Research Inventy: International Journal of Engineering And Science
Issn (e): 2278-4721, Issn (p):2319-6483, PP: 08-11
www.researchinventy.com

Analysis of voltage stability margin using ds/dy method for IEEE-6 bus as well as 39 Bus New England power systems

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Abstract
In modern power system, electrical energy is delivered from the generating station to the consumers through a network of transmission and distribution. Now a day, the management of power system has become more challenging than earlier because power systems operate closer to security limits and environmental constraints restrict the expansion of transmission network. Voltage stability is one of the major parameters of stability and many blackouts have been reported due to voltage instability. Identification of voltage stability margin and improvementof voltage stability limit are thus very much essential to ensure desired power transfer at rated voltage and frequency. In this work, the mathematical modeling ds of method has been developed. The proposed method has been tested using IEEE-6 bus as well as 39 Bus New England power systems to ensure the efficacy. A detailed analysis of tested results proves that the proposed technique is able to predict the voltage stability condition of a power system efficiently.
Keywords: Electric power, Load admittance, Voltage Stability.

I. Introduction

Zahidi et al. discussed a voltage stability index that is Fast Voltage Stability Index (FVSI) to act as a numerical verification of shedding location to improve the stability of a system [1]. In [2], Gao et al. described the static voltage stability analysis method considering the influence of harmonic effect. ChangHong et al. introduced a thermostatically controlled model for small signal stability analysis and analyzed the parameters on the small disturbance voltage stability. The author also discussed the electromechanical oscillations on the single machine infinite bus thermostat load [3]. Aik and Andersson [4] proposed a comprehensive and fundamental analysis of steady-state voltage and power system stability of single feed voltage -source converter (VSC) high voltage direct current (HVDC) system. A classical stability analysis also developed the authors for this stability analysis of line commutated converter HVDC systems. Zabaiou et al. [5] present a novel voltage stability constrained optimal power flow (VSC- OPF) based on static voltage stability indices for simultaneously improvement of voltage stability and minimize power system loss under stress and contingency conditions and also proposed a voltage collapse proximity indicator to prevent voltage instability. Ghiocel and Chow [6] proposed a new power flow method to directly eliminate the singularity issue by reformulating the power flow problem. The authors introduced a new bus system for steady-state voltage stability analysis. Browsilowicz and Szafran introduced a method for calculating voltage stability margin which is based on an approximate model and measurements of node voltage and also determines the Thevenin's model to calculate the variations of stability margin for different types of loads [7]. Li et al. [8] proposed an online voltage stability margin monitoringapproach which is based on local regression and adaptive database.

Implementation of the Method:

As day by day the demand of electric power has increasing. So, the utility companies are facing a challenge to operate the system closer to the limits of instability. To operate the system with an adequate security margin, it is essential to estimate the voltage stability margin corresponding to the given operating point. The main problem here is that the maximum permissible loading of the transmission system is not a fixed quantity. It depends on various factors such as network topology, availability of reactive power support, generation and load patterns etc. All these factors continuously vary with time. As voltage stability margin corresponding to a given operating point is a concern, hence a new approach to calculate the same has been proposed. Voltage stability can be illustrated by considering the two terminal networks as shown in Fig. 1. It consists of a constant voltage source E_{TH} supplying load impedance Z_L through series impedance Z_{TH}

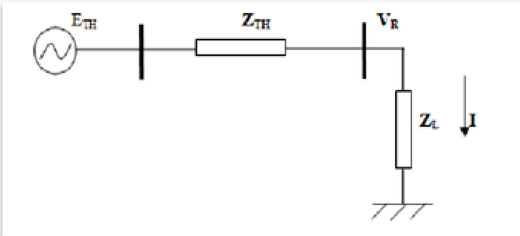


Fig. 1. Simplified equivalent circuit of a local bus and rest of the system treated as The veninequivalent.

