# An Optimal Power Flow (OPF) Method with Improved Voltage Stability Analysis

I. Kumaraswamy[1], W. V. Jahnavi[2], T. Devaraju[3], P. Ramesh[4]

*Abstract*: **Voltage stability is given very high importance in the power system studies, In the present studies, the voltage stability is determined by a method of on line monitoring of power system based using measurements like voltages, active power and reactive power etc. This is proposed with the aim of detection of the voltage instability.An indicator is derived from the fundamental kirchoff-laws. Since in the transient process, at any time point, the electrical power of the system is in balance, and Kirchoff-laws is obeyed, this indicator still works during transient process. From the indicator, it is proposed to predict the voltage instability or the proximity of collapse.The advantage of the method lies in the simple numerical calculation and strong adaptation in steady state and transient process. Through the indicator of voltage stability, it is to find the impacts of other loads, areas and power transactions.An IEEE 9-bus system is taken as a study case to test the efficacy of the proposed systems. The optimal load flow studies for the given bus data are conducted using Newton Raphson method. An IEEE 6-bus system is taken as a study case to test the efficacy of the proposed systems. The optimal load flow studies for the given bus data are conducted using PSAT tool.**

**Keywords: opimal power flow, voltage stability,Voltage collapse,**

## I INTRODUCTION

The function of a power station is to deliver power to a large number of consumers. However, the power demands of different consumers vary in accordance with their activities. The result of this variation in demand is that load on a power station is never constant; rather it varies from time to time. Most of the complexities of modern power plant operation arise from the inherent variability of the load demanded by the users. Unfortunately, electrical power cannot be stored and, therefore, the power station must produce power as and when demanded to meet the requirements of the consumers. On one hand, the power engineer would like that the alternators in the power station should run at their rated capacity for maximum efficiency and on the other hand, the demands of the consumers have wide variations. this makes the design of a power station highly complex.

We can form a notion of the quality of supply in terms of how nearly constant are the voltage and frequency at the supply point, and how near to unity is the power factor. In three-phase systems, the degree to which the phase currents and voltage are balanced must also be included in the notion of quality of supply. A definition of "quality of supply" in numerical terms involves the specification of such quantities as the maximum fluctuation in rms supply voltage averaged over a stated period of time. Specifications of this kind can be made more precise through the use of statistical concepts, and these are especially helpful in problems where voltage fluctuations can take place very rapidly. In an ideal ac power system, the voltage and frequency at every supply point would be constant and free from harmonics, and the power factor would be unity. In particular these parameters would be independent of the size and characteristics of consumer's loads. In an ideal system, each load could be designed for optimum performance at the given supply voltage, rather than for merely adequate performance over an unpredictable range of voltage. Moreover, there could be no interference between different loads as a result of variations in the current taken by each one.

## II PROBLEM STATEMENT

The function of a power station is to deliver power to a large number of consumers. However, the power demands of different consumers vary in accordance with their activities. The result of this variation in demand is that load on a power station is never constant; rather it varies from time to time. Most of the complexities of modern power plant operation arise from the inherent variability of the load demanded by the users. Unfortunately, electrical power cannot be stored and, therefore, the power station must produce power as and when demanded to meet the requirements of the consumers. On one hand, the power engineer would like that the alternators in the power station should run at their rated capacity for maximum efficiency and on the other hand, the demands of the consumers have wide variations. This makes the design of a power station highly complex.

In this case the maintenance of voltage stability is difficult. In order to over come this difficulty a method for on line monitoring of power system based on measurements is proposed.

## III (A) voltage stability

Voltage stability is a major concern in planning and operation of power systems. It is well known that voltage instability and collapse have led to major system failures. With the development of power markets more and more electric utilities are facing voltage stability – imposed limits.

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The problem of voltage stability may be simply explained as inability of the power system to provide the reactive power or the egregious consumption of the reactive power by the system it self. It is understood as a reactive power problem and is also a dynamic phenomenon.

Voltage stability analysis is often requires examination of lots of system states and many contingency scenarios. for this reason, the approach based on steady state analysis is more feasible, and it can also provide insight of the voltage reactive power problems. a number of special algorithms have been proposed in the literature for voltage stability analysis using static approached, however these approaches are laborious and does not provide sensitivity information useful in a dynamic process. Voltage stability is indeed a dynamic phenomenon.

Voltage stability and voltage collapse has often been viewed as a steady-state “viability” problem suitable for static (power flow) analysis. The ability to transfer reactive power from production sources to consumption sinks during steady operating conditions is a major aspect of voltage stability.

The network maximum power transfer limit is not necessarily the voltage stability limit

Voltage stability or collapse is a dynamic process. The world” stability” implies a dynamic system. A power system is a dynamic system .we will see that, in contrast to rotor angels (synchronous) stability, the dynamic mainly involves the loads and the means for voltage control. Voltage stability has been called load stability.

Power system stability is the capability of a system that can regain to its normal state of equilibrium after being introduced to a disturbance. In the evolution of stability the concern is the behavior of the power system when subjected to a transient disturbance. The disturbance may be small or large. Small disturbance in the form of load changes take place continually and the system adjusts it self to the changing conditions. the system must be capable of surviving numerous disturbances of a serve nature, such as short –circuit on transmission line, loss of a large generator or load, or loss of a tie between two sub systems.

