IJRR International Journal of Research and Review
www.ijrrjournal.com E-ISSN: 2349-9788; P-ISSN: 2454-2237

Research Paper

Voltage Stability Assessment and Loss Minimisation by Power System Reconfiguration

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ABSTRACT

This paper represents a circuit theory approach for voltage stability assessment in an interconnected power system network. The basic methodology implied in this technique is the investigation of each line of the system by calculating line stability indices. Here, an interconnected IEEE 14-bus network has been reconfigured into 12-, 10- and 8-bus networks using graph theory. The line stability index and fast voltage stability indicators have been used for voltage stability assessment under normal and faulted conditions for the original IEEE 14-bus network and the reconfigured i.e. 12- bus, 10- bus and 8-bus networks. Genetic algorithm has been used to determine the optimal operating condition i.e. optimum value of line stability index and fast voltage stability index with best voltage stability for the original and the reconfigured networks. The voltage stability assessment under normal and faulted conditions can be efficiently determined for the reconfigured networks compared with the original network, this has been shown by the results. It analyses the performance of line stability indices. These indices were tested in IEEE 14 bus bar test systems, with satisfactory results. The effect of reconfiguration of 14 bus power system network on power losses in branches and computation time required for finding stability indices has been observed. Also the effect of reactive load variation on stability indices of respective buses and maximum allowable load or maximum loadability of bus is found.

Key Words- Critical line, line outage, line stability index (Lmn), fast voltage stability index (FVSI), maximum loadability, voltage instability, voltage stability analysis, genetic algorithm (GA)

1. INTRODUCTION

Voltage Stability and Voltage Security are the most important concerns in our power system design, operation and planning. The power system is to be operated closer to its stability limits that cause more stress on the power system, for Providing reliable, consistent, secure and stable electrical power to the customers which is the main duty of power system engineer Therefore, a study that determines the maximum power transfer capability of the power system before voltage collapse occurs, that must be carried out in the voltage tenable and protected environment. The comparison of these different kinds of voltage stability indices is demonstrated [1] and their effectiveness has been tested on various standard IEEE bus test systems using various different scenarios of load increase. In this paper, comparison of voltage stability indices such as FVSI, Lmn, LQP, VCPI (P), VCPI (Q), VCPI (P), VCPI (l) and L-index is presented using the power flow solution in MATLAB programming and their effectiveness is demonstrated through standard IEEE-14 bus test system using novel method of load increment.

The long term objective of throwing focus on the performance of different line voltage stability indices is identifying which index is most suitable for using in control applications of bandwidth of the Wide Area Monitoring Systems (WAMS)) for future power system. To achieve this objective the important step was to create a time-domain baseline model. The results presented [2] will provide a first indication. The voltage stability indices were tested on a l 5-bus system and 39-bus system. Subramani et al. [3,4] have implemented line stability index (L-index) for contingency analysis and screening in the power systems. The performance of line stability index is demonstrated through simulation studies in IEEE 14-bus test system. For effective coordination of protection systems, lower cost of operation and construction, for facilitating efficient load transfer from one feeder to another under normal, abnormal or faulted conditions, reconfiguration of interconnected power distribution networks are often done. [5] Based on system reconfiguration approach, a method for improving voltage stability in a power network which consists of multiple lines & switches has been recommended. Out of a large number of practicable alternative combinations of lines and switches, effort has been made to find out the best possible combination of these lines and switches which results in highest voltage stability of the overall power system. For best possible switching configuration Genetic Algorithm (GA) based fast and efficient optimization technique has been advanced to obtain the global optimum voltage stability. The work reveals that optimum selection of power network lines and inter connection switches can provide the best voltage stability solution for a given loading condition.

The challenge is to find optimum switching pattern which will result least power losses and best voltage stability for the overall system for a given loading. Voltage stability improvement by proposed method is achieved without installation of additional hardware like static capacitor bank, tap-changing transformer etc. A Graph of a network is a collection of set of points or nodes interconnected by some links. [6] For a power network, the buses may be represented as nodes or vertices. The links those connect any pair of nodes are called the edges. [7,8] In the present IEEE 14-Bus Network, apparently all buses interconnected, forming several loops.

In this paper, standard IEEE 14-bus network is reconfigured into 12-, 10- and 8-bus networks with the application of graph theory – a circuit theory approach. Voltage stability assessment is done using Lmn and FVSI indicator under normal and faulted conditions for the reconfigured networks. The optimal operating condition with best voltage stability for the reconfigured networks is obtained with GA tool in MATLAB.

