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Analysis of Symmetrical Fault with Fault Impedance in Power System

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ABSTRACT *A fault represents the structural network change equivalent caused by the addition of impedance at the place of fault. If the fault impedance is zero, the fault is referred to as the bolted fault or solid fault .The prefault bus voltages are obtained from the results of the power flow solution. In order to preserve the linearity feature of the network, loads are converted to constant admittance using the prefault bus voltages. The faulted network can be solved conveniently by the Thevenin's method. The faulted network is reduced into a Thevenin's equivalent circuit as viewed from the faulted bus. Applying Thevenin's theorem, changes in the bus voltages are obtained. Bus voltages during the fault are obtained by superposition of the pre faulted bus voltages and the change in the bus voltages. The current during the fault in all branches of the network are obtained using MATLAB.*

KEYWORDS: Symmetrical fault, Fault Impedance.

1. INTRODUCTION

Normally, a power system works under balance conditions. Under abnormal condition, the system may become unbalanced. If the insulation of the system fails at any point or if two or more conductors that normally operate with a potential difference come in contact with each other, a short-circuit, or fault, is said to be occur. Contact may be a physical metallic one, or it may occur through an arc. Some of the common causes have their origins in natural disturbance like lightning, high speed winds, earthquakes, earth tremors, snow, frost etc. There may be accidental faults such as falling of trees along a line, vehicles colliding with supporting structures, airplane crashing with line. Sometimes sabotage also results in creating faults. Contamination of insulators may also result in a fault. Deterioration of insulation due to ageing and overloading of underground cables result in short circuits. Faults may occur at different points in power system.

Fault studies from an important part of power system analysis. The problem consists of determining bus voltages and line currents during various types of faults. The magnitude of the fault currents depends on the internal impedance of the generators plus the impedance of the intervening circuit.

The system must be protected against flow of heavy short circuit currents by disconnecting the faulty part of the system by means of circuit breakers operated by protective relaying. For proper choice of circuit breakers and protective relaying, we must estimate the magnitude of currents that would flow under short circuit conditions-this is the scope of fault analysis (study). The three phase balanced fault information is used to select and set phase relays, while line-to-ground fault is used for ground relays[1][2][3].

The majority of system faults are not three-phase faults but fault involving one line to ground or occasionally two line to ground fault. 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 system must be protected.

2. MODELING OF POWER SYSTEM COMPONENTS

2.1 Buses model

The goal of a power flow study is to obtain complete voltage angle and magnitude information for each bus in a power system for specified load and generator real power and voltage conditions. Once this information is known, real and reactive power flow on each branch as well as generator reactive power output can be analytically determined. Due to the nonlinear nature of this problem, numerical methods are employed to obtain a solution that is within an acceptable tolerance. The solution to the power flow problem begins with identifying the known and unknown variables in the system. The known and unknown variables are dependent on the type of bus. A bus without any generators connected to it is called a Load Bus. With one exception, a bus with at least one generator connected to it is called a Generator Bus. The exception is one arbitrarily-selected bus that has a generator. This bus is referred to as the bus. In the power flow problem, it is assumed that the real power PD and reactive power QD at each Load Bus are known. For this reason, Load Buses are also known as PQ Buses. For Generator Buses, it is assumed that the real power generated PG and the voltage magnitude |V| is known. For the Slack Bus, it is assumed that the voltage magnitude |V| and voltage phase Θ are known. Therefore, for each Load Bus, the voltage magnitude and angle are unknown and must be solved for; for each Generator Bus, the voltage angle must be solved for; there are no variables that must be solved for the Slack Bus. In a system with N buses and R generators, there are then unknowns. In order to solve for the unknowns, there must be equations that do not introduce any new unknown variables. The possible equations to use are power balance equations, which can be written for real and reactive power for each bus. Equations included are the real and reactive power balance equations for each Load Bus and the real power balance equation for each Generator Bus. Only the real power balance equation is written for a Generator Bus because the net reactive power injected is not assumed to be known and therefore including the reactive power balance equation would result in an additional unknown variable. For similar reasons, there are no equations written for the Slack Bus[1]

