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Analysis of Distribution System Voltage Security Using the Gauss-Seidel Method

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Abstract*: Voltage security is an attractive asset to power distribution system processes and ensures reliability and stability of voltage distribution amid various loading conditions. In this work, Gauss-Seidel iterative methodology is employed to perform analysis on voltage security of distribution networks. The technique allows the in depth assessment of the voltage bus profiles by solving power flows. Identification of the weak nodes and potential violations of the voltage achieves with the assessment of the voltage stability margin of the system, simulating the different loading conditions. Gauss-Seidel method is efficient and simple to go about distribution network analysis due to the simplicity of this method in radial systems. The results outlined the usefulness of the method in the planning and operational decision making in achieving enhanced voltage security in distribution systems by indicating how the voltage drops and voltage stability issues vary with the variations in the loads.*

Keywords*: Bus voltages DSSI Load multiplier factor Phasor measurement unit Voltage security*
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I. Introduction

Voltage security is a fundamental requirement so that electrical power distribution system can be relied upon and can work steadily. It becomes increasingly difficult to maintain voltage levels at reasonable levels as modern power networks struggle with increased demand, changing loads, and combination of scattered energy sources. Otherwise, Voltage instability can lead to black out, undesirable power quality, or losses in the system. Power flow analysis is important in measuring the performance of a system when it experiences varying operating conditions. GaussSeidel method is probably one of the simplest yet most efficient methods to work with and it has a special application in radial distribution systems as well as loosely meshed systems. This paper analyses voltage security in a distribution network through the Gauss-Seidel iterative method. It is called a technique to evaluate system-wide voltages profiles in loads conditions. The research is conducted to assist in plan and carry out strategies in enhancing the maintenances of volts stability and avoiding failure of the system through noting weak buses and tracking of voltage differences [1].

II. Research Method

This paper examines voltage security of a radial distribution system through the Gauss-Seidel method of solving. The procedure begins with modelling distribution network with specified line impedances, load requirements and bus arrangements. This method involves the Gauss-Seidel method of solving the load flow equations repeatedly using a trial set of values of voltages until convergence of the voltages is achieved to a level of tolerance. Some loading scenarios are simulated to observe how the system will behave in normal and load conditions [4-6]. The identification of weak nodes having possible voltage drops is achieved through recording and analysis of the voltage profiles of each bus. Then the ability of the system to operate in a steady pace is determined by calculating the voltage security margin. The method provides a practical and computationally efficient method of determining the stability of voltage and actively intervening in it.

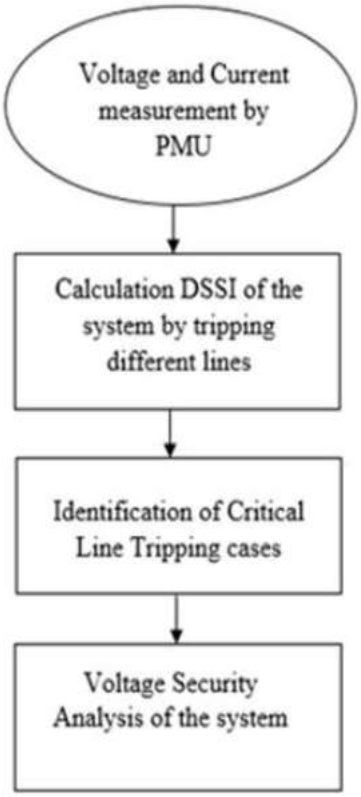

Fig 1: Proposed method flow chart

III. Proposed Index from Gauss Seidel Equation

An alternative to test the voltage security using the Gauss-Seidel method is proposed, which is based on a Voltage Security Index (VSI) of bus voltages variations identified during iterating the load flow analysis process. The Gauss-Seidel method allows calculating the magnitude of the voltages at each step by updating bus voltages with known system parameters. The proposed index would gauge how near a bus would be to its critical voltage limit.

