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A Study on Voltage Collapse Phenomenon by Using Voltage Collapse Proximity Indicators

Mr. Ponnada Anirudh[1], Mr.N.Rammohan[2]
Jawaharlal Nehru Technological University Kakinada
[1, 2]V R Siddhartha Engineering College, Vijayawada, India

Abstract—In present days, electrical load demand is growing day by day and in order to meet the increasing electrical load demand, power generating plants are operating their plants at their maximum capacity. So there is always a risk of voltage collapse, which will cause the shutdown of entire power system and its block out, which will cause an inconvenience to the customers and great losses to the power utility companies. It is always a better practice to know about the weakest elements in the system and weakest buses and their maximum loading limit. This paper deals with the study of weaker elements in the power system by means of a voltage stability index FVSI and its feasibility. Its feasibility is checked by comparing the results obtained with the FVSI with those of the results obtained with the already proved stability index LQP. By comparing the results it is proved that the results are very much in agreement with the other indices. So by using the FVSI, weaker elements in the system and the weaker buses in the system are identified and they are ranked according to the maximum load that they can afford without losing stability. Different combinations of contingencies that are expected to occur in the real time are simulated with the help of Gauss seidal load flow solution in c++ language.

Keywords—Voltage collapse; Fast voltage stability index (FVSI); Line stability index, LQP.

I. INTRODUCTION

Voltage stability problems have received increased attention over the last few years. Many published papers have demonstrated the importance of the problem and several occurrences all around the world have shown that the problem may have serious consequences [1, 2, 3] , such as excessive voltage drop or dynamic instability. The following formal definitions of terms related to voltage collapse are given in reference [4]:

1. Voltage stability is the ability of the power system to maintain steady and stable voltage levels at all the buses when load on the system is increased.
2. Voltage collapse is the most complex form of the voltage instability which is characterized by drop of voltage levels in some significant form of the power system.
3. Voltage security is the ability of the power system, not only to operate stable but also to remain stable following any reasonable contingency.

So, in order to analyze the system voltage stability and voltage collapse points, it is necessary to observe the system response to different loading conditions and analysis of weaker buses and weaker elements and assessment of maximum loading limits becomes necessary. Estimation of weaker elements always requires running load flow iterations and increasing electrical load at each bus until the load flow solution diverges. Estimation by using stability indices is a different method.

In this paper, two stability indices FVSI and LQP are used, which are formulated by solving the basic line current flow equation and equating the discriminant of the roots of the equation to zero. For an element to be stable in terms of stability indices, the value of index for a particular line flow must be less than one i.e. until the value of index is less than one. The system is stable and if the value of the index becomes equal to one that is the limiting point for the stability. Power systems are generally supposed to operate below that loading limit which causes the system to be unstable. If at all the power systems operate beyond those loading limit, it will cause instability in some part of the system and if it continues it will lead to more dangerous phenomenon of voltage collapse which is characterized by block out of voltage levels in significant part of the power system. So, the loading should be limited to the maximum allowable loading limits that are found by this method.

II. METHODOLOGY

A. FVSI (Fast Voltage Stability Index):

A novel voltage stability index FVSI [5] is formulated by solving the basic current equation

$$\frac{\mathrm{Pr} - \mathrm{jQr}}{Vr\angle-\delta} = \frac{Vs\angle 0 - Vr\angle\delta}{R + jX} \qquad (1)$$

By solving the above equation we get a quadratic expression for voltage whose roots discriminant should be less than zero in order to have the real roots and the discriminant when made equal to zero will give the limiting point of stability and the index formed is of the expression

$$FVSI = \frac{4 * Z^2 * Qr}{Vs^2 * X} \qquad (2)$$

Where,
Z=impedance of the line;
V_s=sending end voltage of the line;
Q_r= receiving end reactive power;
X=reactance of the line;

The line that gives the index value close to one will be the most critical line of the system.

B. Line stability index, (LPQ):
Line stability index, LPQ [6] is given by,

$$LQP = 4 * \frac{X}{Vs^2} * \left(\frac{X}{Vs^2} * Ps^2 + Qr\right); \qquad (3)$$

Where,
X=line reactance;
Q_r=reactive power flow at the receiving end;
V_s=voltage on the sending end bus;
P_s=active power flow at the sending end bus;
Operating at secure and stable conditions requires the value of index to be maintained less than one.

