Three Phase Fault Currents Evaluation for 11 Bus 132 kV Transmission System, kotkapura

Kuljinder Kaur
Department of Electrical Engineering
Bhai Gurdas Institute of Engineering and Technology
Sangrur, India

Simerpreet Singh
Department of Electrical Engineering
Bhai Gurdas Institute of Engineering and Technology
Sangrur, India

ABSTRACT

Modern power system is very complex in nature, having number of buses, transmission lines, which increases the complexity of power system and fault level of power system increases to large extent. Fault studies are important power system analysis for stable and economical operations of power systems. In this paper, short circuit analysis was performed on three phase balanced fault using 132 kV transmission system model in Power World Simulator. Load flow studies were performed which determined pre-fault conditions for the power system based on Newton- Raphson method. Further, voltage and current magnitudes were determined by imposing three phase balanced fault on the system for rated current of 400 and 630 Amp. The information gained from the analysis can be used for proper relay selection, settings, performances and coordination.

Keywords

Power system; Power flow; Three-Phase Fault; Short- Circuit Current.

1. INTRODUCTION

The purpose of an electrical power system is to generate and supply electrical energy to consumers with reliability and economy. The greatest threat to the power system is the short circuit. A fault is defined as the flow of a massive current through an improper path which could cause enormous equipment damage which will lead to interruption of power, personal injury, or death. The evaluation of fault currents on a power system is therefore significant because the protective devices to be installed on the system depend on the values of the fault currents.

Faults can be broadly grouped into symmetrical and unsymmetrical faults. A fault which gives rise to equal fault currents in the lines with 120 degree displacement is known as three phase fault or symmetrical fault while a fault which gives rise to unequal fault currents in the lines with unequal displacement is known as unsymmetrical fault. Single Line-to-ground, Line-to-line and Double line-to-ground faults are unsymmetrical faults. Faults could happen when a phase establishes a connection with another phase, lightning, insulation deterioration, wind damage, trees falling across lines, etc.

The effects of fault on power system are:

1. Due to overheating and mechanical forces developed by faults, electrical equipments such as bus-bars, generators and transformers may be damaged.
2. The voltage profile of the system may be reduced to unacceptable limits as a result of fault. A frequency drop may lead to instability.

Though the symmetrical faults are rare, the symmetrical fault analysis must be carried out, as this type of fault generally leads to most severe fault current flow against which the system must be protected. Symmetrical fault analysis is simpler to carry out as compared to unsymmetrical fault analysis. However, the circuit breaker rated MVA breaking capacity is based on three phase symmetrical faults. The reason is that a three phase fault produces the greatest fault current and causes the greatest damage to a power system.

Short circuit studies involve determining the voltages and currents during fault conditions so that protective devices can be selected as to minimize the harmful effect in the power system.

Power flow analysis in the power system is the steady state solution of the power system network. The state at which a power system is before a fault occurs is known as steady state of the power system. In this paper, the power system is modeled by an electric network using POWER WORLD SIMULATOR and solved for the steady state powers and voltages at various buses.

Power flow analysis is called the backbone of power system analysis. Power system fault analysis is one of the basic problems in power system engineering. The result of power system fault analysis are used to determine the type and size of the protective system to be installed on the system so that continuity of supply is ensured even when there is a fault on the power system.

The current trend of power supply of 132 kV transmission systems has made this study important to the nation’s power industry.

The single line diagram of 132 kV transmission systems, Kotkapura is shown in figure1.

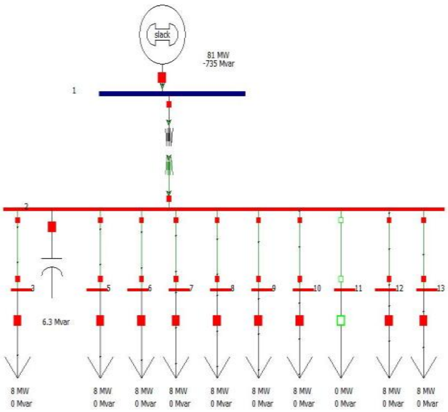

Figure 1. 11- Bus 132 kV transmission systems

2. PROBLEM FORMULATION

2.1. Power Flow Studies

In short circuit studies, it is necessary to have the knowledge of pre-fault voltages and currents. The main information obtained from the power flow study comprises of magnitudes and phase angles of bus voltages, real and reactive powers on transmission lines, real and reactive powers at generator buses, other variables being specified. The pre-fault conditions can be obtained from results of load flow studies by the Newton-Raphson iteration method.

