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Voltage Stability Estimation of Electric Power System Using L-Index

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Abstract: Voltage stability of Power system has become an issue for both power system planning and operation, because of a number of major black outs that have been experience in many countries by voltage stability problems [1, 2]. This has been mainly due to power systems operated closer to their stability limits [1]. To determine voltage stability many studies have been carry out. In this study L-Index is use to calculate voltage stability of power system. References [3, 4] present comparative studies and analysis of six different voltage stability indices, while [5]. Introduce the voltage stability L-index to be a simple but effective means of measuring the distance of a power system to its stability limit. Estimation of voltage stability by L-index in this study applied for monitoring voltage stability in a power system.

Keywords: Power system voltage stability, load flow, voltage stability line-index.

I. INTRODUCTION

Electrical power systems are operating under heavy loaded and stressed conditions due to various economic, environmental changes. So with the increased loading of the power system, the problem of voltage stability and voltage collapse has been attracting more attention and maintaining voltage stability has become a growing concern for electric power utilities [6,7].

Voltage stability is concerned with the ability of a electrical power system to maintain acceptable voltages at all buses of the system after being subjected to a disturbance from a given initial operating condition [8].

Therefore, a power system is said to have a situation of voltage instability when a disturbance causes a progressive and uncontrollable decrease in voltage level. In order to know the critical bus and to determine the point of collapse for detecting and predicting voltage collapse of an electrical power system, several stability indices have been proposed. They are used to determine the closeness of an operating point to the critical point.

II. VOLTAGE STABILITY L-INDEX

The mathematical formulation of the Voltage Stability L-index technique used in this paper is derived from voltage equations of a two bus network as shown in Figure1.Consider a line connecting two buses 1 and 2 where P1 and Q1 are the power injected into the line as shown above. The following equations can be derived.

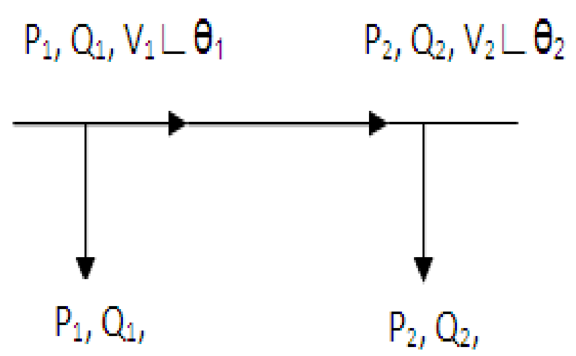

Figure: 1. Two bus network

$$|I_1|^2 = \frac{P_1^2+Q_1^2}{V_1^2} \quad \ldots (1)$$

$$P_2 = P_1 - P_{Loss} \quad \ldots (2)$$

$$Q_2 = Q_1 - Q_{Loss} \quad \ldots (3)$$

$$P_{Loss} = \left(\frac{P_2^2+Q_2^2}{V_2^2}\right) * r_1 \quad \ldots (4)$$

$$Q_{Loss} = \left(\frac{P_2^2+Q_2^2}{V_2^2}\right) * x_1 \quad \ldots (5)$$

$$|I_1|^2 = \frac{\left[P_2^2+\left(\frac{P_2^2+Q_2^2}{V_2^2}\right)*r_1\right]^2+\left[Q_2^2+\left(\frac{P_2^2+Q_2^2}{V_2^2}\right)*x_1\right]^2}{V_1^2} \quad \ldots (6)$$

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The voltage equation is

$$V_2^4 + V_2^4[2(P_2r_1 + Q_2x_1) - V_1^2] + (P_2^2 + Q_2^2)(r_1^2 + x_1^2) = 0..........(7)$$

This is a quadratic equation and it has a real root when

$$8P_2Q_2r_1x_1 - 4V_1^2(P_2r_1 + Q_2x_1) + V_1^4 - 4(P_2^2r_1^2 + Q22x12\geq 0...(8)$$