2. Assessment of voltage stability

Voltage stability assessment in a power network can be done by the methods such as power flow Jacobian method, conventional power flow method, continuation power flow method, participation factor method, P-V curves method, Q-V curves method, model analysis, minimum singular value, sensitivity analysis, reactive power optimisation, artificial neural networks, neuro-fuzzy networks, reduced Jacobian determinant, energy function methods, Thevenin’s impedance indicator and loading margin by multiple power-flow solutions. [9]

The condition of voltage stability in a power system can also be determined using voltage stability indicator. These indicators may be based on static analysis or dynamic analysis of the power systems. There are different types of stability indicators (i.e.) loading margin, L-index, voltage collapse prediction index, power transfer stability index, line stability index, fast voltage stability index. Out of which line stability index and fast voltage stability index will be used for voltage stability analysis.

2.1 Stability criterion

Stability indicators are used to analyse stability conditions of a particular power system. Depending on the values of stability indicators, the following criterions are used for the stability assessment of the system.

If value of the stability indicators is lesser than one, then that bus or line is in stable condition.

If value of the stability indicators is greater than or equal to one, then the bus or line is in unstable condition.

2.2 Line Stability Index (Lmn)

The stability criterion is used to find the line stability index for each line connected between two bus bars in an interconnected network. Voltage collapse can be accurately predicted using the stability indices of lines,. Primitive element of an interconnected network [10] where the line stability index is derived from is shown in Fig. 3.7, V_s and V_r are sending and receiving end voltages. R+jX is impedance of the transmission line and P+jQ is receiving end apparent power.

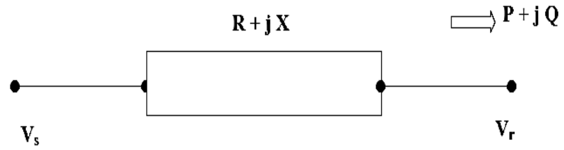

Figure 2.2 Primitive element of an interconnected network [10]

The formula used for calculating the line stability index (Lmn) is given below [11,12]

$$L_{mn} = \frac{4XQ}{[V_s \sin(\theta - \delta)]^2}$$

where ,

Vs is sending end voltage (per unit),

X is reactance ofthe transmission line (per unit),

Q is receiving end reactive power (per unit),

θ is impedance angle (degree),

δ is angle between the sending end voltage and receiving end voltage (degree).

As long as the stability index L_{mn} remains less than I, the system is stable and when this index exceeds the value 1, the whole system loses its stability and voltage collapse occurs. That is the reason, the proposed line stability index can be used in voltage collapse prediction.

2.3. Fast Voltage Stability Index (FVSI)

The FVSI stability index is calculated as: [13]

$$FVSI_{sr} = \frac{4Z^2 Q_r}{V_s^2 X}$$

Where,

Z is the line impedance;

X is the line reactance;

Q_r is the reactive power flow at the receiving end;

V_s is the sending end voltage.

Also, for the FVSI operations at secure and stable conditions require values of below 1. The line that exhibits FVSI closest to 1 is the “weakest” of the system, as this would be the line where the first instability would occur. As a side note the simplification on the angle makes it obvious that using this index in dynamic conditions when the system has already deviated from the “normal” equilibrium point would lead to incorrect results.

3. Circuit theory approach

In this paper, proposed approach is circuit theory approach i.e. network reconfiguration technique is used. IEEE 14 bus system is reconfigured into 12-bus,10-bus and 8-bus system.

3.1 Test System: IEEE 14 Bus System

Simulink model of IEEE- 14 bus system with base MVA is 100 and base voltage 69 KV is designed. [14] It consists of 14 transmission lines, 10 static loads and 4 transformers. IEEE 14 reliability system is used to study the comparison of the performance of selected line stability indices i.e. line stability index and fast voltage stability index for validation purposes.