III. DATA FOR THE SYSTEM- IEEE14 BUS SYSTEM

Here, IEEE 14 bus system [7] is used as a standard test system. This system enables us to compare the results obtained with this system with the other systems.

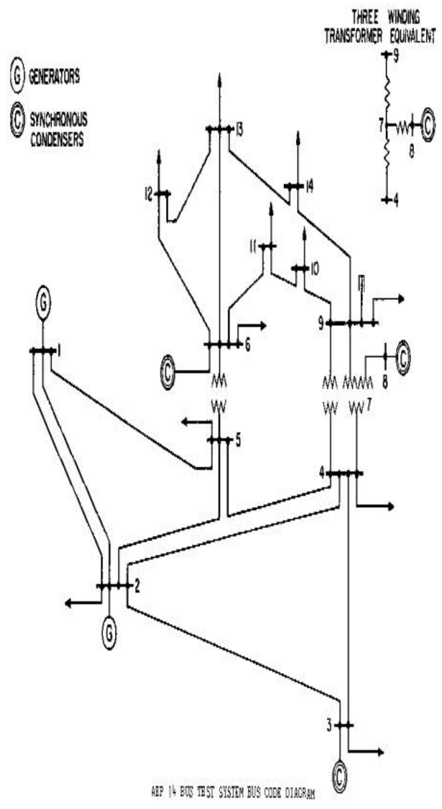

Figure 1.IEEE 14 bus system

IV. FLOW CHART FOR THE EVALUATION OF WEAK ELEMENTS

A basic Gauss seidal iterative method is used for the power flow solution [8, 9]. This computed line and bus power flows are used in auto contingency analysis.