Power system network can be divided three major sub networks. Such as generation sub network, transmission sub network and distribution sub network. Generation sub network consists mostly of 3-phase synchronous generators, transmission sub network consist mostly of 3- phase transmission network and distribution sub network consist of distribution system including loads. These loads can be static, dynamic such as synchronous motors and induction motors etc. or composite loads.

There are two forms of instability in power systems: the loss of synchronism between two synchronous machines, and the

stalling asynchronous loads. The power system stability can be divided in to three categories: steady-state stability, transient stability and dynamic stability. The power system voltage stability analysis will be done mainly based on p-v curves and q-v curves.

## III (B) VOLTAGE INSTABILITY

Voltage instability is an absence of voltage stability, and results in Progressive voltage decreases (or increases).

Voltage stability normally involves large disturbances (including rapid increases in load or power transfer). Furthermore the Instability is almost always a periodic decrease in voltage.

Voltage instability in a power system occurs due to lack of reactive power. It occurs either at the sources due to var output limit or inability of the network to deliver the real power due to lack of local reactive power at the network locations. The first form of voltage instability is source dependent. The second form of voltage instability is network dependent.

A system enters the state of voltage instability when an increase in load demand or change in system conditions causes a progressive and uncontrollable fall of voltage. Load variations or contingencies in general cause voltage collapse. In this voltage collapse due to load variations is considered.

Power transmission capability has traditionally been limited by either angle stability or by the thermal loading capabilities of the lines. But with the developments in faster short circuit clearing times, quicker and effective excitation systems and developments in serval stability control devices, the system problems associated with transient instability

Have been largely reduced. However, voltage instability limits are more prominently significant in the context of a secure power system operation.

## III (c) . INTRODUCTION TO INDICATOR

In this project we used an indicator to determine the proximity of a system to voltage collapse. Without this the voltage collapse point cannot be determined. Based on the value of indicator the stability margin of a particular load bus can be determined. This indicator is derived using fundamental kirchoff-laws and power flow equations for simple power system; which consists of one generator bus and one load bus. then indicator formula is applied to the multi bus system .

## IV CLASSIFICATION OF VOLTAGE STABILITY

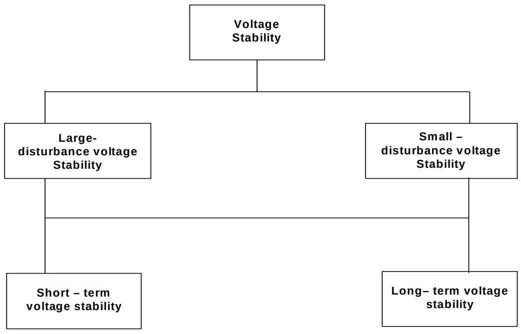

**Fig1:** classification of voltage stability

(a) **Large disturbance voltage stability**: It refers to the systems ability to maintain, steady voltages following large disturbances such as system faults, loss of generation ,or circuits contingencies

(b) **Small disturbance voltage stability**: It refers to the systems ability to maintain steady voltage when subjected to small disturbances such as incremental changes in system load.Short- term voltage stability: It involves dynamic of fast acting load components such as induction motors, electronically controlled load, and HVDC converters.

(c) **Long-tem voltages stability**: It involves slower acting equipment such as tap-changing transformers, thermostatically controlled loads, and generator loads and current limiters.

## V VOLTAGE COLLAPSE

The term "voltage collapse" is generally used to refer to the shutdown of a power system resulting from an inability to maintain adequate voltage levels. Under normal circumstances power system voltages are maintained at relatively steady levels. Reactive resources are adjusted in response to variations in system loading, as generation is dispatched to meet a changing level of demand. Even if an unexpected event were to occur, such as the tripping of a circuit, corrective action would restore voltage levels within minutes. This corrective action may include the automatic response of generator excitation systems, the automatic or manually initiated tapping of transformers, and the switching of static compensation devices. Each form of action would make a positive contribution to restoring the system voltage levels. Under extremes of system loading the situation may well be different.

A phenomenon, which characterizes the process of voltage collapse, may see the same automatic control action actually reducing an already low voltage. Voltage levels would steadily deteriorate until all control action had ceased. The resulting low voltage level may not be sustainable. There will be some minimum level below which one would not expect the continuity of electricity supply to be maintained. As voltages progressively fell, there may come a point when circuit protection systems ceased to be stable and operated, whether as a direct result of the low voltage or the consequential effect of angular instability which may well occur at low voltage. Whichever the cause, the cascade tripping of circuits would be likely and ultimately the system would shut down.

The sequence of events leading to collapse may take only minutes. The challenge facing power system control engineers is to recognize conditions, which might lead to voltage collapse, and to avoid the risk of it occurring whilst not unduly compromising his objective of dispatching generation in an economic order.