This can be simplified to

$$\frac{4[V_1^2(P_2r_1+Q_2x_1)+(P_2r_1-Q_2x_1)^2]}{V_1^2} \leq ....(9)$$

Therefore the voltage stability index is given by

$$L = \frac{4[V_1^2(P_2r_1+Q_2x_1)+(P_2r_1-Q_2x_1)^2]}{V_1^2}......................(10)$$

Since

$$(P_2r_1 + Q_2x_1) = V_1V_2\cos(\theta_1 - \theta_2) - V_2^2........... (11)$$

And

$$(P_2r_1 - Q_2x_1) = V_1V_2\sin(\theta_1 - \theta_2)................. (12)$$

Thus the L-Index is given by

$$L = \frac{4[V_1V_2\cos(\theta_1-\theta_2) - V_2^2\cos^2(\theta_1-\theta_2)]}{V_1^2}.................. (13)$$

The value of L-index varies from 0 to 1.0. L-index value close to 0 indicates stable voltage condition while L-index value close to 1.0 indicates unstable voltage condition. In order to maintain a stable voltage condition in the system network, the value of L-index at any load bus must be kept to a small value close to 0. If the values of L-index at any load bus approaches 1.0, it shows that the load bus is close to its instability limit and if L-index is equal to 1.0. The system has already in the state of voltage collapse.

III.RESULT AND DISCUSSION

The test system presented in this study is the IEEE six-bus system, [9] for which the single line diagram shown in Figure 2.The IEEE six-bus system is composed of a slack bus (1) and one voltage controlled bus (2) and four load buses (3, 4, 5 and 6). The load flow programs are run by using N-R method and calculate the corresponding value of L-index of load bus 3. The L-index corresponding to the slack bus and voltage controlled buses are not considered in the input and output list since they are always zeros as long as the bus voltages remain controlled. The obtain result are shown in Figure3. The result show the magnitude of voltage are decreases by increasing the active and reactive power loading at the same bus, and corresponding value of L-index are increased.

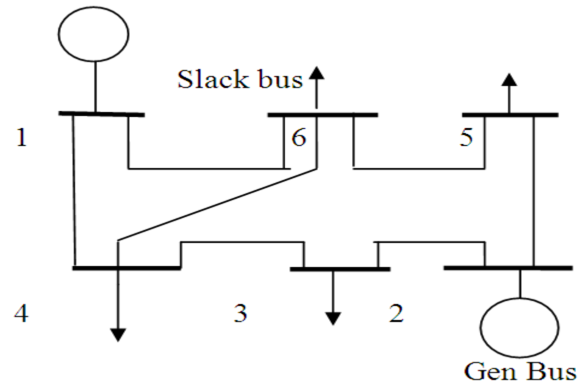

Figure. 2. IEEE 6-bus test system

Case-I: Increase loading of bus 3 from zero to the voltage collapse point, keeping the load at other buses fixed at the normal value. Observe the effect on index L (3) at bus 3.

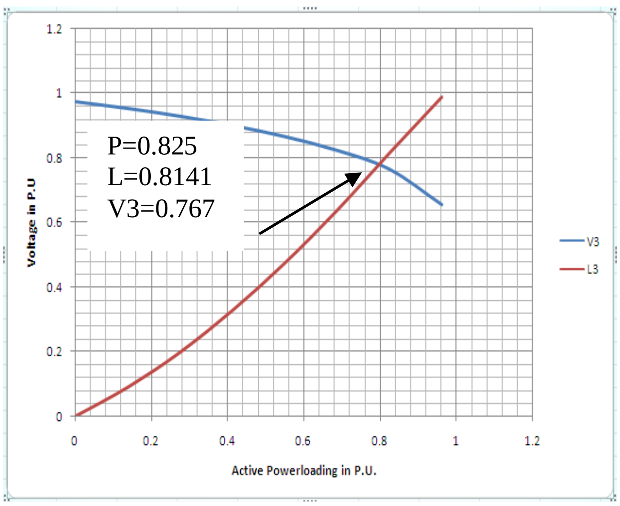

Figure: 3 L-Index & Voltage characteristics at load bus 3.

