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Identification of Weak and Critical Buses in Electrical Power System

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Abstract - *This paper introduces voltage stability analysis method in finding critical or less stable load buses in electrical power system. Voltage stability analysis technique discussed in this research are the Active Power- Voltage curve (PV) and Active Power-Reactive Power (PQ) curve analysis methods. The P-V curve method was utilized in determining the weak buses of a standard IEEE 30-bus system. The standard IEEE 30-bus system was simulated with Matlab software using Newton Raphson Continous Power Flow algorithm.*

Key Words: **Critical bus, PQ curve analysis, PV curve analysis, Voltage stability analysis, Weak bus**

1. INTRODUCTION

WEAK or critical buses in electrical power system can be described as a load bus that experience excessive voltage decline with small load increase or variation. Load buses placed far from a generation bus can also experience high voltage drop from load variation. Weak buses have small active power margin and therefore excessive load increase can cause them to exceed their voltage limit. Identifying weak buses in electrical power system have become an essential activity in electrical power operation [1]. The role of identifying weak buses for renewable energy integration has become crucial due to recent increase in renewable energy sources. Renewable based energy sources have been experiencing rapid development all over the world. Renewable sources minimize pollution and reduces excessive dependence on fossil fuels. Wind Power energy has become one of the leading renewable energy sources on a global scale. The rapid growth of renewable energy around the world is partly due to the recognition of their benefits to the environment which has led to the establishment of renewable based policy implementation in most developed countries [2]. The growth of the renewable energy sources around the world makes it necessary to adopt stability analysis for especially load buses to ensure high efficiency and stability. Method for investigating steady-state voltage region was presented in [3]. The stability region was determined by gradually increasing the active power demand on a load bus while monitoring its voltage level. The method provided the active power requirement for a given load connected to a load bus. However, the analysis failed to present approach for finding voltage limit for the buses in the electrical power system.

Voltage stability analysis for normal and contingency operational grid was introduced in [4]. The analysis deployed active PV curve analysis to investigate voltage limits for stable operation of wind energy integrated power grid. The analysis concluded that the level of load demand on the grid increases with an increase in wind penetration and addition of compensators. However, principles behind the selection of location for both renewable energy and compensator was not discussed. Voltage stability analysis for electrical power system with wind energy connected at multiple location was presented in [5]. According to the analysis wind energy placed at multiple locations was able to increase system loadability and reduce real power losses as compared to a single location in the grid system.

Although the multiple location approach seems to be effective in improving voltage stability of the power system but the identification of the best connection points might prove to be more difficult since a precise analysis for the multiple locations was not highlighted. In most renewable energy integrated systems reactive power compensators are integrated at the weak bus of the electrical power system [4]. In this paper, the approach for extracting the weak buses of power system is presented. The method that is utilized in weak or critical bus identification in this paper is the P-V curve method.

2. VOLTAGE STABILITY ANALYSIS

The two methods discussed in this paper for voltage stability analysis (VSA) are the P-V curve and the P-Q Curve methods. The P-V curve method is used for identifying the weak buses in the IEEE 30 bus system.

2.1 P-Q Curve an P-V Curve Analysis

Active power demand at a load bus influences voltage level at the bus. P-V curve is utilized in finding the voltage variation at a bus due to active electrical power transfer from a source to the load bus (Fig. 1). As the load demand increases high current is transferred to the load bus while voltage level gradually reduces. Voltage level reduction continues for excessive load demand which causes the bus to eventually to reach or even exceed it voltage limit.