## V (A) IDENTIFICATION OF VOLTAGE COLLAPSE MARGIN

In most cases, once the voltages have reached the point where they start to decrease rapidly, corrective actions are often too slow or are ineffective at averting the collapse. Therefore most of the effort focused on voltage collapse has centered on predicting the occurrence of a collapse by finding an estimate or index of how close the system is to critical point.One of the straightest forward of these indices is the measure of the bus voltage sensitivity to changes in a load parameter. The motivation for this particular index comes from a study of the PV curve at normal operating voltages, there is a very little change in the voltage level for an increase in load, and thus the sensitivity of the voltage to changes in load is small. However, as the load increases and the voltages begin to decline, the voltage levels become increasingly sensitive to changes in load, until the point of maximum power transfer when the voltage becomes infinitely sensitive to changes in the load. This sensitivity concept may be extended to a large-scale system. The PV curve for each bus in the system can be calculated, which will record that particular bus behavior as a function of system load increase. This methodology enables the utility system planner to isolate areas, which exhibit large sensitivities. These areas are the regions in which voltage collapse is most likely to occur.

## V(B) REASONS FOR VOLTAGE COLLAPSE

- Stressed power systems.
- Inadequate Reactive power Recourses
- Load characteristics at low voltage magnitudes
- Tap – changers respond to demand side voltage
- Unexpected relay operations during decreased Voltage conditions.

## VI VOLTAGE STABILITY ANALYSIS:

The slower forms of voltage instability are often analyzed as steady state problems power flow simulation is primarily study method." Snapshots" in time following an outage or during by used P – V curves and Q-V curves. These methods determine steady state load ability limits which are related to voltage stability. Conventional power flow programs can be used for approximate analysis. The voltage stability will affect the system. This system depends on the relation ship between load real power (p), and receiving end voltage (v) voltage stability can be analyzed using these relation ships.

### P-V CURVE:

The P-V curves, active power-voltage curve, are the most widely used method of predicting voltage security. They are used to determine the mw distance from the operating point to the critical voltage. A typical p-v curve is shown in Figure 2.1. Consider a single, constant power load connected through a transmission line to an infinite-bus. Let us consider the solutions to the power flow equations, where p, the real power of the load, is taken as parameter that is slowly varied, and v is the voltage of the load bus. It is obvious that three regions can be related to the parameter p. in the first region, the power flow has two distinct solutions for each choice of p one is the desired stable voltage and the other is the unstable voltage. As p is increased, the system enters the second region, where the tow solutions intersect to form one solution for p, which is the maximum. If p is further increased, the power flow equations fail to have a solution. This process can be viewed as a bifurcation of the power flow problem; in a large-scale power system the conventional parametric studies are computationally prohibitive. The method of maximum power transfer determines critical limits on the load bus voltages, above which the system maintains steady-state operation.

The most famous P-V curve shown in figure 2.1. each value of the transmissible power corresponds a value of the voltage at the bus until V=Vcrit after which further increase in power results in deterioration of bus voltage. The top portion of the curve is acceptable operation whereas the bottom half is considered to be the worsening operation. The risk of voltage collapse is much lower if the bus voltage is further away, by an upper value, from the critical voltage corresponding to pmax.

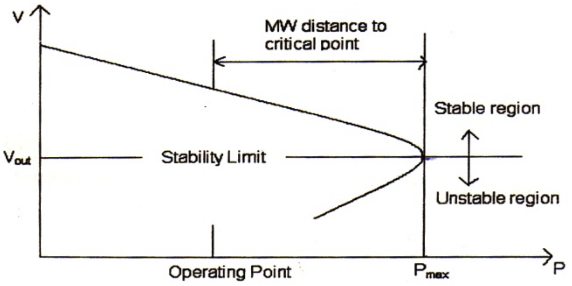

**Figure : 2.1 Typical P-V curve**

Q-V CURVE:

Q-V curve technique is a general method of evaluating voltage stability. It mainly presents the sensitivity and variation of bus voltages with respect to the reactive power injection Q-V curves can be used by many utilities for determining proximity to voltage collapse so that operators can make a good decision to avoid loosing system stability. In other words, by using Q-V curves, it is possible for the operators and the planners to know, the maximum voltage limit or voltage limit or voltage instability. Furthermore, the calculated MVAR margins could relate to the size on shunt capacitor or static VAR compensation in the load area.

V-Q or voltage- reactive power curves are generated by series of power flow simulation. They plot the voltage at a test bus or critical bus versus reactive power at the same bus. Most of the time these curves are termed Q-V curves rather than V-Q curves. Scheduling reactive load rather than voltage produces Q-Curves. These curves are a more general method of assessing voltage stability. They are used by utilities as a workhorse for voltage stability analysis to determine the proximity to voltage collapse and to establish system design criteria based on Q and V margins determined from the curves. Operators may use the curves to check whether the voltage stability of the system can be maintained or not and take suitable control actions. The sensitivity and variation of bus voltages with respect to the reactive power injection can be observed clearly. The main drawback with Q-V curves is that is generally not know previously at which buses the curves should be generated.

As a traditional solution is system planning and operation, the voltage level is used as index of system voltage instability. If it exceeds the limit, reactive support is installed to improve voltage profiles. With such action, voltage level can be maintained within acceptable limits under a wide range of MW loadings. In reality. Voltage level may never decline below that limit as the system approaches its steady state stability limits. Consequently, voltage levels should not be used as a voltage collapse warning index. Figure 2.2 shows a typical Q-V curve.

The Q axis shows the reactive power that needs to be added or removed from the bus to maintain a given voltage at a given load. The reactive power margin is the MVAR distance from the operating point to the bottom of the curve., the curve can be used as an index for voltage instability (PQ/PV goes negative). Near the nose of a Q-V curve, sensitivities get very large and then reverse sing. Also, it can be seen that the curve shown two possible values of voltage for the same value of power.

