Voltage StabilityIndicators for Prognosticationof VoltageCollapse in thePowerSystem

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Abstract

Several significant voltage collapse incidents in recent years have been caused by voltage instability. The intricacy of the voltage collapse problem grew as interconnections between independent power systems were determined to be economically advantageous. This predicament is a result of several trends in system design and operation. Identification of weak buses is crucial for achieving voltage stability. Important indicators of the weak buses in the overloaded system are line stability indices. In this study, power system voltage stability indices such as Fast Voltage Stability Index (FVSI),Line Stability Factor (LQP) forecastthe voltage collapseand examined. The maximum capacity before voltage collapse can be calculated using voltage stability indices, allowing the required precautions to be taken to prevent system capacity violations. The suggested voltage stability indices are tested on IEEE-5bus system and New England 39 bus system using MATLAB

Key words :

Voltage Collapse, Indices, Stability, FVSI,LQP

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Introduction

Nowadays, the power systems are operated at the boundaries of the safe region, and then exists ahigh probability of experience stability problems. In case of hazardous operating conditions,systemoperatorsrequireof atimely situationalawarenesstodeterminethebestcorrectivedecision,whichhelpstoassurethepowersystemsecurity.Additionally,reactivepowerhasagreatimpact on the voltage stability. A fast and accurate determination of voltage stability weak areasallows the power system operator to execute preventive actions, aimed to maintain an adequateoperationunderchangingconditions.However,duetothelargenumberofpossiblepowersystemoperating conditions, the determination of weak areas becomes a challenging task.

R. Asghari,[1] A Novel line stability index (NLSI) referred to a line initiated from the voltage quadratic equation at the sending and receiving end of a representation of a 2-bus system. The line index in interconnected system in which the value that is closed to one indicates that the line has reached its instability limits which could cause sudden voltages for sinusoidal variation. The proposed index considers both active and reactive power to investigate the voltage stability because this index provides more precise results than those which consider only reactive power.The weak areas of voltage stability allow power system operator to execute preventive actions under change in conditions. Identification of weak areas in power system helps in monitoring and operation by focusing control actions. Operating conditions of power system are considered to determine voltage control areas of large-scale power systems. Generally, voltage control areas are defined based on rated operating condition analyzed power system. For the determination voltage stability index load flow is executed at different operating conditions to obtained data base of operating conditions contains node voltages and power flowing through lines, Then the estimated values of voltage index is obtained by all the operating conditions provided. Voltage collapses occur quite frequently in power systems and may cause widespread power failure, even blackout. In order to avoid voltage instability, many voltage stability indexes have been proposed for evaluating the distance between the current state of power system and the voltage collapse point[2].The indexes based on the singularity of the power flow Jacobian matrix, such as the singular value index and Eigen value index. Near the voltage collapse point, the Jacobian matrix is close to singular, hence the minimum singular value or Eigen value index could measure the distance of the current state from the voltage collapse point. These indexes indicate the global stability of the system [3].The countries like Belgium, France, Germany, Japan, Sweden, and USA are victims of some renowned instances of VS incidents. "Voltage stability is the ability of a system to maintain voltage so that, when load admittance is increased, load power will increase and so that both power and voltage are controllable System variable &parameter-based indices uses the info acquired through the measurements or load flow solution. The indices which are built with the property of multiple solutions explore the multiple-solution power flow equations characteristics. Global indices reflect the stability of the entire system but they do not locate the weak region. On the other hand, the local indices could identify the weak regions and they are only concerned with the VS of the buses and branches [4]. In recent years deregulation of the power system has ignitedcompetitive business environment between Generating Companies (Genco's) and Distribution Companies. Hence, reliability of power system has become a major concern in this environment. Voltage stability analysis is necessary to identify the critical buses in a power system so that the planning engineers and operators may take appropriate actions to avoid the voltage collapse. The use of line index termed as Fast Voltage Stability Index (FVSI) and Line Stability Index (Lmn) in order to examine the maximum loadability in power system. Voltage stability analysis is conducted using line index indicated by FVSI and Lmn to indicate the stressfulness of a line in a transmission system. The reactive power at a particular bus is increased until it reaches the instability point [5].A comparison of various line voltage stability indices. These indices provide reliable information on the proximity of a power system to voltage instability. The results are obtained from simulation on various standard test systems. Usually the values of voltage stability indices change between 0 (no load) and 1(voltage collapse). Once the weak bus is identified by these Voltage stability indices, CPF feature of PSAT is used for determining the proper location of STATCOM in the system for enhancement of voltage stability.[6] Voltage stability is said to be the ability of a power system to maintain acceptable voltages atall network buses of the system under normal operating conditions and after being subjected to a disturbance. The power system utilities have been much more concerned about the incessant occurrence of voltage instability as a result of continuous increase in load demands and lack of Transmission capability. Recently, the problem of voltage instability has been observed as the main cause of numerous major network blackouts experienced in various countries such as France, Sweden, Belgium, Sweden, Germany, Japan, Iran and USA. Thus, the need for a reliable method for voltage stability assessment in