$$I = \frac{E_{TH}}{\sqrt{Z_{TH}^2 + Z_L^2 + 2Z_{TH}Z_L\cos(\theta - \varphi)}} \tag{1}$$

Where θ=phase angle of impedance Z_{TH} and φ=phase angle of impedanceZ_L.The magnitude apparent power supplied to the load is$S = V_R^2 Y_L = \frac{E^2 Z_L}{Z_{TH}^2+Z_L^2+2Z_{TH}Z_L\cos(\theta-\varphi)}$ where $Y_L = \frac{1}{Z_L}$ and the derivative of the apparent load power S is calculated against the load admittance Y, we get the following result.

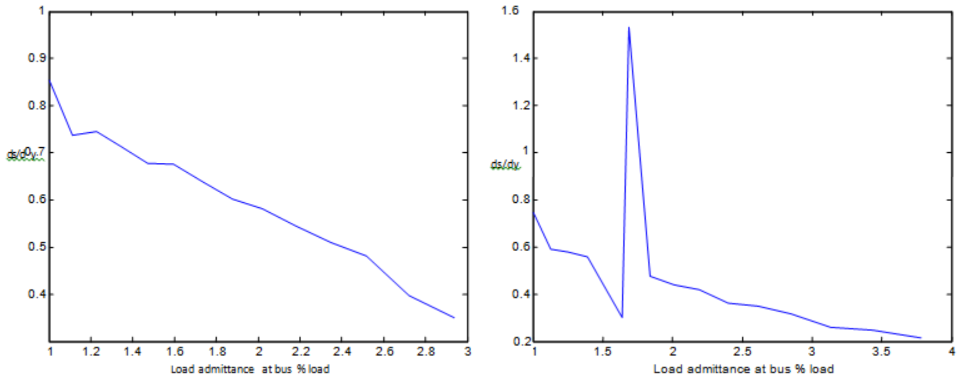
$$\frac{dS}{dY} = \frac{E_{TH}^2(1-Y^2Z_{TH}^2)}{(1+Z_{TH}^2Y^2+2Z_{TH}Y\cos(\theta-\varphi))^2} \tag{2}$$

The condition for maximum load apparent power can be written as: $\frac{ds}{dy}=0$.The solution of this equation confirms the well-known fact that at critical point of voltage instability $Z_{TH} = Z_L$. The Above equations indicate that$\frac{ds}{dy}$depends on the Thevenin parameters and also on the magnitude and power factor of the load admittance. At no load i.e. when load admittance Y=0, $\frac{ds}{dy} = E_{TH}^2$ .When $Z_{TH} = Z_L$, $\frac{ds}{dy}=0$. Therefore, $\frac{ds}{dy}$close to zero also indicates the proximity to 'voltage collapse point".

II. Simulation and result:

In a power system, the load admittance is continuously varying. Variation in load is caused by natural tripping of load, operation of the on load tap changing devices etc. Here the approach is based on the measurement of the change in apparent power supplied to the load S and the load admittance Y. S and Y can be calculated easily from the voltage and current vectors measured at the high tension side of the station transformer. From the measured values of S and Y, the factor $\frac{ds}{dy}$ can be determined using the following expression: $\frac{ds}{dy} = \frac{S_2 - S_1}{Y_2 - Y_1}$