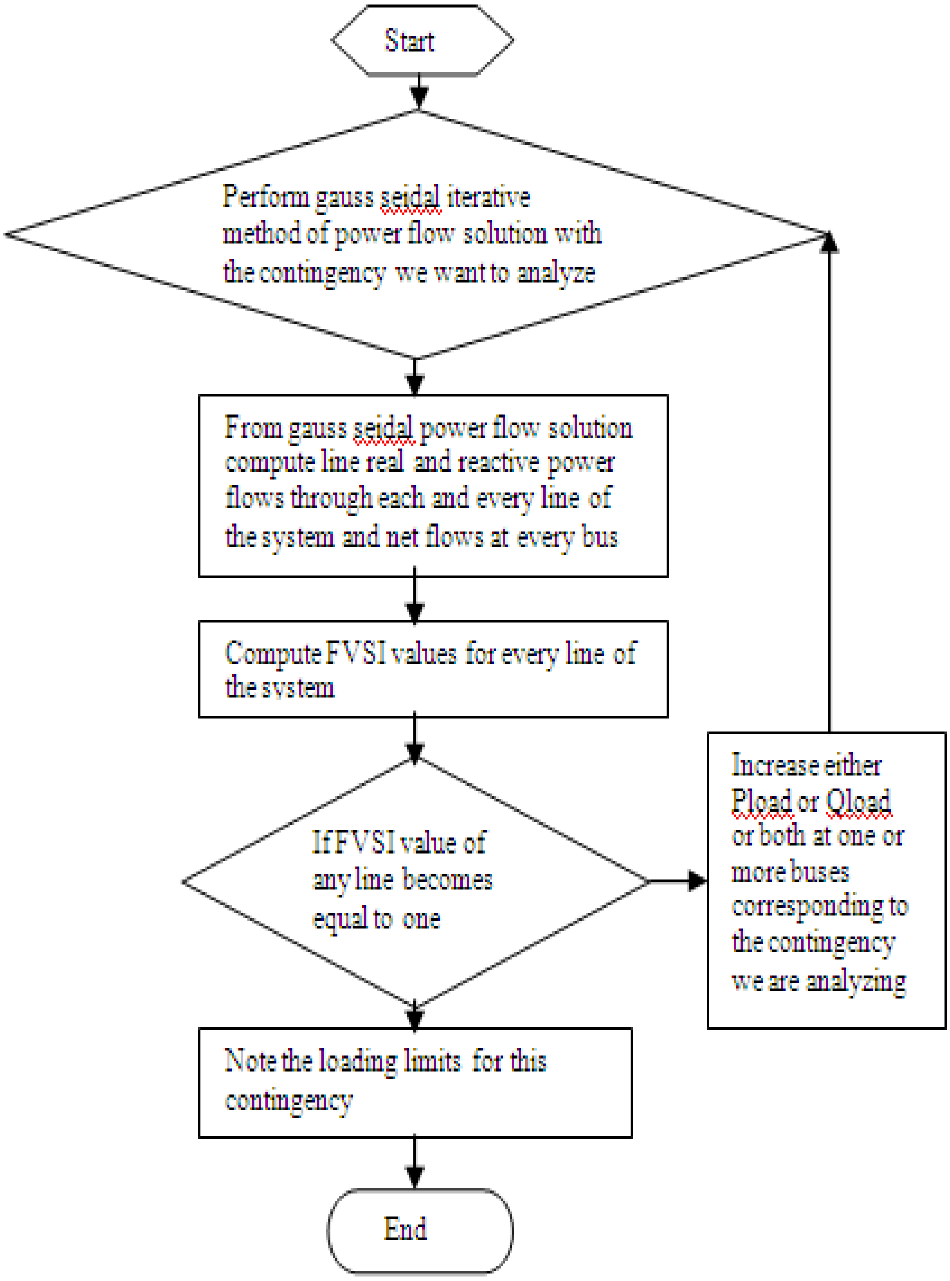

Figure 2. Flow chart for contingency analysis

V. AUTO CONTINGENCY ANALYSIS AND RANKING

Generally, in order to know about the consequences of possible contingencies, it is always preferable to do off-line monitoring rather than on-line monitoring. Generally, the contingencies on the power system are

1. Real load change at single bus.
2. Reactive load change at single bus.
3. Both real and reactive load change at single bus.
4. Multiple load change at different buses.

VI. TEST RESULTS

A. Real Load Change At Single Bus:

Real power load at load buses is varied one at a time, until the FVSI value of any line becomes equal to one. That value is the maximum loading limit for that bus when the contingency is real load at single bus. All the elements are sorted in the order of decreasing FVSI values. The element which is having highest value of FVSI is the weaker element corresponding to this contingency and all the elements are sorted in that order. This makes us to take care about the weaker elements during that contingency. As a case, load bus number 4 is chosen and the real power load is increased until the FVSI value of any element become one.

Real power load at bus number 4 is varied up to 717 MW. The elements are sorted according to the decreasing values of FVSI.The element which is having highest value of FVSI will be the most unstable element corresponding to that contingency. The results obtained with FVSI are compared with the results obtained with that of LQP. The comparison shows the results are obtained with FVSI are feasible and comparative. Thus, the FVSI index can be effectively utilized for the voltage stability analysis. .

In the same way, single real power load change contingency is done off-line for all the buses and weak buses for the single load change are sorted based on the maximum allowable power loading. Ranking of weak buses is as below.

Table- I RANKING OF WEAK ELEMENTS WHEN REAL LOAD AT BUS 4 IS CHANGED

Rank	Element	FVSI	LQP
1	5-6	1.04	1.03
2	4-7	0.69	0.7
3	7-8	0.63	0.66
4	4-9	0.53	0.6
5	1-2	0.37	0.55
6	1-5	0.33	1.1
7	2-3	0.28	0.56
8	2-4	0.25	0.97

Table- II RANKING OF WEAK BUSES FOR REAL LOAD CHANGE AT SINGLE BUS

Rank	Load bus no	Max load
1	10	269.5MW
2	14	283.3MW
3	11	303.5MW
4	12	336.15MW
5	9	359.5MW
6	13	373.5MW
7	7	400MW
8	4	717.8MW

B. Reactive power load change at single bus:

It is done in the same way as above, reactive power load is varied at a single load bus at a time in the same manner as above and it is done upto the point when FVSI values of any element becomes nearer to or equal to one. The value of reactive power load at which the FVSI value becomes one will the limiting point of reactive power loading for that bus. Elements are sorted in the order of decreasing FVSI. The process was done for all the load buses and ranking of elements for each bus is done and ranking of buses is also done. Ranking of buses is done on the same principle of maximum allowable power loading. A simple table showing ranking of elements for reactive load at bus number 12 is increased to 105MVAR. Thus the maximum allowable load at the bus number 12 is 105MVAR . Similarly, the same analysis is done for all the load buses and ranking of buses is done on the basis of maximum allowable load at that bus.

