Voltage Stability Analysis Using Voltage Stability Indices

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Abstract - *A Modern power systems are operating under very stressed conditions and this is making the system to operate closer to their operating limits. Since a couple of decades ago voltage stability assessment has received an increasing attention due to the complexity of power system. With the increase in power demand and limited power sources has caused the system to operate at its maximum capacity. Therefore, a study that is able to determine the maximum capacity limit before voltage collapse must be carried out so that necessary precaution can be taken to avoid system capacity violation. This paper discuss a Fast Voltage Stability Index (FVSI) for IEEE 30bus system. The FVSI is indicative in predicting the occurrence of system collapse and hence necessary action can be taken to avoid such incident. Here simulation of FVSI has been done for IEEE 30-bus test system to identify more sensitive method to detect the weakest line of the system.*

Key Words: Voltage stability, Line index, Fast Voltage Stability index (FVSI), Reactive power

1. INTRODUCTION

For a good power system voltage stability should be maintained within the safe limit. Voltage stability is defined as "the ability of a power system to maintain acceptable voltage in the system both under normal condition and also after being subjected to a disturbance .voltage instability arises when load dynamics try to restore power beyond the capacity of transmission and generation system[1].The progressive and uncontrollable decrease in voltage leads to blackout in wide spread area or voltage collapse[2].There are many methods to analyze voltage stability like line stability index(Lmn),fast voltage stability index(FVSI). The main objective of this indices is to identify the weak lines which can lead to voltage collapse condition for given bus for small variation in reactive power loading at particular bus.

A main aim of this paper is by using FVSI to identify the weakest line of the system and weakest bus of the system.

2. INDICES TO DETERMINE VOLTAGE STABILITY

Several methods have been proposed to assess the voltage stability of a power system. In this section two voltage stability indices are briefly described.

Voltage stability indices which provides an accurate information about line and bus stability conditions are studied for various loading scenarios. The different voltage stability indices are calculated and compared for IEEE standard 30 bus system.

The voltage stability indices are introduced in order to evaluate the voltage stability limit. These indices can be used on-line or offline to help operators in real time operation of power system or in designing and planning operations. These indices will be presented to show how close to voltage instability a system can be operated and which could lead to blackout in large parts of the interconnected power system. The system can be operated in the stable region by minimizing voltage stability index of buses and lines.

Indices are classified as a 1.Bus indices 2.Line indices. The bus indices as an L-index, Voltage Collapse Prediction Index, Impedance Matching Stability index (ISI), Simplified Voltage Stability index (SVSI) etc. The line indices as a Line Stability Index (Lmn), Fast Voltage Stability index (FVSI), Line Stability Factor (LQP), Voltage Collapse Proximity index (VCPI).

In this paper only line index FVSI is discussed.

Fast voltage stability index (FVSI)

Musirin [3] derived a voltage stability index based on a power transmission concept in a single line.

The 2-bus power system model is shown in Figure 1 and this is used to derive FVSI.

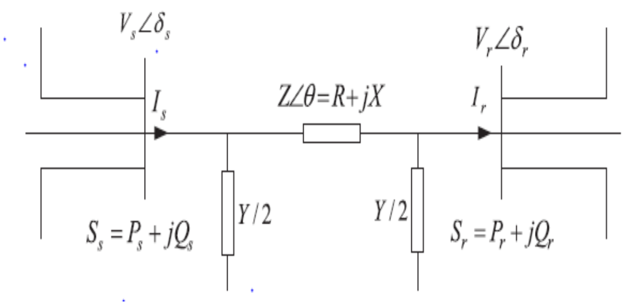

Fig.-1:Two bus power system model [3]

The Symbols in Fig. (1) are as below:

Vs , Vr: voltage magnitude at the sending and receiving buses, respectively.

Ps, Qs: active and reactive power at the sending bus.

Pr, Qr: active and reactive power at the receiving bus.

Ss, Sr: apparent power at the sending and receiving buses, respectively.

δs, δr: voltage angle at the sending and receiving buses, respectively.

Y: line shunt admittance.

R, X, θ: line resistance, line reactance and line impedance angle.

The equation of,

$$FVSI = \frac{4Z^2 Q_r}{V_s^2 X} \quad \text{......................} \ (1)$$

The line which have a FVSI closed to 1.00 implies that it is approaching its instability point, one of the buses to connected this line will experience a sudden voltage drop leading to voltage collapse.

The FVSI of all the lines must be lower than 1 to assure the stability of power system

3. SIMULATION AND RESULTS

A test was conducted on the IEEE 30-bus reliability test system and the single line diagram is illustrated in Fig. 2.

This system has six generator (PV) buses and twenty-four load (PQ) buses with 41 interconnected branches. Three load buses are chosen in order to investigate the effect of reactive power loading on FVSI values which in turn identifies the most critical line with respect to a bus. Reactive load at buses 26, 30 and 29 were gradually increased from the base case until their maximum allowable load or maximum loadability which is maximum load that could be injected to a load bus before the voltage decrease suddenly or voltage collapse.

