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# Monitoring Against Voltage Instabilities using Line Voltage Stability Indices for IEEE 14 and IEEE 30 bus

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**Abstract-**This paper presents a different method of voltage stability index performance in power System network. Such as line and bus voltage stability index, line stability factor and voltage failure point indicators in load and no load condition. Based on these basic concepts it is possible to guess the voltage instability. The proposed method is based on the newton Raphson load flow analysis algorithm. The performance of all the four methods are compared with displaying the total line losses and the loadability of the line is also shown by using IEEE 14 and IEEE 30 bus systems. By using this data we find out the weak line and limit the voltage collapse caused due to heavy loading and burden on these lines can be rectified by using Fact devices. Based on the result the advantage of voltage stability index study is more secured for power system network as the system is operating under normal condition.

***Keywords—****weak line, load flow studies, line voltage indices, loadability of weak line, voltage stability analysis of the standard busses*

## I. INTRODUCTION

Presently in power system instability is a major issues that associate in the system. Some advantage of voltage stability study is for power system planning and operation. The cause of voltage stability is increasing the load beyond its rating and increase of transmission line capacity out of its range. The other disturbance of voltage stability in power system component is isolation of a transformer or generator and transmission line from the system.

The reason of voltage failure can be based on tap changing of transformer, reactive power generated in the system and load variation [6].To control voltage stability index modelling of load is essential

In power system components study of voltage instability is the major issues for current researcher in universities and other research organization [7].Voltage inspection can be done by means of dynamic or static stability analysis. Although dynamic stability study produces more interruptions to the system, on the other hand, static voltage stability analysis is broadly accepted. For static voltage stability analysis, the system is considered to be in steady State.

Consequently the proposed model is easy to model and understand the concept. Quite a few techniques has been adapted to justify voltage stability like P-Q and P-V curves. [5] Jacobian determinant [6] modal analysis [7] line index [4- 6].The resultant of P-V and Q-V curves lead to proximity of voltage collapse whereas the other methods developed show voltage stability indices as indicators. The voltage stability indices are derived for either a bus or a line in power system. Elements like reactive power generating devices, Tap changing transformers are optimally attuned at each operating point to attain the objective of minimizing voltage stability index at every individual bus and minimizing the global voltage stability indices. The system can be operated in the stable region by minimizing voltage stability index of buses and lines.

The issue of the researcher using voltage instability index is to identify the weak line using line voltage stability indicators. These indices utilize the data obtained from the modelling of load flow *for system planning and operational determinations.* The point of a voltage stability index is to compute how close a exact operating point is close to the voltage collapse which approximates the steady state voltage stability limit of the power system. In this paper will first talk about and explain some general aspects and facts regarding the load flows and apply it to find the jacobian matrix using Newton-Raphson method. In the following section we will discuss about the line voltage stability methods by means of some numerical results obtained from the analysis on IEEE14 and IEEE30 bus systems respectively and finally the comparisons are plotted and conclusions are given.

## 2. LOADING MARGIN

It [5] is the fundamental and extensively used traditional method to approximate the voltage collapse in the power system. For a current operating point, the total increment of load in a specified pattern of load increase that would cause a voltage collapse is called the loading margin to voltage collapse.

For a particular load bus in the power system the Q-V and P-V curves need to be developed by slowly increasing the load. The power flows and the bus voltage for that specific. The loading is ceased when the collapse point is reached. After failure of voltage incremental load can be clogged. Power margin between the exciting and voltage failure operating region is mainly used as voltage stability index condition.

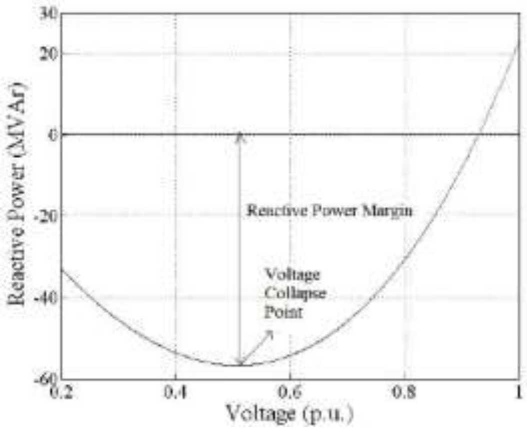



**Fig-1**reactive power margin

In Figure1 the voltage collapse point for reactive power margin and Figure.2 as shown below is a typical Q -V and P-V Curve.

