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Identification of Sensitive Line in IEEE Six Bus System by Using LMP Calculation

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ABSTRACT

Identification of sensitive lines during stressed conditions in a power system is an important task for power system Engineers. The transmission line flow plays a significant role for providing power supply and to meet power demand in an electricity market. The demands of power supply moreover increase rapidly in a day-by-day industries activity. So it is necessary to manage the transmission line in an effective manner. This paper examines the IEEE Six bus system for LMP-based market calculation and compares the various average LMP cost by using power world simulator.

Keywords: Locational Marginal Pricing (LMP), Optimal Power Flow (OPF), Congestion Management, Sensitive Lines.

I. INTRODUCTION

Real-time energy market efficiency is tightly coupled with reliable power supply and to meet the demand [1-2]. For reliable power supply has to be designed to avoid sudden changes of unit output. Its include damage of control equipment’s. To planning the transmission line reliable from deregulated power system to make sure that transmission lines can carry electricity from the generator to distributors in economical manners. The unit cost of power depends on the congestion management; it is a major obstacle for customer accessing low price generator.

The linear power dispatch is one of main activity in the transmission system. The optimal power flow technique helps us to achieve the linear power transmission. Due to unavoidable circumstance an increasing number of bilateral contracts in the electricity market, the possibility of network congestion will happen [3]. Whenever the physical or operational constraints in a transmission network become active, the system is said to be in a state of congestion. The following factors are considered for the congestion: line thermal limits, transformer emergency ratings, bus voltage limits, transient or oscillatory stability, etc. These limits constrain the amount of electric power that can be transmitted between two locations through a transmission network. Flows should not be allowed to increase to levels where a contingency would cause the network to collapse because of voltage instability, etc.

In this deregulated system, generating companies competing in an open transmission access environment, the generation / flow patterns can change drastically over small time periods with the market forces. In such situations, it becomes necessary to have a congestion management scheme in place to ensure that the system stays secure [4].

In recent years, a few papers are given more important for Location marginal price (LMP) to solving the congestion problem in deregulated system [5-6]. For evaluating the congestion line the locational marginal pricing is employed tools for market settlement in the deregulated power system environment. Compare to any other method for evaluating congestion in power transmission line, the LMP has the best approach, and

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it has strong acceptance throughout the world, because of a more efficient method for network capacity allocation. The LMP mainly consists of LMP energy, LMP congestion and LMP losses. Using LMP calculation price signals are generates for following terms are generator location, transmission lines, load centers. This mechanism is helping us to use the resources in an effective manner.

In this paper, the sensitive lines are identified by the impact of critical line outage. The impact of a critical line is determined by the calculation of average LMP cost. The line outage which has highest average LMP is identified as a sensitive line. An IEEE 6 bus system is taken as a test system and Power world simulator tool used for simulation for this analysis. This paper is discussed as follows. Section II discusses the concept of congestion management and optimal power flow in the competitive electricity market. Section III Provides a brief discussion on proposed method. Section IV presents the test system and results for various cases. Section V concludes the paper and provides some discussion of future works.

II. CONGESTION MANAGEMENT AND OPTIMAL POWER FLOW

Congestion is a phenomenon that affects the entire system and, as such, all the players in electricity markets. Once a line becomes congested, the entire system suffers the resulting impacts: the market shifts from a single equilibrium point to possibly different nodal equilibrium points, the individual surplus of each player changes and the market outcomes are, consequently, changed. Congestion has come to play an important role in power systems in the restructuring of the electricity industry. Transmission congestion existed of course, even before restructuring, but was discussed in the context of constrained system operations.

The optimal operation of the system requires the optimization of a specified objective function subject to ensuring that no violation of the constraints occurs. The utilities were vertically integrated, owning and controlling both generation and transmission, so any conflict between security and economics was resolved by the single decision-making entity, which both owned and controlled all the facilities. However, in competitive markets, where generation and transmission are unbundled, there are many players vying for transmission services.

The starting of the 20th century, the optimal power flow problem is dealing with congestion management. The optimization techniques mainly have two part (computing and optimization). These techniques are introduced in the control room after the year of 1960’s. In a power system, there are three types of problems are classified as follows: Load flow, economic dispatch and optimal power flow. The electric network operations are converted to a set of static nonlinear equations. From these equations, we can analysis the load flow problem. Based on the Kirchhoff’s laws the active power, reactive power injections and voltage at each node was derived. For extending the transmission network, the load flow program is considered as a major tool for deriving the network.

