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Line Parameter Sensitivity for Improvement in Power Flow Condition

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ABSTRACT
The changing scenario of power system is essential with its operation and control. Restructuring of power system is a complex issue and it will prove its many advantages if it is handled systematically. The objective of deregulation of power system is to provide electrical power to the end consumer which will be qualitative, quantitative and economic. However this objective could be encountered by the network congestion. Effective design and controlling of power system network can avoid it. This requires determining the sensitivity of power flow for the changes in power at a bus. This paper describes the various studies to carry out power flow sensitivity analysis. From these studies, an attempt is made to formulate the function representing the change in the amount of power transfer capability of each line. This will help the designer to select the line reactance to maintain the system security.

***Keywords* -** Deregulation, Network congestion, Power Transfer capacity, restructuring of power system, Sensitivity analysis**.**

I. INTROCUTION

The changing scenario of power system is essential to attend the problems associated with its operation and control. Restructuring of power industry is a complex issue, and will prove its many advantages if it is systematically handled. Earlier times power system was performed the functions mainly generation, transmission, and distribution in a regulated manner .These functions were performed with the conventional concepts of power system operation.

In [1-3] Sensitivity in Power Systems is defined as the ratio A_x/A_y relating small changes A_x of some dependent variable to small changes A_y of some independent or controllable variable y. In power systems, two dominant types of sensitivity relations are defined, namely

1) Sensitivity of one electrical variable, such as the voltage V_i at node i, with respect to another electrical variable, such as reactive production Q_j at node j, and

2) Sensitivity of the operating cost F with respect to such electrical variables as the consumption C_i at node i and the production P_j at node j. The calculation of the first type of sensitivity relations requires the inversion of the Jacobian matrix associated with the power-flow equations.

Similar research is carried out in [4-6] on sensitivity analysis. In [7] an objective of deregulation of power system is to provide electrical power to consumers, which will be qualitative, quantitative and economic. However this objective could be encountered by the network congestion. Effective design and controlling of power system network can avoid it. This requires determining the sensitivity of power flow for the changes in power at a bus. The paper describes the various studies to carry out power flow sensitivity analysis. From these studies, an attempt is made to formulate the function representing the change in the amount of power transfer capability of each line. This will help the designer to select the line reactance to maintain the system security. Power industry restructuring around the world has a strong impact on Asian power industry as well. Indian power industry restructuring with a limited level of competition since 1991 has already [8] been introduced at generation level by allowing participation of independent power producers (IPPs). The new electricity act 2003 provides the provision of competition in several sectors. In this paper, [9] S. C. Srivastava explained Electric power utilities, throughout the world, are currently undergoing major restructuring process and are adopting the deregulated market operation. This change has been prompted due to two main reasons, one being the lack of adequate funds to set up the required generation, transmission and distribution facilities, especially in the developing countries, and the second to bring in improvement in the overall efficiency of operation. The deregulated structure is aimed at creating some form of electricity market and introducing competition at various levels of electricity sales. The restructured markets normally employ either pool trading that involves bidding in the open market or bilateral/multilateral trading directly between seller(s) and buyer(s) or a combination of the both. Further, the bilateral / multilateral contracts may be firm contracts (non curtailable) or non-firm contracts (curtailable). For integrated operation of such systems, regulating agencies such as pool operator or system operator are created and the open market of electricity is introduced with the help of either a separate power exchange or the system/pool operators themselves.

The power system deregulation is expected to offer the benefit of lower electricity cost through competition, better consumer service and improved system efficiency. However, it poses several technical challenges with respect to its conceptualization and integrated operation. Basic issues of ensuring economic, secure & stable operation of the power system, while delivering power at desired quality in terms of voltage magnitude and frequency, have to be addressed.

II. SENSITIVITY ANALYSIS

Any non linear system equations can be simplified for different variables using the iterative methods. Such as Newton–Raphson, Guass Seidel, etc. However to obtain the small changes in certain variables many times it is required to apply one of such methods, which undergoes several iterations. In such cases where only changes are required to be obtained, sensitivity analysis is found as the most suitable approach. In the earlier research on the application of sensitive analysis in power system belongs to Peschon, Piercy, tinney and Tveit [2].They introduced two methods. First one can be applicable to normal power flow problem for small changes in variable. Similar research was carried out by Kishore A.,Hill E.F [1],Thanikchalam [3],Gribik et al [4] and Talaq J.H. [5].