The single-line diagram of the standard IEEE 14-bus test network is shown in Fig 3.1

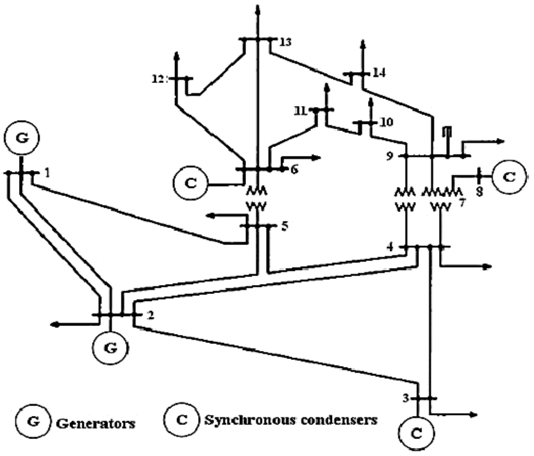

Figure 3.1 Single-line diagram of standard IEEE-14 bus test network [10]

3.2 Procedure for stability assessment

The procedure for voltage stability assessment using Lmn is given as below

Step 1: The graph of the original 14-bus network has been drawn with all the buses indicated by 'dots' and elements are replaced by 'line segments'.

Step 2: The graph is reconfigured into 12-, 10- and 8-bus networks by eliminating the series nodes where the generators are not connected and the corresponding changes in impedances are considered.

Step 3: Load flow analysis is carried out using Newton–Raphson method in matpower for both the original and reconfigured networks.

Step 4: Outputs of load flow analysis are used for the calculation of Lmn values and FVSI values.

Step 5: The optimal values of Lmn are found out using genetic algorithm and the parameters corresponding to the optimal values are identified.

Step 6: Steps 4 and 5 are carried out for the original network and then repeated for all the three reconfigurations.

Step 7: Line outage is considered in both the original and the reconfigured networks, and the Lmn values and FVSI values are calculated under faulted conditions.

Step 8: Stability assessment and the calculation of computation time are determined for the original and the reconfigured networks under normal and faulted conditions.

3.3 Methodology

Voltage stability assessment is done using the procedure specified in Section 3.1. Here, reconfiguration of the original (standard IEEE 14-bus) network shown in Fig. 2 is done on graph concept. Three different reconfigurations, 12-, 10- and 8-bus are selected. The characteristics of the reconfigured networks and the stability assessment are discussed in the following sections.

3.3.1 Network reconfiguration

The graph of the IEEE 14 Bus System network showninFig.3.3.1ahas14nodesand20lines because nodes represent number of buses and lines represent number of branches. Reconfiguration is done on this graph by eliminating the series connected nodes where the generators are not connected, since eliminating a node with generators is not advisable. In the 14-bus network, nodes 1 and 2 are having generators. Hence, those nodes are not involved in the node elimination process.