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a power system. Voltage stability is believed to be a dynamic Phenomenon. If analysis targets system critical bus identification, reactive power compensation or load margin, then the use of static model is adequate. [7]The problem of monitoring long-term voltage instability from a PMU installed at any transmission bus. The well-known impedance matching condition on a radically connected load bus, as well as the Local Identification of Voltage Emergency Situations method based on LTC transformers can be generalized into a New lives Index suitable for any transmission bus feeding a weak area of a system. [8] To obtain the distribution of voltage stability weak buses (VSWB) for power system with multiple power sources integrated, so as to provide a basis for voltage stability control, an analysis method under full time frame is proposed in this paper. Based on the modelling of multiple power sources, combined with the load prediction, the active poweroutput prediction of wind and photovoltaic power and the generation scheduling of conventional power, considering different patterns of load increase and power output increase and allocation of multiple power sources, within a certain period of time and for the specifically selected time sections, the continuation power flow method is respectively used to get the voltage stability critical point (SNB point), where modal analysis is applied, so that the VSWB are obtained of the certain time section.[9] Voltage stability is a long standing issue in power systems. Due to the requirements of on-line monitoring and high computation efficiency, L-index is used as voltage stability metric. A novel L-index sensitivity-based control algorithm for voltage stability enhancement. The proposed method uses both outputs of wind generators and additional reactive power compensators as control variables. The sensitivities between L-index and control variables are introduced. Based on these sensitivities, the control algorithm can minimize all the control efforts, while satisfying the predetermined L-index value. [10] Voltage instability, which is essentially a local phenomenon, has been the cause of many major blackouts in the world. 12 blackouts have been studied from 1965 to 2005 and indicating that voltage instability had been a major incident in 7 cases. The term voltage collapse is also used instead of voltage instability and it is the process by which the sequence of events accompanying voltage instability leads to an abnormally low voltages or blackout in a large part of the power system. [12] The use of line stability index termed as fast voltage stability index (FVSI) in order to determine the maximum load ability in a power system. The bus that is ranked highest is identified as the weakest bus since it can withstand a small amount of load before causing voltage collapse. It involves the experimental process of voltage stability analysis and evaluation of line index based on the load variation. The point at which FVSI close to unity indicates the maximum possible connected load termed as maximum load ability at the point of bifurcation. The slow variation in reactive power loading towards its maximum point causes the traditional load flow solution to reach its non- convergence point. Beyond this point, the ordinary load flow solution does not converge, which in turn forces the system to reach the voltage stability limit prior to bifurcation in the system.

The objective of these indices is to define a scalar magnitude that can be monitored as system conditions change. A review of the main referenced sources

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reveals that these indices, which use different concepts to predict voltage collapse, provide reliable information about critical buses and lines of the power system. This paper isoriented to discuss approaches for online identification of these areas in the power system, whereexistahighriskofexperiencevoltagestabilityproblems.

