposed technique solves the optimal power flow problem efficiently for the three specific objective functions reduce the active power loss, reduction of reactive power flow and improve the voltage profile for power quality improvement of overall system.

A classical technique is developed for optimal placement of FACTS devices to decrease the power losses and improve the voltage profile. In this thesis work four FACTS devices of single type SVC and STATCOM are considered for placement. In work Matlab programs are developed and executed by using Newton Raphson power flow technique. The results of proposed method are obtained for various types of FACTS devices by their placement in IEEE 30 test system at all buses of the network to decrease real power loss, reactive power loss as well as improve the voltage magnitude.

The proposed classical method for obtaining power losses and improve the voltage profile after FACTS placement are now compared with evolutionary swarm based optimization such PSO, genetic algorithm (GA) based gravitational search algorithm, Honey Bee Algorithm (HBA), Bacteria Foraging Algorithm (BFA) and Luus Jaakola (LJ) method as in reference [1,2,3,4,10,11,15, 22]. It can be observed that the proposed method for obtaining real power loss by classical method of placement of FACTS devices is much better than optimization method as this method provides better results.

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