STATIC VOLTAGE COLLAPSE ASSESSMENT FOR BULK POWER SYSTEM NETWORK (SVCA)

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Abstract

This paper presents the static voltage collapse assessment for bulk power system network. The study involves computation of line stability factor termed as LQP to indicate the voltage stability in a Power System. LQP was formulated based on a transmission line model and used to identify the voltage stability condition of all lines in a system. The voltage stability assessment was performed on several loading condition in order to identify the effect of increase in loading to line sensitiveness in the system. The proposed static voltage collapse assessment was tested on the 57 Bus RTS. Several load buses were subjected to load variation for this assessment.

I. INTRODUCTION

During the past few years, the restricted growth of electric transmission system and increasingly higher power demands have forced utilizes to operate power network relatively close to their transmission limits [1]. As system load increases, voltage magnitude throughout a power network will slow decline and continuing increasing in loads may eventually drive a power system to a state of voltage instability and may cause a voltage collapse. These issues have subsequently motivated further research in the area of voltage stability analysis. Many techniques have been developed in order to evaluate voltage stability in a system [1].

This paper presents the static voltage collapse assessment in a bulk power network. The use of a pre developed line stability factor, termed as LQP has been effectively assessed the possibility of voltage collapse in a bulk power system network.

II. POWER SYSTEM STABILITY ASSESSMENT

Power system stability is defined as a characteristic for a power system to remain in a state of equilibrium at a normal operating condition and to restore an acceptable state of equilibrium after disturbance [11]. Voltage stability power system is defined as the ability of system to maintain steady acceptable voltage at all busses in the system at normal operating conditions and after being subjected to a disturbance [2].

A. Classification of Power System Stability

Traditionally, the stability problem has been classification with angle stability and voltage stability. Angle stability is the ability to maintain synchronism operation and voltage stability is ability to maintain steady acceptable voltage with the reactive power is balance. The voltage stability is divided by static voltage stability and dynamic voltage stability [1]. The meaning of Static voltage stability in power system is refused to loading condition of the system where it incrementally and slowly (in certain direction) to the point of voltage collapse [2]. Also dynamic voltage stability is a dynamic power system model including generator, exciter governor and dynamic.

B. Line Stability Factor *LQP*

In this section, the formulation proposed by Mohammad is based on the power transmission concept in a single line on power systems [1]. The transmission line model is shown in Fig.1.0

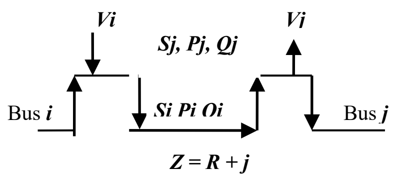


Fig.1.0 single line of power transmission concept

From the figure:

X = line reactance
Q*b* Q*j* = reactive powers at the sending end and receiving end
P*b* P*j* = sending end power and reactive end power
V*i* V*j* = sending end voltage and reactive End voltage

The formula begins with the current equation in a line given by:

$$I = \sqrt{\frac{Pi^2 + Qi^2}{Vi^2}} \quad (1.0)$$

The active and reactive power losses in a line are given by equations (1.0) and (2.0) respectively:

$$Pi - Pj = I^{2R} \quad (2.0)$$

(2.(

$$Qi - Qj = I^2 X \quad (3.0)$$

Taking the square of the current magnitude in equation (1.0) lead to:

$$I^2 = \frac{Pi^2 + Qi^2}{Vi^2} \quad (4.0)$$

Rearranging equation (4.0) for I^2 gives:

$$I^2 = \frac{Qi - Qj}{X} \quad (5.0)$$

Equation (5.0) and (6.0) gives:

$$\frac{Pi^2 + Qi^2}{Vi^2} = \frac{Qi - Qj}{X} \quad (6.0)$$

Rearranging (7.0) into quadratic equation in Q*i* yields

$$\frac{X}{Vi^2} Qi^2 - Qi + \left(\frac{X}{Vi^2} Pi^2 + Qj \right) = 0 \quad (7.0)$$

In order for Q*i* to have real roots the discriminate must be greater than or equal to zero

$$(-1)^2 - 4\left(\frac{X}{Vi^2} \right)\left(\frac{X}{Vi^2} Pi^2 + Qj \right) \geq 0 \quad (8.0)$$

$$4\left(\frac{X}{Vi^2} Pi^2 + Qj \right) = \leq 1 \quad (9.0)$$

The stability factor for line connecting bus i and j can be written as:

$$LQP = 4\left(\frac{Xij}{Vi^2} \right)\left(\frac{Xij}{Vi^2} Pi^2 + Qj \right) \quad (10.0)$$

LQP must be kept less than 1.0 in order to maintain real roots of Q*i* in order to maintain a stable system. LQP will be repetitively.

