SSRG International Journal of Electrical and Electronics Engineering
ISSN: 2348-8379/ https://doi.org/10.14445/23488379/IJEEE-V12I2P110

Volume 12 Issue 2, 82-90, February 2025

Original Article

Identification of Weak Bus in the System for Voltage Stability Analysis by Using Fast Voltage Stability Index

B. Harika[1], B. Suresh kumar[2], J. Upendar[3]

[1,3]*Elelctrical Engineering Department, University College of Engineering, Osmania University, Telangana, India*
[2]*Electrical and Electronics Engineering Department, Chaitanya Bharathi Institute of Technology, Telangana, India.*

[1]*Corresponding Author : harikagnits@gmail.com*

Received: 09 December 2024 Revised: 08 January 2025 Accepted: 06 February 2025 Published: 22 February 2025

Abstract - *In today's intricate power systems, the evaluation of voltage stability is crucial. Due to restricted power sources and rising power demands, the system operates at its full capacity. Therefore, in order to take the appropriate precautions to prevent system capacity violation, a study that can identify the maximum capacity limit before voltage collapse must be conducted. In this work, the Fast Voltage Stability Index (FVSI) is derived from the voltage stability index referenced to a line that was started from the voltage quadratic equation at the transmitting end of a depiction of a two-bus system. A line index value around 1.00 in an interconnected system means that the line's instability limit has been achieved, which may result in an abrupt voltage drop on the related bus due to a change in the reactive load. The developed index was tested on the IEEE 5, 9, and 14 buses to confirm that the suggested indication worked as intended. This method is predictive in estimating the chance of a system failure, allowing for the taking of appropriate measures to prevent such an occurrence.*

Keywords - *FVSI, Maximum capacity limit, Voltage collapse, Voltage stability, Voltage drop.*

1. Introduction

In this modern era of advanced technologies, when demand rises, the system may experience voltage instability as a consequence of an excessive load. This voltage instability might cause voltage collapse in this system. The power system's voltage collapse has been assigned top priority since it will produce congestion, which could result in cascade blackouts that affect the system. The system's voltage collapse might be identified by a study of Voltage Stability (VS) analysis. In the power system, load demand fluctuates constantly, which affects how control systems like turbine governors and automatic voltage regulators react. At different phases and through different mechanisms, a major cause of blackouts is voltage instability. as discussed by [1-3]. Globally, there are still significant obstacles in obtaining adequate information and accurately forecasting these blackout occurrences. Numerous academics have worked tirelessly to use a scientific approach to predict and prevent blackouts [4, 5]. A phenomenon is voltage instability, which can occur when a power system collapses because of a localized issue, creating instability. Therefore, it is imperative that power system voltage instability be continuously monitored and predicted. Among the several methods covered in the literature, reactive power compensation, network reconfiguration, optimally distributed generation, and network load-ability enhancement are some that are known to reduce the phenomena of voltage instability [6-11].

1.1. Research Gap

Recently, studies have been carried out to introduce Renewable Energy Sources (RES)/Distributed Generators (DGs) as a stability management problem solver. RES/DG units can be employed as a hedge against the expenses of expanding transmission and distribution. Sensitivity factors to resolve the difficulty of finding the optimum location RES/DG placement comprises of voltage performance index such as Voltage Collapse Prediction Index (VCPI), Maximum Power Transfer Stability Index (MPSI) as well as Power Transfer Stability Index (PTSI). LMP is a market-pricing technique that has shown potential as an indication to pinpoint the prospective nodes for RES/DG installation in addition to these voltage stability measures. It offers market participants a precise and transparent indication of the price of electricity at each point on the grid.

1.2. Problem Statement

Regarding a power system's capacity to maintain acceptable voltage levels, both normal and after a disturbance, voltage stability is a critical component of power system management and planning. The primary problem is to ensure that voltages at all system buses remain within prescribed limits without resulting in voltage collapse or widespread system instability. To forecast the incidence of voltage collapse along with contingency analysis brought on by line outages in a power system, this research introduces a novel

FVSI. It accelerated the voltage stability analysis procedure by proposing a simple mathematical framework. The IEEE 5,9, and 14-bus test systems were subjected to successive voltage stability and contingency assessments, which yielded encouraging findings. The line with the index value closest to 1.00 in voltage stability investigation will be considered the most crucial line, indicating a bus that could cause instability in the entire system. Reactive load, which can be attached to the bus at this time, has been regarded as the maximum allowable load, and the system's bus ranking can be accomplished by sorting the maximum allowable load in ascending order.