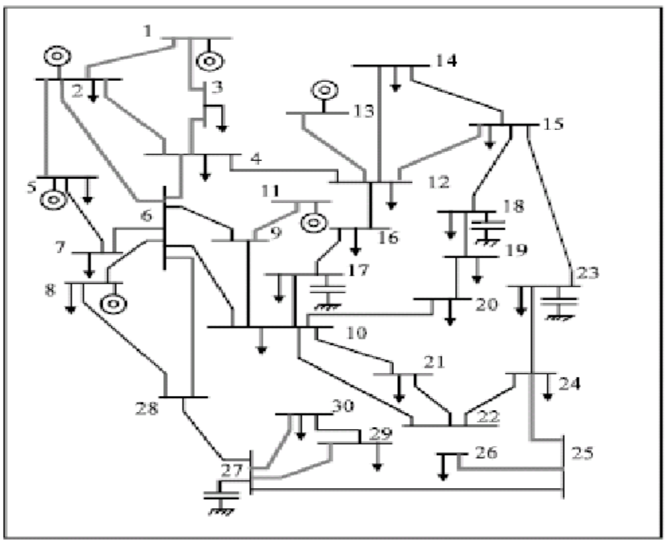

Fig-2: IEEE-30 BUS SYSTEM

FVSI were evaluated for each line in the system for every load increase. The line exhibited the largest index with respect to a load increase will be determined as the most critical line. Any further increase on the load will cause the line to have an index value greater than 1.00 resulting in the entire system instability.

CASE-1: FVSI AT A BUS-26 FOR VARIABLE REACTIVE LOAD

In this set of tests only the reactive power at a single node is changed. The results shown in the Table 3. are only for node 26, although the test was carried out for several load nodes. In most cases the proposed method of voltage collapse prediction has shown satisfactory performance. Single-node reactive load changing for node 26 is illustrated in Table 3. The heavy reactive load at node 26 made line 34 to be most critical with a high stability value of 0.9571.

Table-1;FVSI of Lines for different reactive loading at bus-26

Reactive Load(MVAR)	Line-34 FVSI	Voltage (PU)
Q=2.3	0.0489	1
Q=10	0.2245	0.94
Q=20	0.4915	0.845
Q=30	0.8527	0.7
Q=32	0.9571	0.651

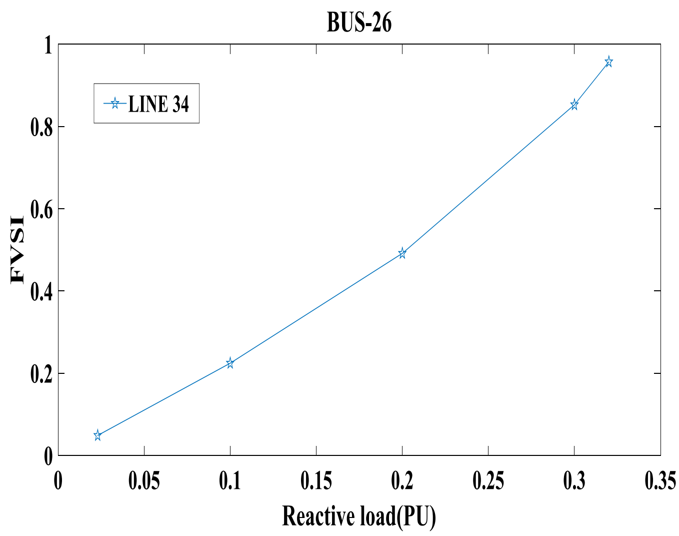

Fig. 3. FVSI versus load variation at bus- 26

CASE-2: FVSI AT A BUS-30 FOR VARIABLE REACTIVE LOAD

Single-node reactive load changing for node 30 is illustrated in Table 4. The heavy reactive load at node 30 made line 38 to be most critical with a high FVSI value of 0.9325.

Table 4. FVSI of Lines for different reactive loading at bus-30

Reactive Load(MVAR)	Line-38 FVSI	Line-39 FVSI	Voltage (PU)
Q=1.9	0.0401	0.0125	0.992
Q=15	0.2942	0.1583	0.891
Q=25	0.5353	0.3166	0.788
Q=30	0.6875	0.4318	0.716
Q=36	0.9325	0.6645	0.629