The Newton-Raphson method is the practical method of load flow solution of large power networks. Convergence is not affected by the choice of slack bus. This method begins with initial guesses of all unknown variables such as 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.

We first consider the presence of PQ buses only apart from a slack bus.

For an ith bus,

Pi =

$$\sum_{k=1}^{n} |Vi|\,|Vk|\,|Yik| \cos(\theta ik + \delta k - \delta i) = Pi(|V|, \delta)$$

(1)

Qi =

$$\sum_{k=1}^{n} |Vi|\,|Vk|\,|Yik| \sin(\theta ik + \delta k - \delta i) = Qi(|V|, \delta)$$

(2)

i.e., both real and reactive powers are functions of (|V|, δ), where

$|V| = (|V_1|,\ldots,|V_n|^T)$ $\delta = (\boldsymbol{\delta}_{1,\ldots,}\boldsymbol{\delta}_n)^T$

We write

Pi (|V|,) = Pi(x)

Qi (|V|,) =Qi(x)

Where,

x = [**δ**/|V|]

Let Pi and Qi be the scheduled powers at the load buses. In the course of iteration x should tend to that value which makes

Pi – Pi(x) = 0 and Qi – Qi(x) = 0 (3)

Writing equation (3) for all load buses, we get its matrix form

$$f(x) = \begin{bmatrix} P(scheduled) - P(x) \\ Q(scheduled) - Q(x) \end{bmatrix} = \begin{bmatrix} \Delta P(x) \\ \Delta Q(x) \end{bmatrix} = 0 \quad (4)$$

At the slack bus, P_1 and Q_1 are unspecified. Therefore, the values $P_1(x)$ and $Q_1(x)$ do not enter into equation (3) and hence (4). Thus, x is a 2(n-1) vector (n-1 load buses), with each element function of (n-1) variables given by the vector x= [**δ**/|V|]

We can write,

$$f(x) = \begin{bmatrix} \Delta P(x) \\ \Delta Q(x) \end{bmatrix} = \begin{bmatrix} -J11(x) & -J12(x) \\ -J21(x) & -J22(x) \end{bmatrix} \begin{bmatrix} \Delta\delta \\ \Delta|V| \end{bmatrix} \quad (5)$$

Where, $\Delta\boldsymbol{\delta} = (\Delta\boldsymbol{\delta}_2,\ldots,\Delta\boldsymbol{\delta}n)^T$

$\Delta|V| = (\Delta|V_2|\ldots \Delta|Vn|)^T$

$$J(x) = \begin{bmatrix} -J11(x) & -J12(x) \\ -J21(x) & -J22(x) \end{bmatrix} \quad (6)$$

J(x) is the jacobian matrix, each J_{11}, J_{12}, J_{21}, J_{22} are (n-1) × (n-1) matrices.

$$-J_{11}(x) = \frac{\partial P(x)}{\partial \delta}$$

$$-J_{12}(x) = \frac{\partial P(x)}{\partial |V|}$$

(3.18)

$$-J_{21}(x) = \frac{\partial Q(x)}{\partial \delta}$$

$$-J_{22}(x) = \frac{\partial Q(x)}{\partial |V|}$$

The elements of $-J_{11}$, $-J_{12}$, J_{21}, $-J_{22}$ are

$$\frac{\partial Pi(x)}{\partial \delta k}, \frac{\partial Pi(x)}{\partial |Vk|}, \frac{\partial Qi(x)}{\partial \delta k}, \frac{\partial Qi(x)}{\partial |Vk|},$$

Where i = 2... n; k = 2... n.