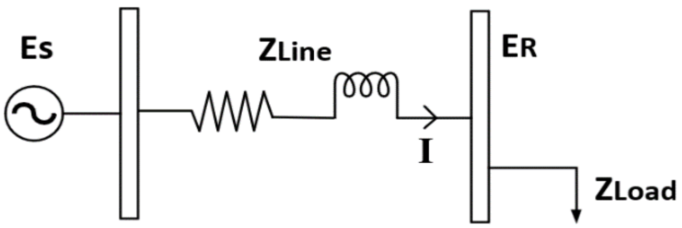

Fig 1. Schematic diagram of two bus system

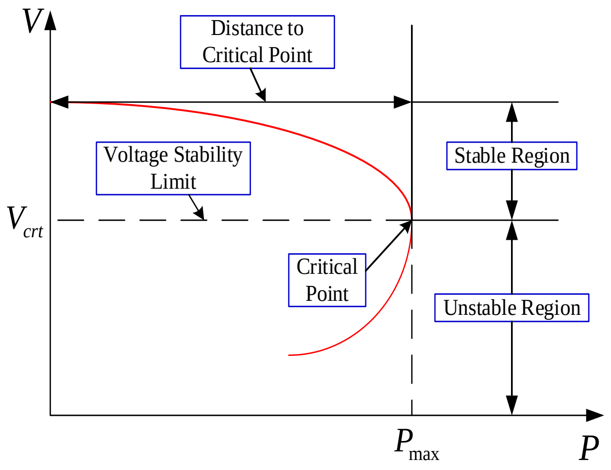

Fig. 2. P-V Curve Analysis

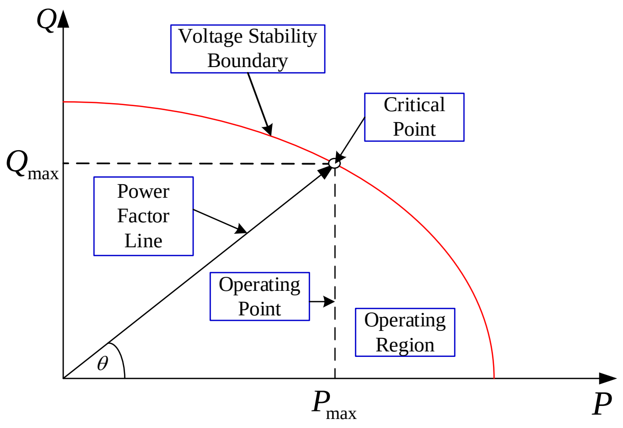

Fig. 3 P-Q Curve Plot Analysis

The critical point as seen on the P-V curve represent the highest demand that a load bus can contain. As shown in Fig. 2a if the load demand exceeds the critical point the bus becomes unstable and therefore a very sharp voltage drop occurs on the load bus [4 6]. As given in equation (1) The difference between the maximum active power demand $P_{\max}$ and the initial demand P_0 on the load bus is referred to as the active power margin P_m. The active power margin can be referred to as the collapse margin. The collapse margin is used as the voltage stability indicator, the higher the collapse margin the more stable the bus or the power system.

$$P_m = P_{\max} - P_0$$
(1)

The variation of voltage level on a bus due to active power demand also affect the reactive power level on the bus. P-Q curve generates the level of reactive power that is required to be added or absorbed from a bus to maintain the bus voltage. As a result, for every active power demand the corresponding reactive power for the bus is determined and this information are used in plotting the P-Q curve. The maximum reactive power for a given bus is dependent on power factor of the system [7-11]. As shown in Fig. 2b the maximum reactive power $Q_{\max}$ can be determined by finding the intersection of the voltage stability boundary of the P-Q curve and the power factor line. The difference between the the initial reactive power Q_0 and maximum reactive power becomes the reactive power margin. The voltage stability boundary is utilized in finding the voltage stability operating region of a bus for a given voltage range or limits.

$$Q_m = Q_{\max} - Q_0 \qquad (2)$$

2.2 Configuration of an IEEE 30 Bus System

An IEEE 30 bus system with total generation capacity of 335 MW and reactive power range of -95 MW and 405.9 MVar is used for the study. The configuration of the IEEE 30 bus sytem is shown in Fig. 3. The total active power demand of the IEEE 30 bus system is 189.2 MW with reactive power demand of 107.2 MVar [6]. The power factor of the system was selected as 0.8. The algorithm employed in the voltage stability analysis is the continuation electric power flow algorithm which is a Newton Raphson's power flow iterative solution.

