Study of sequential tripping in a power distribution network by Distribution Factor Approach

Narayan Nahak, Pritam Rath

Abstract— In this paper an analysis is made to study sequential tripping in an electrical power network by the help of distribution factor, required for contingency analysis. This approach is very simple &efficient. Maintaining power system security is one of the challenging tasks for the power system Engineers. The security assessment is an essential task as it gives the knowledge about the system state in the event of a contingency. Contingency analysistechnique isbeing widely used to predict the effect of outages like failures of equipment, transmission line etc, and to take necessary actions to keep the power system secure and reliable. This analysis uses standard MATLAB programming to find distribution factors for the tripped network.

Index Terms— Contingency, distribution factor,outages,thevenin network

1 INTRODUCTION

The most desirable attribute that a Power system must have is economic operation, minimum damage to the environment and security of energy supply. As power systems become more complex and heavily loaded, along with economical and environmental constraints, voltage instability becomes an increasingly serious problem. Due to this constant overload blackouts have become very common these blackouts are mostly caused due to the tripping of a transmission line or equipment malfunction and if constant maintenance is not taken then blackouts become more frequent. This problem has necessitated the need of techniques for analysing and detecting voltage collapse in bus bars or supply lines.State estimation and contingency analysis are the two most fundamental tools for monitoring the power system. State estimation is the process of fitting data coming in from sensors in the field to a system model and determining an estimate of the power system state. By its nature, state estimation depends on the communication infrastructure, commonly called the SCADA (system control and data acquisition) system. These systems are currently undergoing many changes as new sensors and communications infrastructure is being deployed as part of the smart grid initiative. A lot of research work is done in the field of contingency analysis using fuzzy logic [1] & artificial neural network [4]. The injection shift factors (*ISF*s) are also helpful for contingency analysis [2] In order to carry out the power systems at economical costs and security Contingency Analysis is utilised. Contingency Analysis is one of the most important techniques utilised to carry out the power system operations at economical costs and greater security.An agent based technology in the contingency analysis is also performed in[3].The main function of agents is to speed up the performance A real time approached is done also in [6] . The Line outage distribution factor is utilized for contingency analysis in [5].

Whenever a Circuit breaker switches in-or-out a transmission line or a transformer thereby causing the bus voltages and line currents magnitudes to be reallocated then Contingency Analysis computes the new steady state values following the switching operation. Hence the greatest aim of the Contingency Analysis is to detect the system load ability and to provide reliable information about the proximity of voltage instability in the power system.

During the last few decades, the voltage stability problem has been given more attention due to a number of accidents caused due to these voltage instabilities.

In this paper current shift & current injection distribution factors are presented for contingency analysis.

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2 METHODOLOGY

2.1 FACTORS IN CONTINGENCY ANALYSIS

The Contingency Analysis simulates the power system keeping in consideration two key factors:

Current-Injection Distribution Factors:

The current that flows in all the lines and the bus-bars undergo a change when an extra amount of current is injected into any one of the buses.

Considering a current ΔI_k is injected into a bus k of a power system of a power system of n-buses. The changes in the voltage as a result of the addition of the current injection maybe written as:

$$\begin{bmatrix} \Delta V\mathbf{1} \\ \ldots.. \\ \Delta Vn \end{bmatrix} = \begin{bmatrix} Z11 & .. & Z1n \\ .. & Z2k & .. \\ Zn1 & Znk & Zmn \end{bmatrix} * \begin{bmatrix} 0 \\ \Delta Ik \\ 0\ \ldots \end{bmatrix} = \begin{bmatrix} Zik \\ \ldots. \\ Znk \end{bmatrix}$$

The k^{th}column of the Z_{bus} matrix is changed due to the injection of current at bus k. Hence,

$$\Delta V_{I=}Z_{ik}\Delta I_k \text{ and } \Delta V_j=Z_{ij}\Delta I_k$$

The change in the current flow in the line bus connecting i-j, is given by:

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$$\Delta I_{if}= [(Z_{ik}-Z_{jk})/Z_i]*\Delta I_k$$

The Current-Injection distribution factor which is assigned as K_{ij-k} is defined as the ratio of change in current produced in a line flow to the additional current injected in a bus in power system. Thus

$$K_{ij-k} = (\Delta I_{ij}/\Delta I_k) = (Z_{ik}-Z_{jk})/Z_i$$

Current-Shift Distribution Factors

For the Normal steady state operation of a power system, the overload on the line is relieved by reducing the current value on the line and increasing by the same value in a corresponding line.