III. METHODOLOGY

The algorithm of voltage collapse assessment is represented in the flow chart appeared in Fig.2. The values of LQP computed from the assessment obtained based on the system from collapse point.

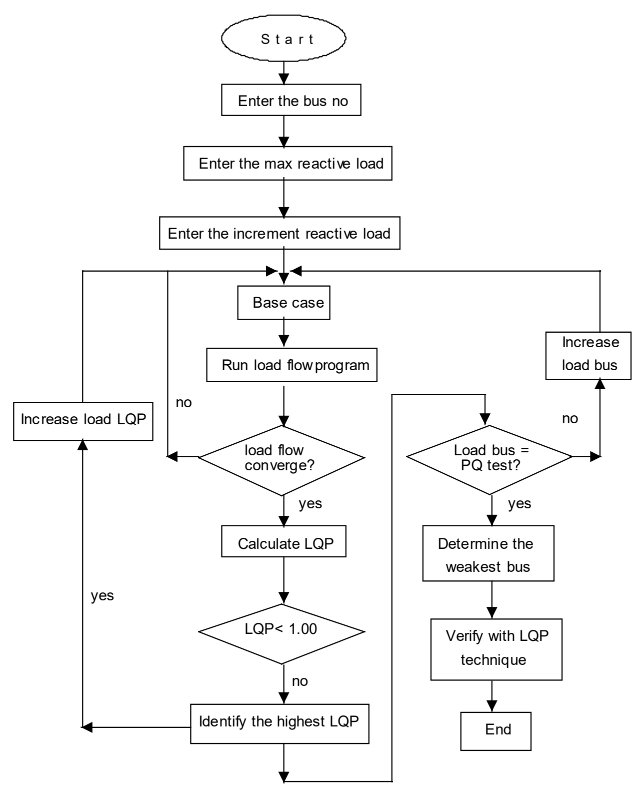


Fig.2: Flow chart for the voltage collapse assessment

Voltage stability condition of a power system is assessed by evaluating the proposed line based Lined Stability Factor index LQP. Several steps are implemented in order to carry out the voltage stability analysis. The following procedures were implemented in the voltage stability analysis:

I. Run the load program (Newton Raphson) at the base case.
II. Use the result from the load flow solution to compute the line index, LQP.
III. If the index is smaller than 1.00, increase the reactive load power and Record the highest index and the corresponding line
IV. Record the highest index and the corresponding line
V. Plot individual graph for line index LQP versus reactive load variation at the tested load bus. This will identify the sensitive line with respect to the load bus.
VI. Repeat the whole, step I to v for other load busses in the system
VII. Plot the curves for bus voltage versus reactive load variation on the same axis. This will estimate/determine the voltage at the stability limit for each load bus.

IV. RESULTS AND DISCUSSIONS

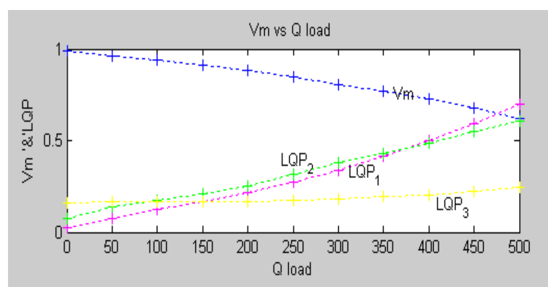
The main objective of this project is to identify the critical line outages and sensitive lines in the system. Voltage collapse assessment was performed on several loading conditions in order to identify the effect of increase in loading to LQP values. The technique was tested on the IEEE 57-RTS. Programming codes were written in MATLAB.

The results for static voltage collapse assessment performed on the bus 14 are tabulated in Table I

TABLE 1.0: Present the reactive power at loading Increase at the bus 14 in the IEEE 57 RTS.

