Voltage Stability and Security Analysis

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ABSTRACT: The existing Power System is growing in leaps and bounds. So also are the complexities associated with it. Disturbances are inherent in the system and occur very frequently at one point or the other on the network. To detect such faults and consequently to analyze the fault requires the use of heavy calculations which requires high dimensionality and complexity. Hence a large amount of time, memory as well as resources are used up for this purpose.

Voltage stability problem have been one of the major concern for electric utilities as a result of heavier loading of power system. Maintaining voltage stability & specified voltage levels at all nodes in a large and heavily loaded power network is a critical and challenging task for power engineers. In this work a method for detecting voltage instability in a power network comprising of multiple lines and switches has been suggested based on L-index approach. Network reconfiguration is intended to enhance voltage stability by determination of switching options that maximize voltage stability the most for a particular set of load and is performed by altering the topological structure of the system. This project is based on detecting the faulty part of network by L-index method so that voltage stability will be enhanced.

Index Terms – 1) Load flow, 2) Newton-Raphson method 3) voltage stability 4) Bus bar 5) power system stability 6) Artificial neural network 7) Voltage collapse

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1. INTRODUCTION

A Power System is said to be well designed if it gives a good quality of reliable supply. By good quality is meant the voltage levels within the reasonable limits. Practically all the equipments on the Power Systems are designed to operate satisfactorily only when the voltage levels on the system correspond to their rated voltage or at the most variations are within the limit. The management of Power Systems has become more difficult than earlier because Power Systems operates closer to security limits, environmental constraints restrict the expansion of transmission network, the need for long distance power transfer has increased and fewer operators are engaged in supervision and operation of Power Systems. Voltage stability has become a measure concern in many Power Systems in many blackouts have been reported, where the reason have been voltage instability.

Voltage control and stability problems are now receiving special attention in highly developed networks as a result of heavier loading. Due to fast growth in power demands incidence of sudden voltage collapse has been experienced. Hence such an incident happens; some industrial loads will be switched off to automatic cut-off switches resulting in severe interruptions. Most of the incident of voltage collapse are related to heavily stressed power system where large amounts f real and reactive power are transported over long extra high voltage(EHV)transmission lines, while appropriate reactive power sources are not available to maintain normal voltage profiles at receiving end buses. Most EHV transmission lines being very sensitive to real and reactive power

changes, frequently suffers from voltage instability. Improvement of voltage stability is very much essential in order to ensure desired power transfer at rated voltage.

2. LOAD FLOW ANALYSIS

The modern approach of power system is interconnections of all the generating stations i.e. forming a grid system. Load demand undergoes wide changes in the day. The generating of power at all the moments should be equal to the demand. One of the advantages of grid system is generation of power always meet the load demand at all times. For most economic operation the load must be shared in equal ratios. Care must be taken so that none of interconnected station may be overloaded. It must be ensured that the transmissions line must not be operate close to stability limit.

- Load flow solution gives the solution of network under steady state condition subject to certain inequity constrains under which the system operates.
- The load flow solution gives the nodal voltages and phase angles and hence the power injection at all the buses and power flows through interconnecting power channels.
- Load flow solution is essential for designing a new power system.
- Load flow solution is essential for extension of the existing one for increased load demand.

Characteristics of load flow equations
- The load flow equations are algebraic and nonlinear.

- Obtaining analytic solutions are difficult but numerical solutions are possible.
- Static load flow equation has three types of variables: (a) Disturbances variables, (b) Independent variables, (c) Dependent variables.
- Load flow equation relate with voltage and power.

Types of buses

Bus type	Quantities specified	Quantities to be obtained
Load bus	P, Q	lVl, δ
Generator bus	P, lVl	Q, δ
Slack bus	lVl, δ	P ,Q

Some of the leading techniques of load flow solutions are :
- Gauss-Seidal method of power flow.
- Newton-Raphson method of power flow.
- Fast decoupled method of power flow.

Using Newton-Raphson method can also solve the power flow problem. In fact, among the numerous solution methods available for power flow analysis, the Newton-Raphson method is considers to be most sophisticated and important. No advantages are attributed to the Newton-Raphson (N-R) approach. Newton-Raphson method is based on Taylor's serious and partial derivaties.The N-R method is recent, take less computer time hence computation cost is less and the convergence is certain. The Newton-Raphson method is more accurate, and is insensitive to factor like slack bus selection, regulating transformers etc and the number of iterations through the G-S method and using the values of voltages so obtained for starting the N-R iterations can considerably speed up convergence. These voltages are used to compute active power is specified. The differences between the specified and calculated values are used to determine the correction of bus voltages. The process of iteration is continued till the difference in the specified and calculated values of P,Q and V are within the given permissible limit.

