Semiconductor Optoelectronics, *Vol. 42 No. 1 (2023), 830-836*
https://bdtgd.cn/

Semiconductor Optoelectronics ISSN: 1001-5868

VOLTAGE STABILITY MARGIN EVALUATION AND ENHANCEMENT USING STATCOM

Padmesh Singh
Madan Mohan Malaviya University of Technology, Gorakhpur, India
padmesh_tech@bbdu.ac.in

Awadhesh Kumar
Madan Mohan Malaviya University of Technology, Gorakhpur, India
akee@mmmut.ac.in

Pankaj Sahu
B.N. College of Engineering and Technology, Lucknow, India
psahu.rs.eee13@itbhu.ac.in

Manu Kumar Singh
Maharishi University of Information Technology, Lucknow, India
deepu.ram1@gmail.com

Abstract— One of the most fascinating fields for engineers and academics is voltage stability. Voltage instability has been seen to cause complete blackouts in the past. Voltage stability can now be accessed and controlled online using the synchrophasor technique. In this study, we use the continuation power flow method and phasor measurement units (PMUs) installed in the system to access the voltage stability margin. Then, we add a Static Synchronous Compensator (STATCOM) to the system to increase the voltage stability margin. STATCOM is situated on a crucial system bus. The sensitivity approach is used to find this critical gap. Results show that the voltage stability margin is increased with the addition of STATCOM to the system. The voltage stability margin evaluation and improvement method that has been suggested has been used with the IEEE 14-bus system.

Keywords— Continuation power flow (CPF), voltage instability, static synchronous compensator (STATCOM)

I. INTRODUCTION

Voltage stability plays an imminent role in the stable operation of power systems. Due to voltage instability, there may be low voltage in a large part of the power system [1]. Many control actions are observed to protect power systems from voltage instability. The main cause of voltage collapse is a deficiency of reactive power in the network. Reactive power transmission becomes difficult under heavy loads. So, reactive energy has to be injected at critical points of the system to prevent instability. The Flexible AC Transmission System (FACTS) can improve the voltage stability of the power system network due to advances in power electronics [2]. The Static Synchronous Compensator (STATCOM), being a member of the FACTS family, is able to increase the voltage stability margin by providing reactive power support. Providing reactive power injection at critical points increases the voltage stability of the system. With the use of L-index-based techniques, we can find critical or weak buses for placing STATCOM in the system [3–4]. P-V and Q-V curves have been utilised in the Tokyo voltage collapse for optimal placing and resizing of STATCOM [5–6]. These methods are expansive and take longer than expected.

The precise location and configuration of the FACTS controllers were discovered using heuristic methods. The size and location of FACTS devices were assessed using mixed integer and non-linear programming. However, local minima and calculation efforts were to blame for the issue [7]. It has been discovered that Particle Swarm Optimization (PSO) is a technique that can be used to assess STATCOM size and location difficulty. Numerous systemic issues, including economical load distribution [8], generation increases [9], and short-duration load predicting [10], were resolved using this approach. A method using particle swarm optimization for the best STATCOM location and resizing has been reported in [11]. [12] illustrates the Innovative Nonlinear (IN) H control used by STATCOM to increase the voltage stability margin. Here, the IN H controller for STATCOM was designed using the Hamiltonian function method. In [13], it was suggested to improve short-term voltage stability in order to evaluate weak buses using the idea of trajectory sensitivity. As a result of reactive power excess or deficit, STATCOM used direct active power control, as reported in [14].

The focus of the earlier research was on STATCOM's injection of reactive power to increase the voltage stability margin in an offline setting. Nowadays, it is possible to assess and improve the voltage stability margin of online power systems thanks to the development of phasor measurement units (PMUs) [15]. Here, we suggest using STATCOM and phasor measurement units to assess and improve the voltage stability margin of online power systems. We initially think of the placement of STATCOM as an offline strategy before adding PMUs to the system. Weak performance is what we get from the system when PMUs are present. After that, we use the Continuation Power Flow (CPF) method [16] to assess the voltage stability margin.

II. EVALUATION OF VOLTAGE STABILITY MARGIN

Utilizing the CPF method, the voltage stability margin has been evaluated. The nose curves are obtained by varying total system loads when we run CPF for a system. The voltage stability margin has now been decided upon as being the separation of the maximum loadability point (nose point) from the base case operating point. In an offline environment, CPF is a tool for supplying voltage stability margin. However, if PMUs are installed in the system, we can access real-time system information, or information that is available online, by using the data collected by the PMUs. The further the system is from voltage instability, the higher the voltage stability margin. The suggested approach to assessing the voltage stability margin is shown in Figure 1.