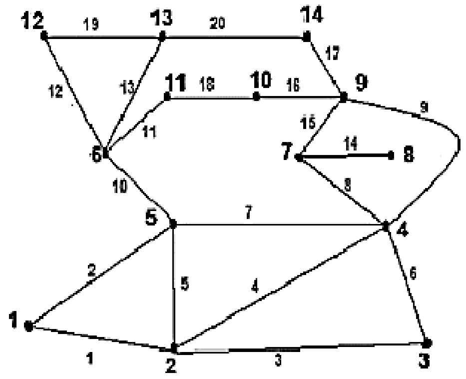

Figure 3.3.1a original 14 bus network

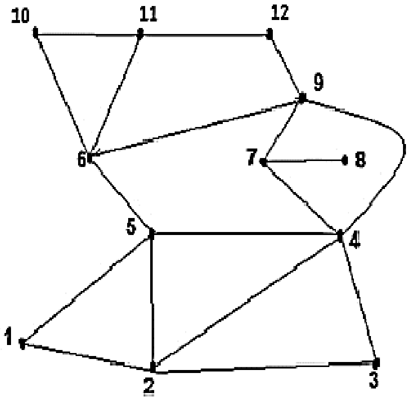

Figure 3.3.1b Reconfigured 12 bus network

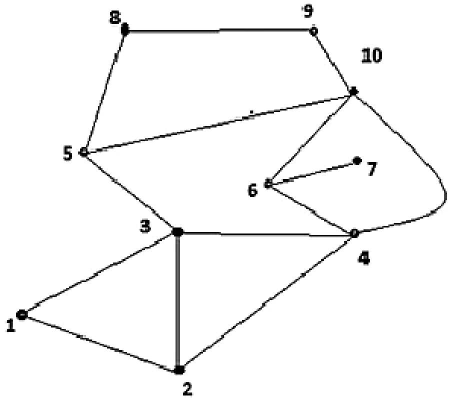

Fig.3.3.1c Reconfigured 10 bus network

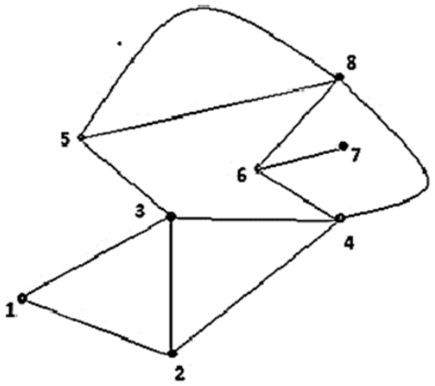

Fig3.3.1d Reconfigured 8 bus network

The corresponding changes in branch data of system because of node elimination are also carried out. To reconfigure the graph of the 14-bus network, the series connected nodes 10 and 11 are eliminated to obtain the reconfigured 12-bus network as shown in Fig. 3.3.1b. Similarly, nodes 3 and 10 in reconfigured 12-bus network are eliminated to obtain reconfigured 10-bus network as shown in Fig. 3.3.1c and also, nodes 8 and 9 in reconfigured 10-bus network are eliminated to obtain reconfigured 8-bus network as shown in Fig. 3.3.1d. The changes in impedances of the line because of this node elimination are carried out.

3.3.2 Effect of reactive load variation:

Test of reactive load variation was conducted on the IEEE 14 bus test system.[15] Three load buses were randomly chosen in order to investigate the effect of reactive power loading on the indices as mentioned. Reactive loads increment is done graduallyat buses 10, 11 and 14 from the based case till their maximum allowable load or maximum loadability. The maximum load that could be injected to a load bus before the power flow solution diverges, is called maximum loadability. Lmn index, FVSI index [16] indices were performed for each line in the system for every load increase. The line with the highest value of voltage stability indices with respect to a load increase will be considered as the most critical line. Any further increment of the load will lead the line to have indices greater than 1.00 and cause the whole system to be unstable.

In order to reveal the critical bus of an electrical power system and the stability of each line connected between two bus in an interconnected network, several line stability indices have been proposed.

4. RESULTS AND DISCUSSIONS

Load flow results using Newton–Raphson method are obtained for the original and the reconfigured networks. Still Newton–Raphson method holds its place for load flow analysis, although several other methods are available for load flow analysis. The real and reactive power losses of original and reconfigured networks are shown in Fig. 4.1. It is observed from the Fig. 4.1 that power losses are minimum in the reconfigured network compared with the original network.

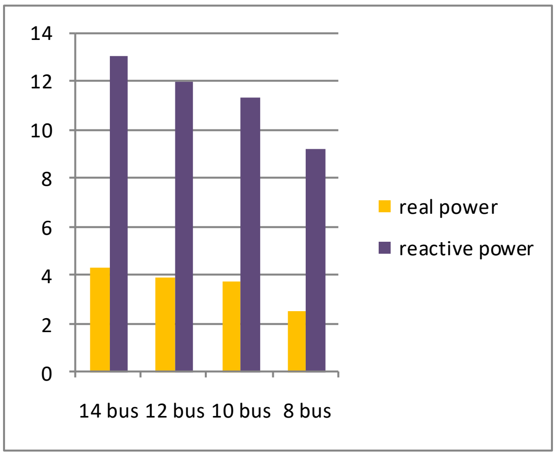

Figure 4.1 Real and reactive power losses in the system

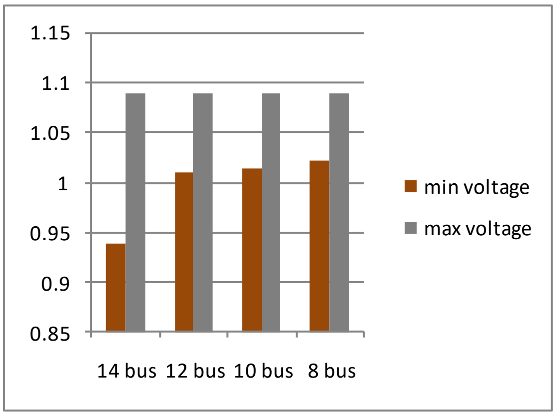

Figure 4.2Voltage profile

Voltage profile of the original and the reconfigured networks are given in Fig.4.2. There is an improvement in the minimum value of bus voltage of the reconfigured networks compared with the original network; however there is no change in the maximum bus voltage.