Newton-Raphson solution method

There are several different methods of solving the resulting nonlinear system of equations. The most popular is known as the Newton-Raphson Method. This method begins with initial guesses of all unknown variables (voltage magnitude and angles at Load Buses and voltage angles at Generator Buses). Next, a Taylor Series is written, with the higher order terms ignored, for each of the power balance equations included in the system of equations. These linearized system of equations is solved to determine the next guess (m + 1) of voltage magnitude and angles based on:

$\theta m + 1 = \theta m \Delta \theta$

$| V | m + 1 = \theta m \Delta | V |$

The process continues until a stopping condition is met. A common stopping condition is to terminate if the norm of the mismatch equations are below a specified tolerance.

3. CONCEPT OF VOLTAGE STABILITY

Voltage stability:

Power system stability is defined as a characteristic for a power system to remain in a state of equilibrium at normal operating condition and to restore an acceptable state of equilibrium after a disturbance. Traditionally, the stability problem has been the rotor angle stability, i.e. maintaining synchronous operation. Definition of voltage stability as follows:"the voltage stability is the ability of a power system to maintain steady state acceptable voltages at all buses in the system at normal operating condition and after being subjected to a disturbance."

Voltage instability:

Power system is voltage stable if voltage after a disturbance is close to voltages at normal operating condition. A power system becomes unstable when voltages uncontrollably decrease due to outage of equipment(generator, line, transformer, bus-bar, etc.),increment of load, decrement of production and/or weakening of voltage control. The definition of voltage instability is "voltage instability stems from the attempt of load dynamics to restore power consumption beyond the capability of the combined transmission and generation system". Voltage control and instability are local problem. However, the consequences of voltage instability may have a widespread impact.

Voltage stability can also call "load stability". A power system lacks the capability to transfer an infinite amount of electrical power to loads. The main factor causing voltage instability is the inability of power system to meet the demands for reactive power in the heavily stressed system to keep desired voltages. Other factors contributing to voltage stability are the generator reactive power limits, the load characteristics, the characteristics of the reactive power compensation devices and the action of the voltage control devices. The reactive characteristics of AC transmission lines, transformers and load restrict the maximum of power transfers. The power system lacks the capability to transfer power over long distances or through high reactance due to the requirement of a large amount of reactive power at some critical value power or distances. Transfer of reactive power is difficult to extremely high reactive power losses, which is why the reactive power required for voltage control is produced and consumed at the control area.

Voltage collapse:

Voltage collapse is defined as the, following voltage instability, a power system undergoes voltage collapse if the post-disturbance equilibrium voltage near loads is below acceptable limits. Voltage collapse in the system may be either total (blackout) or partial.

4. CLASSIFICATION OF POWER SYSTEM STABILITY:

Steady state stability:

Steady state stability is the stability of the power system under condition of gradual or relatively slow change in load. The load is assumed to be applied at a rate which is slow when compared either with the natural frequency of oscillation of the major parts of the system or with the rate of change of field flux in the rotating machine in response to the change in loading. In steady state stability zone the system operates on a single power angle curve and the regulators acts slowly in order to adjust the terminal voltage to the prescribed value.

Transient state stability:

The transient state stability refers to the maximum flow of power possible through a point without losing the stability with sudden and large changes in the network conditions such as brought about by faults, by sudden large increment of loads. The transient stability is due to lack of synchronizing torque and is initiated by large disturbances. Factors affecting transient stability are:
(1) Higher system voltage: which allow the machine to rotate through large angle before it reaches the critical clearing which results in greater critical clearing time and the probability of maintaining stability.
(2) Use of parallels lines to reduce the series reactance.
(3) Use of high speed circuit breakers and auto-reclosing breakers.

Power system stability further classified as: Rotor angle stability & voltage stability:

Rotor angle stability problem is directly associated with the active power transfer, whereas the voltage stability problem is associated with reactive power transfer. Voltage stability is normally inter linked with the rotor angle synchronous stability. Both the rotor angle stability and voltage stability are affected by reactive power control. Rotor angle stability is normally concerned with integrating remote plants to a large system over long transmission lines whereas voltage stability is concerned with load areas and load characteristics. Therefore, rotor angle stability is basically generator stability and voltage stability is basically load stability.

5. CLASSIFICATION OF VOLTAGE STABILITY

Transient voltage stability:

The time frame for transient voltage stability and transient angle stability is almost same and varies about zero to 10 seconds. Because of the overlap of the period it is difficult to differentiate between transient voltage stability and transient angle stability and as such both phenomenons may exist. Therefore it may not be clear whether angle rotor instability led to voltage stability or vice versa. Voltage collapse is caused by unfavorable fast acting load component such as a large induction motors and dc converters.

It has been observed that during electric system islanding and under frequency load shedding, there is possibility that the system voltage may collapse whenever the imbalance in the system reactive power is more than 50%.it is also found that voltage decays much faster than the frequency, the voltage decay affects voltage sensitive loads, thereby the frequency decay slow down and the load shedding due to under frequency relay is delayed. Also, the under frequency relays require certain minimum voltage to operate, and during voltage decay these relays may not operate and under voltage load shedding may be necessary.HVDC circuit used in power system to enhance the power transfer capability caused transient voltage stability problems as the converters and inverters require large amount of reactive power for their operation and pose voltage stability problem specially when power transfer is large.