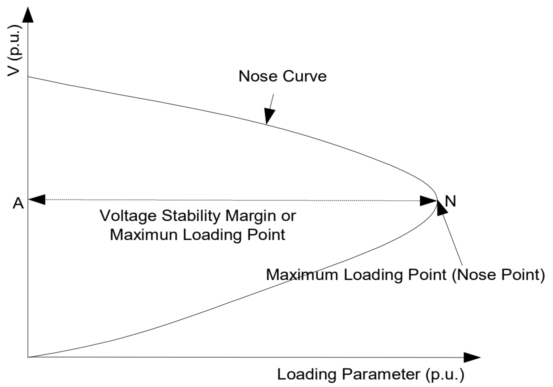

Figure 1: Evaluation of voltage stability margin

III. METHOD FOR STATCOM PLACEMENT

The system's nerve centre is STATCOM. Voltage instability is more likely to occur on a critical bus. Finding the slope of the nose curve before the nose point allows us to assess the critical bus. A critical bus is identified as having the most negative value on this slope. The bus's sensitivity is described by this slope. To obtain the nose curves, we run CPF for both the healthy system and each single-line outage system. The procedure for STATCOM placement is shown in Figure 2.

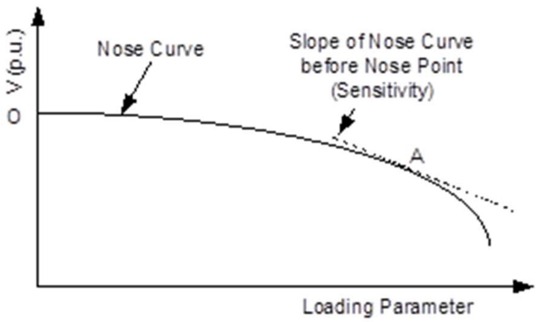

Figure 2: Evaluation of sensitivity of bus

STATCOM injects reactive power into the system's critical bus. Reactive power is added to the critical bus, increasing the system's voltage stability margin. So, the system is no longer susceptible to voltage instability. The STATCOM model used in this study is depicted in Figure 3. In this work, the STATCOM voltage regulator model is utilized. In the event that the bus voltage deviates from the reference value, STATCOM injects reactive power into the bus.

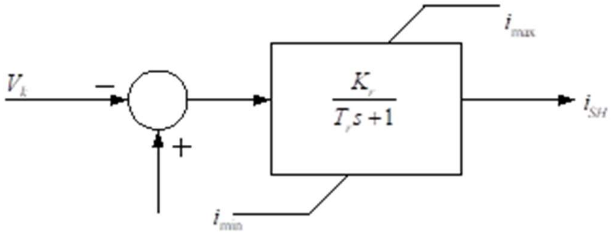

Figure 3: STATCOM modeling

IV. RESULTS AND COMMENTS

On a 14-bus IEEE system, work is done [17]. The 14-Bus IEEE System has 20 transmission lines, three synchronous condensers, and two synchronous generators at buses 1 and 2. (with three transformers). Figure 4 displays a single-line diagram of a 14-bus IEEE system.