The OPF problem will create a profile of active and reactive generations with voltage magnitudes. Similarly, it will satisfy the network security condition and minimizes the operating costs of the network. In the year of 1984, the OPF was successfully implemented and proved [7]. To compare the conventional economic dispatch method, the OPF will give the more reliable solution. With a help of the software, the optimal power flow function will adjust and we can define the LMP cost at very low. It has the feature of modeling the power system network at various higher levels of power flows.With a help of the simulators, to design the transmission network at various conditions is possible. In here power world simulator tool will simulate the power system operation on a time frame ranging. It contains effective power flow analysis package and capable of solving the systems up to 2, 50,000 bus network. This simulator is user –friendly, highly interactive, because of graphical user interface is enabled.

III. RESULTS AND DISCUSSION

The line outage is a vital issue and one of the contingencies in power system network. It is unexpected fault occurs in the power system which disturbance the normal operation. Hence the determination of the effect of line outages in the network is significant for power system operation and planning. IEEE 6 bus system consist of three generator bus, three load bus and 11 transmission lines. Figure 1 shows the single line diagram of IEEE 6 bus system. The line data for the test system is given in table 1. Power world simulator used in this proposal for running LPOPF (Linear Programming OPF) to determine the LMP during individual line outages. For each and every line removal, the LPOPF has run and average LMP cost is calculated. With respect to the value of calculated average LMP cost, the sensitive lines are identified.

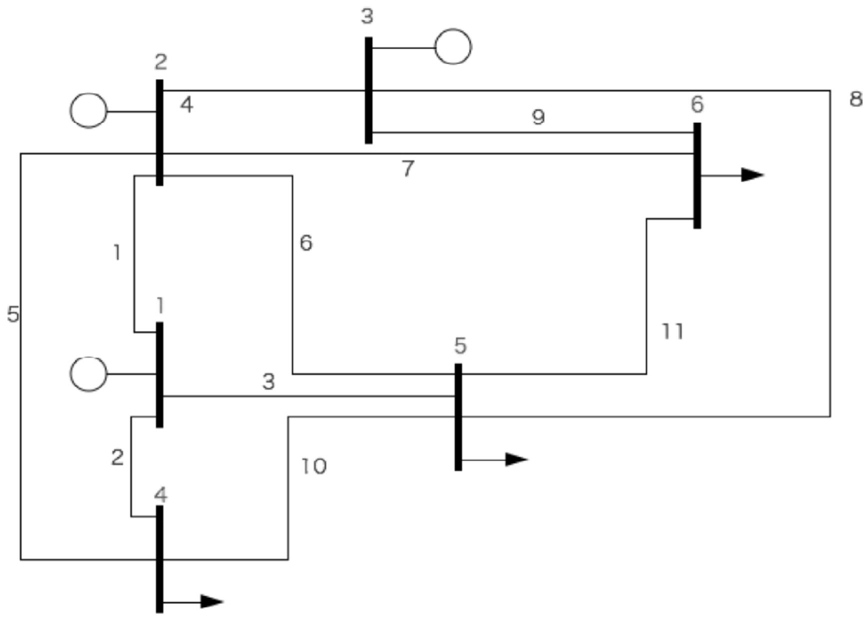

Figure 1: IEEE 6 bus system

Table 1
IEEE 6 bus system line data

Line No.	*From Bus*	*To Bus*	*Resistance (p.u)*	*Reactance (p.u)*	*Susceptance (p.u)*
1	1	2	0.1	0.2	0.04
2	1	4	0.05	0.2	0.04
3	1	5	0.08	0.3	0.06
4	2	3	0.05	0.025	0.06
5	2	4	0.05	0.1	0.02
6	2	5	0.1	0.3	0.04
7	2	6	0.07	0.2	0.05
8	3	5	0.12	0.26	0.05
9	3	6	0.02	0.1	0.02
10	4	5	0.2	0.4	0.08
11	5	6	0.1	0.3	0.06

The figure 2 shows the power flow during the base case load in the test system. No line outage is considered in this case. The LMP cost calculation and other data details are given in table 2. In this case, the average LMP cost is $15.24/MWh.