The result which is showing in the Figure 3 show the magnitude of bus voltage are decreases as loading are increased on the bus 3.Its conclude that the critical operating point L=0.9878, so the voltage stability of this system is guaranteed. The stability limit is reached for L=1.

Case=II: Increase loading of bus 3 from zero to the voltage collapse point, keeping the load at other buses fixed at the normal value. Observe the effect on index L (5) at bus 5.

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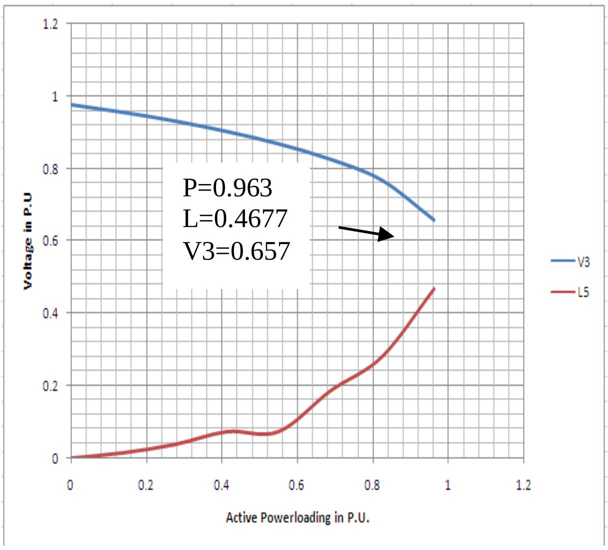

Figure: 4 L-Index of bus 5 & Voltage characteristics at load bus 3.

The result which is showing in the Figure 4 show the magnitude of bus voltage v3 & corresponding the value of L=index at bus 5. The stability limit is reached at L=0.4677, because at the same time the voltage at bus 3, V3=0.657 is reached which critical limit for the system.

Case=III: Increase loading of bus 3 from zero to the voltage collapse point, keeping the load at other buses fixed at the normal value. Observe the effect on index L (6) at bus 6.

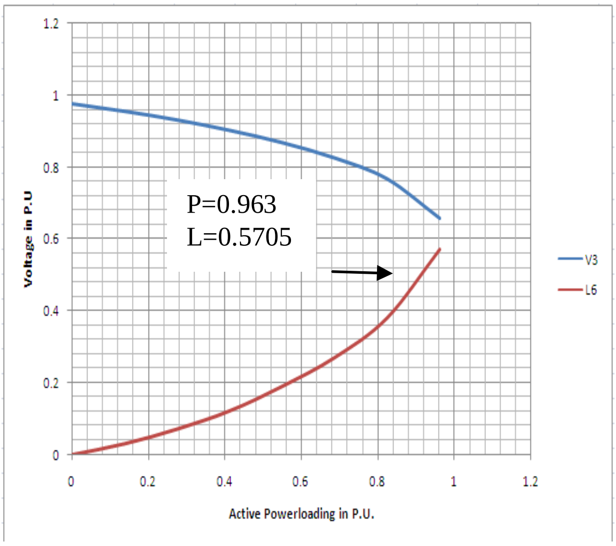

Figure: 5 L-Index of bus 6 & Voltage characteristics at load bus 3.

The result which is showing in the Figure 5 show the magnitude of bus voltage v3 & corresponding the value of L-index at bus 5. The stability limit is reached at L=0.5705, because at the same time the voltage at bus 3, V3=0.657 is reached which critical limit for the system. The voltage stability estimation methodology is tested on IEEE 6 bus system. In this paper, L-index method discussed is used to check the voltage stability of different load buses. The effect of loading at other load bus is assessed at increasing loading at bus no3 to neighboring buses connected to the bus under consideration the result are shown in Figure 6, 7, 8.