Minimum values of Lmn and FVSI or the values nearer to zero indicate that the network is more stable. Line outage fault or open circuit fault is considered in Line (4–5) of the original network. Lmn and FVSI values are very much greater than 1 which gives the stability condition as ‘Unstable’ without any ambiguity. This is an advantage of the proposed method compared with the conventional methods where ‘Unstable’ conditions would have Lmn and FVSI values slightly greater than 1. The line with minimum value of Lmn, FVSI and the faulted line with Lmnand FVSI greater than1 are highlighted in Tables 1-4.

Table1: Lmn and FVSI values and stability of 14 bus system

From BUS	To BUS	Normal condition			Faulted condition		
		Lmn	**FVSI**	**Stability condition**	**Lmn**	**FVSI**	**Stability condition**
1	2	0.0689	0.0646	STABLE	0.0689	0.0646	STABLE
1	5	0.0207	0.0187	STABLE	0.0207	0.0187	STABLE
2	3	0.0133	0.0123	STABLE	0.0133	0.0123	STABLE
2	4	0.0232	0.0216	STABLE	0.0232	0.0216	STABLE
2	5	0.0155	0.0148	STABLE	0.0155	0.0148	STABLE
3	4	0.0363	0.0374	STABLE	0.0363	0.0374	STABLE
4	5	0.025	0.0254	STABLE	6.9808	7.0951	UNSTABLE
4	7	0.0922	0.0919	STABLE	0.0922	0.0919	STABLE
4	9	0.0375	0.0372	STABLE	0.0375	0.0372	STABLE
5	6	0.0788	0.0781	STABLE	0.0788	0.0781	STABLE
6	11	0.0297	0.0294	STABLE	0.0297	0.0294	STABLE
6	12	0.0263	0.0259	STABLE	0.0263	0.0259	STABLE
6	13	0.0396	0.0389	STABLE	0.0396	0.0389	STABLE
7	8	0.1102	0.1102	STABLE	0.1102	0.1102	STABLE
7	9	0.0194	0.0194	STABLE	0.0194	0.0194	STABLE
9	10	0.0145	0.0145	STABLE	0.0145	0.0145	STABLE
9	14	0.0406	0.0398	STABLE	0.0406	0.0398	STABLE
10	11	0.0135	0.0135	STABLE	0.0135	0.0135	STABLE
12	13	0.012	0.0119	STABLE	0.012	0.0119	STABLE
13	14	0.026	0.0256	STABLE	0.026	0.0256	STABLE

Table2: Lmn andFVSI values and stability of 12 bus system

From BUS	To BUS	Normal condition			Faulted condition		
		Lmn	**FVSI**	**Stability**	**Lmn**	**FVSI**	**Stability**
1	2	0.06234	0.05857	STABLE	0.06234	0.05857	STABLE
1	5	0.02318	0.02113	STABLE	0.02318	0.02113	STABLE
2	3	0.0105	0.00966	STABLE	0.0105	0.00966	STABLE
2	4	0.03726	0.03475	STABLE	0.03726	0.03475	STABLE
2	5	0.007	0.0067	STABLE	0.007	0.0067	STABLE
3	4	0.01978	0.0204	STABLE	0.01978	0.0204	STABLE
4	5	0.0286	0.02919	STABLE	6.90881	7.0363	UNSTABLE
4	7	0.07246	0.07246	STABLE	0.07246	0.07246	STABLE
4	9	0.0017	0.0017	STABLE	0.0017	0.0017	STABLE
5	6	0.1089	0.1086	STABLE	0.1089	0.1086	STABLE
6	9	0.09802	0.10028	STABLE	0.09802	0.10028	STABLE
6	10	0.03325	0.03285	STABLE	0.03325	0.03285	STABLE
6	11	0.05014	0.04959	STABLE	0.05014	0.04959	STABLE
7	8	0.10537	0.10536	STABLE	0.10537	0.10536	STABLE
7	9	0.0286	0.02869	STABLE	0.0286	0.02869	STABLE
9	12	0.00997	0.00965	STABLE	0.00997	0.00965	STABLE
10	11	0.022	0.02207	STABLE	0.022	0.02207	STABLE
11	12	0.06529	0.06554	STABLE	0.06529	0.06554	STABLE