Power flow equations of n-bus system can be generalized by the function,

g (**x,u,p**)=0 (1)

Where, g is 2n dimensional vector and n is number of buses. All the variables involved in power flow equation can be categorized as-

i) Dependent Variables (**x**): These are the controlled variable and are unknown. **x** is a 2n dimensional vector.
ii) Independent Variables (**u**): These are the operating variables or imposed variables of the system. **u** is an m dimensional vector.
iii) Parameter Variables (**p**): These are uncontrollable variables and are normally specified in the power flow problem. Depending upon the variables to be determined, the variables in the power flow problem can be selected as x, u and p.

Consider the PF equation of the form,

$$g(x_0, u_0, p_0) = 0 \quad (2)$$

Suppose it is desired to determine the changes Δx in x corresponding to small changes Δu in u and Δp in p, will satisfy the new equations,

$$g(x_0+\Delta x, u_0+\Delta u, p_0+\Delta p) \quad (3)$$

Expanding (3) by Taylor's series and neglecting higher order term

$$g(x_0+\Delta x,u_0+\Delta u,p_0+\Delta p)=g(x_0,u_0,p_0)+g_x\Delta x+g_u\Delta u+g_p\Delta p \quad (4)$$

Where g_x , g_u and g_p are the partial derivatives of g w.r.t x,u and p respectively and are given by,

$$g_x = \frac{\partial(g_1, g_2, g_3, ...g_{2n})}{\partial(x_1, x_2, x_3, ...x_{2n})}$$

$x_1, x_2, x_3, ...x_{2n}$ are the elements of x

$$g_u = \frac{\partial(g_1, g_2, g_3, ...g_{2n})}{\partial(\mathrm{u}_1, \mathrm{u}_2, \mathrm{u}_3, ...\mathrm{u}_{2n})}$$

$u_1, u_2, u_3, ...u_{2n}$ are the elements of u

$$g_p = \frac{\partial(g_1, g_2, g_3, ...g_{2n})}{\partial(p_1, p_2, p_3, ...p_{2n})}$$

$p_1, p_2, p_3, ...p_{2n}$ are the elements of p

When changes are small, solution for Δx will be

$$\Delta x = S_u \Delta u + S_p \Delta p \quad (5)$$

Where S_u and S_p are the sensitivities of x w.r.t u and p respectively and are obtained as-

$$S_u = -g_x^{-1} g_u \quad (6)$$

$$S_p = -g_x^{-1} g_p \quad (7)$$

Where, g_x, g_u, g_p are Jacobian of x, u and p respectively.

On the similar ground, if the problem is to determine the changes in p for specified changes in Δx and Δu,

$$\Delta p = S_p^{-1} \Delta x - S_p^{-1} S_u \Delta u \quad (8)$$

In this way the changes in power system parameters can be obtained by simplifying the non-linear power flow equations using sensitivity analysis.

III. CASE STUDY

To test the suitability of various methods so as to determine ΔP_{ij} and ΔI_{ij} a three bus system (Fig.1) is considered as a case study .Bus 1,2 and 3 are the slack bus,load bus and generator bus respectively.For a small change in real power flow at load bus,change in line currents and power flow are determined and new operating values are obtained separately using following methods-

- Newton –Raphsson Load Flow Analysis
- Sensitivity Analysis
- Simulation using PWS 8.0

IV. ALGORIOTHM

An algorithm for the case study under consideration is stated below-

1. Compute initial system conditions i.e. bus voltage, bus angles, bus currents and power flows using Newton-Raphson LF method.Table-1 represents the initial system conditions and line parameters.
2. Change the real and reactive power at load bus (bus2) by small amount.
3. For this change, carry out sensitivity analysis by the method described in[2],[3]and [7].In this analysis, use the initial system conditions as obtained in step 1,to determine the change in required quantities. Further compute the new system conditions. Corresponding results are given in Table-2.
4. Repeat Newton –Raphson method to determine line flows and bus parameters for the change as per step 2.Table -3 represents the consolidated results.
5. Simulate the same case using Power Word Simulator 8.0.Corresponding results are shown in Table-4.