Longer term voltage stability:

The longer term voltage stability involves high loads, high power imports from remote generation and a sudden large disturbance which could be in the form of loss of large generators in a load area or loss of a major transmission line (large capacity line). The system is transiently stable. However, the disturbance causes high reactive power losses and voltage sags in load areas. The distribution voltage regulators and the tap changer on bulk power delivery LTC transformer sense the low voltages and act in a way to restore distribution voltage and thus the load power levels are restored. This restoration of load further cause's sag of transmission voltage and nearby generators are overexcited and overloaded.

6. PREVENTION OF VOLTAGE COLLAPSE

Different types of reactive power compensating device can be used for maintaining voltage stability.

Shunt capacitors:

Switched shunt capacitor compensating generally provides the economical reactive power source for voltage control. It is ideally suitable for compensating transmission lines if reduction of the effective characteristic impedance, rather than reduction of the effective line angle is the primary consideration. They can effectively use up to a certain point to extend the voltage stability limits by correcting the

receiving end power factor. They can also be used to free up" spinning reactive reserve" in generators and thereby help prevent voltage collapse in many situation. Shunt capacitors, however, have a number of inherent limitations from the viewpoint of voltage stability and control.

- In heavily shunt capacitor compensated systems, the voltage regulation tends to be poor.
- Beyond a certain level of compensation, stable operation is unattainable with shunt capacitor.
- The reactive power generated by a shunt capacitor is proportional to the square of the voltage, during system condition of low voltage the var support drops, thus compounding the problem.

Series capacitors:

Series capacitors are self regulating. The reactive power supplied by series capacitor proportional to square of the line current and is independent of the bus voltages. This has favorable effect on voltage stability. Series capacitors are ideally suited for effectively shortening long lines. Unlike shunt capacitors, series reduces both the characteristic impedance and rotor angle of the line. As a result, both voltage regulation and stability are significantly improved. Series capacitor compensation could causes sub-synchronous resonance problems requiring special solution measure. In addition, protection of lines with series capacitor requires special attention.

Synchronous capacitors:

A great advantage of the synchronous capacitor is its flexibility for use for all load condition because it supplies vars when over-exited, i.e. during peak load condition and it consumes vars when under-exited during light load conditions. There is smooth variation of reactive vars by synchronous capacitors as compared with step by step variation by the static capacitors. Synchronous machines can be overloaded for short periods whereas static capacitors cannot. For large outputs the synchronous capacitors are much better than the static capacitor from economic point of view because otherwise a combination of shunt capacitors and reactors is required.

Static var compensation techniques (SVC):

Static var compensation techniques are ideally suited for application requires direct and rapid control of voltage. It has a distinct advantage over series capacitor where compensation is required to prevent voltage sag at a bus involving multiple lines. Under this compensation two techniques are there: 1) FC-TCR (fixed capacitor thyristor controlled reactor) 2) TCS-TCR (thyristor switched capacitor thyristor controlled reactor).

7. VOLTAGE STABILITY INDICATOR

Voltage instability is a state of power system encountering an unacceptable voltage level. This paper describes the expressions of Fast Voltage Stability Index (FVSI) and Line Quality Factor (LQF), which may be considered as indication of voltage collapse under constrained condition of an interconnected power system. Artificial Neural Network Technique has been applied to identify the voltage collapse condition. The novelty of this method is that, once the ANN model of the system is developed, through on line checking of the load of the weak bus, the present method can immediately calculate the FVSI and LQF without going through the complex classical calculations. The developed ANN technique has been tested in IEEE 30 bus .Test system and is found to be in excellent agreement with the result obtained by classical method.

The continuous increase in demand for electric power has resulted in an increasingly complex interconnected system, forced to operate closer to the limit of stability. Voltage instability is characterized by the inability of the system to retain its voltage near the nominal value, even with a change in connected susceptance at the load bus. In a multiuse interconnected system, if load (active and/or reactive) increases continuously the voltage of each bus decreases. From this condition, different voltage stability limits may be obtained. Researches are going for long to study voltage instability of an interconnected power system. A review of literature reveals that, researchers have been trying to investigate the static aspect of load flow solutions by applying various methods for identifications of the point of bifurcation and to estimate the stability margin of the system. This paper focuses on two different methods of stability indices.

8. THEORY OF FVSI AND LQF

An interconnected system is reduced to a single line network and applied to assess the overall system stability. Utilizing the same concept but using it for each line of network stability criteria can be developed. Consider a single line of interconnected network shown in fig.1. The line is connected to other lines forming a grid network. Any of the lines from that network can be represented with the following parameters shown in fig.1.

$$R + jX$$
$$\longrightarrow I$$
$$V_1 \angle 0, S_1 = P_1 + jQ_1 \qquad V_2 \angle -\delta, S_2 = P_2 + jQ_2$$
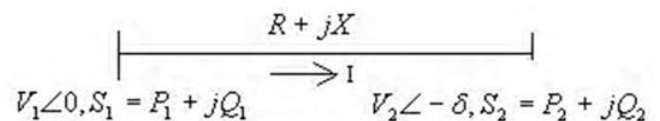
Fig.1 Typical one line diagram of transmission line