Table3: Lmn and FVSI values and stability of 10 bus system

From BUS	To BUS	Normal condition			Faulted condition		
		Lmn	FVSI	Stability	Lmn	FVSI	Stability
1	2	0.0582	0.0548	STABLE	0.0582	0.0548	STABLE
1	3	0.0151	0.01384	STABLE	0.0151	0.01384	STABLE
2	4	0.0272	0.0255	STABLE	0.0272	0.0255	STABLE
2	3	0.0111	0.0106	STABLE	0.0111	0.0106	STABLE
3	4	0.0301	0.0296	STABLE	7.139	7.0205	UNSTABLE
4	6	0.0934	0.0933	STABLE	0.0934	0.0933	STABLE
4	10	0.0504	0.0502	STABLE	0.0504	0.0502	STABLE
3	5	0.0987	0.098	STABLE	0.0987	0.098	STABLE
5	10	0.0017	0.00167	STABLE	0.0017	0.00167	STABLE
5	8	0.0345	0.03392	STABLE	0.0345	0.03392	STABLE
6	7	0.0885	0.0885	STABLE	0.0885	0.0885	STABLE
6	10	0.0071	0.00708	STABLE	0.0071	0.00708	STABLE
10	9	0.0508	0.0498	STABLE	0.0508	0.0498	STABLE
8	9	0.0113	0.01114	STABLE	0.0113	0.01114	STABLE

Table4: Lmn and FVSI values and stability of 8 bus system

From BUS	To BUS	Normal condition			Faulted condition		
		Lmn	FVSI	Stability	Lmn	FVSI	Stability
1	2	0.0157	0.01465	STABLE	0.0157	0.01465	STABLE
1	3	0.0089	0.02404	STABLE	0.0089	0.02404	STABLE
2	4	0.0489	0.04773	STABLE	0.0489	0.04773	STABLE
2	3	0.0064	0.04001	STABLE	0.0064	0.04001	STABLE
3	4	0.0263	0.00526	STABLE	7.1175	6.9654	UNSTABLE
4	6	0.065	0.0866	STABLE	0.065	0.0866	STABLE
4	8	0.0283	0.05206	STABLE	0.0283	0.05206	STABLE
3	5	0.0887	0.06572	STABLE	0.0887	0.06572	STABLE
5	8	0.0265	0.04849	STABLE	0.0265	0.04849	STABLE
6	8	0.0577	0.00363	STABLE	0.0577	0.00363	STABLE
6	7	0.1571	0.00317	STABLE	0.1571	0.00317	STABLE

4.1 Determining the Maximum Loadability for Weak Bus Identification

To find maximum loadability of any bus first its base case loading is found out using newton Raphson's load flow. Hence, the value of base case loading of buses 10,11 and 14 are given and also the values of line stability index and fast voltage stability index are given below.

Table-5Line Stability Indices for IEEE 14 Bus Test System with Base Case Loading

Load (p.u.)	Line	Lmn	FVSI
Q10 =0.058	9-10	0.0145	0.0145
	10-11	0.0135	0.0135
Q11 =0.018	6-11	0.0297	0.0294
	10-11	0.0135	0.0135
Q14 =0.050	9-14	0.0406	0.0398
	13-14	0.0260	0.0256

In order to determine the weak buses of the power system, the reactive load at each load bus is slowly increased with the level of voltage collapse. Values of all the line stability indices raise as the reactive power loading is increased. The reactive load to the bus where the line stability indices are close to 1 is considered as maximum permissible reactive load at that particular bus. The results are verified by using the different types of line voltage stability indices such as Lmn, FVSI.

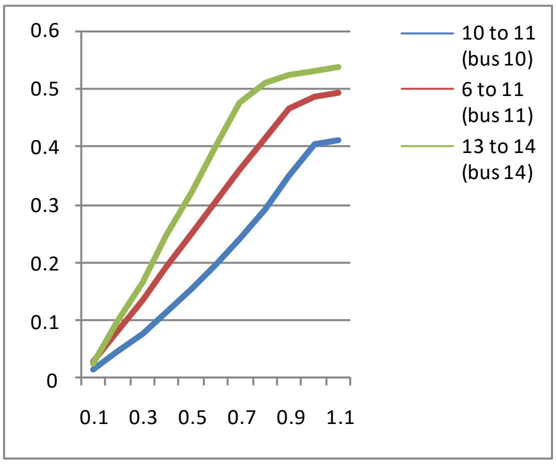

Figure 4.1.1L$_{mn}$ versus reactive load variation for IEEE 14 bus test system

Table6: Line Stability Indices for 14 Bus Test Systemswith Heavy Reactive Loading