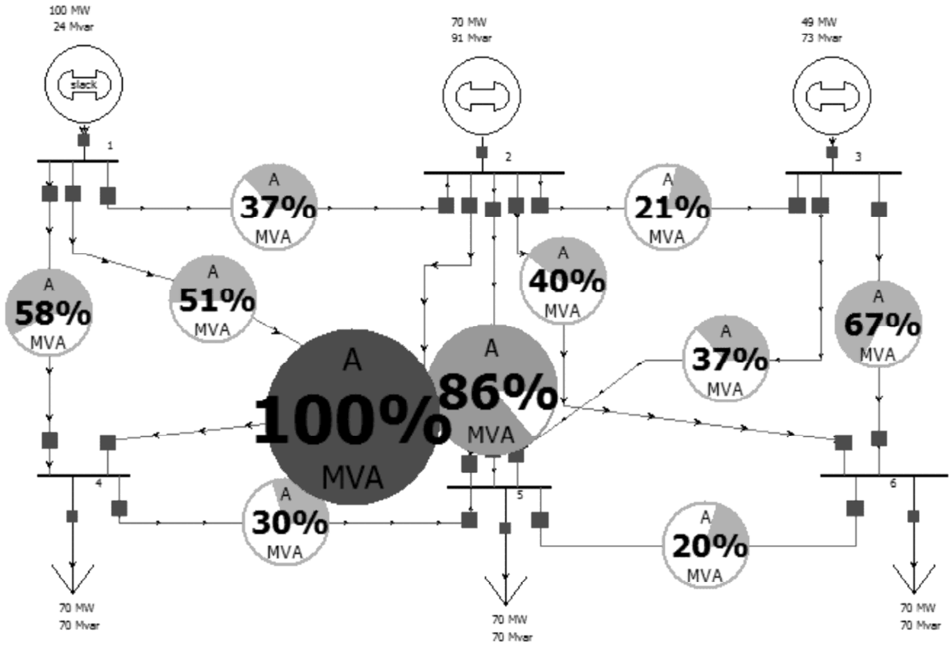

Figure 2: OPF on IEEE 6 bus system during base case

Table 2
Simulation result for IEEE 6 bus system during base case

General Results	
Solution Start Time	6/29/2016 9:50:59 AM
Solution End Time	6/29/2016 9:50:59 AM
Total Solution Time	0.000 Seconds
Last Solution Status	Successful Solution
Number of LP Iterations	2
Initial Cost Function Value	2941.11 $/hr
Final Cost Function Value	2941.11 $/h
Final Slack Cost Value	0.00 $/h
Final Total Cost Value	2941.11 $/h
Number of Buses in OPF	6
Highest Bus Marginal Cost	25.49 $/MWh
Lowest Bus Marginal Cost	11.37 $/MWh
Average Bus Marginal Cost	15.24 $/MWh
Bus MC Standard Deviation	4.75 $/MWh

The figure 3 shows the power flow with line 2 is removed in the test system. The LMP cost calculation and other data details are given in table 3. In this case, the average LMP cost is $138.35/MWh. Based on this average LMP cost, line 2 is recommended as a sensitive line.

