Placement of FACTS Device Using Real Power Flow Performance Index Sensitivity Indices Analysis Method

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Abstract - *The expansion of power generation and transmission has been severely limited due to limited resources and environmental restriction because in recent years, power demand has increased substantially. Power system stability has been recognized as an important problem for its secure operation. Safe operation of electric power system is largely related to its stability which depends upon on the ability of an electric power system for a given initial operating condition to regain a state of operating equilibrium after being subjected to a physical disturbance, with most system variables bounded so that practically the entire system remains intact. Several attempts have been made to improve operating margins necessary for system stability from the conventional use of power system stabilizer. To overcome this difficulty, a rapid development of power electronic devices such as Flexible AC Transmission System (FACTS) devices are used, but the location of these FACTS devices has been enormous challenge. This can be overcome by using Sensitivity Indices analysis method. Here real power flow performance index sensitivity indices are used and 'MATLAB' software is used here to write a programming code for finding real power flow performance index sensitivity Indices. For the study purpose electrical IEEE-14 bus system is used here.*

***Key Words*: sensitivity analysis, sensitivity indices, power system security, FACTS.**

1. INTRODUCTION

Network of electrical components that used to supply, transmit and use electric power is nothing but the power system. For particular small regions, this power system is known as grid and can be broadly divided into the generator that supply the power, the transmission system that carries the power from the generating centre to the load centre and the distribution system that feeds the power to nearby homes and industries. The power system needs to be operationally secure, i.e. with minimal probability of blackout and equipment damage [1][2]. An important component of power system security is the systems.

Ability to withstand the effects of contingencies. A contingency is basically an outage of a generator, transformer and or line, and its effects are monitored with specified security limits [3]. When the power flows and the bus voltages are within acceptable limits despite changes in load or available generation then this condition of power system is said to be normal condition of power system and the operation is normal. From this point of view, security is the probability of a power system's operating point remaining in a viable state of operation [4].

The system operation is governed by three sets of generic equations – one differential and two algebraic (generally non-linear). The two algebraic sets consists of, one set comprises equality constraints (E) which express balance between the generation and load demand and other set consists of inequality constraints (I) which express limitation of the physical equipment. 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 [5].

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 and this leads to power system security problem. It is necessary that, though load demand increases, the power system transmission networks should work within their safe limits [6]. This insecure problem of power system can be overcome by optimally locating FACTS devices and the optimal location can be found out by using sensitivity indices analysis method, i.e. 'Real Power Flow Performance Index method' depending upon the criteria for that particular sensitivity indices analysis method [7] [8].

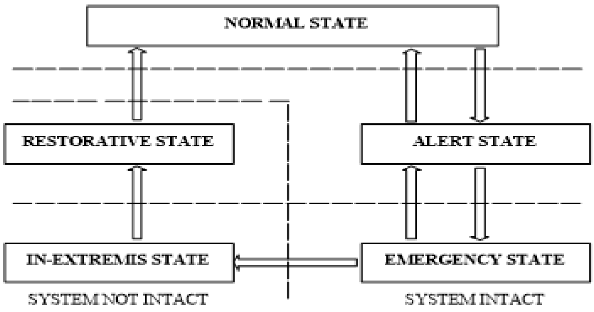

Fig 1: Power system operating state.

2. 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 [9]. The real (P_{ij}) and reactive (Q_{ij}) power flows from bus-i to bus-j can be written as;

$$P_{ij} = V^2{}_i g_{ij} - V_iV_j(g_{ij}Cos\delta_{ij} + b_{ij}Sin\delta_{ij}) \quad (1)$$

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

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

Hence real & reactive power flow from bus-j to bus-i can be expressed as;

$$P_{ji} = V^2{}_j g_{ij} - V_iV_j (g_{ij}Cos\delta_{ij} - b_{ij}Sin\delta_{ij}) \quad (3)$$

$$Q_{ji} = - V^2{}_j (b_{ij}+ B_{sh}/2)+V_iV_j(g_{ij}Sin\delta_{ij}+b_{ij}Cos\delta_{ij}) \quad (4)$$

Where, B_{sh} is full line charging impedance

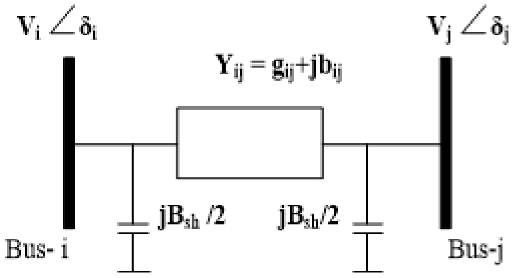

Fig 2: Static model of transmission line

3. PROPOSED SENSITIVITY ANALYSIS METHOD

To decide the optimal location of FACTS devices, following are two sensitivity indices analysis methods are there [10] [11];

a. Reduction of Total System Reactive Power Loss.

b. Real Power Flow Performance Index Sensitivity Indices.