Load (p.u.)	Line	Lmn	FVSI
Q10 =0.948	9-10	0.2501	0.2538
	10-11	0.4060	0.4001
Q11 =0.858	6-11	0.4916	0.5099
	10-11	0.2359	0.2423
Q14 =0.72	9-14	0.5066	0.5220
	13-14	0.5367	0.5554

By referring to Table 6, line 13-14 connected to bus 14 is the most critical line as the results are supported by the various types of line stability indices. Comparison of indices demonstrates that FVSI index is closest to 1. For the same loading, Lmn index show almost consistent results. Results show that the line 6-11 is the most critical line referred to bus 11 because it gives the highest indices values for the maximum loadability of the bus. Alike line 10-11 is the most critical line with respect to bus 10.The line stability indices can also be used to identify the weakest bus in the system by considering the maximum permissible load at the particular bus. By referring to Fig 4.1.2, the buses 10, 11 and 14 indicated 94.80 MVAR, 85.8 MVAR and 72MVAR as the maximum permissible of reactive load respectively in IEEE 14 bus test system.

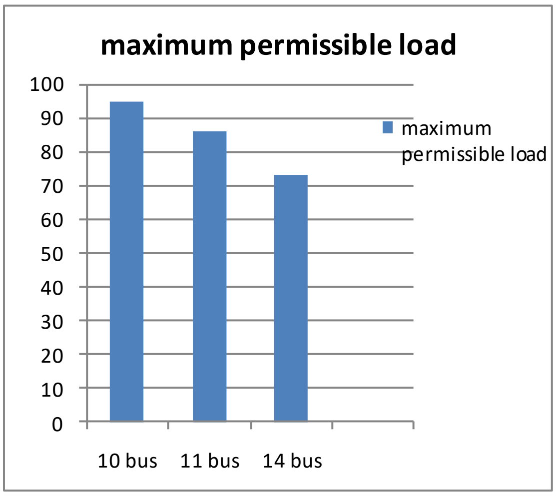

Figure 4.1.2 Maximum permissible reactive load on IEEE 14 bus test system

Therefore, the bus 14 has the smallest maximum loadability; it is considered to be the most critical unstable bus because this bus sustains the lowest load in IEEE 14 bus test system. The voltage at the maximum computable FVSI prior to the divergence of the load flows are found out. The minimum and maximum voltages at different buses for reactive loadings at chosen bus are given below.

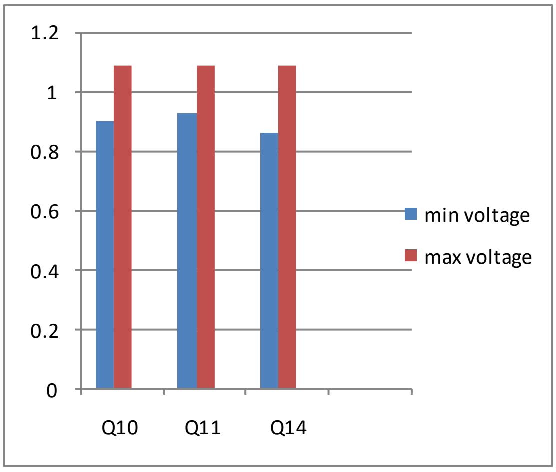

Figure 4.1.3 minimum and maximum voltages at different reactive loading

It can be observed from graph given in figure 4.1.3 that minimum voltages are obtained at buses which are loaded i.e. the maximum load that could be injected to a load bus before the power flow solution diverges applied to bus 10 then minimum voltage is at bus 10. If maximum reactive load is applied at bus 11 then minimum voltage is obtained at bus 11.Same thing is applicable for 14 bus. It is seen that reactive load at bus and voltage at that bus are inversely proportional.

4.2 Lmn and FVSI using genetic algorithm

Calculation of Lmn and FVSI is considered as an optimisation problem with the objective function as the minimisation of the value of Lmn and FVSI. The ranges of the parameters given in Table 7 are determined from the output of Newton–Raphson load flow analysis.