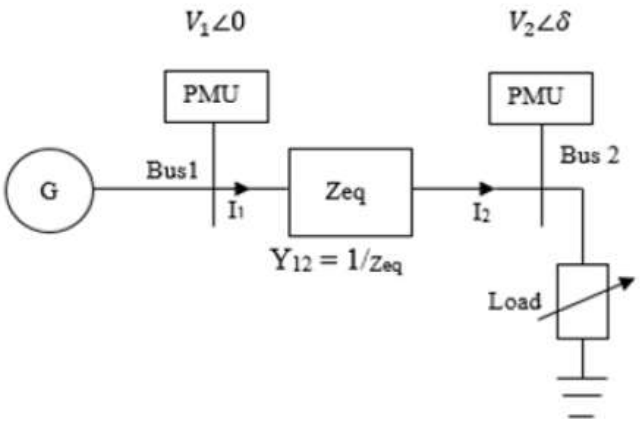

Fig 2: Two bus network of PMU

IV. Simulation and Results

Simulation and analysis of voltage security in outage condition under different loading conditions in a typical radial distribution network was performed by application of Gauss-Seidel load flow algorithm on a conventional radial distribution system. The system was modelled by a slack bus, load needs and known line impedances. MATLAB simulations were executed to observe the behaviour of the voltage at all the buses using load that was increased gradually up to base load and up to critical load.

