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Placement of FACTS Device using Reduction of Total System Reactive Power Loss Sensitivity Indices Analysis Method

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ABSTRACT

Now a day electric power sector had over all activities of generation, transmission and distribution of power within its domain of operation, Such utilities referred to as vertically integrated utility (VIU). Due to continuous increase in industrialization and urbanization there is need of electrical energy. This gives rise into rapid growth of power system. The main focus of engineers to reshape above three components of VIU. The restructuring is used to increase customer focus, power system performance and reduce the cost revenue. Congestion is one of the technical issues in power system restructuring. In restructured power system transmission congestion take place when there is less transmission capacity to transmit the power. This paper propos to relieve congestion using FACTS device and location is found by using reduction of total system reactive power loss sensitivity indices analysis method based on electrical IEEE-14 bus and MATLAB software is used here for study purpose.

KEYWORDS

Congestion management, restructured power system, FACTS, sensitivity indices, IEEE-14 bus.

I. INTRODUCTION

With ever-increasing demand for electricity, the power transfer grows, consequently the power system becomes increasingly more difficult to operate, and more insecure with unscheduled power flows and higher losses. With the rapid development of self-Commutated power electronics devices, known as the Flexible AC Transmission Systems devices it is easy to control the power flow in transmission line [1] [2]. These devices allow the increasing of the usable transmission capacity to its Maximum line loading limits [3]. With the help of FACTS devices, it is also possible to control the phase angle, firing angle, the voltage magnitude at chosen buses and /or line impedances of a transmission system [4]. In the FACTS devices, FACTS is one of the most attractive and popular method for increasing the transfer capability of the transmission system for enhancing the stability, to make voltage profile stable, to reduce transmission losses and to improve the dynamic characteristics of power system[5]. However, to achieve the above benefit, the FACTS device should be properly installed in the network with appropriate parameters. Different concepts about the placement and sizing of the TCSC, GA, PSO and DA Algorithms are proposed In the many research paper. There are many different load flow analysis with incorporated FACTS controllers from different operating conditions in multimachine power systems for optimal power flow control [6]. The Newton Raphson Methods has been proposed for different types of Modeling of Series and shunt FACTS controllers [7]. The system is said to be "congested‟, when producers and consumers of electric energy desire to produce and consume in amounts that would cause transmission system to operate at or beyond one or more transfer limits. To overcome the problem of congestion proper action should take place, That action is called as congestion management. If congestion is not eliminated then it may cause to tripping of overloaded lines and may cause tripping of other lines and in some cases to voltage stability related problems. Hence to avoid this problem congestion need to be solved. In this not regulate power market independent system operator (ISO) has to eliminate the congestion, so that the system is maintained in secure state. To relieve the congestion ISO can use mainly two Types of methods which are as follows [8]:

1) Cost free method

i. Out-ageing of main congested lines
ii. Operation of transformer
iii. Series devices Operation of FACTS devices

2) Cost based methods:

i. It is possible to Re-dispatching the generation amounts. By using this method, some generators increase their output while back down others.
ii. Curtailment of loads and the exercise of load interruption options.

Cost free methods is more economical compare to cost based such as without disturbing economic matter. FACTS device, like Thyristor Controlled Series Capacitor (TCSC) and Static VAR compensator [9].

II. POWER SYSTEM OPERATING STATE

The system operation is governed by three sets of generic equations – one differential and two algebraic (generally non-linear). Out of two sets of algebraic sets, one set comprises equality constraints (E) which express balance between the generation and load demand. The other set consists of inequality constraints (I) which express limitation of the physical equipment (such as current and voltages must not exceed maximum limits). The classification of the system states is based on the fulfillment or violation of one or both sets of these constraints, Fig.1 shows the system operating state [10][11].

A. Normal State:- Here all equality(E) and Inequality(I) constraints are satisfied. In this state, generation is adequate to supply the existing load demand and no equipment is overload.

B. Alert State:- The difference between this and the previous state is that in this state, the security level is below some threshold of adequacy. This implies that there is a danger of violating some of the inequality (I) constraints when subjected to disturbances enables the transition from an alert state to secure state.