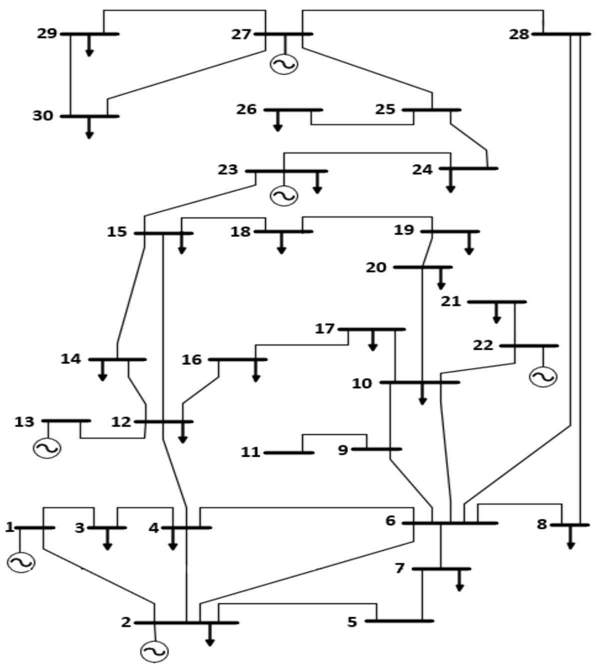

Figure 3. Schematic Diagram of IEEE 30-Bus Test System

3. RESULTS AND DISCUSSION

P-V curve for load buses after Newton Raphson continuous power flow simulation is shown in Fig. 4 and Table 1. The P-V curve analysis is conducted only for a certain load bus. Load buses connected directly to generator buses are excluded in the P-V curve analysis. The effect of load variation on voltage stability is examined only on load buses with no connection link to a generator bus. As a result, load buses selected for the P-V curve analysis are bus 7, 8, 9, 11, 14, 16, 17, 18, 19, 20 and 26. Bus 3, 4, 5, 6, 10, 12, 15, 21, 24, 25, 28, 29 and 30 are connected to generator bus and are therefore excluded. Difference between the initial active power demand and the maximum power on a load bus is referred to as the collapse margin. Load bus with low collapse margin is considered as a weak bus. Therefore, load margin of the selected load buses is compared to determine the weak buses in the IEEE 30 system. As illustrated in Fig. 4 and Table 1 the bus with the highest load margin is bus 8 with a margin of 234.6 MW. Bus 26 had the least collapse margin with only 29.7 MW which makes it the most unstable or the weakest load bus.

The weakest bus also called the critical bus can be selected as the optimum connection point for reactive power compensators such as static-var compensators and renewable energy sources [2].