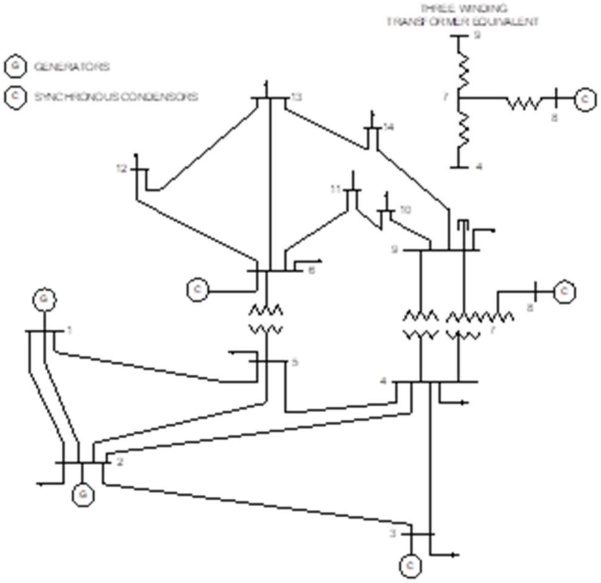

Figure 4: 14-Bus IEEE System

With PMUs installed in the system, CPF was run to assess the maximum loading margin (in this case, voltage stability margin). Using PMUs installed in the system, we identified the nose curves of the system with total system load variation. Each nose curve's sensitivity to these curves has been identified. Along with the system as it is, we also take into account all of the system's potential outcomes. We chose the critical system contingencies with the smallest voltage stability margin (lowest maximum loading margin) from among these. The bus that is most crucial to the system is a load bus with the most adverse sensitivity value. It has been observed that bus line 5 has the lowest sensitivity reading. Bus 5 has been chosen as the bus that is most important. STATCOM has been positioned on this vital system bus.

When there is a lack of reactive power in the system, STATCOM injects reactive power into the most important bus. The voltage stability margin of the system improves with the addition of reactive power, i.e., the voltage stability margin is increased with the addition of STATCOM to the system. Table I displays the voltage stability margin without using STATCOM in the system for the intact case and a few critical contingency cases.

Table II displays the voltage stability margin for an intact system and a few significant contingency scenarios with STATCOM. As can be seen from Tables I and II, the addition of STATCOM to the system has increased the voltage stability margin for both the intact system and the system under contingencies. As a result, the addition of STATCOM increases the system's voltage stability margin. Figure 5 contrasts critical bus 5's nose curve with and without STATCOM for critical contingencies 2-3. This graph shows how the system's voltage stability margin under contingencies 2-4 has increased as a result of the addition of STATOM. This is due to STATCOM injecting reactive power into the critical bus of the system. As a result, the voltage stability margin of the system increases. Bus-5 has been identified as the study's critical bus using the sensitivity method. As a result, the system's bus 5 now includes STATCOM. The addition of STATCOM to the system has increased the voltage stability margin for other critical contingencies like 1-2, 1-5, etc., as shown in Tables I and II.

TABLE I
VOLATGE STABILITY MARGIN FOR INTACT SYSTEM AND UNDER CRITICAL CONTINGENCIES OBTAINED USING CPF METHOD WITHOUT USING STATCOM IN SYSTEM (14-BUS IEEE SYSTEM)

Critical Contingency	Voltage Stability Margin
Intact Case	4.1
1-2	1.3
2-3	2.2
1-5	3.0
2-4	3.2
2-5	3.2

TABLE II
VOLATGE STABILITY MARGIN FOR INTACT SYSTEM AND UNDER CRITICAL CONTINGENCIES OBTAINED USING CPF METHOD USING STATCOM IN SYSTEM (14-BUS IEEE SYSTEM)

Critical Contingency	Voltage Stability Margin
Intact Case	4.4
1-2	1.4
2-3	2.3
1-5	3.1
2-4	3.4
2-5	3.8

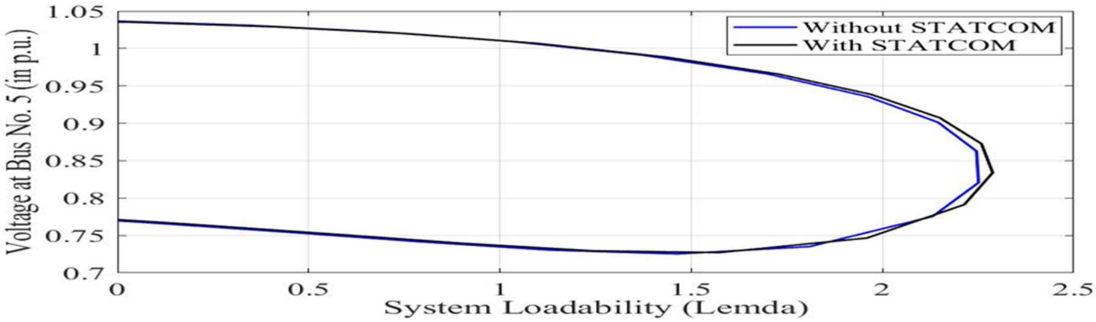

Figure 5: Comparison of nose curves of critical bus 5 with STATCOM and without STATCOM for line outage 2-3

V. CONCLUSIONS

The evaluation of voltage stability and the improvement of offline systems were the main topics of previous research. In this work, STATCOM has been used for real-time evaluation and enhancement of the voltage stability margin. Using voltage measurements from PMUs, the voltage stability margin is increased in real time. The system's critical bus can receive reactive power injection from STATCOM. With STATCOM in the system, the voltage stability margin is increased. The results for the 14-bus IEEE system demonstrate that the addition of STATCOM increases the voltage stability margin.