It is implied that the bus is the system's weakest bus if the allowable load of the smallest maximum is rated top and vice versa. Contingency ranking resulting from line outages is then ranked as per their severity. The system's most critical outage is indicated by the greatest FVSI, and vice versa. FVSI for each outage is arranged in descending order. The test system was examined utilizing the line stability index, L, and the line stability factor, LQP, to validate the suggested method. The outcomes demonstrated that the created FVSI has an indicative tool for rating the contingencies and forecasting when voltage collapse will occur. Practical implementation is feasible. This paper's primary goal is to talk about voltage stability monitoring. This kind of monitoring makes it possible to obtain data about the voltage stability of a particular transmission system. For control signals to be effectively and promptly sent to the appropriate location, the prediction needs to be accurate and timely. Voltage stability is monitored utilizing the FVSI.

2. Formulation of Index

The FVSI index has been frequently utilized to identify power system contingency analysis and voltage collapse caused by line failures. This index helps expedite voltage stability analysis by being based on a comparatively straightforward mathematical calculation. According to analysis, the critical line is the line that is close to 1.00, suggesting a bus that has the potential to disturb the whole system. To rank the system's buses, the maximum load might be put in ascending order. The weakest bus in this system has the lowest maximum allowable load, rated first in the list. The system's weakest line, which corresponds to the weakest bus, is also identified. If the system reaches this limit, it collapses.

- By gradually loading a bus, the values of the FVSI index can be found.
- Once the FVSI index value exceeds 0.9999, take note of the associated maximum capacity limit.
- Apply the same process to each system's buses and record the appropriate maximum capacity limit value.
- The maximum capacity limit values for each bus were compared.
- The system's weakest bus is the one with the lowest maximum capacity limit.

The FVSI index provides an impressive tool for identifying different voltage collapse incidences. Practical implementation is feasible, as proposed by [12].

3. Fast Voltage Stability Index

Studying the various VS conditions of the power system's bus or line is made easier with the aid of this index. A crucial line or lines connected to a weak bus are referenced by the FVSI index employed in the study. It is a simple index since the quadratic equations for voltage or power are created using a basic current equation. Setting the value of the denominator is the criterion applied in this suggested index.

The system has been considered unstable if the roots of the voltage quadratic equations are <0; otherwise, it is considered stable. For ease of comprehension and the derivation of the FVSI Index, let us consider a power system of the 2-Bus model, as seen in Figure 1. Below is a detailed explanation of the 2-Bus power system model. The FVSI Index formula also results from utilizing this same abbreviation.

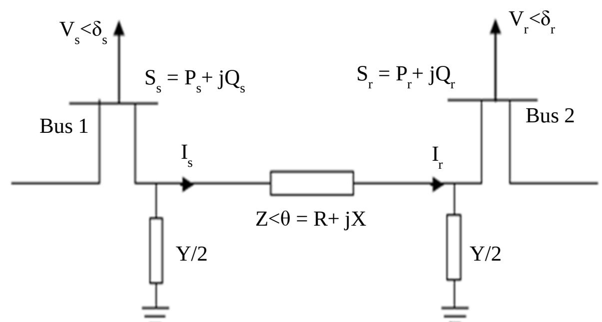

Fig. 1 2 Bus model of power system

The power system's 2-Bus model, represented symbolically in Figure 1, is:

V_s, V_r : Voltage magnitudes at the sending-end and receiving-end buses
P_s, Q_s : Active, reactive powers of the sending-end bus
P_r , Q_r : Active, reactive powers of the receiving-end bus
δs, δ_r : Voltage angles at sending-end and receiving-end buses
$Ss,_r$: Apparent powers of the sending-end and receiving-end buses
X : Reactance of a transmission line
Y: Shunt admittance (neglected for simplicity) of a transmission line
Z : Impedance of a transmission line
R : Resistance of a transmission line
θ : Angle of a line
Is, I_r : Currents of sending-end and receiving-end buses

The following formula determines the current flowing in lines (1-2):

$$I = \frac{V_s \angle 0 - V_r \angle \delta}{R + jX} \quad (1)$$

Here, V_s is sending-end bus voltage, which is likewise regarded as the line's reference voltage; as a result, the angle is set to 0.