Where, S1, S2 =Apparent power supplied to the load at the beginning and end of time interval. Y1,Y2 = Load admittance at the beginning and end of time interval. Voltage stability margin can be monitored by on-line tracking of $\frac{ds}{dy}$ using equation . $\frac{ds}{dy}$close to zero indicates the "maximum loading point" and also the proximity to voltage collapse. Implementation of $\frac{ds}{dy}$ method for monitoring the voltage stability margin of a power system was tested on IEEE 6-bus standard test system and 39 Bus New England power systems. The calculation is based on the actual value of load admittance and the apparent power supplied to the load. Thus, it is not affected by the characteristic of the load. The results are obtained from load flow simulations. For this study, all the loads were modeled as constant admittance at all the buses. The admittance was gradually increased from the base case. For determining $\frac{ds}{dy}$ only two successive data sets were used. The bus at which the factor is close to zero is the weakest bus in the system. The variations $\frac{ds}{dy}$ in total apparent power supplied to load with change in load admittance at various buses are shown in following figures. Fig. 2 (a) and (b) show the variation of $\frac{ds}{dy}$ with change in load admittance at bus 2 and bus 4 of IEEE 6 bus system. In Fig. 2 (b) the abrupt change has been noticed from the waveform with respect to change in load admittance. Fig. 3(a) and (b) represent the variation of $\frac{ds}{dy}$ with change in load admittance at bus 5 and bus 6 of IEEE 6 bus system respectively and the variation is smooth with respect to change in load admittance. Also, in Fig. 4 (a) and (b) represent the variation of $\frac{ds}{dy}$ with change in load admittance at bus 15, 19 and 20 of load buses of 39 Bus New England power systems. Here also the abrupt change in the waveform has been noticed with respect to change in load admittance. The abrupt change means that buses are vulnerable bus with respect to the variations of load. So, the following figures represent an idea about the variations in apparent power supplied to load with change in load admittance by $\frac{ds}{dy}$ method that can help to predict the voltage stability condition of different load bus system of IEEE-6 and 39 Bus New England power systems. For the offline studies the necessary data which is obtained from the simulation that helps the power system planners to identify the area in the power system network which is prone to voltage collapse.



(a) (b)

Fig. 2. Variation of $\frac{ds}{dy}$ with change in load admittance (a) at bus 2 (b) bus 4 of IEEE 6 Bus System.

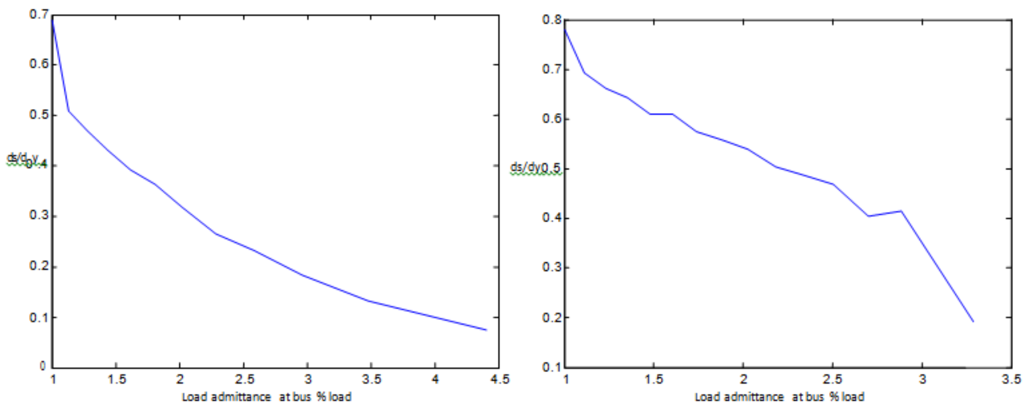
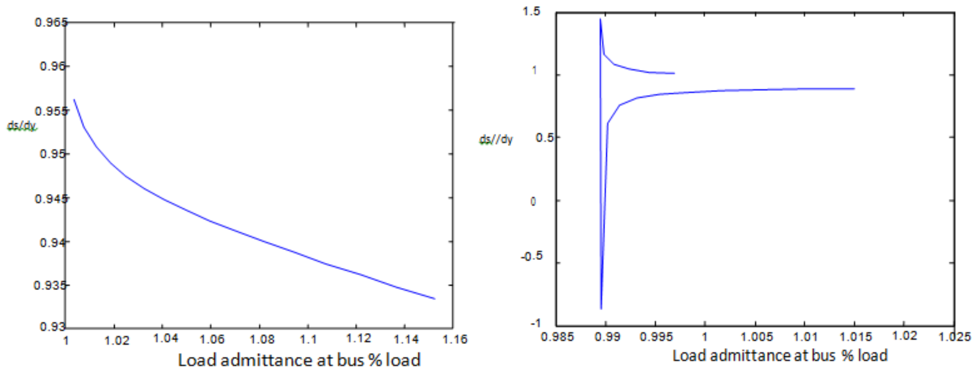