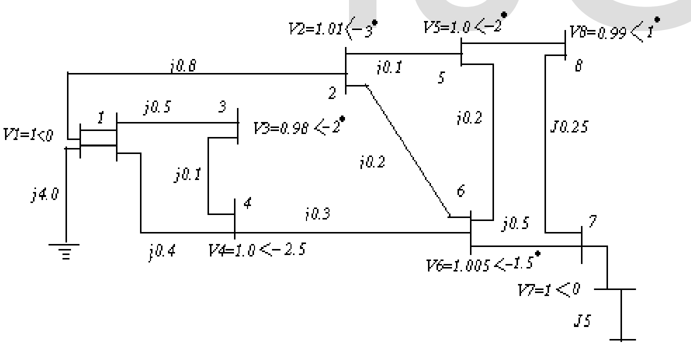
Assuming that changes in current injections at two buses p and q are represented by ΔI_p and ΔI_q, then the changes in line currents connecting buses i-j can be expressed as

$$\Delta I_{if} = K_{if-p}\Delta I_p \text{and} \Delta I_{if-q}=K_{if-q}\, \Delta Iq$$

By Super-Position Principle both the currents are added and hence the result: is :

$$\Delta I_{if} = K_{if-p}\Delta I_p + K_{if-q}\Delta I_q$$

3 CONTINGENCY ANALYSIS OF A 8 BUS SYSTEM BY MATLAB PROGRAMMING



(The 8 bus distribution network)

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%Contingency Analysis Of two sequential outage for a 8-bus System

%Considering 2-6 and  5-8  are  tripped simultaneously
clc;
closeall;
clearall;

%Creation OfYbus Matrix
Ybus=zeros(8,8);%Creation of 4x4 null  matrix
Ybus(1,1)=1/(1i*4.0)+1/(1i*0.80)+1/(1i*0.50)+1/(1i*0.4);
Ybus(1,2)=-1/(1i*0.80);Ybus(2,1)=Ybus(1,2);
Ybus(1,3)=-1/(1i*0.50);Ybus(3,1)=Ybus(1,3);
Ybus(1,4)=-1/(1i*0.40);Ybus(4,1)=Ybus(1,4);
Ybus(2,2)=1/(1i*0.80)+1/(1i*0.10)+1/(1i*0.20);
Ybus(2,5)=-1/(1i*0.10);Ybus(5,2)=Ybus(2,5);
Ybus(2,6)=-1/(1i*0.20);Ybus(6,2)=Ybus(2,6);
Ybus(3,3)=1/(1i*0.50)+1/(1i*0.10);
Ybus(3,4)=-1/(1i*0.10);Ybus(4,3)=Ybus(3,4);
Ybus(4,4)=1/(1i*0.40)+1/(1i*0.10)+1/(1i*0.30);
Ybus(4,6)=-1/(1i*0.30);Ybus(6,4)=Ybus(4,6);
Ybus(5,5)=1/(1i*0.40)+1/(1i*0.10)+1/(1i*0.20);
Ybus(5,6)=-1/(1i*0.20);Ybus(6,5)=Ybus(5,6);
Ybus(5,8)=-1/(1i*0.40);Ybus(8,5)=Ybus(5,8);
Ybus(6,6)=1/(1i*0.20)+1/(1i*0.30)+1/(1i*0.50)+1/(1i*0.20);
Ybus(6,7)=-1/(1i*0.50);Ybus(7,6)=Ybus(6,7);
Ybus(7,7)=1/(1i*5.0)+1/(1i*0.25)+1/(1i*0.50);
Ybus(7,8)=-1/(1i*0.25);Ybus(8,7)=Ybus(7,8);
Ybus(8,8)=1/(1i*0.40)+1/(1i*0.25);
Ybus %FormationOfYbus Matrix

Zbus=inv(Ybus);
Zbus%Formation of Zbus matrix

%Calculation OfThevenin's Equivalent of tripped line
Zth26=Zbus(2,2)+Zbus(6,6)-2*Zbus(2,6);
Zth26 %Thevenin's Equivalent of 2-6