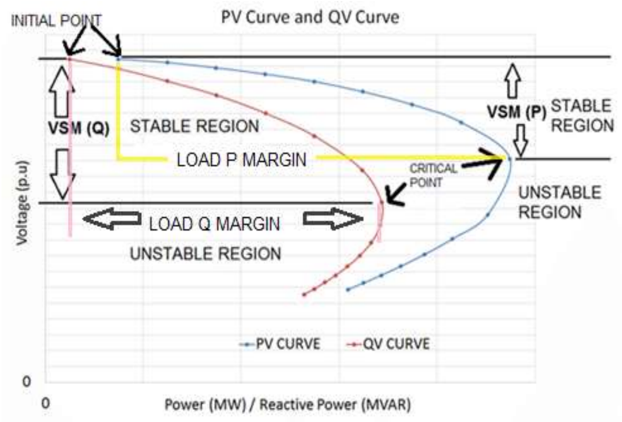



**Fig-2** Q -V and P-V Curve

Generally Q -V and P-V Curves are developed using load flow methods, such as, classical, direct and continue methods. The advantage of the loading margin is simple and easy to understand. The procedure of making curves can be programmed. Hence, the curves are to be generated at every bus. Besides it needs information of the system which is above its limit and hence the cost of calculations will be very high.

## 3. FORMULATION OF VOLTAGE STAILITY INDICES

### 3.1 Definition of Voltage Stability

Voltage stability is useful for power system to maintain steady state values for all busses, after a small or large disturbance. Besides the voltage stability consequence is to balance the generated power with load demand [8][6].When voltage instability happened the voltage rise or fall at the busses are sensed. The cause of voltage instability is the sudden load variation, line loss and failure of protection equipment.

### 3.2. Voltage stability indices formulation

It is linked to recover the voltage stability of the power system after system disturbances. Indices are scalar magnitudes which apply to detect the change of parameters in the system and distinguish the location of the specific operating region to the region of the voltage collapse. [6].various types of indices are applied for optimization in Power system components. Few of the available indices for identifying the voltage stability are Line Stability Index (LMN)Fast voltage stability index (FVSI), Line stability factor (LQP) and Voltage Collapse point indicators (VCPI).

### 3.2.1 Line Stability Index (LMN)

It was derived by M.Moghavemmi et al. [8] based on the power transmission model in a particular line. It can be defined as

$$Lmn = \frac{4.Qr.x}{[|Vs|.\sin(\theta-\delta)]^2} \qquad (8)$$

Where δ is the load angle

θ is impedance angle

Lmn presents values close to 1which shows that those lines are very near to outage and had reached their instability for the line to be in safe limits and sustain a protected condition,

### 3.2.2 Fast Voltage Stability Index (FVSI)

FVSI is developed by I.Musirin et al [9] based on the concept of load flow in a single line. For a usual transmission line, the stability index is calculated by

$$FVSI_{ij} = \frac{4Z^2Q_j}{V_i^2 X} \qquad (9)$$

Where Qj is the reactive power flow at the receiving end, Z is the line impedance, X is the line reactance and Vi is the Voltage at sending end. At the line indices approach to one or greater the exciting line become more exposed to instability. To determine the weakest bus on the system calculated values of FVSI can also be used. The minimum voltage permitted on a load bus determines the weakest bus. The most critical bus in a system correlates with the minimum permitted bus voltage. The motive in choosing FVSI index is that it is capable of identifying the critical areas in large power system and also a dept in defined the failure of voltage region, large load and lines in the interrelated system .FVSI approach is proposed to be the superior, to the other methods due to the above mentioned reasons in this proposed work. In finding the power system stability ,the exposed weak line and bus are recognized to show where the FACTS devices are to be placed to decrease the burden on the lines which are heavily loaded.

**3.2.3 Line Stability Index (LQP)**

It is developed by Mohamed et al [10] and utilizing the notion in [8][9] where the quadratic power equations discriminant is larger than zero. The obtained LQP is as

$$LQP = 4\left(\frac{X}{V_i^2}\right)\left(\frac{X}{V_i^2}\,p_i^{\,2} + Q_j\right) \qquad (10)$$

Where Vi is the sending end voltage, Pi is the sending bus active power flow, X is the line reactance, Qj is the receiving buses reactive power flow. The value of LQP index for a secured condition should be maintained less than one.