Active power at the receiving (bus 2) has been determined by:

$$S_r = (V_r \angle \delta) * I^* \quad (2)$$

Equation (2) can be arranged like:

$$I^* = (S_r / V_r \angle \delta) \quad (3)$$

receiving-end bus (bus 2) Apparent power has been written as

$$Sr = Pr + jQr$$

We get I from Equation (2),

$$I = \frac{P_r - jQ_r}{V_r \angle -\delta} \quad (4)$$

From (1) and (4),

$$V_s V_r \angle -\delta - V_r^2 \angle 0 = (R + jX)(P_r - jQ_r) \quad (5)$$

real and imaginary parts of Equation (5), we find

$$V_s V_r \cos\delta - V_r^2 = RP_r + XQ_r \quad (6)$$

And

$$-V_s V_r \sin\delta = XP_r - RQ_r \quad (7)$$

after rearranging Equation (7), we obtain

$$P_r = \frac{RQ_r - V_s V_r \sin\delta}{X} \quad (8)$$

placing Equation (8) in Equation (6), rearranging it in a quadratic form in terms of the Vr

$$V_r^2 - \left(\frac{R}{X}\sin\delta + \cos\delta\right) V_s V_r + (X + \frac{R^2}{X}) Q_r = 0 \quad (9)$$

By solving it, we find

$$V_r = \frac{-\alpha V_s \pm \sqrt{\alpha {V_s}^2 - 4(X + \frac{R^2}{X}) Q_r}}{2}$$

Where,

$$a = \frac{R}{X}\sin\delta + \cos\delta$$

The denominator must be greater than or equal to zero to get real roots.

$$(\alpha V_s)^2 - 4\left(X + \frac{R^2}{X}\right) Q_r \geq 0 \quad (10)$$

As δ is very, very small, then

$\delta \approx 0$, Rsin $\delta \approx 0$ and Xcos $\delta \approx X$, we find

$$\frac{4Z^2 Q_r X}{(V_s)^2 (R\sin\delta + X\cos\delta)^2} \leq 1 \quad (11)$$

The suggested mathematical formula assists in the power system's voltage stability prediction, with or else without there are outages. Either bus, the line, or both may be referred to. When the index gets close to "1.0," it suggests voltage instability, which could lead to the system's collapse. All buses and related lines' voltage stability is examined utilizing the index. The sending bus as well as receiving bus are denoted by the subscripts "i" and "j," respectively, in the expression (12).

The FVSI is recommended as follows:

$$FVSI_{ij} = \frac{4Z^2 Q_j}{V_i^2 X} \quad (12)$$

4. The Technique Used for FVSI Implementation

Determining the system's weakest line in relation to its weakest bus is possible. DGs can be installed on this weakest line to help reduce congestion. This suggested approach effectively offers more details on maximum load-ability and voltage collapse issues. FVSI value of 1.00 suggested a voltage collapse point, and voltage magnitude reflects the system's congestion management behavior. The flow chart used to determine the FVSI considered in this study is displayed in Figure 2.

4.1. Methodology Followed for Implementation of FVSI

For the purpose of figuring out the system's power-flow solution, a load-flow program was first created. With the utilization of the load-flow analysis results, the FVSI index values were then determined for each and every system bus or line. Start with the base case and progressively augment the value until load-flow computation ceases to converge. Every load bus should be evaluated one after the other in order to accurately analyze the system's overall behavior. The simulation outcomes indicate the system's weak bus, critical line, and maximum load-ability limit, along with the point of voltage instability and collapse.