2.1 Transmission Line Model

The transmission line transmits electrical power from one end of the line, sending End, to another, receiving end. A common method of analyzing this behaviour is through Parameterization and modelling of the transmission lines with passive components. The Passive components used in this modelling are resistors, capacitors and inductors. The Quantity of these parameters depends mainly on the conductors used in the lines and the Physical or geometrical configuration of the lines. The conductors themselves will have certain characteristics such as resistance and reactance both in series from sending to Receiving ends of the line and shunt from the line to electrical ground associated with Them. In addition, there is inherently mutual inductance, or coupling, of the lines with Respect to each other as they are bundled together or placed in close proximity to one Another in a multi-phase system. This can all be taken into account through proper Analysis and parameterization of the transmission lines. This chapter does not derive the Parameterization of the lines but provides an overview of steady state analysis of Transmission lines after the line parameters have been obtained. in this thesis only the sinusoidal steady state of the transmission lines is Examined. No dynamic analysis or consideration is taken. The work here is geared mainly towards power-flow studies in which the steady state behaviour of the transmission Lines is focused on with the dynamics neglected. In a power system the dynamics of Generators and loads are much more substantial in both magnitude and time duration and Affect the system more than the transmission line dynamics. It is a reasonable assumption to neglect the transmission line dynamics for power-flow studies and generator/load [2].

2.1.1 Lumped Parameter Transmission Line Models

The prior sections introduced both distributed and lumped parameter transmission line modelling. Specifically the lumped parameter model was a π-equivalent circuit which incorporates shunt resistive and capacitive elements along with series resistive and inductive elements. Certain simplifying assumptions can be made to this lumped equivalent circuit based on the length of the transmission line. Four different line models are presented here based on the transmission line length. As the lines become shorter certain parameters have a minimal effect on the terminal voltages and currents of the line and can then be neglected for a long transmission line (l >150 miles) no approximations should be made.

2.1.2 Short Model

The shunt capacitance for a short line is almost negligible. The series impedance is assumed to be lumped If the impedance per km for an l km long line is $z0 = r + jx$, then the total impedance of the line is $Z = R + jX = lr + jlx$. Therefore the ABCD parameters are given by

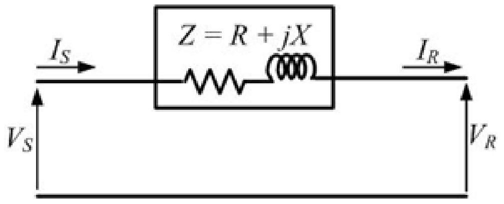

Fig.1: Short Transmission line representation.

2.1.3 Medium Model

Medium transmission lines are modeled with lumped shunt admittance. There are two different representations - nominal- π and nominal-T depending on the nature of the network.

2.1.3.0 Nominal- π Representation:

In this representation the lumped series impedance is placed in the middle while the shunt admittance is divided into two equal parts and placed at the two ends. This representation is used for load flow studies, as we shall see later. Also a long transmission line can be modeled as an equivalent π -network for load flow studies.

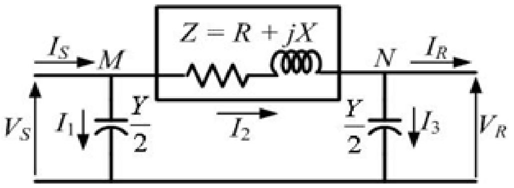

Fig.2: Nominal- π Representation

2.3.3.1 Nominal-T representation.

In this representation the shunt admittance is placed in the middle and the series impedance is divided into two equal parts and these parts are placed on either side of the shunt admittance. Let us denote the midpoint voltage as VM . Then the application of KCL at the midpoint results in