Qd	Vm	LQP 1	LQP 2	LQP 3
0	0.9890	0.0242	0.0759	0.1606
50.0000	0.9629	0.0776	0.1363	0.1639
100.0000	0.9396	0.1219	0.1704	0.1655
150.0000	0.9142	0.1680	0.2089	0.1673
200.0000	0.8847	0.2161	0.2495	0.1702
250.0000	0.8460	0.2731	0.3144	0.1755
300.0000	0.8048	0.3387	0.3791	0.1831
350.0000	0.7692	0.4131	0.4300	0.1927
400.0000	0.7256	0.4965	0.4886	0.2047
450.0000	0.6773	0.5912	0.5477	0.2209
500.000	0.6200	0.6673	0.6041	0.2461

Reactive power loading was gradually increased from 0 MVAR to 500 MVAR until the load flow diverges. From the table I.0 it is observed that as the reactive power loading at particular load bus was increased, the values of lines 13 as a LQP 1, lines 15 as LQP 2 and lines 46 as a LQP 3 connected to the load bus in the power system was also increased accordingly until one of them reaches a maximum value. At the same time, the increase in reactive power loading has caused the voltage profile to reduce until the reactive power loading reached the maximum. From the figure, line 13 is identified as the most sensitive line with respect to the increase in reactive power loading at the bus 14. Beyond the maximum reactive power loading limit, the system stars to lose its stability. Sudden voltage drop is expected on the loaded bus.



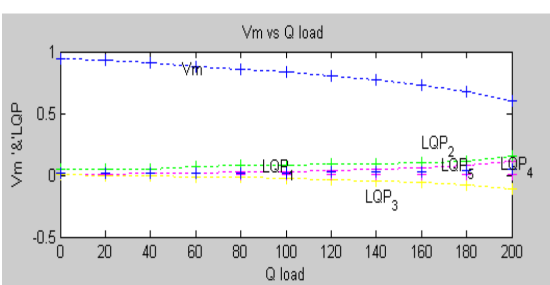
The responses of LQP for connecting lines to the bus 14 and voltage profile at bus 14 are illustrated in Fig.3

The results for static voltage collapse assessment performed on the bus 38 are tabulated in Table II

TABLE 1I: Present the reactive power at loading Increase at the bus 38 in the IEEE 57 RTS.

Qd	Vm	LQP 1	LQP 2	LQP 3	LQP 4	LQP 5
0	0.9448	0.0021	0.0436	0.0036	0.0128	0.0163
20	0.9256	0.0068	0.0457	-0.0041	0.0118	0.0168
40	0.9057	0.0115	0.0495	-0.0068	0.0111	0.0174
60	0.8782	0.0171	0.0726	-0.0133	0.0107	0.0184
80	0.8558	0.0229	0.0770	-0.0199	0.0099	0.0193
100	0.8317	0.0293	0.0817	-0.0272	0.0091	0.0203
120	0.8021	0.0375	0.0876	-0.0366	0.0082	0.0219
140	0.7699	0.0467	0.0957	-0.0474	0.0078	0.0239
160	0.7330	0.0583	0.1033	-0.0603	0.0069	0.0269
180	0.6801	0.0765	0.1160	-0.0801	0.0069	0.0328
200	0.5985	0.1093	0.1552	-0.1094	0.0103	0.0496

Reactive power loading was gradually increased from 0 MVAR to 200 MVAR until the load flow diverges. From Table II it is observed that as the reactive power loading at particular load bus was increased, the values of lines 37 as a LQP 1, lines 22 as a LQP 2, lines 44 as a LQP 3, lines 49 as a LQP 4 and lines 48 as a LQP 5 connected to this bus in the power system was also increased accordingly until one of them reaches a maximum value. At the same time, the increase in reactive power loading has caused the voltage profile to reduce until the reactive power loading reached the maximum. From the figure, line 22 is identified as the most sensitive line with respect to the increase in reactive power loading at the bus 38. Beyond the maximum reactive power loading limit, the system stars to lose its stability. Sudden voltage drop is expected on the loaded bus.