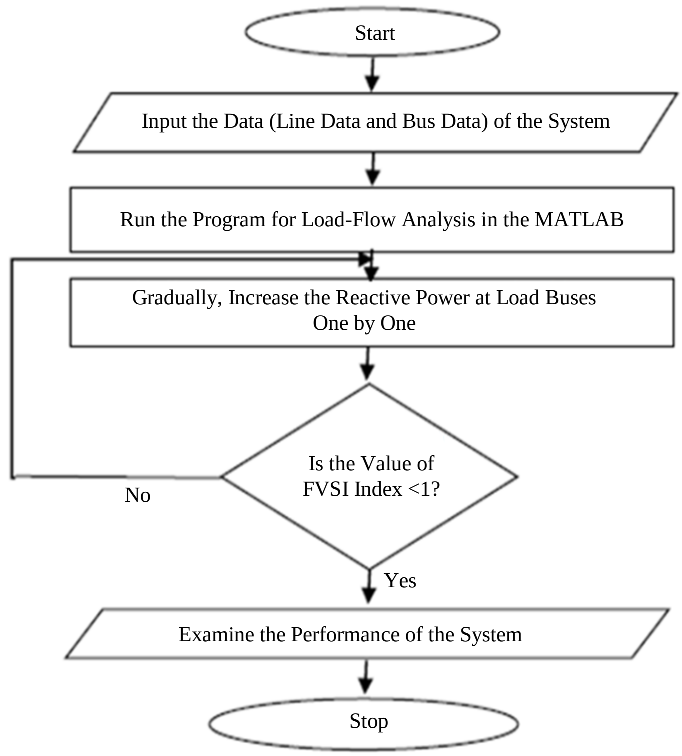

Fig. 2 Flowchart illustrating the stages involved in determining the FVSI Index

The steps that follow outline the algorithm utilized to determine the system's maximum load-ability limit:

- Step I: To find a solution for the system's power flow, the first load-flow software has been developed.
- Step II: Next, determine the FVSI index values for each system line utilizing the findings of the load-flow computation study.
- Step III: Starting with the base case, load flow should be gradually raised.
- Step IV: Determine which bus has the lowest value; the line that corresponds to that bus will be the most vital line.
- Step V: The critical line w.r.t that bus of the entire system may now be found by selecting the next load bus and repeating the previous processes.
- Step VI: A series of tests are conducted on each load bus to assess overall performance.
- Step VII: The findings show that both the system's crucial line and the weak bus's voltage instability condition
- Step VIII: While the maximum load-ability for the system of each individual bus indicates the weak bus, values derived from the FVSI index discovered close to 1.00 determine the voltage instability situation along with critical line specifying a specific bus.
- Step IX: The bus with the lowest value of the system's maximum permissible load-ability limit has been considered the weakest.

5. FVSI Application on Different Test Systems

The FVSI index is tested on a range of transmission systems, and the results indicate that it can assess the system's maximum load-ability limit values. MATLAB R2016a software has been utilized for this purpose. The FVSI index value is computed for every line of a system for every rise in load. The most important line is the one with the biggest index and the lowest maximum load-ability limit in relation to load increment; this critical line is considered the ideal location for DG deployment. The line will have an index value >1.00 if the load is pushed above the limit, which will cause instability and eventual collapse.

The test systems taken into consideration in this research for voltage stability analysis utilizing this index are as follows:

The test systems taken into consideration in this investigation for the voltage stability analysis utilizing this index are as follows:

- IEEE 5-Bus transmission system
- IEEE 9-Bus transmission system
- IEEE 14-Bus transmission system

The coding utilized for buses is as follows:

- 0 for Load Bus, that is, PQ Bus
- 1 for Slack Bus, that is, Swing Bus
- 2 for Generator Bus, that is, PV Bus

A detailed description of every transmission system has been illustrated in Table 1.

Table 1. Description of each considered transmission system

S.No.	Parameters		Various Test Systems		
			IEEE 5-Bus TransmissionSystem	IEEE 9-Bus Transmission System	IEEE 14-Bus TransmissionSystem
1.	Single Line Diagram		Shown in Figure 3	Shown in Figure 4	Shown in Figure 5
2.	Number of	Slack Bus	1	1	1
		Load Bus	4	8	11
		Generator Bus	1	3	5
3.	Number of Transmission Lines		7	11	20
4.	Frequency		50Hz	50Hz	50Hz
5.	Base Voltage		132kV	132 kV	132kV
6.	Base Power		100MVA	100MVA	100MVA
7.	Totalload	Active Power Load	1.65MW	345MW	259 MW
		Reactive Power Load	0.45MVAR	235MVAR	81.3 MVAR
8.	Calculation Maximum Ability Limit	Forload-	Shown in Table 2	Shown in Table 3	Shown in Table 4
9.	Weakest Bus(s)		Bus Number 5	Bus Number3	Bus Number13 14
10.	Critical Line		Line (2-5)	Line (3-9)	Line (13-14)