**3.2.4 Voltage Collapse point indicators (VCPI)**

The power system components stability of each line is developed by M.Moghavvemi et al[11] where the VCPI indices investigate the study for a line which is having maximum power.

$$VCPI(loss) = \frac{P_R}{P_{R(\max)}} \qquad (12)$$

$$VCPI(power) = \frac{Q_R}{Q_{R(\max)}} \qquad (13)$$

By using conventional power flows calculations the values of PR and QR are obtained. QR (max) and PR (max) are the maximum reactive and active power to be transferred through a line. The Voltage collapse indices varies from the range 0 (no load condition) to 1(voltage collapse). Due to the extreme power transfer through the line or too much absorption of power by the line is the essential cause for voltage collapse. Based on the theory of Maximum power transfer the amount of power is restricted. Now these indicators will calculate the point of voltage collapse exactly. When there is raise in demand of extra power from the system there is a rapid flow of the power in a line, which results in a fall of slow voltage at the ending bus which in turn increases the line power flow by increases the line losses. As a result both VCPI(power) and VCPI(1oss) are increased to a greater extent. For light loads, the VCPI (loss) indicator has a small value compared to VCPI (power). For line power flows, both shows an almost linear relationship to light loading conditions on comparison. While the loading condition approaches closer to the critical operating point both will combined to be as VCPI (power) is considered a reduced amount to additional loading. While VCPI(1oss) is found to be very sensitive. These values are sufficient in signifying the voltage collapse, with an added advantage locating the voltage collapse point precisely.

**IV. TEST RESULTS AND DISCUSSION**

The voltage stability indexes were analyzed by considering IEEE-14 and 30 Bus. For the given line under normal loading the voltage stability indices Lmn, LQP, and FVSI index, as well as, VCPI and VCPI indices was done. The line with the highest index in accordance as the load increased, the transmission line becomes carry maximum power rating and stressed. Due to this, the indices value is more than one and the system become unstable. This proposed work helps us to find out the weak line and by power, losses to identify the weak bus for the placement of FACT devices to reduce the burden and prevent outages. The graphs were plotted against a number of lines versus fast voltage stability index, line losses and power losses and also bus number against bus stability index and delta (load bus angle).