The sending end bus voltage is actually the summation of live drop and receiving end bus voltage.

$$V_2 \angle -\delta + \left[\frac{P_2 - jQ_2}{V_2 \angle +\delta} \right] (R + jX) = V_1 \angle 0$$

$$\text{or, } V_2^2 + P_2 R + Q_2 X + j(XP_2 - Q_2 R) = V_1 V_2 \cos\delta + jV_1 V_2 \sin\delta \qquad (1)$$

Now from (1), after separating the real and imaginary part and eliminating δ, we have the following equation,

$$V_2^4 + V_2^2 (2Q_2 X - V_1^2) + X^2 (P_2^2 + Q_2^2) = 0 \qquad (2)$$

To have real solutions for voltage, Equation (2) must have real roots. Thus the following conditions which can be used as stability criteria need to be satisfied.

$$(2Q_2 X - V_1^2)^2 - 4X^2(P_2^2 + Q_2^2) \geq 0$$

Or,

$$\text{LQF} = \frac{4X\left[Q_2 + \frac{XP_2^2}{V_1^2} \right]}{V_1^2} \leq 1.00 \qquad (3)$$

Again from (1), the real and imaginary parts are separated; value of P2 is obtained from real part and substituted in reactive part to get

$$V_2^2 + Q_2 X + V_1 V_2 \left[\frac{\sin\delta}{\tan\theta} - \cos\delta \right] = 0 \qquad (4)$$

Where, $Z \sin\theta = X$

For getting real solutions of voltage,(4) should have real roots and at limiting conditions the following criteria should be satisfied,

$$\text{FVSI} = \frac{4XQ_2}{V_1^2 [\sin(\delta - \theta)]^2} \leq 1.00 \qquad (5)$$

The stability criteria (3) & (5) are used to find the stability index for each line connected between the two bus bars in an interconnected power network. Based on the stability indices if the lines, voltage collapse can be accurately predicted. As long as stability indices are less than 1, the system is stable and when these exceeds the value 1, the whole system loses its stability and voltage collapse occurs.