V. RESULT

We developed the programs SENS1 and SENS2 using MATLAB.SENS1 can compute the line flows using Newton-Raphson LF method and sensitivity analysis. Real and reactive powers at load bus are the inputs to run NR method. Change in power at various buses is the input data required for sensitivity analysis. It outputs change in the line flows. Another program SENS2 computes the change in real power flow in the line i-j for change in power at bus k.Table -1 to 4 represents the results of different methods, to obtain the real power change and the power capacity improvement in line i-j.

VI. FIGURE

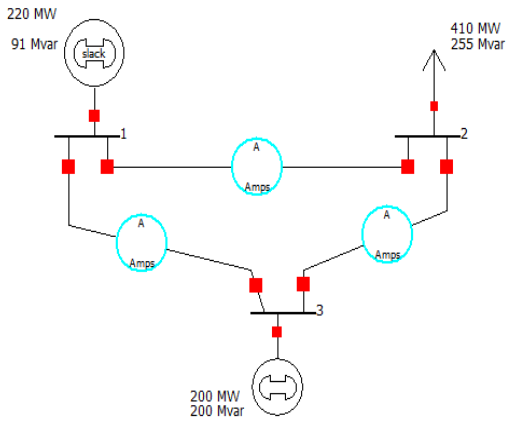

Figure 1:- 3 Bus System with bus 1 as slack bus and bus 2 as load bus

VII. DISCUSSION

This concept will be applied to various applications of power systems such as ATC enhancement, Improvement in stability limits etc.With the use of sensitivity analysis we will be able to develop fast computational model. In the deregulated environment the major obstacle is congestion of transmission network. It can be overcome by improving the power transfer capability of the line. This is possible by adopting advance techniques such as use of FACTS devices.

VIII. CONCLUSION

Table 2 to 4 represents the results obtained by various methods. It is observed that more accurate results are obtained using sensitivity analysis and time required to compute corresponding changes is less as compared to numerical methods. With this research we will be able to design a suitable controller which will maintain the desired power flow of the system with the suitable change in line parameter.

IX. TABLES

Test System

Table-1

Base MVA =100

Bus Data (Initial)					Power Flow (Initial)					
Bus No.	Power (MW)	Power (MVAR)	Voltage (pu)	Angle (deg)	From	To	Impedance (Ohm)	Installed Line Capacity	MW	MVAR
1	218.403	140.848	1.05	0	1	2	0.02+j0.04	180	179.362	118.73
2	400	250	0.972	-2.696	1	3	0.01+j0.03	40	39.067	22.118
3	200	146.161	1.040	-0.499	3	2	0.0125+j0.025	240	238.88	167.746

Test Result-
Sample result for-
Change in Real Power at 2= 10 MW
Change in Reactive Power at 2= 5 MVAR

I) Sensitivity analysis-

Table-2

From	To	Power (MW)	Power (MVAR)	Change in Real Power (MW)	Change in Admittance (mho)	Change in Angle (deg)	New Impedance (Ohm)	Improvement in Line Capacity
1	2	185.79	123.48	6.438	-1.962	0.0136	0.02266+j0.04344	5.79
1	3	43.439	21.54	4.37	-0.109	0.0696	0.01206+j0.02931	3.44
3	2	243.55	170.8	4.67	-8.0518	-0.0749	0.01367+j0.0334	3.55

II) By NR Method (Using MATLAB)

Table-3

From	To	MW	MVAr	Change in Real Power	Change in Admittance	Change in angle	New Impedance	Improvement required in line capacity (MW)
1	2	185.476	120.58	6.114	-1.962	0.0136	0.02266+j0.04344	5.476
1	3	43.93	20.54	4.87	-0.109	0.0696	0.01206+j0.02931	3.93
3	2	243.71	172.8	4.84	-8.0518	-0.0749	0.01367+j0.0334	3.71

III) By Power World Simulator

Table-4

From	To	MW	MVAr	Change in Real Power	New Impedance	Improvement required in line capacity (MW)
1	2	185.83	120.58	6.468	0.02266+j0.04344	5.83
1	3	43.63	20.54	4.57	0.01206+j0.02931	3.63
3	2	243.41	172.8	4.53	0.01367+j0.0334	3.4 1

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