Zth58=Zbus(5,5)+Zbus(8,8)-2*Zbus(5,8);
Zth58 %Thevenin's Equivalent of 5-8

%BUS VOLTAGE PRIOR TO OUTAGE
V=[1.0*exp(1i*0*pi/180);1.01*exp(1i*(-3.0)*pi/180);...
    0.98*exp(1i*(-2)*pi/180);1.0*exp(1i*(-2.5)*pi/180);...
    1.0*exp(1i*(-2.0)*pi/180);1.005*exp(1i*(-1.5)*pi/180);...
    1.0*exp(1i*0*pi/180);0.99*exp(1i*1*pi/180)];
V

%LINE CURRENTS PRIOR TO OUTAGE
I12=[V(1,1)-V(2,1)]/(1i*0.80)
I13=[V(1,1)-V(3,1)]/(1i*0.50)
I14=[V(1,1)-V(4,1)]/(1i*0.40)
I25=[V(2,1)-V(5,1)]/(1i*0.10)
I26=[V(2,1)-V(6,1)]/(1i*0.20);
I34=[V(3,1)-V(4,1)]/(1i*0.10)
I46=[V(4,1)-V(6,1)]/(1i*0.30)
I56=[V(5,1)-V(6,1)]/(1i*0.20)
I58=[V(5,1)-V(8,1)]/(1i*0.40);
I67=[V(6,1)-V(7,1)]/(1i*0.50)
I78=[V(7,1)-V(8,1)]/(1i*0.25)
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%CALCULATION OF DISTRIBUTION FACTORS FOR 2-6 OUTAGE
Za=-1i*0.2;
Zden=Zth26-Za;

L1226=Za/(1i*0.80)*((Zbus(1,2)-Zbus(1,6))-(Zbus(2,2)-Zbus(2,6)))/Zden;
L1326=Za/(1i*0.50)*((Zbus(1,2)-Zbus(1,6))-(Zbus(3,2)-Zbus(3,6)))/Zden;
L1426=Za/(1i*0.40)*((Zbus(1,2)-Zbus(1,6))-(Zbus(4,2)-Zbus(4,6)))/Zden;
L2526=Za/(1i*0.10)*((Zbus(2,2)-Zbus(2,6))-(Zbus(5,2)-Zbus(5,6)))/Zden;
L3426=Za/(1i*0.10)*((Zbus(3,2)-Zbus(3,6))-(Zbus(4,2)-Zbus(4,6)))/Zden;
L4626=Za/(1i*0.30)*((Zbus(4,2)-Zbus(4,6))-(Zbus(6,2)-Zbus(6,6)))/Zden;
L5626=Za/(1i*0.20)*((Zbus(5,2)-Zbus(5,6))-(Zbus(6,2)-Zbus(6,6)))/Zden;
L5826=Za/(1i*0.40)*((Zbus(5,2)-Zbus(5,6))-(Zbus(8,2)-Zbus(8,6)))/Zden;
L6726=Za/(1i*0.50)*((Zbus(6,2)-Zbus(6,6))-(Zbus(7,2)-Zbus(7,6)))/Zden;
L7826=Za/(1i*0.25)*((Zbus(7,2)-Zbus(7,6))-(Zbus(8,2)-Zbus(8,6)))/Zden;

%CALCULATION OF DISTRIBUTION FACTORS FOR 5-8 OUTAGE
Zb=-1i*0.4;
Zden1=Zth58-Za;

L1258=Zb/(1i*0.80)*((Zbus(1,5)-Zbus(1,8))-(Zbus(2,5)-Zbus(2,8)))/Zden1;
L1358=Zb/(1i*0.50)*((Zbus(1,5)-Zbus(1,8))-(Zbus(3,5)-Zbus(3,8)))/Zden1;
L1458=Zb/(1i*0.40)*((Zbus(1,5)-Zbus(1,8))-(Zbus(4,5)-Zbus(4,8)))/Zden1;
L2558=Zb/(1i*0.10)*((Zbus(2,5)-Zbus(2,8))-(Zbus(5,5)-Zbus(5,8)))/Zden1;
L2658=Zb/(1i*0.20)*((Zbus(2,5)-Zbus(2,8))-(Zbus(6,5)-Zbus(6,8)))/Zden1;
L3458=Zb/(1i*0.10)*((Zbus(3,5)-Zbus(3,8))-(Zbus(4,5)-Zbus(4,8)))/Zden1;
L4658=Zb/(1i*0.30)*((Zbus(4,5)-Zbus(4,8))-(Zbus(6,5)-Zbus(6,8)))/Zden1;
L5658=Zb/(1i*0.20)*((Zbus(5,5)-Zbus(5,8))-(Zbus(6,5)-Zbus(6,8)))/Zden1;
L6758=Zb/(1i*0.50)*((Zbus(6,5)-Zbus(6,8))-(Zbus(7,5)-Zbus(7,8)))/Zden1;
L7858=Zb/(1i*0.25)*((Zbus(7,5)-Zbus(7,8))-(Zbus(8,5)-Zbus(8,8)))/Zden1;