9. RESULTS AND ANALYSIS

Newton-Raphson Programming with MATLAB simulator:

```
function [Ybus, theta] =
LFNR(nbus,nlns,linedata,sh,mbus,pfbd)
% INITIALISATION OF YBUS and CALCULATION OF
YBUS MATRIX INCLUDING CHARGING
%SUCEPTANCE & TRANSFORMER TAP SETTING:
nl = linedata(:,1); nr = linedata(:,2); R = linedata(:,3);
X = linedata(:,4); Bc = j*linedata(:,5); a = linedata(:, 6);
```

```
nbr=length(linedata(:,1)); nbus = max(max(nl), max(nr));
Z = R + j*X; y= ones(nbr,1)./Z;
  Ybus=zeros(nbus,nbus);
 for k=1:nbr;
            Ybus(nl(k),nr(k))=Ybus(nl(k),nr(k))-y(k)*a(k);
            Ybus(nr(k),nl(k))=Ybus(nl(k),nr(k));
  end

for n=1:nbus
  if sh(n)>0
    Ybus(n,n) = Ybus(n,n)+ j*sh(n);
  else
  end
   for k=1:nbr
     if nl(k)==n

       %  Ybus(n,n) = Ybus(n,n)+y(k) +Bc(k);     %a:1
         Ybus(n,n) = Ybus(n,n)+y(k)*(a(k)^2) + Bc(k);
     elseif nr(k)==n
         %  Ybus(n,n) = Ybus(n,n)+y(k)*(a(k)^2) + Bc(k);
%a:1
         Ybus(n,n) = Ybus(n,n)+y(k) +Bc(k);
     end

   end
end
Ybus;
theta = angle(Ybus);
Ybus=abs(Ybus);
%INITIALISATION THE PROCESS:
Vmag(1)= pfbd(1,3);
delta(1)= pfbd(1,4);
for k=2:nbus;
   delta(k)=pfbd(k,4);
   Vmag(k)=pfbd(k,3);
end
itr=0;
count=0;
while count <2*(nbus-1)-mbus;
  itr=itr+1;
%Q LIMIT CHECKING:
 for k=2:nbus;
  sum = 0;
    if pfbd(k,2)==2;
      for m= 1:nbus;
        sum = sum +
Ybus(k,m)*abs(Vmag(m))*sin(theta(k,m)-
delta(k)+delta(m));
      end
        Q1 = -(abs(Vmag(k))* sum);
        Q = Q1 + pfbd(k,6)- pfbd(k,11);
      if Q>pfbd(k,9);
        Q=pfbd(k,9);
        pfbd(k,2)=0;
```

```
        mbus=mbus-1;
      elseif Q<pfbd(k,10);
         Q=pfbd(k,10);
         pfbd(k,2)=0;
         mbus=mbus-1;
       end
    end
  end
%CALCULATION OF JACOBIAN MATRIX (H-L-M-N
FORM):
JJ=zeros((2*(nbus-1)-mbus),(2*(nbus-1)-mbus));
x=0;
for i=2:nbus;
   y=0;
   for m=2:nbus;
     sum=0;
     if m ==i;
        for k=1:nbus;
          if k ~=m;
           sum = sum+ Ybus(i,k)*Vmag(k)*sin(theta(i,k)-
delta(i)+delta(k));
          end
        end
        JJ(i-1+x,m-1+y)= Vmag(i)*sum;
        if pfbd(m,2)==0;
           y=y+1;
        else
        end
     else
        JJ(i-1+x,m-1+y)=-
Vmag(i)*Ybus(i,m)*Vmag(m)*sin(theta(i,m)-
delta(i)+delta(m));
        if pfbd(m,2)==0;
           y=y+1;
        else
        end
     end
   end
  if pfbd(i,2)==0;
    x=x+1;
  else
  end
end

I=0;x=0;
for i=2:nbus;
   z=0; I=I+1; J=0;
     for m=2:nbus;
        if pfbd(m,2)==0;
           sum1=0; J=J+2;
           if i == m;
             for k=1:nbus;
               if k ~=m;
                sum1 = sum1 +
Ybus(i,k)*Vmag(k)*cos(theta(i,k)-delta(i)+delta(k));
               end
```

```
               end
             JJ(I+x,J+z)= 2*Vmag(i)*Ybus(i,i)* cos(theta(i,i))+
sum1;
           else
             JJ(I+x,J+z)=Vmag(i)*Ybus(i,m)*cos(theta(i,m)-
delta(i)+delta(m));
           end
        else
           z=z+1;
        end
     end
     if pfbd(i,2)==0;
        x=x+1;
     else
     end
end

I1=0;x=0;z=0;
for i=2:nbus;
   y1=0;
   if pfbd(i,2)==0;
     x=x+1;
     I1=I1+1;
     J=0;
     for m=2:nbus;
        sum1=0;J=J+1;
        if i ==m;
           for k = 1:nbus;
             if k ~=m;
sum1=sum1+Ybus(i,k)*Vmag(k)*cos(theta(i,k)-
delta(i)+delta(k));
             end
           end
           JJ(I1+x+z,J+y1)= Vmag(i)*sum1;
           if pfbd(m,2)==0;
              y1=y1+1;
           else
           end
        else
           JJ(I1+x+z,J+y1)=-
Vmag(i)*Ybus(i,m)*Vmag(m)*cos(theta(i,m)-
delta(i)+delta(m));
           if pfbd(m,2)==0;
              y1=y1+1;
           else
           end

        end
     end
   else
     z=z+1;
   end
end

I2=0; x=0;
```

```
for i=2:nbus;
   if pfbd(i,2)==0;
     y=0; I2=I2+2;
     J=0;
     for m=2:nbus;
        if pfbd(m,2)==0;
          sum1=0; J=J+2;
          if i == m;
            for k=1:nbus;
               if k ~=m;
                  sum1 = sum1 +
Ybus(i,k)*Vmag(k)*sin(theta(i,k)-delta(i)+delta(k));
                  end
               end
            JJ(I2+x,J+y)=-2*Vmag(i)*Ybus(i,i)* sin(theta(i,i))-
sum1;
            else
               JJ(I2+x,J+y)=-Vmag(i)*Ybus(i,m)*sin(theta(i,m)-
delta(i)+delta(m));
            end
          else
            y=y+1;
          end
        end
     else
       x=x+1;

     end
end
JJ;
JJ1=inv(JJ);
%CALCULATION OF delP AND delQ FROM GIVEN
DATA:
  ddpq=zeros((2*(nbus-1)-mbus),1);
  x=0;
  for k=2:nbus;
     sum = 0;
     if pfbd(k,2)==0;
        for m= 1:nbus;
           sum = sum +
Ybus(k,m)*Vmag(m)*cos(theta(k,m)-delta(k)+delta(m));
        end
        sum1=Vmag(k)*sum;
        ddpq(k-1+x)= (pfbd(k,7)-pfbd(k,5))-sum1;
        sum=0;
        for m= 1:nbus;
           sum = sum +
Ybus(k,m)*Vmag(m)*sin(theta(k,m)-delta(k)+delta(m));
        end
        sum2=-Vmag(k)*sum;
        ddpq(k+x)= (pfbd(k,8)-pfbd(k,6)+pfbd(k,11))-
sum2;
        x=x+1;
     else
        for m= 1:nbus;
```

```
        sum = sum +
Ybus(k,m)*Vmag(m)*cos(theta(k,m)-delta(k)+delta(m));
        end
        sum1=Vmag(k)*sum;
        ddpq(k-1+x)= (pfbd(k,7)-pfbd(k,5))-sum1;
     end
  end
  ddpq;
  ddv= JJ1*ddpq;
 % CALCULATION OF NEW VOLTAGE AND ANGLE:
  x=0;
  for k = 1:nbus-1;
     n=k+1;
     delta(n)= delta(n)+ddv(k+x);
     delta1(n)=(delta(n)*180)/pi;
     if pfbd(n,2)==0;
       Vmag(n)= abs(Vmag(n)+ddv(n+x));
       x=x+1;
     else
     end
  end

 % CHECKING OF POWER MISMATCH AT BUSSES:
    for k=1:size(ddpq)
       if abs(ddpq(k))<= 0.000001
         count = count+1;
       end
    end
 %clear JJ ddpq ddv JJ1;
end
fprintf('                 No. of Iterations = %g \n\n', itr)
JJ;
mbus

head =[' Bus   Voltage  Angle      Angle '
     ' No.   Magnitude  Radian     Degree'
     '                            '];
disp(head)
for n=1:nbus
   fprintf(' %5g', n), fprintf(' %10.5f', Vmag(n)), fprintf('
%12.5f', delta(n)),fprintf('%12.5f\n',delta1(n)),

end
```