C. Emergency State: - Due to severe disturbance the system can enter into emergency state. Here inequality (I) constraints are violated. The system, however, would still be intact, and emergency control action could be initiated to restore the system to alert state. If these measures are not taken in time or are ineffective, and if the initiating disturbance or a subsequent one is severe enough to overstress the system, the system will break down and reach 'In-Extremis' state.

D. In-Extremis State: - Here both equality (E) and inequality (I) constraints are violated. The isolation of equality constraints implies that part of systems load is lost. Emergency control action should be directed at avoiding total collapse.

E. Restorative State:- This is a transitional state in which inequality(I) constraints are met from the emergency control actions taken but the equality(E) constraints are yet to be satisfied. From this state, the system can transit to either the alert or the normal state depending on the circumstances. Now a day's loads on the power system increases rapidly and power system network becomes more complex hence it is difficult to transmit the more power and leading the power system networks to its thermal limit. Due to this, power system security problem arises. It is necessary that, though load demand increases, the power system transmission networks should work within their safe limits [12]. This insecure problem of power system can be overcome by optimally locating FACTS devices [13] [14].

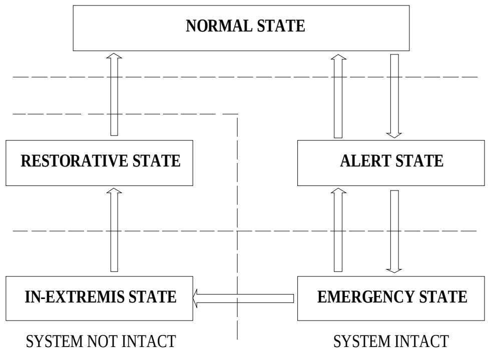

Fig 1: Power System Operating State

III. STATIC MODEL OF TRANSMISSION LINE

A simple transmission line, connected between bus-I and bus-j with the line admittance given as $g_{ij}+jb_{ij}=1/(r_{ij}+jx_{ij})$, can be represented by its limped π equivalent parameters as shown in Fig. 2 [15] [16].

The real (P_{ij}) and reactive (Q_{ij}) power flows from bus-i to bus-j can be written as;

$$P_{ij} = V^2{}_i g_{ij} – V_iV_j(g_{ij}Cos\delta_{ij} + b_{ij}Sin\delta_{ij}) \quad (5)$$

$$Q_{ij} = -V^2{}_i(b_{ij}+ B_{sh}/2)–V_iV_j(g_{ij}Sin\delta_{ij}-b_{ij}Cos\delta_{ij}) \quad (6)$$

Where, $\delta_{ij} = \delta_i - \delta_j$

Similarly, the real (Pij) and reactive (Qij) power flows from bus-j to bus-I can be expressed as;

$$P_{i} = V^2{}_j g_{ij}–V_iV_j (g_{ij}Cos\delta_{ij} - b_{ij}Sin\delta_{ij}) \quad (7)$$

$$Q_{i} =-V^2{}_j(b_{ij}+B_{sh}/2)+V_iV_j(g_{ij}Sin\delta_{ij}+b_{ij}Cos\delta_{ij}) \quad (8)$$

Where,

B_{sh} is full line charging impedance.

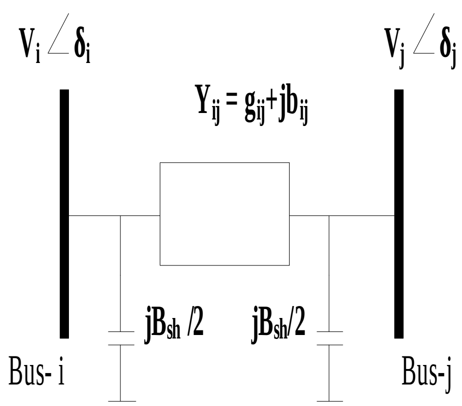

Fig 2. Static Model of Transmission Line

IV. POWER FLOW EQUATION

Basically power flow problem involves solving the set of non-linear algebraic equations which represent the network under steady state conditions. Newton-type methods, with their strong convergence characteristics, have proved most successful to solve power flow problem. To illustrate the power flow equations, the power flow across the general two-port network element connecting buses i and j shown in Fig. 3 is considered and the following equations are obtained.