From equation (1) and (2), we have

$$\frac{\partial Pi(x)}{\partial \delta k} = -|Vi|\,|Vk|\,|Yik| \sin(\theta ik + \delta k - \delta i)\ (i \neq k)$$

$$= \sum_{\substack{k=1 \\ k \neq i}}^{n} |Vi|\,|Vk|\,|Yik| \sin(\theta ik + \delta k - \delta i)\ (i = k) \quad (7)$$

$$\frac{\partial Pi(x)}{\partial |vk|} = |Vi|\,|Yik| \cos(\theta ik + \delta k - \delta i)(i \neq k) \quad (8)$$

$$= 2|Vi|\,|Yii| \cos\theta ii + \sum_{\substack{k=1 \\ k \neq i}}^{n} |Vk|\,|Yik| \cos(\theta ik + \delta k - \delta i)\ (i = k)$$

$$\frac{\partial Qi(x)}{\partial \delta k} = |Vi|\,|Vk|\,|Yik| \sin(\theta ik + \delta k - \delta i)\ \ (i \neq k)$$

$$= \sum_{\substack{k=1 \\ k \neq i}}^{n} |Vi|\,|Vk|\,|Yik| \cos(\theta ik + \delta k - \delta i)\ (i = k) \quad (9)$$

$$\frac{\partial Qi(x)}{\partial |Vk|} = |Vi|\,|Yik| \sin(\theta ik + \delta k - \delta i)\ \ (i \neq k)$$

$$= 2|Vi|\,|Yii| \sin\theta ii + \sum_{\substack{k=1 \\ k \neq i}}^{n} |Vk|\,|Yik| \sin(\theta ik + \delta k - \delta i)\ \ (i = k)$$

(10)

An important observation can be made with respect to the elements of Jacobian matrix. If there is no connection between ith and kth bus, then Yik =0. The process continues until a stopping condition is met.

2.2. Short Circuit Analysis

Short circuit studies involve finding the voltages and currents distribution throughout the power system during fault conditions so that the protective devices may be set to detect and isolate the faulty portion of the power system so as to minimize the harmful effects of such contingencies.

Steps for symmetrical fault analysis in POWER WORLD SIMULATOR:

1. Draw a single line diagram of the complete network indicating the ratings, voltage and other parameters of each element of the network.
2. Determination of pre-fault conditions of simulated model using Newton- Raphson method.
3. Calculation of short circuit current magnitudes for rated current of 400 and 630 Amp by imposing three phase balanced fault on buses.
4. Calculation of voltage magnitudes for rated current of 400 and 630 Amp when three phase balanced fault occurs on the system.
5. Study of behaviour of power system according to step 3 and 4.

2.3 Standard Parameters

Table 1: Three Core Armoured Cable (Copper Conductor) Parameters as Per IEC 60502-2

Nominal Area of conductors	Thickness of Insulation	Conductor resistance (R)	Conductor Reactance (X)	Shunt Charging Capacitance (B)
300 sq.mm	3.4 mm	0.0797 Ω/km	0.086 Ω/km	0.53 µF/km

Table 2: Impulse and Power Frequency Withstand Voltage as Per IEC 60071 and 60298

Normal operating voltage (kV rms)	Rated voltage (kV rms)	Rated power-frequency withstand voltage (kV rms)	Rated lightning impulse withstand voltage1.2/50 µs 50 Hz(kV peak)	
			list 1	list2
10 t0 11	12	28	60	75

3. RESULTS AND DISCUSSION

The load flow analysis was carried out using Newton-Raphson load flow method as shown in Table 3 & 4.

After load flow analysis, a three phase balanced fault was simulated on the power system at 3 and 7 buses, the currents flowing in transmission line were calculated. Table 5 & 7 shows the voltages magnitudes and angles when three phase fault occur on 3 and 7 buses. Table 6 & 8 shows the fault current magnitudes and angles on 3 and 7 buses

Table 3: Power Flow List Using Newton-Raphson Method

From Bus	To Bus	MW	Mvar	MVA	MW Loss	Mvar Loss
1	2	149.9	-723.3	738.6	0	387.36
2	3	16.7	-122.7	123.8	1.41	-122.66
2	5	16.7	-122.7	123.8	1.41	-122.66
2	6	16.7	-122.7	123.8	1.41	-122.66
2	7	16.7	-122.7	123.8	1.41	-122.66
2	8	16.7	-122.7	123.8	1.41	-122.66
2	9	16.7	-122.7	123.8	1.41	-122.66
2	10	16.7	-122.7	123.8	1.41	-122.66
2	11	0	0	0	0	0
2	12	16.7	-122.7	123.8	1.41	-122.66
2	13	16.7	-122.7	123.8	1.41	-122.6