The power system operated at lower voltage value would require very high current to produce the power. That is why the bottom portion of the curve is classified as an unstable region the system cannot be operated in steady state in this region. The steady state voltage problem analysis will be focused on the practical range of an operating system the top portion of the curve. Hence, the top portion of the curve represents the stability region while the bottom portion from the stability limit indicates the unstable operating region.

It is preferred to keep the operator will attempt to correct the low voltage condition by increasing the terminal voltage. However, if the system is operating on the lower. Portion of the curve, the unstable region, increasing the terminal voltage will cause an even further drop in the load voltage

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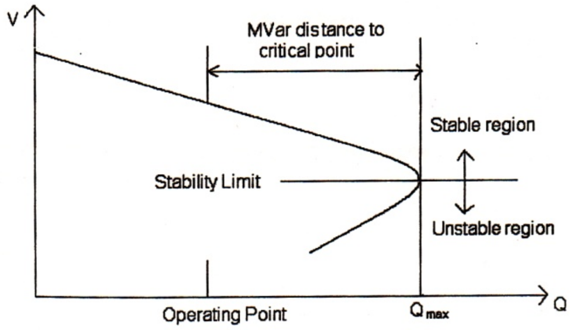


**Figure: 2.2 Typical Q-V curve**

## VII PROBLEM FORMULATION

The objective function and all related constraints of the problem are shortly described as follows:

### *A. Objective Function*

The minimization of fuel cost of all generating units and indicator L at the weakest bus is considered as the objective function. It can be expressed mathematically as follows:

$$F = \sum_{i=1}^{NG} F_i(P_{Gi}) + \alpha \cdot \mathrm{Max}(L_j) \qquad j = 1, 2, \ldots, NLB \qquad (1)$$

where *F* is the objective function; *Fi(PGi)* is the *i*-th generating unit's fuel cost which is a function of active power generation output (*PGi*); *NG* is the total number of generating units; α is the scaling factor; *Lj* is the value of indicator L at load bus *j*;*NLB* is the total number of load buses.

### *B. Conventional Constraints*

The conventional equality and inequality constraints related to the problem are defined as follows:

$$P_{Gi} - P_{Di} - V_i \sum_{j=1}^{N} V_j \left( G_{ij} \cos\theta_{ij} + B_{ij} \sin\theta_{ij} \right) = 0 \qquad i = 1, 2, ..., N \quad (2)$$

$$Q_{Gi} - Q_{Di} - V_i \sum_{j=1}^{N} V_j \left( G_{ij} \sin\theta_{ij} - B_{ij} \cos\theta_{ij} \right) = 0 \qquad i = 1, 2, ..., N \quad (3)$$

$$P_{Gi,\min} \le P_{Gi} \le P_{Gi,\max} \qquad i = 1, 2, ..., NG \quad (4)$$

$$Q_{Gi,\min} \le Q_{Gi} \le Q_{Gi,\max} \qquad i = 1, 2, ..., NG \quad (5)$$

$$V_{i,\min} \le V_i \le V_{i,\max} \qquad i = 1, 2, ..., N \quad (6)$$

$$T_{i,\min} \le T_i \le T_{i,\max} \qquad i = 1, 2, ..., NT \quad (7)$$

$$\left| S_{Li} \right| \le S_{Li,\max} \qquad i = 1, 2, ..., NL \quad (8)$$

where (2) and (3) are active and reactive power balance equations; (4)-(8) are active and reactive power generation limits, voltage limits, transformer tap setting limits, and line loading limits, respectively; *PDi* and *QDi* are the total active and reactive power demands at bus *i*; *QGi* is the total reactive power generation at bus *i*; *Vi* and *Vj* are the voltage magnitudes at buses *i* and *j*; *Gij* and *Bij* are the real and imaginary parts of the *ij*-th element of the admittance matrix (*Ybus*); θ*ij* is the difference of voltage angles between buses *I* and *j*; *Ti* is the tap setting of the *i*-th transformer; |*SLi*| is the line loading in MVA at line *i*; *N, NL*, and *NT* are the total numbers of buses, lines, and transformers. The subscripts *x*max and *x*min are the upper and lower limits of variable *x*.

VII (A) Voltage Stability Indicator L

The indicator L [3] is a quantitative measure for estimating the voltage stability margin of the current operating point.Normally, the value of indicator L is between 0 (no load) and 1 (voltage collapse). Therefore, the lower the value of indicator L is, the larger the voltage stability margin will be.To obtain this value, first the hybrid representation derived from the original admittance matrix (*Ybus*) is built as follows:

$$\begin{bmatrix} V_L \\ I_G \end{bmatrix} = \begin{bmatrix} Z_{LL} & F_{LG} \\ K_{GL} & Y_{GG} \end{bmatrix} \begin{bmatrix} I_L \\ V_G \end{bmatrix} \qquad \text{-------( 9)}$$

where *VL*, *IL* are the voltage and current vectors at the load buses; *VG*, *IG* are the voltage and current vectors at the generator buses including slack bus; *ZLL*, *FLG*, *KGL*, *YGG* are the sub-matrices of the hybrid matrix.The hybrid representation is obtained by a partial inversion, where the voltages at the load buses are exchanged against their currents. Through the utilization of this representation, the voltage stability indicator L at load bus *j* can then be calculated as follows:

$$\begin{aligned} L_j &= \left| 1 + \frac{V_{0j}}{\overline{V_j}} \right| = \left| \frac{S_j + S_{jcorr}}{Y^*_{jj+} \cdot V_j^2} \right| \\ V_{0j} &= -\sum_{i=1}^{NG} F_{ji} \cdot \overline{V}_i \, , \\ S_{jcorr} &= \left( \sum_{\substack{i=1 \\ i \neq j}}^{NLB} \frac{Z^*_{ji}}{Z^*_{jj}} \cdot \frac{S_i}{\overline{V_i}} \right) \cdot \overline{V_j} \, , \; Y_{jj+} = 1/Z_{jj} \end{aligned} \qquad \text{----10}$$

where *Fji* is the *ji*-th element of sub-matrix *FLG*; *Zjj* is the *jj*-th element of *ZLL*; *Z*jj* and *Z*ji* are the conjugate of the *jj*-th and *ji*th elements of *ZLL*; *Si* and *Sj* are the complex power demands at load buses *i* and *j*; *Vj* is the voltage magnitude at bus *j*;*Vi* and *Vj* are voltage vectors at bus *i* and bus *j* respectively.

## VIII TEST SYSTEM AND RESULTS

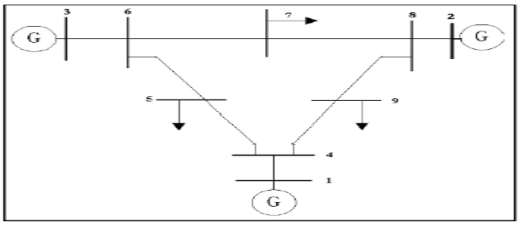


Figure 3: WSCC 9 bus system

The normal base loading at load buses are:

Bus 5: 90 + j 30 MVA
Bus 7: 100 + j 35 MVA
Bus 9: 125 + j 50 MVA

Buses 1 to 3 are generation buses; there are no generators or loads at buses 4, 6 and 8.Three case scenarios have been simulated to study the steady state voltage collapse at the load buses and their respective L index.

Case 1

Increase loading of bus 5 from zero to the voltage collapse point, keeping the load at other buses fixed at the normal value. Observe the effect on index L (5).

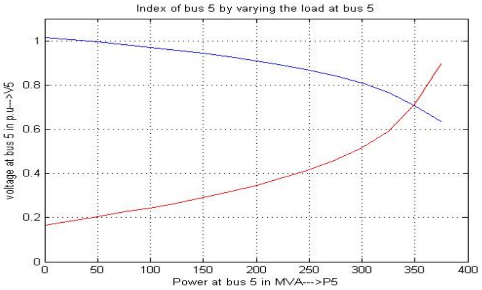


Fig 4 indicator for bus 5 with increased loading at bus 5

Case 2

Increase loading of bus 9 from zero to the voltage collapse point, keeping the load at other buses fixed at the normal value. Observe the effect on index L (9).

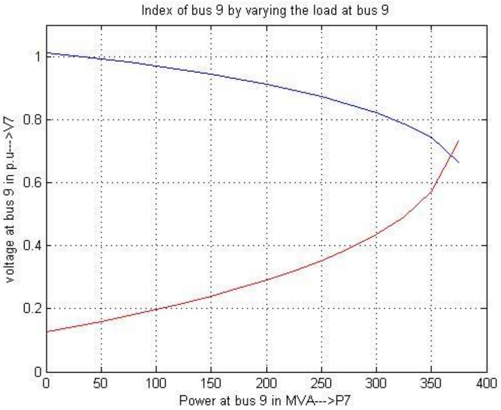
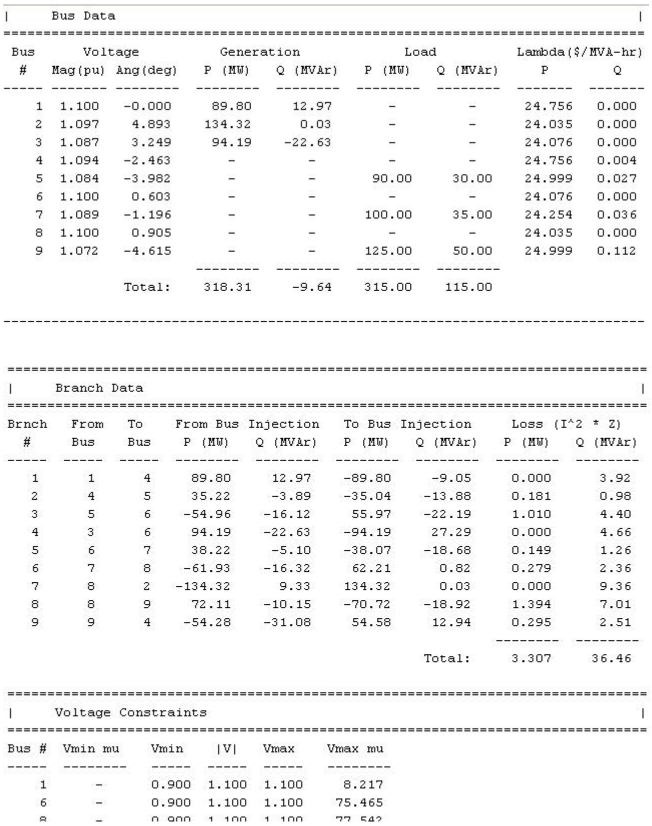