Problem formulation

The power flow problem is solved to determine the steady-state complex voltages at all buses of the network, from which the active and reactive power flows in every transmission. A popular approach to assess the steady-state operation of a power system is to write equations stipulating that at a given bus the generation, load, and powers exchanged through the transmission elements connecting to the bus must add up to zero. This applies to both active power and reactive power.

$$P_p = \sum_{q=1}^{n} \left|V_p Y_{pq} V_q\right| \cos(\theta_{pq} + \delta_p - \delta_q)$$

$$= \left|V_p^{\,2} Y_{pp}\right| \cos\theta_{pp} + \sum_{\substack{q=1\\ q\neq p}}^{n} \left|V_p Y_{pq} V_q\right| \cos(\theta_{pq} + \delta_p - \delta_q) \text{ --- (1)}$$

$$Q_p = \sum_{q=1}^{n} \left|V_p Y_{pq} V_q\right| \sin(\theta_{pq} + \delta_p - \delta_q)$$

$$= \left|V_p^{\,2} Y_{pp}\right| \sin\theta_{pp} + \sum_{\substack{q=1\\ q\neq p}}^{n} \left|V_p Y_{pq} V_q\right| \sin(\theta_{pq} + \delta_p - \delta_q) \qquad \text{------- (2)}$$

Fast Voltage Stability Index

To evaluate the voltage stability of an electrical power system, a Fast voltage stability index (FVSI) is used to denote a system's weakness and capacity to voltage collapse. [13-15]

$$FVSI_{pq} = 4\frac{X_{pq}}{V_{pq}^2}\left(\frac{P_q^2}{Q_q} + Q_q\right) \text{-------- (3)}$$

($FVSI_{pq}$ = FVSI for the line linked bus p and bus q. A highly loaded line has FVSI magnitude closer to unity. FVSI values are therefore expected to be held at a lower level than unity for ensuring system stability.

Line Stability Factor (LQP) The LQP index derived by Mohamed et al., (1989) [16-18] is obtained in which the discriminant of the power quadratic equation is set to be greater than or equal to zero. The line stability factor for this model is reproduced as

$$\mathrm{LQP} = 4\left(\frac{X}{V_p^2}\right)\left(\frac{X}{V_p^2}P_p + Q_q\right) \text{-------(4)}$$

where X is the line reactance, Qq is the reactive power flow to the receiving bus, Vp is the voltage at the sending bus and Pp is the active power flow from the sending bus. For stable system, the value of LQP index should be maintained at less than 1, otherwise, collapse is imminent [18].

Results and Discussion

The load flow for IEEE-5bus system and NewEngland39-Bussystem are considered. A comprehensive study on the use of the line stability factors as a static voltage indicatorhasbeenproposed.Theperformance andeffectivenessofthelinestabilityfactorhasbeenevaluated.Fromthecomparisonresults,itcanbeconsideredthatthestabilityfactormethodoffers the advantages of fact computation and determination of the cause the voltagecollapse. Comparing the FVSI results with line stability factor values, it is clear that thevaluesofFVSIareslightlylessthanthatofline stabilityfactorvalues.Fromtheseresults,FVSI values are more compatible as compared to line stability factorvalues.