Loading at bus 3		Bus 3 voltage	Bus 3 L-Index	Bus 5 L-Index	Bus6 L-Index
Pl	Ql				
0	0	0.976	0	0	0
0.138	0.033	0.955	0.0899	0.0147	0.0305
0.275	0.065	0.931	0.198	0.0375	0.0712
0.413	0.098	0.902	0.3279	0.073	0.1219
0.55	0.13	0.868	0.4737	0.073	0.1898
0.688	0.163	0.825	0.6377	0.186	0.2703
0.825	0.195	0.767	0.8141	0.2804	0.3801
0.963	0.228	0.657	0.9878	0.4677	0.5705

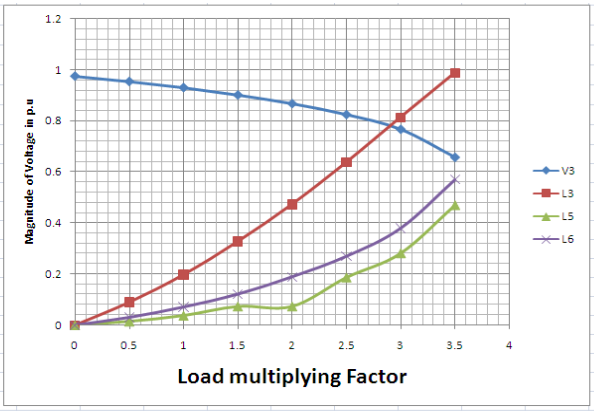

Figure: 6 L-Index of bus 3, 5, 6 & Voltage characteristics at load bus 3.

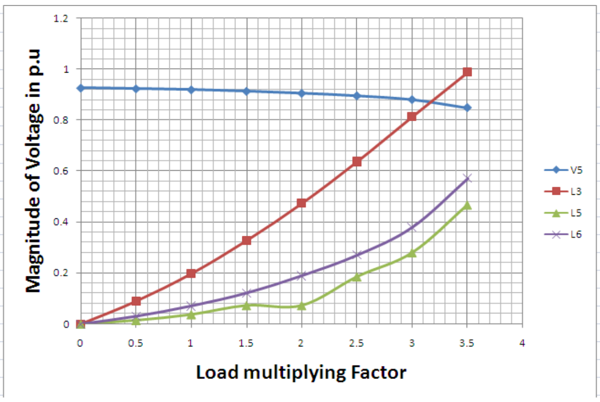

Figure: 7 L-Index of bus 3, 5, 6 & Voltage characteristics at load bus 5.

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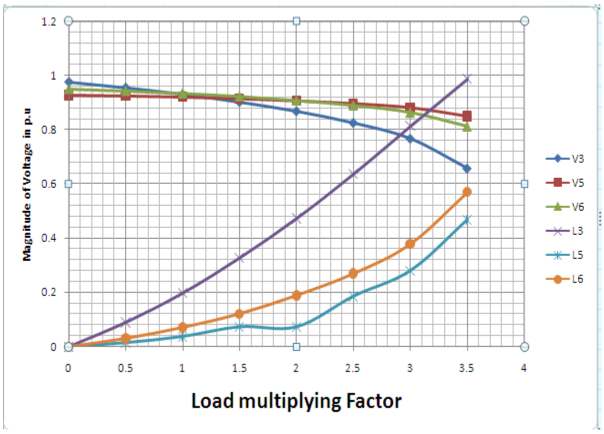

Figure: 8 L-Index of bus 3, 5, 6 & Voltage characteristics at load bus 3, 5, 6.

IV. CONCLUSION

The power systems are highly complex and working under heavily stressed conditions Therefore voltage stability has become one of the important issues in power system planning, operation and control. In this paper, the values of L-index are determine from IEEE 6-bus data, and the corresponding results in the form of L-index are calculated to know the closeness of current operating point to the critical point.

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