"OPTIMAL PLACEMENT OF FACTS USING 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. Several methods are being used conventionally to improve operating margins necessary for system stability. Many of these suffer with excessive response time and considerable amount of power loss. To overcome this difficulty, a rapid development of power electronic devices such as Flexible AC Transmission System (FACTS) devices are used, their primary application is to enhance power transfer capabilities, power system stability and allow more flexible control of power flows. By installing FACTS equipment at optimal sites, the overall system benefits are sought. But the location of these FACTS devices has been big challenge. This challenge is overcome by using Sensitivity Indices analysis method. The 'MATLAB' software is used here to write a programming code for finding out the sensitivity indices. IEEE-5 bus system is used here for the study purpose

Keywords: sensitivity analysis; sensitivity indices; power system security; PI; FACTS

1. INTRODUCTION

Power system is a network of electrical components used to supply, transmit and use electric power. An example of an electric power system is the network that supplies a region like homes and industry with power [2]. For sizable 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 [3]. The power system operation is said to be normal when the power flows and the bus voltages are within acceptable limits despite changes in load or available generation. From this perspective, 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). 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 [5].

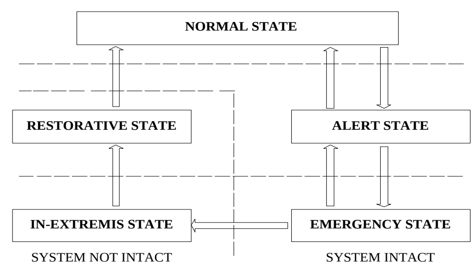

Figure 1: Power System Operating State

In the present day scenario, transmission systems are becoming increasingly stressed, more difficult to operate, and more insecure with unscheduled power flows and greater losses because of growing demand for electricity and restriction on the construction of new lines. Now, more advanced technology is used for reliable operation of transmission and distribution in power system and this is nothing but the use of Flexible AC Transmission System (FACTS) devices. FACTS devices are effective and capable of increasing the power transfer capability of a line and support the power system to work with comfortable margins of stability and used to overcome the insecure problem of power system [6] [7].

FACTS is defined by the IEEE as "a power electronic based system and other static equipment that provide control of one or more AC transmission system and increase the capacity of power transfer" [8].

In this paper, the optimal location of FACTS devices is find out using sensitivity indices analysis method. The 'MATLAB' software is used here to write a programming code for finding out the sensitivity indices. For the study purpose electrical IEEE-5 bus system is used here.

2. BENEFITS OF UTILIZING FACTS DEVICES

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

- Existing transmission system can be utilize in better way with the help of FACTS devices.
- Reliability and availability of transmission system increases.
- Environmental friendly.

In many countries, increasing the energy transfer capacity and controlling the load flow of transmission lines are of vital importance. Frequently, adding new transmission lines to meet increasing electricity demand is limited by economical and environmental constraints. FACTS devices help to meet increasing electricity demand with the existing transmission systems [9].

3. 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 [10].

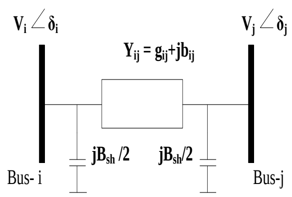

Fig. 2. Static Model Of Transmission Line

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,

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

Similarly, the real (Pij) and reactive (Qij) power flows 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.

4. PROPOSED SENSITIVITY ANALYSIS METHOD

Following sensitivity analysis method used for finding the optimal location of FACTS devices [11].

- Real Power Flow Performance Index Sensitivity Indices.

A. Real Power Flow Performance Index (PI)Sensitivity Indices

The severity of the system loading under normal and contingency cases can be described by a real power line flow performance index, as given below [13] [14];

$$PI = \sum_{m=1}^{N_L} \frac{W_m}{2n} \left(\frac{P_{Lm}}{P_{Lm}^{max}}\right)^{2n} \quad (5)$$

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.

5. CRITERIA FOR OPTIMAL PLACING OF FACTS DEVICES

The FACTS devices should be placed on the most sensitive line. Following criteria can be used for deciding optimal placement [12].

- In real power flow performance index method, the FACTS devices should be placed in a line having most negative sensitive index.

SYSTEM DESCRIPTION

Study of power system stability using sensitivity indices is done here. In this paper, idea about, which line is most sensitive in network is explain here. The analysis is done on IEEE-5 bus system. The single line diagram of the IEEE-5 bus standard test system is shown in Fig. 3, This typical system consist of three generators and five buses as shown in Fig. 3. Three generators are connected on bus 1, bus 2, bus 3 whereas the loads are connected on bus 2, bus 3, bus 4 and bus 5. The generating capacity of each generator, value of load and value of resistance and reactance are also shown in it.

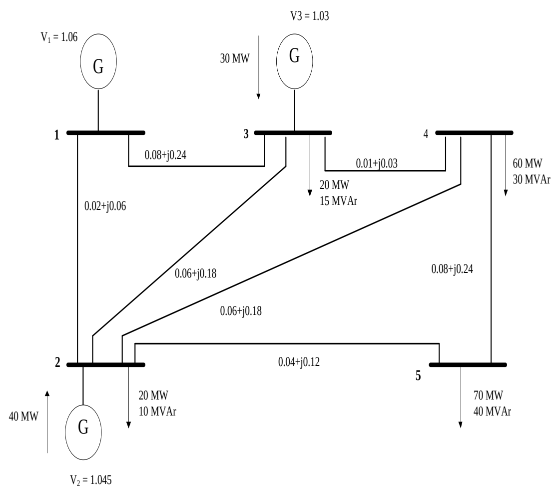

Figure 3: IEEE-5 bus system

6. RESULT AND DISCUSSION

The result obtained from the MATLAB programming are shown in TABLE I real power flow performance index sensitivity indices analysis method. Column 3rd gives sensitivity indices by using real power flow performance index sensitivity analysis method and it is denoted by b_{ij}. According to real power flow performance index method (column 3rd), line no. 1 (bij = $-4.11798e^{08}$) is most sensitive and line no. 1 is suitable for optimal placement of FACTS device. In this way to overcome the security problem of power system, optimal placement of FACTS devices can done with the help of sensitivity analysis indices method.

TABLE I. CALCULATED SENSITIVITY INDICES

Line	**i-j**	$\mathbf{b_{ij}}$
1	1-2	$\mathbf{-4.11798e^{08}}$
2	1-3	-29579.4
3	2-3	-26.9698
4	2-4	0
5	2-5	$1.45617e^{07}$
6	3-4	$6.99824e^{08}$
7	4-5	0

7. CONCLUSION

To improve power system state from the security point of view, optimal placing of FACTS devices is important. By introducing sensitivity analysis method, optimal place of FACTS devices is find out here. In this way to overcome the security problem of power system, optimal placement of FACTS devices can done with the help of Real power flow performance index sensitivity analysis indices method.

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