Table 4: Bus Records Using Power World Simulator

Name	Nom Kv	PU Volt	Volt (kV)	Angle (Deg)	Gen MW	Gen Mvar	Switched Shunts Mvar
1	132	1	132	0	149.9	-723.26	
2	11	1.51726	16.69	-4.02			6.27
3	11	1.54405	16.985	-5.58			
5	11	1.54405	16.985	-5.58			
6	11	1.54405	16.985	-5.58			
7	11	1.54405	16.985	-5.58			
8	11	1.54405	16.985	-5.58			
9	11	1.54405	16.985	-5.58			
10	11	1.54405	16.985	-5.58			
12	11	1.54405	16.985	-5.58			
13	11	1.54405	16.985	-5.58			

Table 5: Voltage Magnitudes and Angles for Fault on Bus 3 And 7(For 400amp)

Bus	Bus 3 Voltage magnitude(PU)	Angle(degree)	Bus 7 Voltage magnitude(PU)	Angle(degree)
1	1.07884	127.13	1.07884	127.13
2	0.89824	105.95	0.89824	105.95
3	**0.00000**	**0.00**	0.91605	104.56
5	0.91605	104.56	0.91605	104.56
6	0.91605	104.56	0.91605	104.56
7	0.91605	104.56	**0.00000**	**0.00**
8	0.91605	104.56	0.91605	104.56
9	0.91605	104.56	0.91605	104.56
10	0.91605	104.56	0.91605	104.56
12	0.91605	104.56	0.91605	104.56
13	0.91605	104.56	0.91605	104.56

Table 6: Current Magnitudes and Angles for Fault on Bus 3 And 7(For 400amp)

From Bus	**To Bus**	**Bus 5** **Current magnitudes(PU)**	**Bus 7** **Current magnitudes(PU)**
1	2	5.69598	5.69598
2	3	**7.66076**	0.02947
2	5	0.02947	0.02947
2	6	0.02947	0.02947
2	7	0.02947	**7.66076**
2	8	0.02947	0.02947
2	9	0.02947	0.02947
2	10	0.02947	0.02947
2	12	0.02947	0.02947
2	13	0.02947	0.02947

Table 7: Voltage Magnitude and Angles for Fault on Bus 3 And 7(For 630 Amp)

Bus	**Bus 3** **Voltage magnitude(PU)** **Angle(degree)**	**Bus 7** **Voltage magnitude(PU)** **Angle(degree)**
1	1.06002 123.56	1.06002 123.56
2	0.87947 101.91	0.87947 101.91
3	**0.00000 0.00**	0.89602 100.43
5	0.89602 100.43	0.89602 100.43
6	0.89602 100.43	0.89602 100.43
7	0.89602 100.43	**0.00000** **0.00**
8	0.89602 100.43	0.89602 100.43
9	0.89602 100.43	0.89602 100.43
10	0.89602 100.43	0.89602 100.43
12	0.89602 100.43	0.89602 100.43
13	0.89601 100.43	0.89602 100.43

Table 8: Current Magnitudes for Fault on Bus 3 and 7(For 630amp

From Bus	**To Bus**	**Bus 5** **Current magnitudes(PU)**	**Bus 7** **Current magnitudes(PU)**
1	2	5.71194	5.71194
2	3	**7.50451**	0.04541
2	5	0.04541	0.04541
2	6	0.04541	0.04541
2	7	0.04541	**7.50451**
2	8	0.04541	0.04541
2	9	0.04541	0.04541
2	10	0.04541	0.04541
2	12	0.04541	0.04541
2	13	0.04541	0.04541

When a short circuit occurs, the voltage at faulted point is reduced to zero. Comparing the voltage magnitude in Table 4, 5 & 7, it is observed that voltage magnitudes are lowered to zero when fault occurs at bus 3 and 7. From Table 6 & 8, it is observed that when fault occurs at bus 3 and 7, the current magnitudes are excessively high which leads to damage to switchgear equipments.

4. CONCLUSION

As power system designing is very serious issue and complex in nature, so it very necessary to design a system with excellent protective system. Now- a – days, the parallel transmission lines are increasing which leads to decrease in resistance. As a result, impedance of system is also decreasing and hence short circuit level is increasing day by day. To avoid this problem the short circuit analysis is performed in this research work. Information gained from this result can be used to obtain the ratings of protective switchgears installed on the power system.

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