Fig 6 indicator for bus 9 with increased loading at bus 9



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|     Bus Data                                                              |
=============================================================================
 Bus      Voltage          Generation             Load        Lambda($/MVA-hr)
  #   Mag(pu) Ang(deg)   P (MW)   Q (MVAr)   P (MW)   Q (MVAr)    P        Q
----- ------- --------  --------  --------  --------  --------  -------  -------
    1  1.100   -0.000    89.80     12.97       -         -      24.756   0.000
    2  1.097    4.893   134.32      0.03       -         -      24.035   0.000
    3  1.087    3.249    94.19    -22.63       -         -      24.076   0.000
    4  1.094   -2.463      -         -         -         -      24.756   0.004
    5  1.084   -3.982      -         -       90.00     30.00    24.999   0.027
    6  1.100    0.603      -         -         -         -      24.076   0.000
    7  1.089   -1.196      -         -      100.00     35.00    24.254   0.036
    8  1.100    0.905      -         -         -         -      24.035   0.000
    9  1.072   -4.615      -         -      125.00     50.00    24.999   0.112
                        --------  --------  --------  --------
               Total:    318.31     -9.64    315.00    115.00

-----------------------------------------------------------------------------


=============================================================================
|     Branch Data                                                           |
=============================================================================
Brnch   From   To    From Bus Injection   To Bus Injection     Loss (I^2 * Z)
  #     Bus    Bus    P (MW)   Q (MVAr)   P (MW)   Q (MVAr)   P (MW)   Q (MVAr)
-----  -----  -----  --------  --------  --------  --------  --------  --------
   1      1      4     89.80     12.97    -89.80     -9.05    0.000      3.92
   2      4      5     35.22     -3.89    -35.04    -13.88    0.181      0.98
   3      5      6    -54.96    -16.12     55.97    -22.19    1.010      4.40
   4      3      6     94.19    -22.63    -94.19     27.29    0.000      4.66
   5      6      7     38.22     -5.10    -38.07    -18.68    0.149      1.26
   6      7      8    -61.93    -16.32     62.21      0.82    0.279      2.36
   7      8      2   -134.32      9.33    134.32      0.03    0.000      9.36
   8      8      9     72.11    -10.15    -70.72    -18.92    1.394      7.01
   9      9      4    -54.28    -31.08     54.58     12.94    0.295      2.51
                                                             --------  --------
                                                    Total:    3.307     36.46