5.1. IEEE 5-Bus Transmission System

Figure 3 illustrates the IEEE 5-Bus transmission system's single line diagram. Table 2 displays the IEEE 5-Bus transmission system's bus data, whereas Table 3 displays the system's line data. The maximum capacity limit (MVar)of the IEEE 5-Bus transmission system has been displayed in Table 4. Table 4 indicates that Bus number 5 in the IEEE 5-Bus transmission system would be the ideal location for DG deployment to maintain VS and reduce congestion.

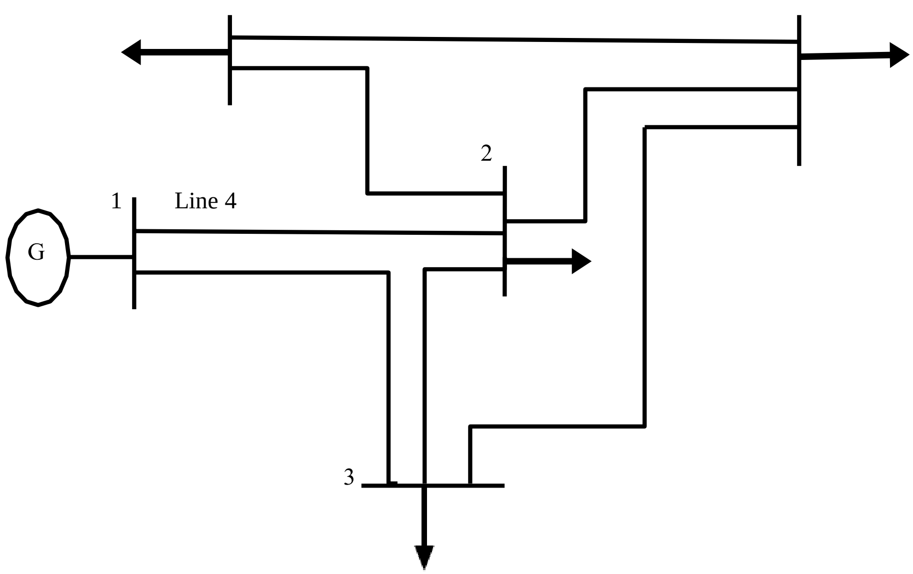

Fig. 3 The single-line diagram of the IEEE 5-bus transmission system

Table 2. Bus data of IEEE 5-bus transmission system

Bus	Maximum Capacity Limit (MVar)	Index
1	Generator Bus	-
2	403.1	0.9997
3	234.8	0.9997
4	247.3	0.9997
5	189	0.9989

Table 3. Line data of IEEE 5-bus transmission system

Bus No	Bus Code	Voltage Magnitude	Angle Degree	Load		Generator	
				MW	MVAR	MW	MVAR
1	1	1.06	0	0	0	0	0
2	0	1	0	0.20	0.10	0.4	0.3
3	0	1	0	0.45	0.15	0	0
4	0	1	0	0.40	0.05	0	0
5	0	1.0	0	0.60	0.15	0	0

Table 4. Maximum capacity limit of IEEE 5-bus transmission system

Bus Ns	Bus Nr	R (pu)	X (pu)	1/2B (pu)
1	2	0.02	0.06	0.03
1	3	0.08	0.24	0.025
2	3	0.06	0.18	0.02
2	4	0.06	0.18	0.02
2	5	0.04	0.12	0.015
3	4	0.01	0.03	0.01
4	5	0.08	0.24	0.025

5.2. IEEE 9 Bus Transmission System

A single-line diagram of the IEEE 9-Bus transmission system has been displayed in Figure 4: Bus data of IEEE 9 -Bus transmission system has been displayed in Table 5. Line data of IEEE 9 –Bus transmission system is shown in Table 6. The maximum capacity limit (MVar) of the IEEE 9-Bus transmission system is presented in Table 7. Table 7 indicates that Bus number 3 in the IEEE 9-Bus transmission system would be the ideal location for DG deployment to maintain voltage stability and reduce congestion.