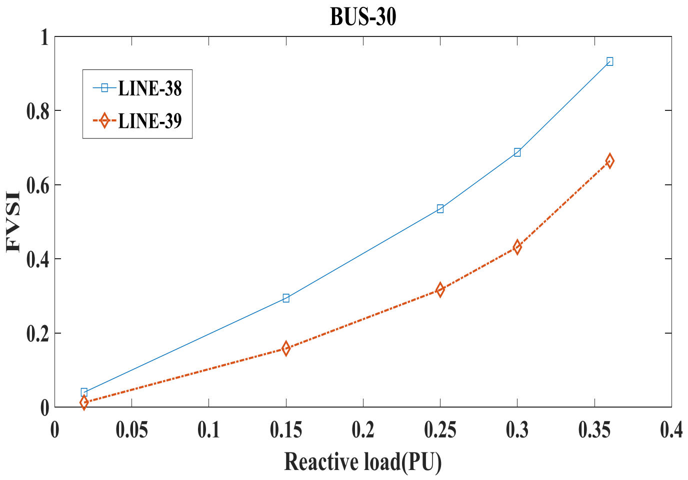

Fig. 4. FVSI versus load variation at bus- 30

CASE-3: FVSI AT A BUS-29 FOR VARIABLE REACTIVE LOAD

Single-node reactive load changing for node 29 is illustrated in Table 5. The heavy reactive load at node 29 made line 37 to be most critical with a high stability value of 0.8421.

Table 5. FVSI of Lines for different reactive loading at bus-29

Reactive Load(MVAR)	Line-37 FVSI	Line-39 FVSI	Voltage (PU)
Q=0.9	0.0306	0.0125	1.004
Q=12	0.208	0.0666	0.929
Q=24	0.4423	0.1873	0.828
Q=30	0.5899	0.2746	0.761
Q=40	0.8421	0.5949	0.64

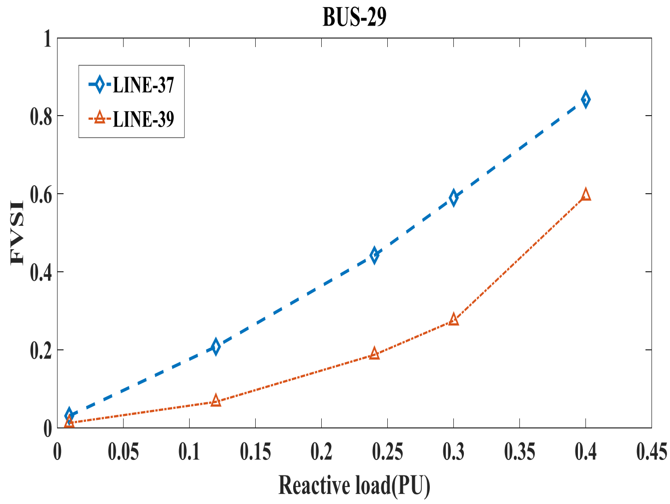

Fig. 5. FVSI versus load variation at bus- 29

The voltage profile against reactive load variation is illustrated in Fig. 6. From the figure, it is observed that bus voltages decay accordingly as the reactive power loading increased. The curve for bus 29 stops at a reactive loading of 0.401 p.u. with voltage at this point is 0.640 p.u. Similarly, the minimum voltage for bus 26 is 0.651 p.u. while for bus 30 it is at 0.629 p.u. Since bus 26 can withstand load of 0.32 p.u. which is the lowest compared to the rest, therefore it is identified as the weakest bus. Conversely, bus 29 is the most secure bus since the maximum permissible load is the largest. The determination of the weakest bus is based on the maximum permissible load before voltage collapse.

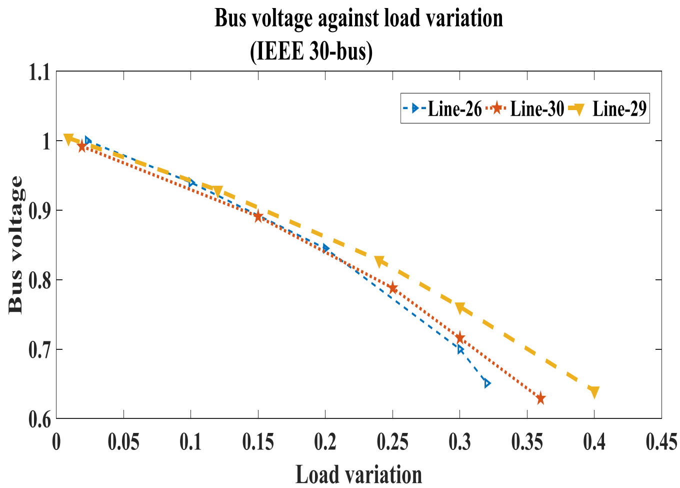

Fig.6. Voltage profile against load variation

4. CONCLUSION

A rigorous investigation on the effect of reactive power loading was carried out and tests were performed on the IEEE 30-bus power test system. Results show that the FVSI index is capable at determining the point of voltage instability, critical line referred to a bus and the weakest bus in the system. Voltage instability point is indicated by the FVSI value closed to 1.0.

5. REFERENCES

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