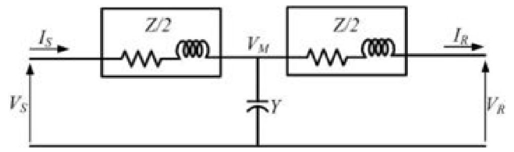

Fig.3: Nominal-T representation

3. FAULTS

A fault is any abnormal flow of electric current. Short circuit is a fault in which current flow bypasses the normal load. An open-circuit fault occurs if a circuit is interrupted by some failure. In three-phase systems, a fault may involve one or more phases and ground, or may occur only between phases. In a "ground fault" or "earth fault", current flows into the earth. The prospective short circuit current of a fault can be calculated for power systems. In a polyphase system, a fault may affect all phases equally which is a "symmetrical fault". If only some phases are affected, the resulting "asymmetrical fault" becomes more complicated to analyze due to the simplifying assumption of equal current magnitude in all phases being no longer applicable. The analysis of this type of fault is often simplified by using methods such as symmetrical component.[3]

Faults can be broadly classified as

3.1 Transient fault:

A transient fault is a fault that is no longer present if power is disconnected for a short time. Many faults in overhead power lines are transient in nature. At the occurrence of a fault power system protection operates to isolate area of the fault. A transient fault will then clear and the power line can be returned to service.

3.2 Persistent Fault:

A persistent fault does not disappear when power is disconnected. Faults in underground power cables are most often persistent due to mechanical damage to the cable, but are sometimes transient in nature due to lightning.

3.3 Symmetrical faults:

A symmetric or balanced fault affects each of the three phases equally. In transmission line faults, roughly 5% are symmetric. This is in contrast to an asymmetric fault, where the three phases are not affected equally. In practice, most faults in power systems are unbalanced. With this in mind, symmetric faults can be viewed as somewhat of an abstraction; however, as asymmetric faults are difficult to analyze, analysis of asymmetric faults is built up from a thorough understanding of symmetric faults

3.4 Asymmetrical faults:

An asymmetric or unbalanced fault does not affect each of the three phases equally. Common types of asymmetric faults, and their causes:

- Line-to-line - a short circuit between lines, caused by ionization of air, or when lines come into physical contact, for example due to a broken insulator.
- Line-to-ground - a short circuit between one line and ground, very often caused by physical contact, for example due to lightning or other storm damage
- Double line-to-ground - two lines come into contact with the ground (and each other), also commonly due to storm damage

4. ALGORITHIM

The following steps are involved

Step 1: Read the bus data, line data and load data.
Step 2: Run the Load flow with N-R method.
Step 3: Create the symmetrical fault at each bus one at a time.
Step 4: Change the fault impedance from 0 to 1.0 per unit and calculate the new Zbus.
Step 5: Run Load flow and note down the bus voltage magnitudes.
Step 5: Only Resistance was varied from 0 to 1.0 per unit as Resistance and reactance both can be varied.

5. CASE STUDY AND RESULTS

A standard 11 bus system [3] has been taken for simulation purpose. The symmetrical fault at bus 1 has been created by increasing the fault impedance in steps of 0.05 per unit.

From table 1 the bus voltages were given for variation of resistance. The voltage at bus number 10 was higher than that of the other buses compared to the base case i.e when the fault impedance is zero.