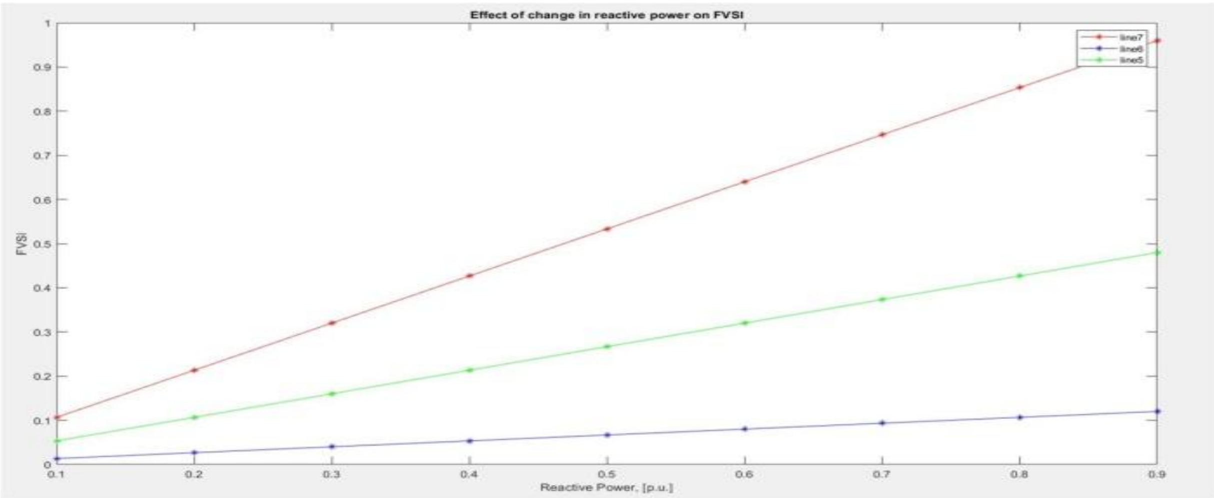


Fig :1(a)

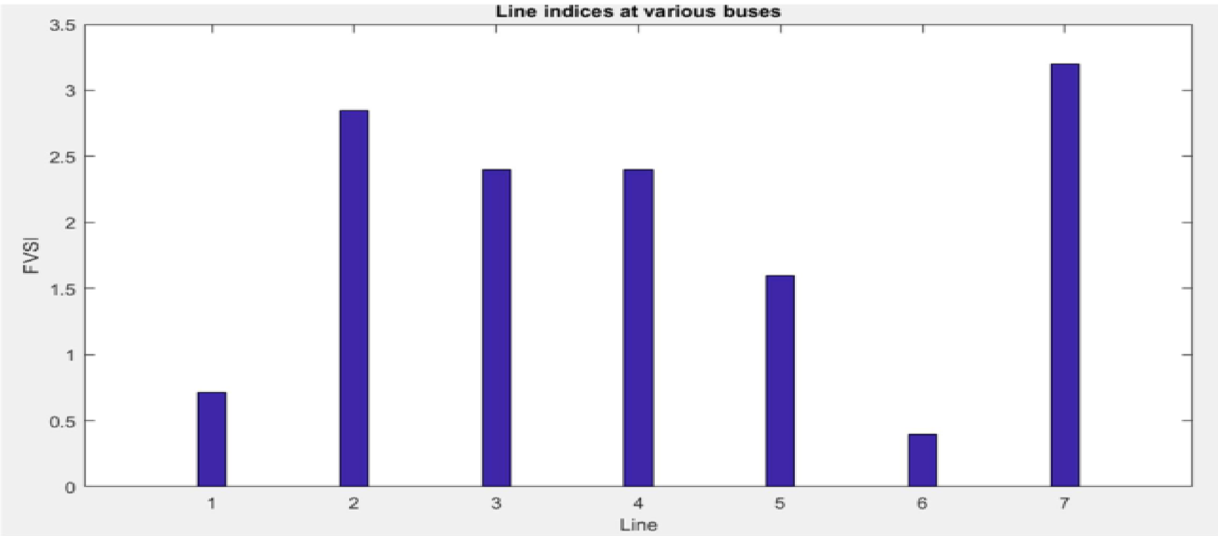


Fig :1(b)

Fast voltagestabilityindex profileforvarious lines-7,6,5withthechangeinreactivepower shown in above figure 1(a). Fastvoltagestabilityindexvaluesat various buses of the IEEE-5 bus system shown in theabove figure 1(b)