=============================================================================
|     Voltage Constraints                                                   |
=============================================================================
Bus #  Vmin mu    Vmin   |V|   Vmax    Vmax mu
-----  --------   -----  -----  -----   --------
    1     -       0.900  1.100  1.100     8.217
    6     -       0.900  1.100  1.100    75.465
```

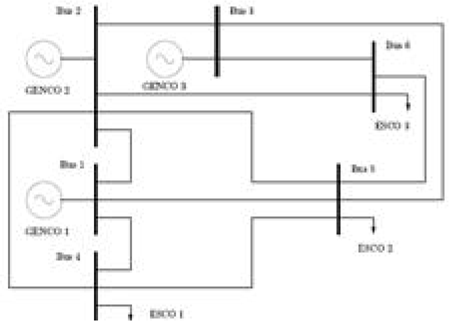
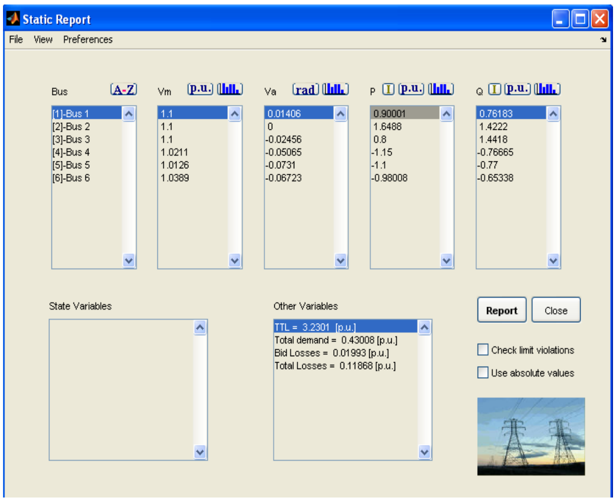


Figure 7. six bus test system

## STATIC REPORT



| Bus | Vm | Va | P | Q |
|---|---|---|---|---|
| [1]-Bus 1 | 1.1 | 0.01406 | 0.90001 | 0.76183 |
| [2]-Bus 2 | 1.1 | 0 | 1.6488 | 1.4222 |
| [3]-Bus 3 | 1.1 | -0.02456 | 0.8 | 1.4418 |
| [4]-Bus 4 | 1.0211 | -0.05065 | -1.15 | -0.76665 |
| [5]-Bus 5 | 1.0126 | -0.0731 | -1.1 | -0.77 |
| [6]-Bus 6 | 1.0389 | -0.06723 | -0.98008 | -0.65338 |

Other Variables

TTL = 3.2301 [p.u.]
Total demand = 0.43008 [p.u.]
Bid Losses = 0.01993 [p.u.]
Total Losses = 0.11868 [p.u.]

☐ Check limit violations
☐ Use absolute values

Fig 8 OPTIMAL POWER FLOW REPORT

TABLE I
NETWORK STATISTICS

| | |
|---|---|
| Buses: | 6 |
| Lines: | 11 |
| Generators: | 3 |
| Loads: | 3 |
| Supplies: | 3 |
| Demands: | 3 |

TABLE II SOLUTION STATISTICS

| | |
|---|---|
| Objective Function [$/h]: | -121.0522 |
| Active Limits: | 8 |
| Number of Iterations: | 11 |
| Barrier Parameter: | 0 |
| Variable Mismatch: | 0 |
| Power Flow Equation Mismatch | 0 |
| Objective Function Mismatch: | 0 |

TABLE III POWER SUPPLIES

| **Bus** | **mu min** | **Ps Min MW** | **Ps MW** | **Ps Max MW** | **mu max** |
|---|---|---|---|---|---|
| **1** | **0.75271** | **0.001** | **0.001** | **20** | **0** |
| **2** | **0** | **0.001** | **25** | **25** | **0.10771** |
| **3** | **0** | **0.001** | **20** | **20** | **2.0711** |

TABLE IV POWER DEMANDS

| **Bus** | **mu min** | **Pd Min MW** | **Pd MW** | **Pd Max MW** | **mu max** |
|---|---|---|---|---|---|
| **4** | **0** | **0.001** | **25** | **20** | **2.2542** |
| **5** | **0** | **0.001** | **10** | **10** | **0.63952** |
| **6** | **0** | **0.001** | **8.0079** | **20** | **0** |

TABLE V REACTIVE POWERS

| **Bus** | **mu min** | **Qg Min Mvar** | **Qg Mvar** | **Qg Max Mvar** | **mu max** |
|---|---|---|---|---|---|
| **1** | **0** | **-150** | **44.7741** | **150** | **0** |
| **2** | **0** | **-150** | **77.1924** | **150** | **0** |
| **3** | **0** | **-150** | **73.8596** | **150** | **0** |

TABLE VI VOLTAGES

| **Bus** | **mu min** | **Vmin p.u** | **V** | **Vmin p.u** | **mu max** | **Phase rad** |
|---|---|---|---|---|---|---|
| **1** | **0** | **0.9** | **1.1** | **1.1** | **1.4441** | **0.01406** |
| **2** | **0** | **0.9** | **1.1** | **1.1** | **0.72115** | **0** |
| **3** | **0** | **0.9** | **1.1** | **1.1** | **0.32306** | **0.02456** |
| **4** | **0** | **0.9** | **1.0211** | **1.1** | **0** | **0.05065** |
| **5** | **0** | **0.9** | **1.0126** | **1.1** | **0** | **0.0731** |
| **6** | **0** | **0.9** | **1.0389** | **1.1** | **0** | **0.06723** |

TABLE VII POWER FLOW

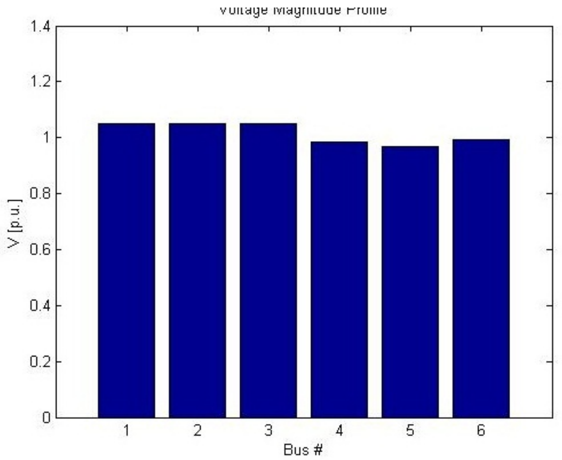
| Bus | P MW | Q Mvar | Rho p$/MWh | Rho q$/MWh | NCP $/MWh | Pay $/h |
|---|---|---|---|---|---|---|
| 1 | 90.001 | 44.7741 | 8.9473 | 9e-005 | -0.04483 | -805 |