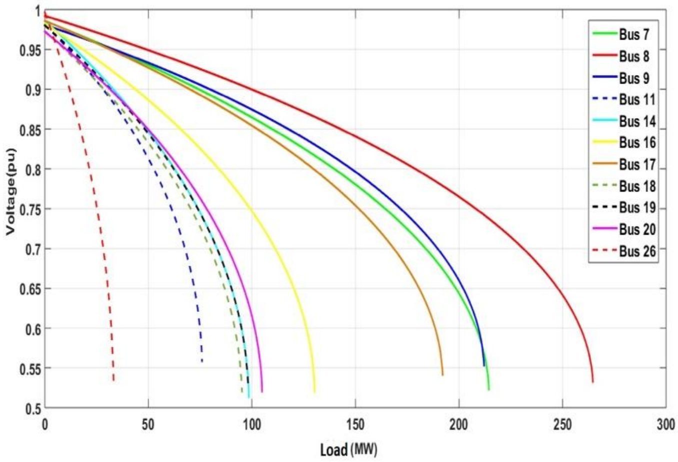

Figure 4. P-V Curve Plots of Load Buses of IEEE 30 Bus System

Table 1. Maximum demand and collapse margin of load buses of IEEE 30 bus system

Load Bus	Initial Demand (MW)	Maximum Demand (MW)	Collapse Margin (MW)
7	22.80	214.42	191.62
8	30.00	264.60	234.60
9	0.00	212.10	212.10
11	0.00	75.92	75.92
14	6.21	98.53	92.32
16	3.52	130.32	126.80
17	9.01	192.10	183.09
18	3.22	95.22	92.00
19	9.50	98.22	88.72
20	2.20	104.91	102.71
26	3.51	33.20	29.69

4. CONCLUSION

Method for identifying weak or critical buses in electrical power system was introduced in this paper. The P-V curve method was utilized in identifying the weak bus by comparing the active power margin of the load buses. Newton Raphson Continuous Power flow algorithm was utilized in carrying out the P-V curve method from which active power demand of a load bus was computed. The active power demand which are also used to compute for the collapse margin of the load buses were used for finding the weak or less stable bus. Information on bus stability helps to identify the strong and weak regions of the electrical power system and also to determine the right location for compensators.

REFERENCES

[1] Y. Chi, Y. Liu, W. Wang and H. Dai, “Voltage Stability Analysis of Wind Farm Integration into Transmission Network,” International 43Conference on Power System Technology, PowerCon 2006, pp. 1-7, 22-26 October 2006.

[2] GWEC, “Global Wind Report 2021”, Global Wind Energy Council, 25 March 2021. https://gwec.net/global-wind-report-2021/

[3] Nguyen Tung Linh, "Voltage stability analysis of grids connected wind generators," 2009 4th IEEE Conference on Industrial Electronics and Applications, 2009, pp. 2657-2660, doi: 10.1109/ICIEA.2009.5138689.

[4] Bukola B. Adetokun, Christopher M. Muriithi, Joseph O. Ojo, "Voltage stability assessment and enhancement of power grid with increasing wind energy penetration," International Journal of Electrical Power & Energy Systems, 2020, ISSN 0142-0615.

[5] I. S. Naser, O. Anaya-Lara and K. L. Lo, "Study of the impact of wind generation on voltage stability in transmission networks," 2011 4th International Conference on Electric Utility Deregulation and Restructuring and Power Technologies (DRPT), 2011, pp. 39-44, doi: 10.1109/DRPT.2011.5993859.

[6] Z. Chen, Y. Hu and F. Blaabjerg, “Stability Improvement of Induction Generator-Based Wind Turbine Systems,” IET Renewable Power Generation, Vol. 1, No. 1, pp. 81-93, March 2007

[7] E. Camm and C. Edwards, “Reactive Compensation Systems for Large Wind Farms,” IEEE/PES Transmission and Distribution Conference and Exposition, pp. 1-5, 21-24 April 2008

[8] Fritz W. Mohn, C. Zambroni de Souza: Tracing PV and QV Curves with the Help of a CRIC Continuation Method, IEEE Trans. on Power Systems, Vol. 21, Nº 3, pp.1115- 1122, 2006.

[9] Monyei, Chukwuka & Viriri, Serestina & Adewumi, Aderemi & Davidson, Inno & Akinyele, Daniel. (2018). A Smart Grid Framework for Optimally Integrating Supply-Side, Demand-Side and Transmission Line Management Systems. Energies. 11. 10.3390/en11051038.

[10] P.Kundur: Power: System Stability and Control, NY: McGraw-Hill, 1994

[11] I. K. Otchere, B. Arhin, K. A. Kyeremeh and E. A. Frimpong, "Investigation of Voltage Stability for Transmission Network with High Penetration of Wind Energy Sources," 2020 IEEE PES/IAS PowerAfrica, 2020, pp. 1-5, doi: 10.1109/PowerAfrica49420.2020.9219937.