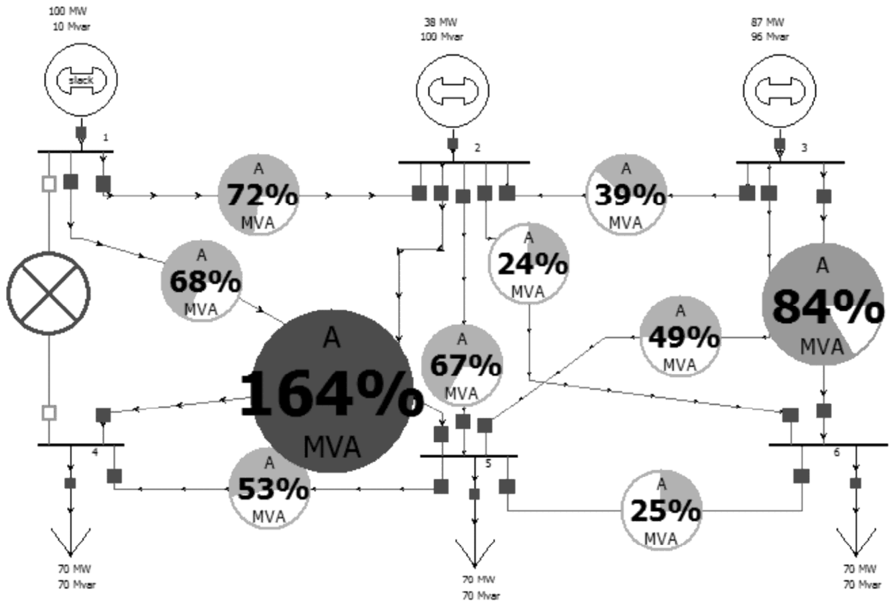

Figure 3: OPF on IEEE 6 bus system with line 2 removal

The figure 4 shows the power flow with line 5 is removed in the test system. The LMP cost calculation and other data details are given in table 4. In this case, the average LMP cost is $194.91/MWh. Based on this average LMP cost, the line 5 is also commended as a sensitive line.

Table 3
Simulation result for IEEE 6 bus system with line 2 removal

General Results	
Solution Start Time	6/29/2016 9:53:45 AM
Solution End Time	6/29/2016 9:53:45 AM
Total Solution Time	0.000 Seconds
Last Solution Status	Successful Solution
Number of LP Iterations	11
Initial Cost Function Value	3044.42 $/hr
Final Cost Function Value	3044.49 $/h
Final Slack Cost Value	38356.65 $/h
Final Total Cost Value	41401.13 $/h
Number of Buses in OPF	6
Highest Bus Marginal Cost	705.70 $/MWh
Lowest Bus Marginal Cost	-24.73 $/MWh
Average Bus Marginal Cost	138.35 $/MWh
Bus MC Standard Deviation	256.32 $/MWh