The injected active and reactive power at bus-I (Pi and Qi) are:

$P_i = G_{ii}V_i^2 + (G_{ij}Cos\delta_{ij} + B_{ij}Sin\delta_{ij})V_iV_j$ (1)

$Q_i = -B_{ii}V_i^2 + (G_{ij}Sin\delta_{ij} - B_{ij}Cos\delta_{ij})V_iV_j$ (2)

$P_j = G_{jj}V_j^2 + (G_{ji}Cos\delta_{ji} + B_{ji}Sin\delta_{ji})V_iV_j$ (3)

$Q_j = -B_{jj}V_j^2 + (G_{ji}Sin\delta_{ji} - B_{ji}Cos\delta_{ji})V_iV_j$ (4)

Where;

$\delta_{ij} = \delta_i - \delta_j = -\delta_j$,

$Y_{ii} = Y_{jj} = G_{ii} + jB_i = Y_{i0} + Y_{ij}$ and

$Y_{ij} = Y_{ji} = G_{ij} + jB_{ij} = -Y_{ji}$

The nodal power flow equations,

$P = f(V,\theta,G,B)$ and

$Q = g(V,\theta,G,B)$

P and Q are vectors of real and reactive nodal power injections as a function of nodal voltage magnitudes V and angles θ, and network conductance G and suceptance B.

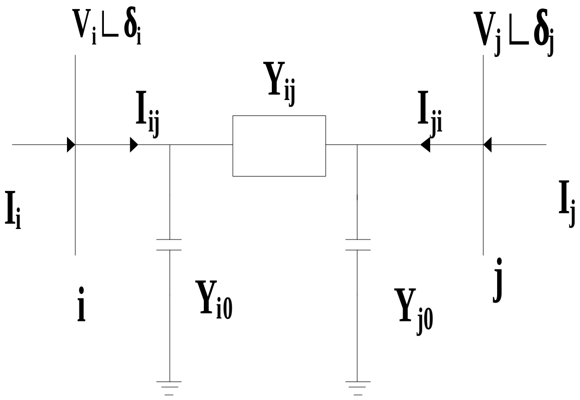

Fig 3. General two-port network

V. BENEFITS OF UTILIZING FACTS DEVICES

The advantages of utilizing FACTS devices in power system can be given as below;

1) Existing transmission system can be utilizing in better way with the help of FACTS devices.
2) Reliability and availability of transmission system increases.
3) Environmental friendly.

In many countries, increasing the energy transfer capacity and controlling the load flow of transmission lines are of vital importance, especially in de-regulated markets, where the locations of generation and the bulk load centers can change rapidly. Frequently, adding new transmission lines to meet increasing electricity demand is limited by economical and environmental constraints. FACTS devices help to meet these requirements with the existing transmission systems [10].

VI. TOTAL SYSTEM REACTIVE POWER LOSS SENSITIVITY ANALYSIS METHOD

Reduction of Total System Reactive Power Loss and Real Power Flow Performance Index Sensitivity Indices These are the two method of sensitivity indices method for optimal location of FACTS. Reduction of total system reactive power loss can be calculating by following formulas [10].

$$a_{ij}= \frac{\delta Q_L}{\delta X_{ij}} = [V_i^2+ V_j^2 - 2V_iV_j \mathrm{Cos}\delta_i\ ]\frac{(r_{ij}^2 - X_{ij}^2)}{(r_{ij}^2 + X_{ij}^2)^2}$$

The FACTS devices should be placed on the most sensitive line. Following criteria can be used for deciding optimal placement. According to reduction of total system reactive power loss sensitivity analysis method, the FACTS should be placed in a line having the most positive loss sensitivity index [16].