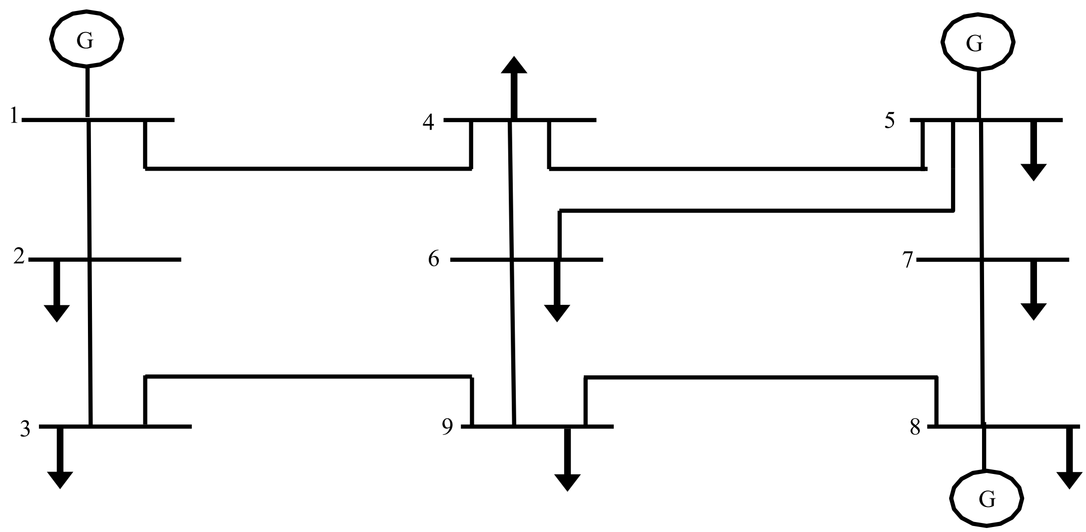

Fig. 4 Single line diagram of IEEE 9-bus transmission system

Table 5. Bus data of IEEE 9-bus transmission system

Bus No	Bus Code	Voltage Magnitude	Angle	Load		Generator	
				MW	MVAR	MW	MVAR
1	1	1.03	0	0	0	0	0
2	0	1	0	10	5	0	0
3	0	1	0	25	15	0	0
4	0	1	0	60	40	0	0
5	2	1.06	0	10	5	80	0
6	0	1	0	100	80	0	0
7	0	1	0	80	60	0	0
8	2	1.01	0	40	20	120	0
9	0	1	0	20	10	0	0

Table 6. Line data of IEEE 9-bus transmission system

Bus Ns	Bus Nr	R (pu)	X (pu)	1/2B (pu)
1	2	0.018	0.054	0.009
1	4	0.015	0.450	0.0076
2	3	0.018	0.560	0.0
3	9	0.020	0.600	0.0
4	5	0.013	0.036	0.006
4	6	0.02	0.066	0.0
5	6	0.06	0.030	0.056
5	7	0.014	0.036	0.006
6	9	0.01	0.05	0.0
7	8	0.032	0.076	0.0
8	9	0.022	0.065	0.0

Table 7. Maximum capacity limit of IEEE 9-bus transmission system

Bus Ns	Bus Nr	R (pu)	X (pu)	1/2B (pu)
1	2	0.018	0.054	0.009
1	4	0.015	0.450	0.0076
2	3	0.018	0.560	0.0
3	9	0.020	0.600	0.0
4	5	0.013	0.036	0.006
4	6	0.02	0.066	0.0
5	6	0.06	0.030	0.056
5	7	0.014	0.036	0.006
6	9	0.01	0.05	0.0
7	8	0.032	0.076	0.0
8	9	0.022	0.065	0.0

5.3. IEEE 14-Bus Transmission System

IEEE 14-Bus transmission system's single-line diagram is displayed in Figure 5. Bus data of IEEE 14 -Bus transmission system is shown in Table 8. The line data of IEEE 14 -Bus transmission system is displayed in Table 9. The maximum capacity limit of the IEEE 14-Bus transmission system has been displayed in Table 10. Since buses 13 and 14 have the lowest maximum load-ability limits, they have been regarded as the system's weakest lines and buses, respectively. Therefore, it may be considered that this is the ideal position for DG placement.