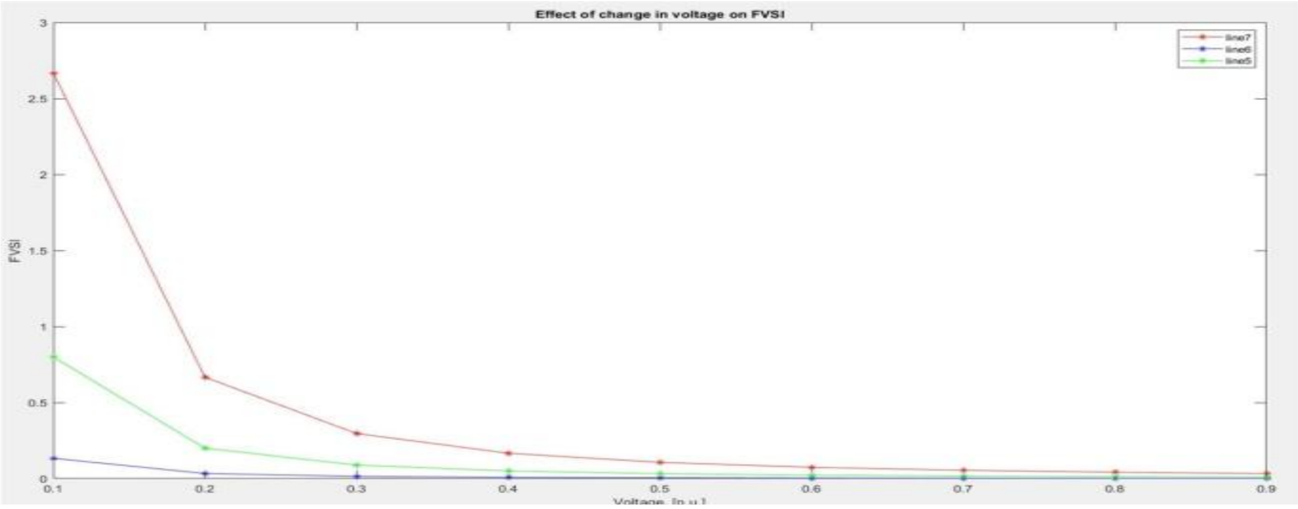


Fig :2(a)

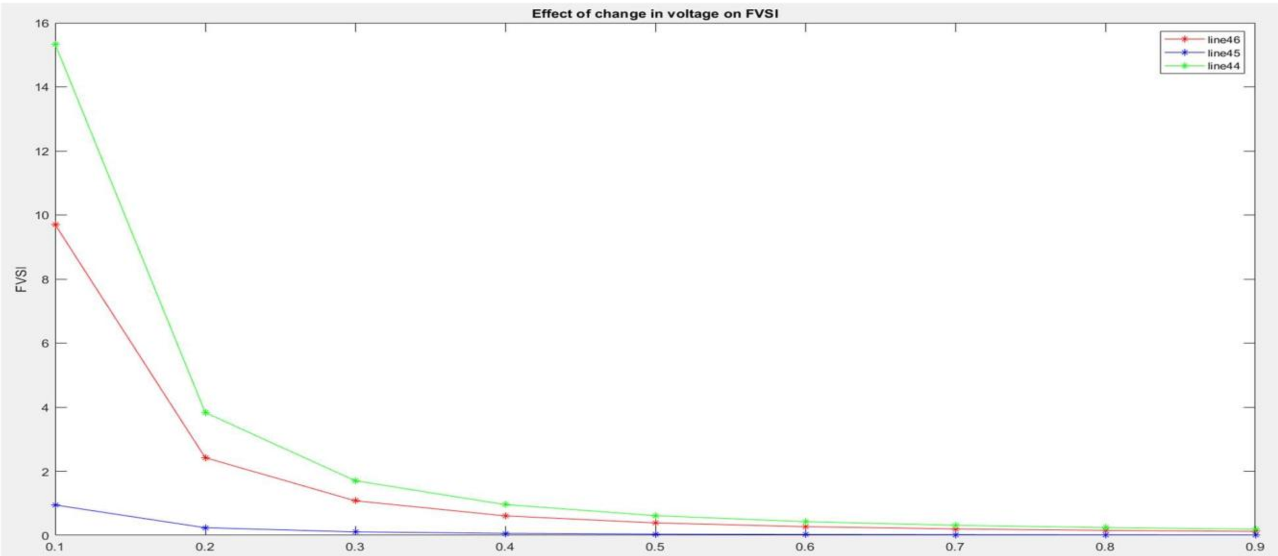
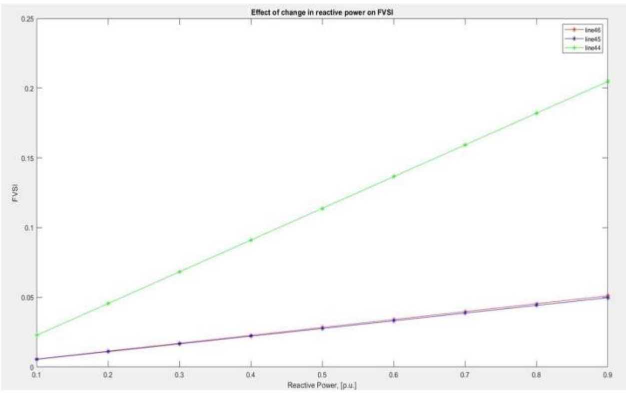