VII. SYSTEM DESCRIPTION

Study of power flow, power system stability and power system security using sensitivity indices is done here. In this paper, by considering the line loading limits of each line, means in which line power flow is exceeds than prescribe limit is explain here. The analysis is done on IEEE-14 bus system [15]. The single line diagram of the IEEE-14 bus standard test system is shown in Fig.4, which consists of five synchronous machine, including two generators, located at bus 1 and 2 as well as three synchronous compensators used only for reactive power support, located at bus 3, 6 and 8. Bus 1 is a slack/ reference bus while bus 2, 3, 6 and 8 are PV bus and other all are PQ bus [17][18].

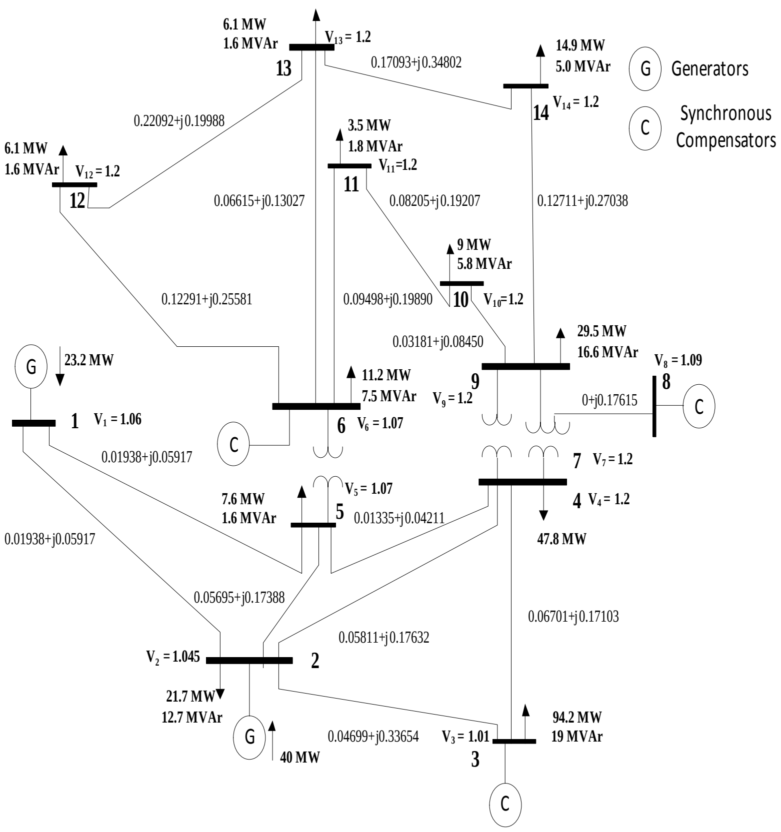

Fig 4. IEEE-14 bus system

VIII. RESULT AND DISCUSSION

The sensitivity indices obtained using proposed sensitivity indices analysis method are shown in Table I and denoted by a_{ij}. By considering the criteria for given sensitivity analysis method, the line no. 19 (column 3rd) is more sensitive and it is suitable for placing the FACTS device.

TABLE I. CALCULATED SENSITIVITY INDICES

LINE NO.	LINE(i-j)	SENSITIVITY INDICES (aij)
1	1 -2	-0.0500978
2	1 -5	-0.00172195
3	2 -3	-0.0116109
4	2 -4	-0.561089
5	2 -5	-0.015215
6	3 -4	-0.786861
7	4 -5	-7.10478
8	4 -7	-0.00229181
9	4 -9	-4.74885e-05
10	5 -6	-7.11635e-06
11	6 -11	-0.218704
12	6 -12	-0.131154
13	6 -13	-0.467266
14	7 -8	-0.389977
15	7 -9	-0.00315425
16	9 -10	-0.00169992
17	9 -14	-0.00169992
18	10 -11	-0.000148184
19	**12 -13**	**9.49569e-06**
20	13 -14	-3.49601e-07

CONCLUSION

From the power system stability and system security point of view, congestion management is very important as per expected goal optimal placement of FACTS devices to relieve congestion is important and this goal can be achieved by using reduction of total system reactive power loss sensitivity indices analysis method

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