REFERENCES

[1] Byung Ha Lee and Kwang Y. Lee, “A Study on Voltage Collapse Mechanism in Electric Power Systems,” IEEE Trans. on Power Systems, vol. 6, no. 3, August 1991.

[2] N. G. Hingorani and L. Gyugyi, “Understanding FACTS; Concepts and Technology of Flexible AC Transmission System,” IEEE Press, NewYork, 2000.

[3] Mishra, P., Udupa, H. N., & Ghune, P., “Calculation of Sensitive Node for IEEE–14 Bus System when Subjected to Various Changes in Load,” In Proceedings of IRAJ International Conference, 21st July 2013.

[4] Sanivarapu, Nagalakshmi, R. Kalaivani, and Dr SR Paranjothi. "Optimal Location of STATCOM to Improve Voltage Stability using PSO." International journal of advanced engineering technology, vol. 2, no. 4, 2011.

[5] W. Taylor, Power System Voltage Stability, McGraw-Hill, 1994.

[6] P.Kundur, Power System Stability and Control, McGraw-Hill, 1993.

[7] N. Yorino, E. E. El-Araby, H. Sasaki and S. Harada, “A New Formulation for FACTS Allocation for Security Enhancement Against Voltage Collapse,” IEEE Trans. on Power Systems, vol. 18, no. 1, pp. 3-10, February 2003.

[8] Park, Jong-Bae, Ki-Song Lee, Joong-Rin Shin, and Kwang Y. Lee. "A Particle Swarm Optimization for Economic Dispatch with Non-Smooth Cost Functions." IEEE Transactions on Power systems, vol. 20, no. 1, pp. 34-42, February 2005.

[9] Kannan, S., S. Mary Raja Slochanal, and Narayana Prasad Padhy, "Application and Comparison of Metaheuristic Techniques to Generation Expansion Planning Problem." IEEE Transactions on Power Systems, vol. 20, no. 1, pp.466-475, February 2005.

[10] Huang, Chao-Ming, Chi-Jen Huang, and Ming-Li Wang. "A Particle Swarm Optimization to Identifying the ARMAX Model for Short-Term Load Forecasting." IEEE Transactions on Power Systems, vol. 20, no. 2 pp. 1126-1133, May 2005.

[11] J. Vishnu et al, “A Strategy for Optimal Loading Pattern of a Typical Power System – A Case Study,” International Conference on Advances in Green Energy (ICAGE), pp. 112-117, 17-18 December 2014, Trivandrum, India.

[12] Bangjun Lei and Shumin Fei, “IN H∞ Control for STATCOM to Improve Voltage Stability of Power System,” Electronics Letter, vol. 53, no. 10, pp. 670-672, May 2017.

[13] Yan Xu et al, “Multi-Objective Dynamic VAR Planning Against Short-Term Voltage Instability Using a Decomposition-Based Evolutionary Algorithm,” IEEE Trans. on Power Systems, vol. 29, no. 6, pp. 2813-2822, November 2014.

[14] Kamel Sayahi,Ameni Kadri, Ridha Karwi and Faouzi Bacha, “Study and Implementation of a Static Compensator (STATCOM) Using Direct Power Control Strategy,” IEEE 9th International Renewable Energy Congress (IREC), 20-22 March 2018, Hammamet, Tunisia.

[15] Pankaj Sahu and M. K. Verma, “Online Voltage Stability Monitoring and Control in Smart Grid-A Survey,” IEEE UP Section Conference on Electrical, Computer and Electronics (UPCON), pp. 1-6, 4-6 December 2015, Allahabad, India.

[16] V. Ajjarapu, C. Christy, “The Continuation Power Flow: A Tool for Steady State Voltage Stability Analysis,” IEEE Trans. on Power Systems, vol. 7, no. 1, pp. 416-423, February 1992.

[17] IEEE 14-Bus System; [Available:

http://www.ee.washington.edu/research/pstca/pf14/pg_tca14bus.htm].