Table 8. Bus data of IEEE 14-bus transmission system

Bus No	Bus Code	Voltage Magnitude	Angle Degree	Load		Generator	
				MW	MVAR	MW	MVAR
1	1	1.06	0	0	0	40	-40
2	2	1.045	0	21.7	12.7	232	0
3	2	1.010	0	94.2	19.0	0	0
4	0	1	0	47.8	3.9	0	0
5	0	1	0	7.6	1.6	0	0
6	2	1.070	0	11.2	7.5	0	0
7	0	1	0	0	0	0	0
8	2	1.090	0	0	0	0	0
9	0	1	0	29.5	16.6	0	0
10	0	1	0	9.0	5.8	0	0
11	0	1	0	3.5	1.8	0	0
12	0	1	0	6.1	1.6	0	0
13	0	1	0	13.5	5.8	0	0
14	0	1	0	14.9	5.0	0	0

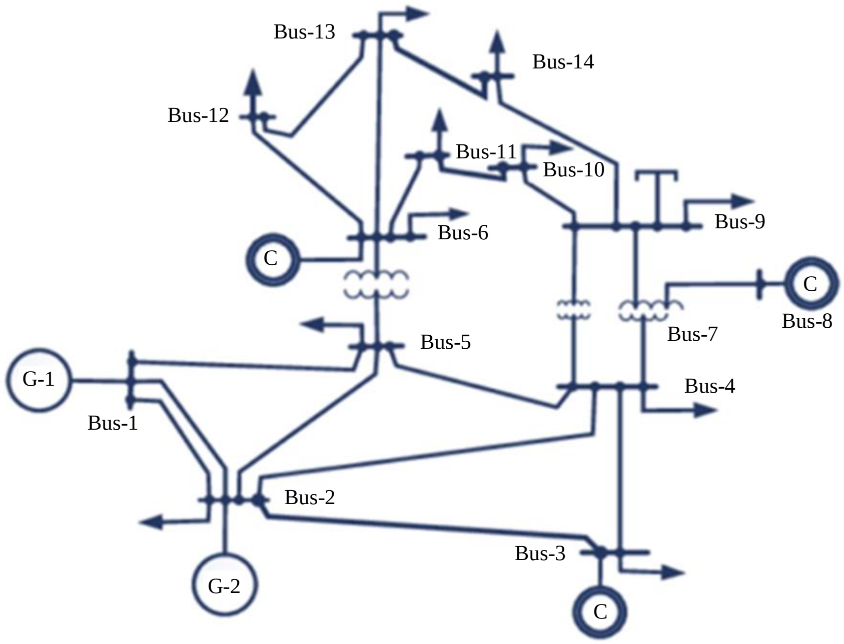

Fig. 5 Single line diagram of IEEE 14-bus transmission system

Table 9. Line data of modified IEEE 14-bus transmission system

Bus Ns	Bus Nr	R (pu)	X (pu)	1/2B (pu)
1	2	0.01938	0.05917	0.0264
1	5	0.05403	0.22304	0.0246
2	3	0.04699	0.19797	0.0219
2	4	0.05811	0.17632	0.0187
2	5	0.05695	0.17388	0.0170
3	4	0.06701	0.17103	0.0173
4	5	0.01335	0.04211	0.0064
4	7	0	0.20912	0
4	9	0	0.55618	0
5	6	0	0.25202	0
6	11	0.09498	0.19890	0
6	12	0.12291	0.25581	0
6	13	0.06615	0.13027	0
7	8	0	0.17615	0
7	9	0	0.11001	0
9	10	0.03181	0.08450	0
9	14	0.12711	0.27038	0
10	11	0.08205	0.19207	0
12	13	0.22092	0.19988	0
13	14	0.17093	0.34802	0