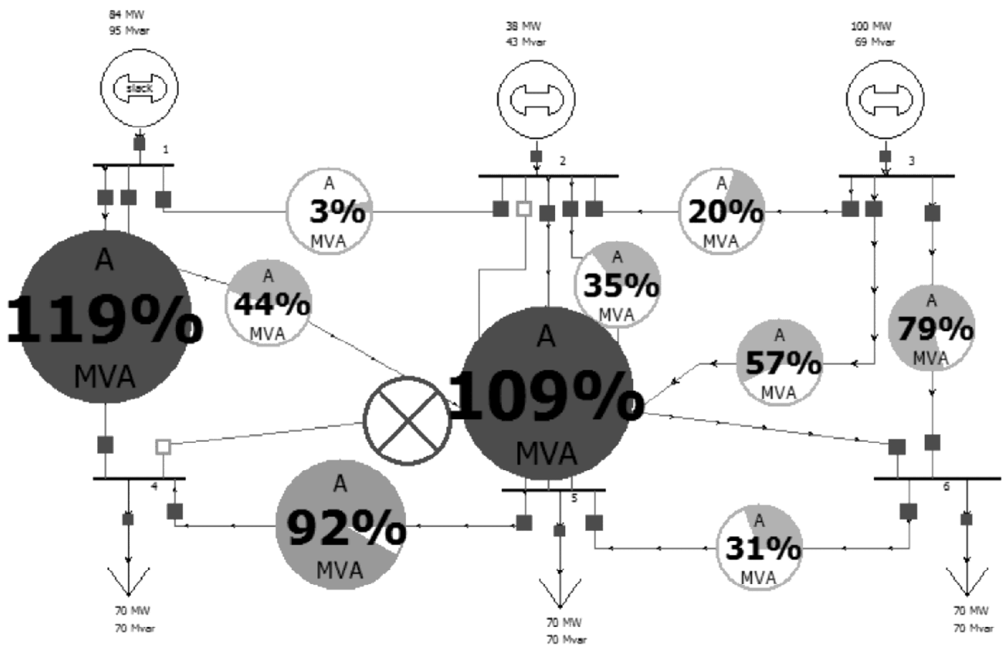

Figure 4: OPF on IEEE 6 bus system with line 5 removal

Table 4
Simulation result for IEEE 6 bus system with line 5 removal

General Results	
Solution Start Time	6/29/2016 9:55:35 AM
Solution End Time	6/29/2016 9:55:35 AM
Total Solution Time	0.016 Seconds
Last Solution Status	Successful Solution
Number of LP Iterations	11
Initial Cost Function Value	3009.60 $/hr
Final Cost Function Value	3009.60 $/h
Final Slack Cost Value	18154.16 $/h
Final Total Cost Value	21163.76 $/h
Number of Buses in OPF	6
Highest Bus Marginal Cost	835.12 $/MWh
Lowest Bus Marginal Cost	-49.61 $/MWh
Average Bus Marginal Cost	194.91 $/MWh
Bus MC Standard Deviation	306.23 $/MWh

Similarly, all the 11 transmission lines are removed one by one. Finally, all the congested cases average LMP costs are tabulated in table 5. Also, average LMP cost vs line number graph is given in figure 5.

Table 5
Average LMP cost for every line removal

Line No.	*Removed Transmission Line*		*Average LMP Cost*
	From Bus	*To Bus*	*($/MWh)*
1	1	2	12.58
2	1	4	138.35
3	1	5	44.39
4	2	3	13.63
5	2	4	194.91
6	2	5	55.80
7	2	6	26.03
8	3	5	28.16
9	3	6	13.19
10	4	5	13.15
11	5	6	13.70

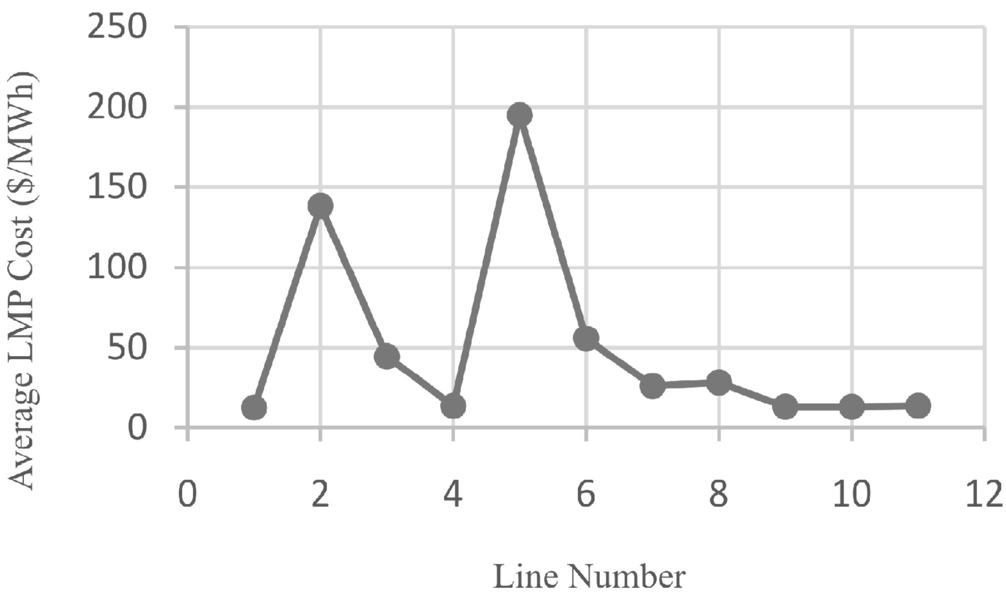

Figure 5: Graph between Average LMP cost vs Line Number

As an application, the concept of LMP is applied in the IEEE six bus systems foridentifying the sensitive line. In this case, the congestion cost is used as an indicator to detect the weak transmission line of the given six bus system under different operating condition. It represents the economic operation of the system for reliable power supply. In this system Line Number five from bus 2 to 4 is having the highest average LMP Cost of $194.91 per MWh. Similarly, the line number two from bus 1 to 4 is also having the second highest average LMP Cost of $ 138.35 per MWh.

IV. CONCLUSION

In this paper, the average LMP cost has calculated effectively by LPOPF with the help of power world simulator. The sensitive lines are identified with respect to the value of average LMP cost during the particular line outage in the system. The result shows that the lines 2 and 5 are very sensitive and the power flow through these lines should be maintained within the limit in the test system. Also, the regular monitoring may take by the power system operator to avoid the stressed condition in the system.

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