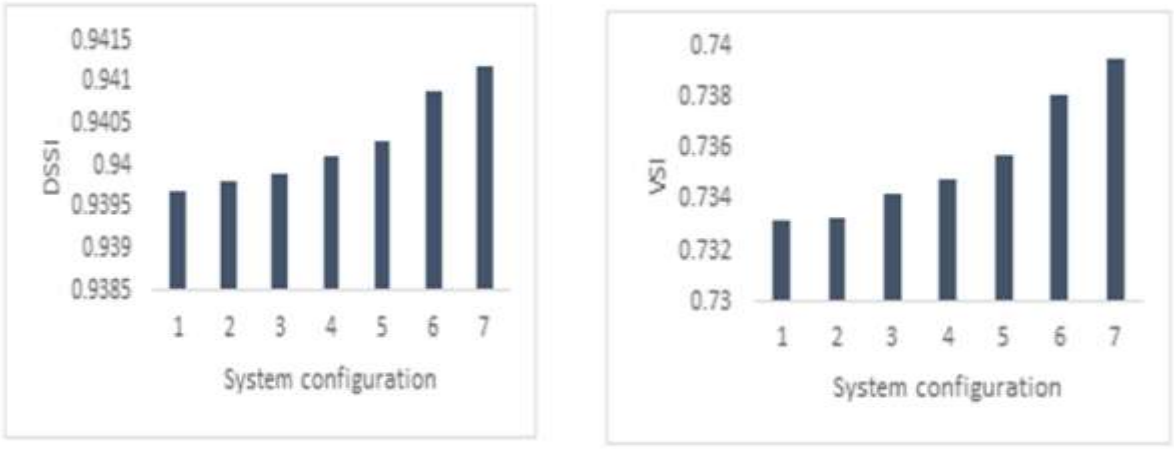

Fig 3: Plot of VSI indicator for different configurations

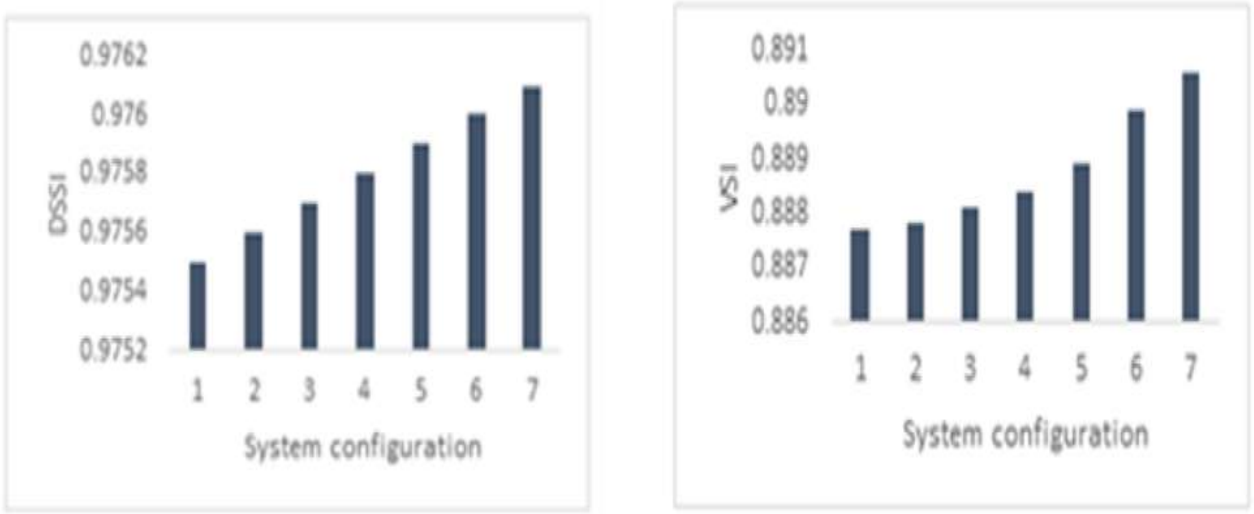

Fig 4: Plot of VSI indicator at maximum loading

Then the power flow equations were iteratively solved to convergence at each load level by Gauss-Seidel at each level, and voltages with respect to buses were recorded. To identify the degree of agreement between the measured voltage with the nominal level (1.0 p.u.), a Voltage Security Index (VSI) was calculated at each bus. The results were that the change in the security of voltage reduced with the increase in loads and voltage of a distant bus in decreasing and also VSI values. The weak nodes were assumed to be buses that were the most remote to the substation and tend to be the end buses and exhibited the largest voltage dips. At higher loads some VSI values approached the critical value of around 0.9 p.u and this is an indication that the system may be unstable [1-3].

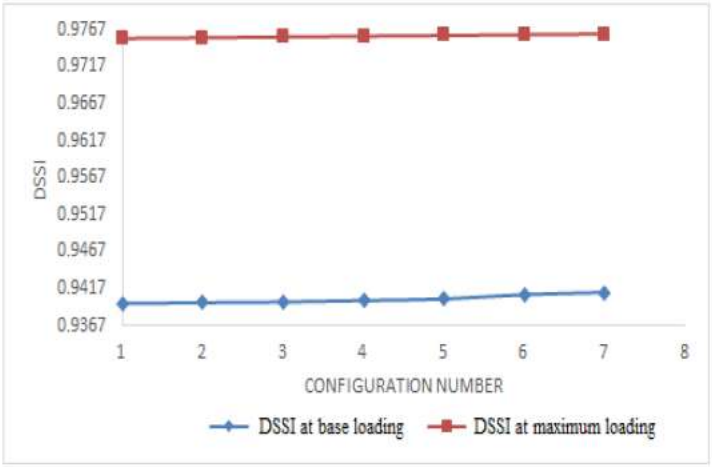

Fig 5: DSSI at base loading and at maximum loading

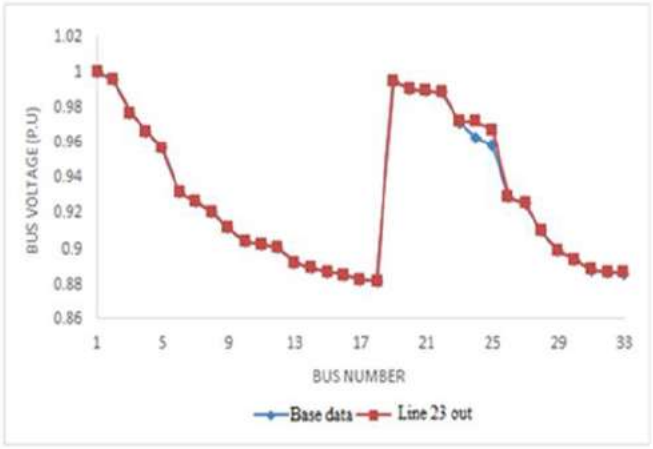

Fig 6: Outage of line number 23 at base loading

The efficiency of the Gauss-Seidel approach in assessing the security of voltage and identifying the vulnerable buses is proved by the simulation. The results give plausibility to the utility of VSI as an effective tool in monitoring and enhancing voltage stability of the distribution system.

V. Conclusion

The given research demonstrates the effectiveness of the Gauss-Seidel approach to investigate the security of the distribution network in terms of voltage. The computation pattern resounds well in detecting an increase or decrease in voltage and weak buses along the network through iterative seasoned analysis of the network in alternate states of loading. The proposed Voltage Security Index (VSI) is an easily understood but useful measure of the proximity of the bus voltages to dangerous levels, and would assist in giving early warning of instability hazards. The findings of the simulation showed that voltage drops are most conspicuous at higher loading especially at end buses. Considering all these facts, Gauss-Seidel method coupled with VSI offers a reliable and computationally viable means of assessing the voltage security and can be used in enhancing operational and planning decisions within the power distribution systems.

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