Fig :2(b)

Fast voltagestabilityindex valuesforlines-7,6,5 and 46,45,44with changein loadvoltage are shown in fig 2(a) and 2(b) of the IEEE-5 bus system and NewEngland39-Bussystem respectively



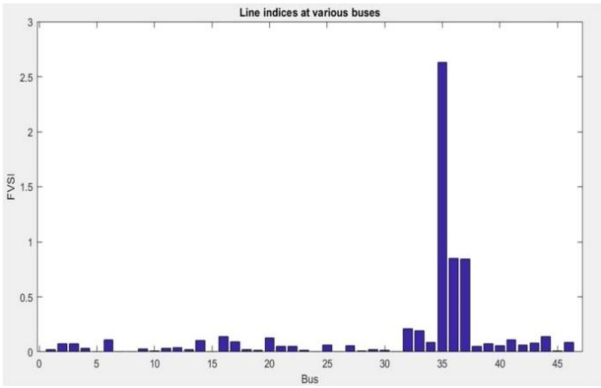


Fig :3(a) Fig :3(b)

Fast voltagestabilityindex profilefor various lines-46,45,44withthechangeinreactivepower shown in above figure 3(a). Fastvoltagestabilityindexvaluesat various buses of the NewEngland39-Bussystem shown in the above figure 3(b)

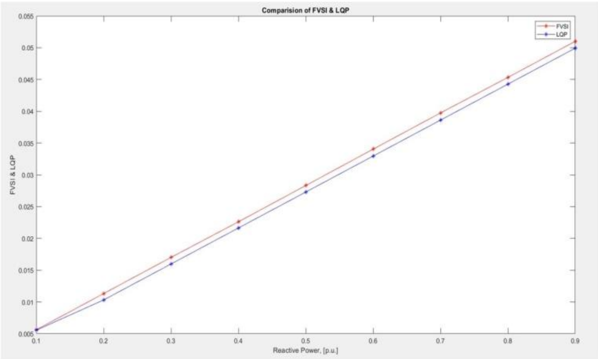


Fig :4(a)

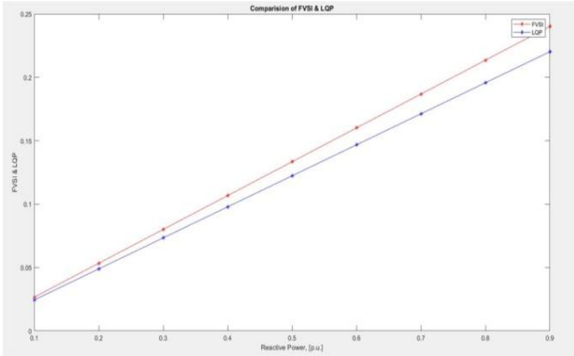


Fig :4(b)

ComparisonofindicesplotsforIEEE5-Bussystemwithchangeinreactivepowerforline-7 are shown in figure 4(a) and comparisonofindicesplotsforNewEngland39-Bussystemwithchangeinreactivepowerforline-46 are shown in figure 4(b)

Conclusion

This paper presents comparative analysis of fast voltage stability index (FVSI) and LQPfactor for better assessment of fault detection in a given power system network. In order toinvestigatetheeffectofincreasingreactivepoweronindicesasinglelineisconsidered fromeachexistingpowersystemswhichareIEEE5-bussystem andNewEngland39-bussystemand the reactive power of bus is gradually increased and the results are plotted. Fromthe comparative results it is observed that fast voltage stability indices (FVSI) give moreaccurate results than LQP factor, since it is able to detect instability prior to LQP factor. The loadflow results for all three system are obtained using Newton-Raphson method is bettersuitableforlargesystem becauseconvergence can be obtainedina smallernumberofiterations.

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