| 2 | 164.8754 | 77.1924 | 8.9077 | 0.00015 | 0 | -1469 |
| 3 | 80 | 73.8596 | 9.0711 | 0.00015 | 0.07048 | -726 |
| 4 | -115 | 76.665 | 9.4856 | 0.3903 | 0.19303 | 1091 |
| 5 | -110 | -77 | 9.5758 | 0.40666 | 0.27007 | 1053 |
| 6 | 98.0079 | 65.3385 | 9.3526 | 0.22105 | 0.22238 | 917 |

TABLE VII FLOWS IN TRANSMISSION LINES

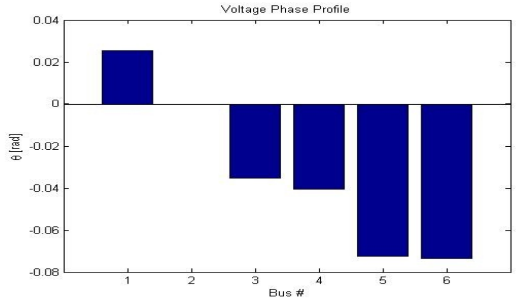
| From Bus | To Bus | Iij | Iji | Iij max | Mu Iij | Mu Iji |
|---|---|---|---|---|---|---|
| 2 | 3 | 0.11666 | 0.10424 | 0.3082 | 0 | 0 |
| 3 | 6 | 0.7406 | 0.7549 | 1.3973 | 0 | 0 |
| 4 | 5 | 0.07115 | 0.06388 | 0.1796 | 0 | 0 |
| 3 | 5 | 0.33824 | 0.36831 | 0.6585 | 0 | 0 |
| 5 | 6 | 0.11217 | 0.06066 | 0.2 | 0 | 0 |
| 2 | 4 | 0.84808 | 0.85843 | 1.374 | 0 | 0 |
| 1 | 2 | 0.0813 | 0.06235 | 0.2591 | 0 | 0 |
| 1 | 4 | 0.49425 | 0.51854 | 0.9193 | 0 | 0 |
| 1 | 5 | 0.3926 | 0.42283 | 0.8478 | 0 | 0 |
| 2 | 6 | 0.45449 | 0.45449 | 0.9147 | 0 | 0 |
| 2 | 5 | 0.37854 | 0.37854 | 0.714 | 0 | 0 |

| | |
|---|---|
| TOTAL LOSSES [MW]: | 11.868 |
| BID LOSSES [MW] | 1.993 |
| TOTAL DEMAND [MW]: | 43.0079 |
| TOTAL TRANSACTION LEVEL [MW] | 323.0079 |
| IMO PAY [$/h]: | 61.2032 |

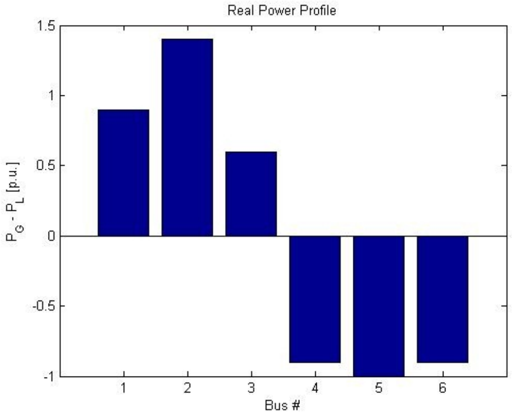
VOLTAGE MAGNITUDE PROFILE



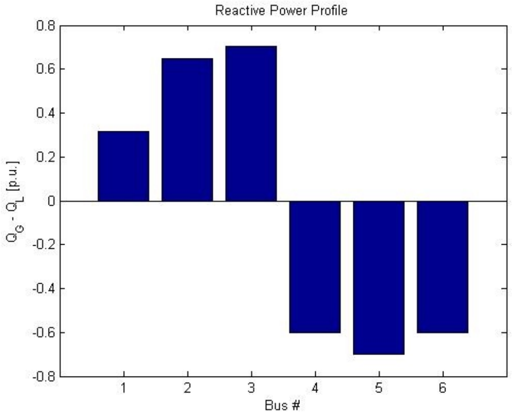
VOLTAGE-PHASE PROFILE



REAL POWER PROFILE:



REACTIVE POWER PROFILE:



## IX CONCLUSIONS

In this project work we have estimated voltage collapse margin point for different loading conditions at different buses, For achieving this we have designed index proximity and we have used the Newton's Raphson method to run the optimal power flow. This project work results are certainly useful/helpful to the power engineer for securing power system or analyzing power system online for the voltage collapse situations at any point and at any node in the power system.

A real time measurement based voltage stability indicator for monitoring of the power systems is presented. We conclude that. The indicator can predict the voltage stability problem correctly and properly Through the indicator, it is very easy to locate the vulnerable locations of the system. Here we find the voltage magnitude profiles, Voltage phase profiles, active, reactive profiles by using matlab software.

## REFERENCES

[1] Analysis of Voltage Stability using L-Index Method 483-498 *I. Kumaraswamy and P. Ramanareddy*

[2] J. A. Momoh, *Electric Power System Applications of Optimization*, New York: Marcel Dekker, 2001.

[3] A. J. Wood and B. F. Wollenberg, *Power Generation,Operation, and Control*, New York: John Wiley &Sons,1996.

[4] P. Kessel and H. Glavitsch, "Estimating the Voltage Stability of a Power System," *IEEE Trans. Power Delivery*, vol. PWRD- 1, no. 3, pp. 346-354, July 1986.

[5] J. Yuryevich and K. P. Wong, "Evolutionary Programming Based Optimal Power Flow Algorithm,"*IEEE Trans. Power Systems*, vol. 14,no.4, pp. 1245-1250,Nov. 1999.

[6] P. M. Anderson and A. A. Fouad, *Power System Control and Stability*,Iowa: The Iowa State University Press, 1977.

[7] R. Zimmerman, E. Murillo-Sánchez, and D. Gan,"MATPOWER: MATLAB Power System Simulation Package," 2006.[7] N. Mo, Z. Y. Zou, K. W. Chan,and T. Y. G. Pong, "Transient stability Constrained optimal power flow using particle swarm optimization,"*IET Generation Transmission and Distribution*, vol. 1,no. 3, pp. 476-483,May. 2007.