Fig. 3. Variation of $\frac{ds}{dy}$ with change in load admittance (a) at bus 5 and (b) at bus 6 of IEEE 6 Bus System.



(a) (b)

Fig. 4. Variation of $\frac{ds}{dy}$ with change in load admittance (a) at bus 15 (b) at 19 of 39 Bus New England power system.

III. Conclusion:

With the deregulation of the power network, more numbers of private players are now engaged in transmission and distribution. Centralized monitoring of the entire network and reliability and quality of power has become a major issue. There is a limit of voltage variation (which is standard specified value) and beyond which disturbance may be created in the system. Voltage variation beyond standard specified value leads to voltage collapse. To operate the system with an adequate stability or security margin, it is essential to estimate the voltage stability margin corresponding to the given operating point. In this paper, the proposed method has been discussed and tested on IEEE 6 and 39 bus New England power system. The figures from the tested data give a clear idea about the variation of $\frac{ds}{dy}$ with respect to load admittance that will help to predict voltage stability margin of the different bus system and also identify the vulnerable buses with respect to change in load of the system. The operators may set an alarm lower than the actual operating conditions. This technique can use as an efficient tool in offline as well as in online monitoring of voltage stability margin.

References

[1]. Study of static voltage stability index as an indicator for Under Voltage Load Shedding schemes, R. A. Zahidi, I. Z. Abidin, H. Hashim, Y. R. Omar, N. Ahmad and A. M. Ali, 3rd International Conference on Energy and Environment (ICEE), Malacca, (2009): 256-261.

[2]. Static Voltage Stability Assessment Considering Harmonic Effects, Mengnan Gao; Ruipeng Lu; Wenping Qin; Rui Cao; Jinhao Wang, IEEE 3rd Conference on Energy Internet and Energy System Integration (EI2), Changsha, China,(2019) :1183-1187.

[3]. Small disturbance voltage stability considering thermostatically controlled load," ChangHong Xu;PeiQiang Li;XinRan Li;DeSheng Chen;Yan Zhang; Bo Lei International Conference on Advanced Power System Automation and Protection, (2011): 862-866.

[4]. Fundamental Analysis of Voltage and Power Stability of Single-Infeed Voltage-Source Converter HVDC Systems, Denis Lee Hau Aik;Göran Andersson, IEEE Transactions on Power Delivery, 34.1(2019): 365-375.

[5]. Preventive control approach for voltage stability improvement using voltage stability constrained optimal power flow based on static line voltage stability indices, Tarik Zabaiou, Louis-A Dessaint , Innocent Kamwa , IET Generation, Transmission & Distribution, 8.5 (2014): 924-934.

[6]. A Power Flow Method Using a New Bus Type for Computing Steady-State Voltage Stability Margins, Scott G. Ghiocel;Joe H. Chow , IEEE Transactions on Power Systems, 29.2 (2014), 958-965.

[7]. Voltage stability estimation based on approximate model and voltage measurement, Bartosz Brusilowicz and Janusz Szafran, 16th International Scientific Conference on Electric Power Engineering (EPE), Kouty nad Desnou, (2015):227-232.

[8]. Adaptive Online Monitoring of Voltage Stability Margin via Local Regression, Shiyang Li, Venkataramana Ajjarapu and Miodrag. Djukanovic , IEEE Transactions on Power Systems, 33.1(2018): 701-713.