Table 10. Maximum capacity limit of IEEE 14-bus transmission system

Bus	Maximum Capacity Limit	Index
1,2,3,6,8	Generator bus	-
4	68	0.9937
5	67.6	0.9901
9	115	0.9915
10	111	0.9975

11	56	0.9926
12	47	0.9914
13	31	0.9769
14	32	0.9970

6. Conclusion

The bus with the lowest load-ability limit is the weakest bus, and the critical line must be established in accordance with this bus. The FVSI index values have been raised for each system under consideration until the index exceeds the 0.99 limit. The system's voltage collapse point has been indicated when the FVSI value hits 1.00. Accordingly, the voltage's magnitude reflects the system's behavior, which is highly helpful for managing congestion. It has also been noted that the system's weakest bus does not always have to be the one with the last number. The voltage instability condition, also known as the critical line and referring to the system's weakest bus, can be detected by the FVSI index. In the IEEE-5 bus system, bus 5 is considered a weak bus; in the IEEE-9 bus, bus 3 is considered a weak bus; similarly, in the IEEE-14 bus, buses 13 and 14 have been regarded as weak buses of the system.

References

[1] A. Kurita, and T. Sakurai, "The Power System Failure on July 23, 1987 in Tokyo," *Proceedings of the 27th IEEE Conference on Decision and Control*, Austin, TX, USA, vol. 3, pp. 2093-2097, 1988. [CrossRef] [Google Scholar] [Publisher Link]

[2] Yusheng Xue, "Towards Space-Time Cooperative Defence Framework against Blackouts in China," *IEEE Power Engineering Society General Meeting*, Tampa, FL, USA, PP. 1-6, 2007. [CrossRef] [Google Scholar] [Publisher Link]

[3] Dunjian Xie et al., "Operating Reserve Capacity Evaluation of Aggregated Heterogeneous TCLs with Price Signals," *Applied Energy*, vol. 216, pp. 338-347, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[4] Hongbo Shao et al., "A Three-Stage Procedure for Controlled Islanding to Prevent Wide-Area Blackouts," *Energies*, vol. 11, no. 11, pp. 1-15, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[5] Chang Han et al., "Critical Lines Identification for Skeleton-Network of Power Systems under Extreme Weather Conditions Based on the Modified VIKOR Method," *Energies*, vol. 11, no. 6, pp. 1-18, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[6] M.S.S. Danish, A. Yona, and T. Senjyu "Optimum Loadability Improvement of Weak Buses using Shunt Capacitors to Enhance Voltage Stability Margin," *Proceedings of the International Conference on Engineering and Applied Science (ICEAS)*, Japan, pp. 15-17, 2013. [Google Scholar]

[7] Heng-Yi Su, Yi-Chung Chen, and Yu-Liang Hsu, "A Synchrophasor Based Optimal Voltage Control Scheme with Successive Voltage Stability Margin Improvement," *Applied Sciences*, vol. 6, no. 1, pp. 1-12, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[8] Warid Warid et al., "Optimal Power Flow Using the Jaya Algorithm," *Energies*, vol. 9, no. 9, pp. 1-18, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[9] Yunhwan Lee, and Hwachang Song, "A Reactive Power Compensation Strategy for Voltage Stability Challenges in the Korean Power System with Dynamic Loads," *Sustainability*, vol. 11, no. 2, pp. 1-19, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[10] Sai Ram Inkollu, and Venkata Reddy Kota, "Optimal Setting of FACTS Devices for Voltage Stability Improvement using PSO Adaptive GSA Hybrid Algorithm," *Engineering Science and Technology, an International Journal*, vol. 19, no. 3, pp. 1166-1176, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[11] M.J. Vahid-Pakdel, Heresh Seyedi, and B. Mohammadi-Ivatloo, "Enhancement of Power System Voltage Stability in Multi-Carrier Energy Systems," *International Journal of Electrical Power and Energy Systems*, vol. 99, pp. 344-354, 2018.[CrossRef] [Google Scholar] [Publisher Link]

[12] D.A. Ingole, and V.N. Gohokar, "Voltage Stability Improvement in Multi-Bus System Using Static Synchronous Series Compensator," *Eenrgy Procedia*, vol. 117, pp. 999-1006, 2017. [CrossRef] [Google Scholar] [Publisher Link]