Table-III RANKING OF ELEMENTS WHEN REACTIVE POWER LOAD AT BUS 12 IS INCRESED TO 105MVAR

Rank	Element	FVSI	LQP
1	12-13	1.03	0.47
2	12-6	0.7	0.6
3	13-6	0.28	0.2
4	5-6	00.19	0.19
5	7-8	0.18	0.18
6	14-9	0.13	0.1
7	4-7	0.11	0.11
8	9-7	0.09	0.09

Table-IV RANKING OF BUSES FOR SINGLE LOAD REACTIVE POWER CHANGE

Rank	Bus no	Max load in MVAR
1	12	105
2	10	148
3	7	165
4	9	216
5	14	219
6	13	245
7	11	285
8	5	290
9	4	429

C. Multiple load change:

In practical power system, both real and reactive load change will occur and they may change for more than one bus at a time and hence there is need for offline monitoring of multiple load change contingency.

As a case of contingency, ranking of buses for real and reactive load changes for single bus at a time is done. And another case of contingency is considered with random variation of real and reactive power loads at buses 7, 10, 12, 14.And weaker elements corresponding to this contingency are sorted and ranked .And the allowable loads at these buses when multiple load change contingency is created are: at bus 7 is 60mw and 60mvar, at bus 10 is 69 mw and 65.8mvar, at bus 12 is 66.1mw and 61.6mvar, at bus 14 is 74.9mw and 65mvar.

Table-V RANKING OF BUSES WHEN BOTH REAL AND REACTIVE LOAD CHANGES OCCUR

Rank	Bus no	Max P mw, Q mvar
1	4	350, 320
2	5	227.6, 221.6
3	7	150, 130
4	9	179.5, 156.6
5	10	139 , 111.8
6	11	203.5 , 184.1
7	12	106.1, 85
8	13	183.5 , 185.8
9	14	134.9 , 140

Table-VI CONTINGENCY RANKING OF ELEMENTS FOR MULTIPLE LOAD CHANGES AT BUSES 7, 10, 12, 14

Rank	Element	FVSI
1	7-8	1.59
2	10-11	1.25
3	9-4	0.66
4	12-6	0.63
5	13-6	0.61
6	9-7	0.56
7	11-6	0.52

VII. CONCLUSION

As the consequences of voltage collapse are very dangerous and they give great losses to the utility service persons it is essential to know about the maximum allowable loading limits i.e. both real and reactive and both at same time are to be calculated so that proper care may be taken if we know the weaker elements and weaker buses for that particular contingency.

Generally, by using this tool of stability analysis, any contingency can be analyzed and it is advisable for a power system engineer to observe the load cycle and forecast the load variations in the nearby future and then perform stability analysis.

Stable analysis and contingency ranking by using FVSI index shows good results which are comparable with the already proved index LQP and the computations involved in this analysis are very simple and fast. Thus, there a lot of advantages with this technique and shows promising results .It will definitely help in the planning of power system in real time.

REFERENCES

[1]. G.Bronwell and H.Clark, "Analysis and solution for Bulk System Voltage Instability," IEEE Computer Application in Power Systems, July 1989, pp, 31-35.

[2]. IEEE Work Group on Voltage Stability, system Dynamics Sub-committee, "Voltage Stability of Power Systems," Technical Report 90TH0358-2-PWR, IEEE, 1990.

[3]. R.B. Prada, B.J.Cory, and R. Navarro Perrez, " Assessment of Steady State Voltage Collapse," Proc. of the Tenth Power Systems Computation Conference, Graz, Austria, August 1990, pp,. 1189-1195.

[4]. CIGRE WG 38.02 Task Force No, "Modeling of Voltage Collapse including Dynamic phenomenon," Technical Report of Task Force 38-02-10, CIGRE, June 1992.

[5]. I. Musirin, T.K.A. Rahman, "Novel Fast Voltage Stability Index (FVSI) for Voltage Stability Analysis in Power Transmission system," 2002 student Conference on Research and Development Proceedings, Shah Alam, Malaysia, July 2002.

[6]. A. Mohamed, G.B.Jasmon, S. Yusoff, "A Static Voltage Collapse Indicator using Line Stability Factors," Journal of Industrial Technology, Vol. 7, N1, pp. 73-85, 1989.

[7]. Power Systems Test Case Archive, 14 Bus Power Flow Test Case, Internet Page. 2007. http://www.washingon.edu/research/pstea/pf14/pg_tca14bus.htm.

[8]. Power System Analysis by Hadi Sadat.

[9]. Computer Aided Power System Analysis by Stag Ei- Abiad.