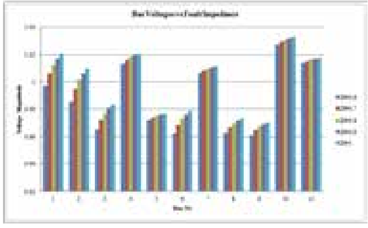

Fig.4: Graph between the bus voltage and fault impedance

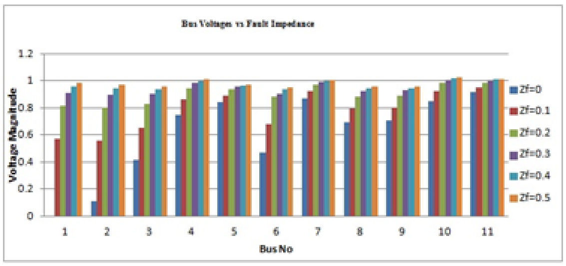

Fig.5: Graph between the bus voltage and fault impedance

Table.1: Voltage Magnitude at each bus with variation of fault impedance

Bus No/ FAULT Zf	0	0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5
1	0	0.3279	0.5685	0.7212	0.8152	0.8744	0.9132	0.9397	0.9585	0.9723	0.9827
2	0.1112	0.3257	0.5571	0.7076	0.8011	0.8604	0.8995	0.9264	0.9455	0.9597	0.9703
3	0.4144	0.5079	0.6514	0.9119	0.8272	0.8717	0.9011	0.9214	0.9357	0.9463	0.9543
4	0.7463	0.7934	0.8599	0.9162	0.9463	0.9685	0.9831	0.9929	0.9998	1.0048	1.0085
5	0.845	0.8617	0.891	0.7729	0.934	0.9459	0.9541	0.9597	0.9638	0.9668	0.969
6	0.4727	0.5515	0.677	0.949	0.8853	0.8765	0.9035	0.9221	0.9353	0.945	0.9523
7	0.8693	0.8895	0.9219	0.8485	0.9677	0.9802	0.9885	0.9943	0.9984	1.0014	1.0036
8	0.6954	0.7313	0.7951	0.8542	0.8853	0.9097	0.9262	0.9377	0.9459	0.9519	0.9565
9	0.7064	0.7425	0.8036	0.8562	0.8889	0.9118	0.9273	0.9379	0.9455	0.9511	0.9553
10	0.8518	0.8811	0.9238	0.9582	0.9815	0.9966	1.0066	1.0134	1.0182	1.0216	1.0242
11	0.9157	0.9299	0.9529	0.9724	0.9859	0.995	1.001	1.0052	1.0082	1.0104	1.0121

Bus No/ FAULT Zf	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95	1
1	0.9907	0.9971	1.0022	1.0064	1.0098	1.0127	1.0152	1.0173	1.0191	1.0207
2	0.9787	0.9852	0.9905	0.9949	0.9985	1.0016	1.0042	1.0064	1.0083	1.01
3	0.9604	0.9653	0.9692	0.9724	0.975	0.9772	0.9791	0.9807	0.982	0.9832
4	1.0112	1.0134	1.0151	1.0164	1.0175	1.0184	1.0191	1.0197	1.0202	1.0207
5	0.9708	0.9722	0.9733	0.9742	0.9749	0.9755	0.9761	0.9765	0.9769	0.9772
6	0.958	0.9625	0.966	0.969	0.9714	0.9734	0.9751	0.9766	0.9779	0.9789
7	1.0054	1.0067	1.0078	1.0086	1.0093	1.0099	1.0104	1.0108	1.0112	1.0115
8	0.9601	0.9629	0.9651	0.967	0.9685	0.9698	0.9708	0.9718	0.9726	0.9732
9	0.9586	0.9612	0.9632	0.9649	0.9663	0.9674	0.9684	0.9692	0.9699	0.9705
10	1.0261	1.0276	1.0288	1.0297	1.0304	1.0311	1.0316	1.032	1.0324	1.0327
11	1.0133	1.0143	1.0151	1.0157	1.0162	1.0167	1.017	1.0173	1.0176	1.0178

6. CONCLUSION

When a fault occurs, the power system will not be in stable condition. Test was performed by using different fault values in per unit system. The variation of voltage magnitude was observed in the system by plotting the graph between voltage magnitude (v) and the incremented fault impedance (Zf). As the impedance carries both resistance and reactance, we have taken only resistance for analysis.

It was observed that, by varying the fault resistance at bus 1 from 0 to 1.0 ohms, the highest value of voltage was 1.0327 at bus10.

The study with reactance and asymmetrical fault will be presented in our next paper.

7. ACKNOWLEDGMENTS

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