%CALCULATION OF LINE FLOW AND LINE LOSSES:

```
SLT = 0;
basemva=100;
SBP =0;
fprintf('\n')
fprintf('           Line Flow and Losses \n\n')
fprintf('     ----Line----        ---line flow--- \n')
fprintf('     from   to      MW       Mvar \n')
nl = linedata(:,1); nr = linedata(:,2); R = linedata(:,3);
X = linedata(:,4); Bc = j*linedata(:,5); a = linedata(:, 6);
nbr=length(linedata(:,1)); nbus = max(max(nl), max(nr));
```

```
Z = R + j*X; y= ones(nbr,1)./Z;

 V=Vmag.*exp(j*delta);

for n = 1:nbus

  for L = 1:nlns;
    if nl(L)==n
      k = nr(L);
      %if a(L)<1

      % In = (V(n) - a(L)*V(k))*y(L)/a(L)^2 +
Bc(L)/a(L)^2*V(n)+j*sh(n)*V(n);
      % Ik = (V(k) - V(n)/a(L))*y(L) + Bc(L)*V(k);
      %        else

      In = (V(n) - V(k)/a(L))*y(L)*a(L)^2 +
Bc(L)*a(L)^2*V(n)+j*sh(n)*V(n);
      Ik = (V(k) - V(n)*a(L))*y(L) + Bc(L)*V(k);
      %end
    Snk = V(n)*conj(In)*basemva;
    Snk1= conj(Snk);

    Skn = V(k)*conj(Ik)*basemva;
    Skn1=conj(Skn);
    SL  = Snk + Skn;
    SLT = SLT + SL;
    if n ==1;
      SBP = (SBP + Snk);
      %SBP1=(SBP/basemva)+(pfbd(1,5)+i*pfbd(1,6));
      SBP1=(SBP/basemva);
      SBP2=real(SBP1)+pfbd(1,5);
      SBP3=imag(SBP1)+pfbd(1,6);
    end

  elseif nr(L)==n  k = nl(L);
    %if a(L)<1
    %In = (V(n) - V(k)/a(L))*y(L) + Bc(L)*V(n);
    %Ik = (V(k) - a(L)*V(n))*y(L)/a(L)^2 +
Bc(L)/a(L)^2*V(k);
    %else

    In = (V(n) - V(k)*a(L))*y(L) + Bc(L)*V(n);
    Ik = (V(k) - V(n)/a(L))*y(L)*a(L)^2 +
Bc(L)*a(L)^2*V(k);
    %        end
    Snk = V(n)*conj(In)*basemva;
    Snk1= conj(Snk);
    Skn = V(k)*conj(Ik)*basemva;
    Skn1=conj(Skn);
    SL  = Snk + Skn;
    SLT = SLT + SL;
  else
  end
   if nl(L)==n | nr(L)==n
     fprintf('%10g',n), fprintf('%10g', k),
```

```
      fprintf('%15.5f', real(Snk1)), fprintf('%15.5f\n', -
(imag(Snk1))),

    else
    end
  end

end
SLT = SLT/2;
fprintf(' \n'), fprintf('    Total loss        ')
fprintf('%10.5f', real(SLT)), fprintf('%17.5f\n', imag(SLT))
fprintf(' \n'), fprintf('    Slack bus power in P.U      ')
fprintf('%10.5f',SBP2), fprintf('%17.5f\n', SBP3)
clear Ik In SL SLT Skn Snk
```