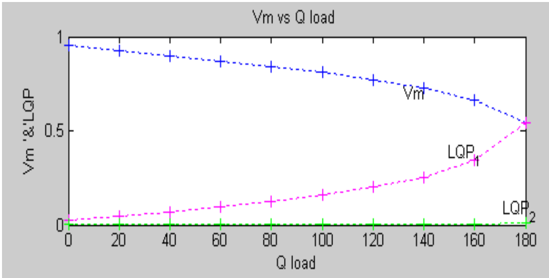
The responses of LQP for connecting lines to the bus 38 and voltage profile at bus 38 are illustrated in Fig.4

The results for static voltage collapse assessment performed on the bus 44 are tabulated in Table III

TABLE III: Present the reactive power at loading Increase at the bus 44 in the IEEE 57 RTS.

Qd	Vm	LQP 1	LQP 2
0	0.9553	0.0232	0.0037
20.0000	0.9286	0.0472	0.0039
40.0000	0.8999	0.0697	0.0041
60.0000	0.8707	0.0971	0.0043
80.0000	0.8418	0.1254	0.0045
100.0000	0.8103	0.1577	0.0047
120.0000	0.7714	0.2027	0.0051
140.0000	0.7271	0.2541	0.0056
160.0000	0.6618	0.3438	0.0065
180.0000	0.5433	0.5393	0.0090

Reactive power loading was gradually increased from 0 MVAR to 180 MVAR until the load flow diverges. From Table III it is observed that as the reactive power loading at particular load bus was increased, the values of lines 38 as a LQP 1 and lines 45 as a LQP 2 are connected at this bus in the power system was also increased accordingly until one of them reaches a maximum value. At the same time, the increase in reactive power loading has caused the voltage profile to reduce until the reactive power loading reached the maximum. From the figure, line 38 is identified as the most sensitive line with respect to the increase in reactive power loading at the bus 44. Beyond the maximum reactive power loading limit, the system stars to lose its stability. Sudden voltage drop is expected on the loaded bus.



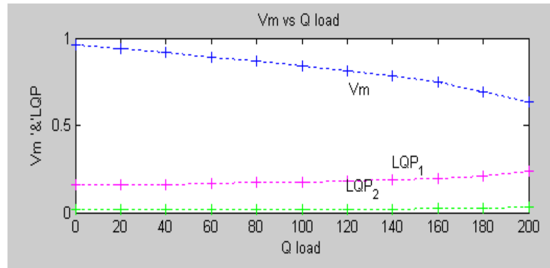
The responses of LQP for connecting lines to the bus 44 and voltage profile at bus 44 are illustrated in Fig.5

The results for static voltage collapse assessment performed on the bus 47 are tabulated in Table IV

TABLE IV: Present the reactive power at loading Increase at the bus 47 in the IEEE 57 RTS.

Qd	Vm	LQP 1	LQP 2
0	0.9638	0.1599	0.0162
20.0000	0.9414	0.1615	0.0166
40.0000	0.9210	0.1631	0.0170
60.0000	0.8932	0.1679	0.0178
80.0000	0.8701	0.1705	0.0183
100.0000	0.8425	0.1745	0.0191
120.0000	0.8120	0.1795	0.0200
140.0000	0.7826	0.1852	0.0209
160.0000	0.7454	0.1941	0.0224
180.0000	0.6933	0.2118	0.0250
200.0000	0.6317	0.2410	0.0291

Reactive power loading was gradually increased from 0 MVAR to 200 MVAR until the load flow diverges. From Table IV it is observed that as the reactive power loading at bus was increased, the values of lines 46 as a LQP 1 and lines 48 as a LQP 2 are connected at this bus in the power system was also increased accordingly until one of them reaches a maximum value. At the same time, the increase in reactive power loading has caused the voltage profile to reduce until the reactive power loading reached the maximum. From the figure, line 46 is identified as the most sensitive line with respect to the increase in reactive power loading at bus 47. Beyond the maximum reactive power loading limit, the system stars to lose its stability. Sudden voltage drop is expected on the loaded bus.



The responses of LQP for connecting lines to the bus 47 and voltage profile at bus 47 are illustrated in Fig.6

V. CONCLUSION

Voltage collapse assessment in a bulk power system network has been presented in this paper. Voltage collapse assessment technique utilized the line power flow in transmission line. The proposed technique was tested on the IEEE reliability test system. Result obtained from the experiment shown that usage of LQP as a voltage collapse indicator is significantly indicative. From these result the distance from voltage collapse point can be determined. The information from the studies could be taken as a guideline for power system operation and planning.

VI. REFERENCES

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VII. BIOGRAPHIES

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