The severity of the system loading under normal and contingency cases can be described by a real power flow performance index sensitivity indices [12][13].

$$PI = \sum_{m=1}^{N_L} \frac{W_m}{2n} \left(\frac{P_{Lm}}{P_{Lm}^{max}}\right)^{2n}$$

Where,

P_{Lm} is the real power flow,

P_{Lm}^{max} is the thermal limit of line m,

n is an exponent used to adjust the index value to avoid the masking effect in the contingency

W_m is the weighting coefficient used to reflect the Importance of lines.

PI will be small when all the lines are within their limits and reach a high value when there are overloads. Thus, for given state of power system, this method provides a good measure of severity of the line overloads [14].

4. CRITERIA FOR OPTIMAL PLACING OF FACTS DEVICES

The FACTS devices should be placed on the most sensitive line. In real power flow performance index method, the FACTS devices should be placed in a line having most negative sensitive index [15].

5. SYSTEM DESCRIPTION

Study of power system stability using Real power flow performance index sensitivity indices Analysis method is done here. The analysis is done on Electrical IEEE-14 bus system. The single line diagram of the IEEE-14 bus standard test system is shown in Fig.3, 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 [16].

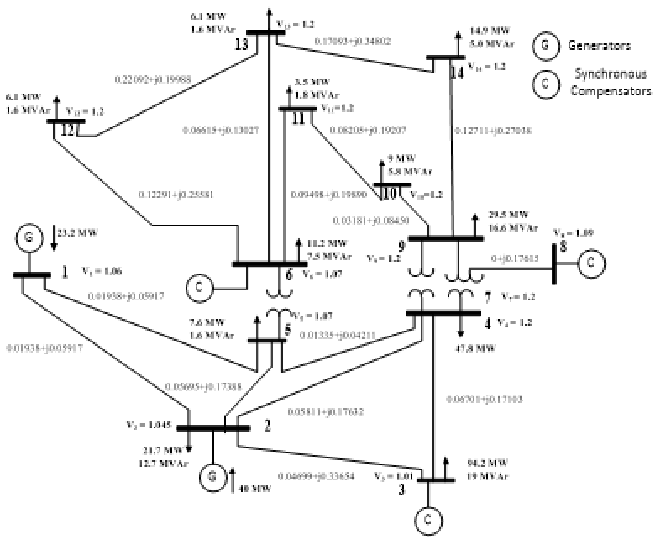

Fig 3: IEEE-14 bus system

6. RESULT AND DISCUSSION

The result obtained from the MATLAB programming is shown in Table 1 by using real power flow performance index sensitivity indices analysis method. Column 3rd gives sensitivity indices by using real power flow performance index sensitivity analysis method. From column 3rd the line no. 6 is more sensitive.

TABLE I. Calculated sensitivity indices

Line No.	Line(i-j)	Sensitivity indices (bij)
1	1-2	-0.113426
2	1-5	0.0102279
3	2-3	-0.16522
4	2-4	-1.69292e-11
5	2-5	-1.4268e-17
6	**3-4**	**-169204**
7	4-5	0
8	4-7	0
9	4-9	0
10	5-6	0
11	6-11	19.1127
12	6-12	-5.21936e-10
13	6-13	-6.81363e-11
14	7-8	0
15	7-9	0
16	9-10	-6931.66
17	9-14	2.39191e-16
18	10-11	-53.3261
19	12-13	5.13135e-08
20	13-14	1.48617e-10

CONCLUSIONS:

The system stability is the important thing in the power system. As per expected goal, in large power system, the finding of the sensitivity of line is the first and important step. The suggested approach is composed of sensitivity indices analysis method using real power flow performance index sensitivity analysis method, the analysis approach has been utilized to find the most sensitive line in power system network. The objective function has been made of the severity of the system loading

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