10. LINEDATA AND BUSDATA FOR IEEE 14 BUS SYSTEM

```
nbus=14;
nlns=20;
linedata=[1   2   0.01938 0.05917 0.0264 1
          2   3   0.04699 0.19797 0.0210 1
          2   4   0.05811 0.17632 0.0187 1
          1   5   0.05403 0.22304 0.0246 1
          2   5   0.05695 0.17388 0.0170 1
          3   4   0.06701 0.17103 0.0173 1
          4   5   0.01335 0.04211 0.0064 1
          5   6   0.0     0.25202 0.0    0.932
          4   7   0.0     0.20912 0.0    0.978
          7   8   0.0     0.17615 0.0    1
          4   9   0.0     0.55618 0.0    0.969
          7   9   0.0     0.11001 0.0    1
          9  10   0.03181 0.8450  0.0    1
          6  11   0.09498 0.19890 0.0    1
          6  12   0.12291 0.25581 0.0    1
          6  13   0.06615 0.13027 0.0    1
          9  14   0.12711 0.27038 0.0    1
         10  11   0.08205 0.19207 0.0    1
         12  13   0.22092 0.19988 0.0    1
         13  14   0.17093 0.34802 0.0    1];
   sh=[0;0;0;0;0;0;0;0;0.19;0;0;0;0;0];
 mbus=4;
 pfbd=[1 1 1.06  0    0     0     2.324 -0.1601 0    0    0
       2 2 1.045 0    0.217 0.127 0.4    0.4541 0.500 -0.40
   0
       3 2 1.010 0    0.942 0.19  0.0    0.2528 0.400 0
   0
       4 0 1.0   0    0.478 -0.039 0.0   0.0    0     0    0
       5 0 1.0   0    0.076 0.016 0.0    0.0    0     0    0
       6 2 1.07  0    0.112 0.075 0.0    0.1362 0.24 -0.06
   0
       7 0 1.0   0    0.0   0.0   0      0.0    0     0    0
       8 2 1.09  0    0.0   0.0   0      0.1824 0.24 -0.06 0
       9 0 1.0   0    0.295 0.166 0      0      0     0.19
      10 0 1.0   0    0.090 0.058 0      0      0     0    0
      11 0 1.0   0    0.035 0.018 0      0      0     0    0
```

	Bus Voltage		Load Data	
	Magnitude	Degree	MW	MVAR
1	1.060	0.0	0.0	0.0
2	1.045	0.0	21.7	12.7
3	1.010	0.0	94.2	19.0
4	1.000	0.0	47.8	-3.9
5	1.000	0.0	7.6	1.6
6	1.070	0.0	11.2	7.5
7	1.000	0.0	0.0	0.0
8	1.090	0.0	0.0	0.0
9	1.000	0.0	29.5	16.6
10	1.000	0.0	9.0	5.8
11	1.000	0.0	3.5	1.8
12	1.000	0.0	6.1	1.6
13	1.000	0.0	3.5	5.8
14	1.000	0.0	14.9	5.0

```
    12 0 1.0   0   0.061  0.016  0   0   0   0   0
    13 0 1.0   0   0.135  0.058  0   0   0   0   0
    14 0 1.0   0   0.149  0.050  0   0   0   0   0];
```

[Ybus,theta]=LFNR(nbus,nlns,linedata,sh,mbus,pfbd);

11. RESULT OF LOAD FLOW BY N-R METHOD(IEEE BUS SYSTEM)

No. of Iterations = 5
mbus = 2

```
Bus    Voltage    Angle      Angle
No.    Magnitude  Radian     Degree

1   1.06000    0.00000    0.00000
2   1.04500   -0.08687   -4.97744
3   1.01000   -0.22149  -12.69046
4   1.02557   -0.18230  -10.44517
5   1.02888   -0.15495   -8.87809
6   0.96330   -0.26744  -15.32308
7   1.02701   -0.24397  -13.97827
```

```
8   1.05740   -0.24397  -13.97827
9   1.02218   -0.27578  -15.80118
10  0.95261   -0.30142  -17.27024
11  0.95386   -0.28755  -16.47563
12  0.95222   -0.28427  -16.28719
13  0.95267   -0.28670  -16.42684
14  0.97278   -0.30036  -17.20944
```

12. CONCLUSION

In this chapter MATLAB programme based Newton Raphson method is proposed. From this work it is concluded that, it requires few iterations to converge the solution for any type of system. The generalized MATLAB programme is tested with different standard IEEE system configurations. The result for IEEE-14 Bus system is described in this chapter. Power flows and line losses are also calculated for IEEE-14 Bus system by using developed programme.

13. RESULT AND ANALYSIS OF VOLTAGE STABILITY INDICATOR

Bus data for IEEE 14 bus system:

LQF and FVSI calculation with linedata:

Lines	Starting Bus	End Bus	R(P.U)	X(P.U)	LQF	FVSI
L1	1	2	.01938	.05917	.027212	
L2	1	5	.05403	.22304	.015423	
L3	2	3	.04699	.19797	.2811752	
L4	2	4	.05811	.17632	.00907	
L5	2	5	.05695	.17388	.011826	
L6	3	4	.06701	.17103	.000513	
L7	4	5	.01335	.04211	.00273	
L8	4	7	.00000	.20912	.070408	
L9	4	9	.00000	.55618	.476983	
L10	5	6	.00000	.25202	.586744	
L11	6	11	.09488	.19890	.0145146	