**Fig-5**number of lines verses Fast Voltage stability index for IEEE-14 bus

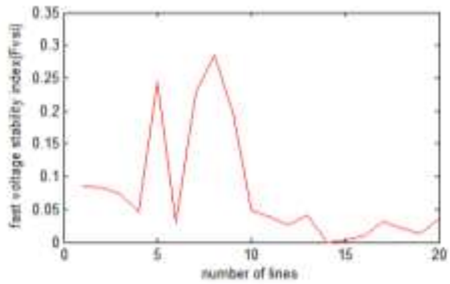



**Fig-6**number of lines verses Line losses for IEEE-14 bus

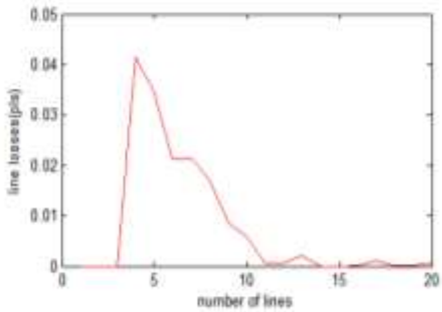


**Fig-7**Bus number verses Voltage magnitude for IEEE-14 bus

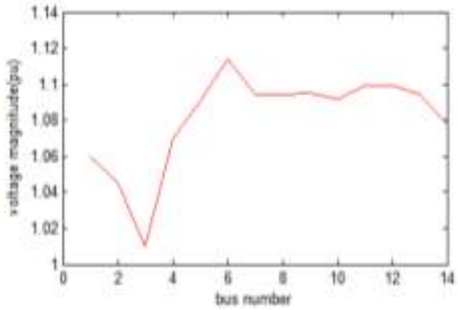



**Fig-8**Bus number verses bus Stability index for 14 bus system

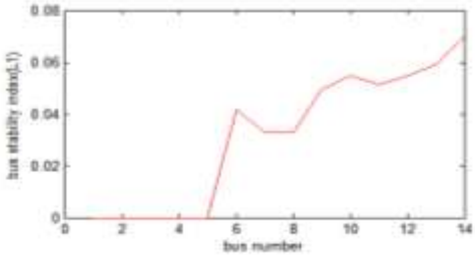



**Fig-9** number of lines verses Power losses for IEEE-14 bus

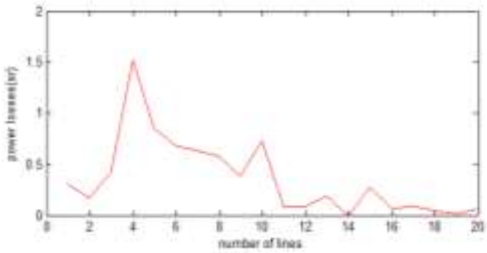



**Fig-10** number of bus verses Delta load bus angle for IEEE- 14 bus

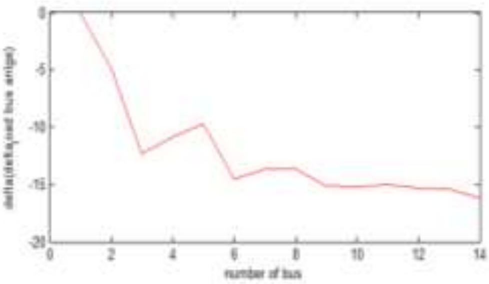



**Fig-11**Bus number verses bus Stability index for 30 bus system

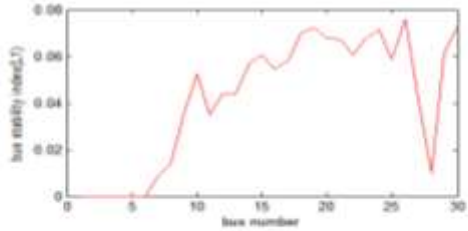



**Fig-12**number of lines verses Fast Voltage stability index for 30 bus system

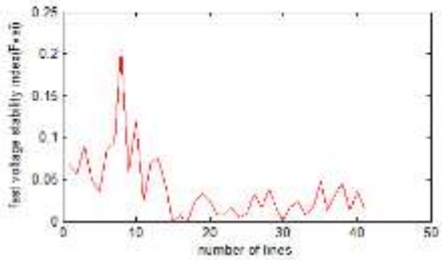



**Fig-13**Bus number verses Voltage magnitude for 30 bus system

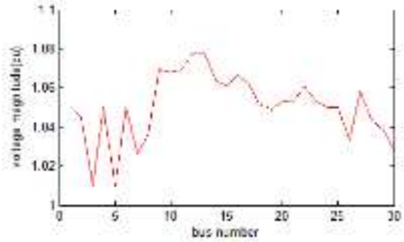



**Fig-14**number of bus verses Delta load bus angle for IEEE-30 bus

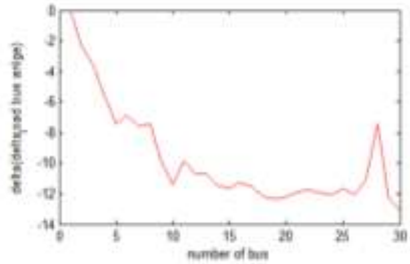



**Fig-15**number of lines verses Power losses for IEEE- 30 bus

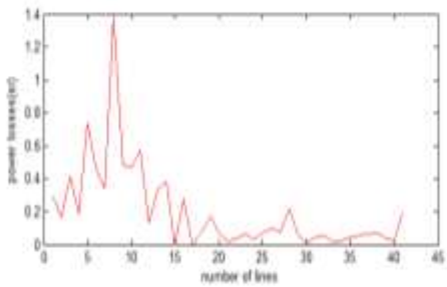
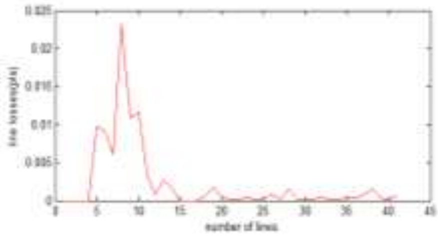


**Fig-16**number of lines verses Line losses for IEEE-30 bus



**VII CONCLUSION**

This paper presented voltage stability indices for selecting the weak bus and line and put the FACTS device on this weak bus and weak line for the improvement of bus voltage and power flow on the transmission line. Based on the work analysis the following points are the main contributions of this paper

a) Weak bus and transmission line are identified using voltage stability indices

b) Graphical representation for IEEE 14 and 30 bus system was shown.

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