% NEW DISTRIBUTION FACTORS DUE TO BOTH 2-6 AND 5-8 TRIPPING

L1226n=(L1226+L1258*L5826)/(1-L5826*L2658);
L1326n=(L1326+L1358*L5826)/(1-L5826*L2658);
L1426n=(L1426+L1458*L5826)/(1-L5826*L2658);
L2526n=(L2526+L2558*L5826)/(1-L5826*L2658);
L3426n=(L3426+L3458*L5826)/(1-L5826*L2658);
L4626n=(L4626+L4658*L5826)/(1-L5826*L2658);
L5626n=(L5626+L5658*L5826)/(1-L5826*L2658);
L6726n=(L6726+L6758*L5826)/(1-L5826*L2658);
L7826n=(L7826+L7858*L5826)/(1-L5826*L2658);

L1258n=(L1258+L1226*L2658)/(1-L5826*L2658);
L1358n=(L1358+L1326*L2658)/(1-L5826*L2658);
L1458n=(L1458+L1426*L2658)/(1-L5826*L2658);
L2558n=(L2558+L2526*L2658)/(1-L5826*L2658);
L3458n=(L3458+L3426*L2658)/(1-L5826*L2658);
L4658n=(L4658+L4626*L2658)/(1-L5826*L2658);
L5658n=(L5658+L5626*L2658)/(1-L5826*L2658);
L6758n=(L6726+L6726*L2658)/(1-L5826*L2658);
L7858n=(L7826+L7826*L2658)/(1-L5826*L2658);

%NEW CURRENT FLOW IN THE EXISTING LINES DUE TO SIMULTANEOUS TRIPPING

I12n=I12+(L1258n*I58+L1226n*I26)
I13n=I13+(L1358n*I58+L1326n*I26)
I14n=I14+(L1458n*I58+L1426n*I26)
I25n=I25+(L2558n*I58+L2526n*I26)
I34n=I34+(L3458n*I58+L3426n*I26)
I46n=I46+(L4658n*I58+L4626n*I26)
I56n=I56+(L5658n*I58+L5626n*I26)
I67n=I67+(L6758n*I58+L6726n*I26)
I78n=I78+(L7858n*I58+L7826n*I26)
```

RESULTS

LINE CURRENTS PRIOR
I12 = 0.0661 + 0.0108i
I13 = 0.0684 - 0.0412i
I14 = 0.1090 - 0.0024i
I25 = -0.1796 - 0.0923i
I34 = 0.0942 + 0.1965i
I46 = -0.0577 + 0.0187i
I56 = -0.0430 + 0.0263i
I67 = -0.0526 - 0.0093i
I78 = -0.0691 - 0.0406i

NEW CURRENT FLOW IN THE EXISTING LINES DUE TO SIMULTANEOUS TRIPPING

I12n = 0.0572 + 0.0094i
I13n = 0.0712 - 0.0408i
I14n = 0.1132 - 0.0018i
I25n = -0.1637 - 0.0905i
I34n = 0.0969 + 0.1969i
I46n = -0.0508 + 0.0197i
I56n = 0.0031 + 0.0338i
I67n = -0.0636 - 0.0111i
I78n = -0.0799 - 0.0424i

4 Conclusion

Contingency Analysis study helps us in strengthening the initial basic plan and is helpful to the system operators to improve their ability to resolve the problem and causes the power system to be efficient and also reduces the chances of blackout. This method is very simple & can be easily applied to network with large number of buses as compared to other techniques. The current flow prior to tripping & after tripping is studied by the help of distribution factor.

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