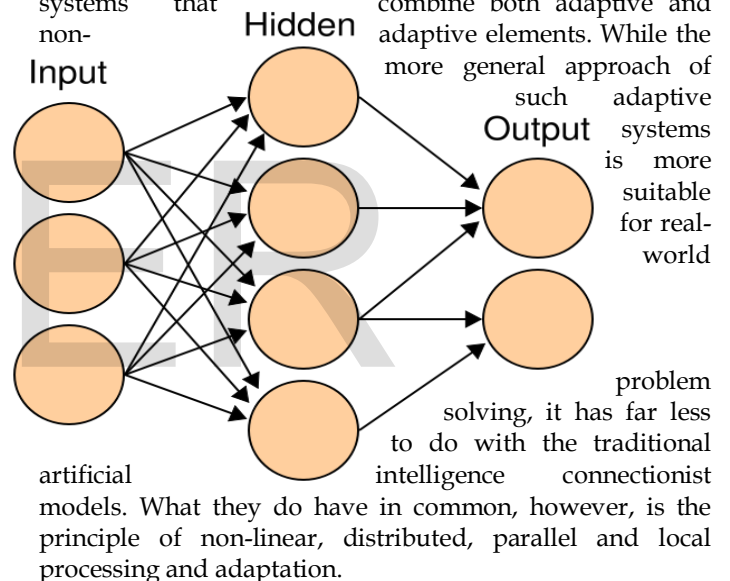| L12 | 6 | 12 | .12291 | .25581 | .01739 | |
L13	6	13	.06615	.13027	.03035	
L14	7	8	.00000	.17615	.59304	
L15	7	9	.00000	.11001	.175573	
L16	9	10	.03181	.08450	0.019853	
L17	9	14	.12711	.27038	.060523	
L18	10	11	.08205	.19207	.0140098	
L19	12	13	.22092	.19988	.046578	
L20	13	14	.17093	.34802	.0803597	

14. ARTIFICIAL NEURAL NETWORK

An artificial neural network (ANN), usually called "neural network" (NN), is a mathematical model or computational model that tries to simulate the structure and/or functional aspects of biological neural networks. It consists of an interconnected group of artificial neurons and processes information using a connectionist approach to computation. In most cases an ANN is an adaptive system that changes its structure based on external or internal information that flows through the network during the learning phase. Neural networks are non-linear statistical data modeling tools. They can be used to model complex relationships between inputs and outputs or to find patterns in data.

There is no precise agreed-upon definition among researchers as to what a neural network is, but most would agree that it involves a network of simple processing elements (neurons), which can exhibit complex global behavior, determined by the connections between the processing elements and element parameters. The original inspiration for the technique came from examination of the central nervous system and the neurons (and their axons, dendrites and synapses) which constitute one of its most significant information processing elements (see Neuroscience). In a neural network model, simple nodes (called variously "neurons", "neurodes", "PEs" ("processing elements") or "units") are connected together to form a network of nodes — hence the term "neural network." While a neural network does not have to be adaptive per se, its practical use comes with algorithms designed to alter the strength (weights) of the connections in the network to produce a desired signal flow.

These networks are also similar to the biological neural networks in the sense that functions are performed collectively and in parallel by the units, rather than there being a clear delineation of subtasks to which various units are assigned (see also connectionism). Currently, the term Artificial Neural Network (ANN) tends to refer mostly to neural network models employed in statistics, cognitive psychology and artificial intelligence. Neural network models designed with emulation of the central nervous system (CNS) in mind are a subject of theoretical neuroscience (computational neuroscience).

In modern software implementations of artificial neural networks the approach inspired by biology has for the most part been abandoned for a more practical approach based on statistics and signal processing. In some of these systems, neural networks or parts of neural networks (such as artificial neurons) are used as components in larger systems that combine both adaptive and non-adaptive elements. While the more general approach of such adaptive systems is more suitable for real-world problem solving, it has far less to do with the traditional artificial intelligence connectionist models. What they do have in common, however, is the principle of non-linear, distributed, parallel and local processing and adaptation.

15. CONCLUSION AND PLANED WORK FOR FUTURE

Conclusion:

Voltage stability problem, once associated primarily with weak system and long lines, are currently a source of concern in highly developed systems as a result of heavy loading. Operators must be able to recognize voltage stability-related symptoms so that appropriate remedial action can be taken for improving voltage stability. From the above results it is concluded that restricting of system topology can improve voltage stability without involving any additional hardware and equipment cost. the present work conclusively demonstrates that for any given loading and generation condition, it is always possible to find out

an optimum configuration for a power network, which can result best voltage stability for the whole system. it can also be concluded that improvement of voltage stability is associated with the reduction in overall power losses in the system and in the most cases, the best voltage stability is achieved when power losses in the system are at minimum value. in this work we found the weakest bus by using different indices, hence this approach is very promising.

Plan of future work:

   In this present study we have used different indices to find out the weakest buses in the power system network, while in the next semester we will propose ANN(artificial neural network) model for the voltage enhancement. The parameters affecting voltage stability of a power system will be identified and then ANN will be used to map the complex non-linear relationship that associates these parameters with the voltage stability margin. The trained ANN model will be able to predict voltage margin of a power system under a given system configuration and given operating condition.

16. REFERENCES

Books:

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