Table 7: Range of parameters for various configurations

14-bus	12-bus	10-bus	8-bus
$0.04211 \le X \le 0.55618$	$0.05917 \le X \le 0.55618$	$0.05917 \le X \le 0.55618$	$0.05917 \le X \le 0.55618$
$0 \le Q \le 0.43711$	$0 \le Q \le 0.5968$	$0 \le Q \le 1.37035$	$0 \le Q \le 0.80497$
$0.940 \le Vs \le 1.09$	$1.010 \le Vs \le 1.09$	$1.014 \le Vs \le 1.09$	$1.022 \le Vs \le 1.09$
$42.13759 \le \theta \le 90$	$42.1376 \le \theta \le 90$	$42.1376 \le \theta \le 90$	$61.0217 \le \theta \le 90$
$0 \le \delta \le 8.141$	$0 \le \delta \le 7.8627$	$0 \le \delta \le 5.209$	$0 \le \delta \le 3.15389$

The optimal value of Lmn and FVSI is obtained using the GA [17] Tool in MATLAB from the randomly selected 40 samples. The optimal values of Lmn and FVSI and its corresponding parameters are tabulated in Table 6. The optimal value of Lmn and FVSI and its corresponding parameters can provide the best voltage stability condition of the network. The options selected in GA tool are as follows:

Population Type: double vector.
Population size: 20 (default).
Creation function: constraint dependent.
Scaling function: rank.
Selection function: stochastic uniform.
Number of iterations: 51.

Other values such as initial population, initial scores and initial range are set with default values.

The variation of Lmn and FVSI for different samples is shown in Fig. 6. These variations help to identify the locations of minimum values of Lmn and FVSI at which the network is more stable.

Line (4–5) in the original 14-bus network shown in Fig. 3.3.1a is same as the line (4–5) in 12-bus configuration shown in Fig. 3.3.1b and line (3–4) in 10-bus shown in Fig. 3.3.1c and 8-bus shown in Fig. 3.3.1d configurations. Line outage fault is considered in the reconfigured networks also. Lmn and FVSI values show the stability condition as 'Unstable' in the faulted line. In the Tables 1-4, the 'Unstable' condition is indicated in the same line of original and the reconfigured networks. Hence, for stability assessment under faulted conditions, reconfigured networks are sufficient instead of the original network. For example in the above case, line (4–5) is identified as faulted line in the original 14-bus network. This line can be identified even with the 8-bus configuration without involving many calculations. The computation time for stability assessment of the original and the reconfigured networks under normal and faulted conditions are given in Table 7. The computation time is very much lesser in 8-bus configuration compared with the other configurations, which will be useful for taking preventive and control actions quickly.

Table 8: computation times of line stability index and fast voltage stability index

BUS	Index	14 BUS	12 BUS	10 BUS	8 BUS
Computation time, s	L_{mn}	0.589081	0.207421	0.035515	0.022289
	FVSI	0.024549	0.016591	0.008882	0.002431

Table9 values of Lmn and FVSI by GA

Buses	14	12	10	8
Line stability index x 10^{-2}	0.0018083	0.038602	0.39995	0.086337
Fast voltage stability index x 10^{-2}	0.001709	0.02954	0.30558	0.073984

CONCLUSION

The introduction of graph theory i.e. circuit theory approach reduces the power loss in the system and computation time required for voltage stability assessment after reconfiguration. . Power loss i.e. real power loss and reactive power loss in the power system is less for 8 bus system. Also, the computation time is least for 8-bus compared to 14-bus,12-bus and 10- bus power system. It is observed that if system becomes unstable then line stability indices values are greater than one. Instability of branch is independent of value of line stability indices which is more than one. If voltage stability index is greater than one it is unstable condition. In case of Lmn the unstable case is immediately indicated by the value greater than one. However, the magnitude of values of line stability indices for unstable line for the different reconfigured networks does not give proper indication towards trend of instability. Hence, it is concluded that the simple reconfigured networks are sufficient for voltage stability assessment instead of the entire complicated original network i.e. voltage stability assessment can be done with reconfigured 8-bus system instead of original 14- bus system network.

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How to cite this article: Molekar P, Pande VN. Voltage stability assessment and loss minimisation by power system reconfiguration. International Journal of Research and Review. 2019; 6(8):468-477.

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