THREE PHASE FAULT ANALYSIS AND BREAKER SIZING USING MIPOWER SOFTWARE

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Abstract - The fault analysis of a power system is required in order to provide information for the selection of switchgear, setting of relays and stability of system operation. A power system is not static but changes during operation (switching on or off of generators and transmission lines) and during planning (addition of generators and transmission lines). Thus fault studies need to be routinely performed by utility engineers. Faults usually occur in a power system due to either insulation failure, flashover, physical damage or human error. These faults may either be three phase in nature involving all three phases in a symmetrical manner, or may be symmetrical where usually only one or two phases may be involved. Faults may also be by either short-circuits to earth or between live conductors, or may be caused by broken conductors in one or more phases. Sometimes simultaneous faults may occur involving both short-circuit and broken-conductor faults (also known as open-circuit faults).

Balanced three phase faults may be analyzed using an equivalent single phase circuit. With asymmetrical three phase faults, the use of symmetrical components help to reduce the complexity of the calculations as transmission lines and components are by and large symmetrical, although the fault may be symmetrical.

In this paper we have assumed IEEE 9 bus system for the study. A 3 phase fault analysis has been conducted to check the existing fault levels on generator bus and line to check the existing capability of the circuit breakers and improvements are also suggested.

Keywords – Three phase fault, stability, protection, breaker sizing, load flow, MiPower software.

I. INTRODUCTION

Successful operation of a power system depends largely on the engineer's ability to provide reliable and uninterrupted service to loads. The reliability of the power supply implies much more than merely being available. Ideally, the loads must be fed at constant voltage and frequency at all times. In practical terms this means that both voltage and frequency must be held within close tolerances so that the consumer's equipment may operate satisfactorily. For example, a drop in voltage of 10-15% or a reduction of the system frequency of only a few hertz may lead to stalling of the motor loads on the system.

As electric utilities have grown in size, and the number of interconnections has increased, planning for future expansion has become increasingly complex. The increasing cost of additions and modifications has made it imperative that utilities consider a range of design options, and perform detailed studies of the effects on the system of each option, based on a number of assumptions: like normal and abnormal operating conditions, peak and off-peak loadings, and present and future years of operation. A large volume of network data must also be collected and accurately handled. To assist the engineer in this power system planning, digital computers and highly sophisticated computer programs are used.

Future transmission systems will be far more complex than those of today. This means that the power system planner’s task will be more complex. If the systems being planned are to be optimal with respect to construction cost, performance, and operating efficiency, better planning tools are required. In general, the major power system planning tools are [6]: Load flow analysis, Short circuit analysis, Stability analysis and system protection and relay co-ordination.

The main objective of load flow analysis is to identify the potential problems, in terms of unacceptable voltage conditions, overloading of facilities, decreasing reliability, or any failure of the transmission system to meet performance criteria. After this analysis stage the planner develops the alternative plans or scenarios that not only will prevent the foreseen problems but also will best meet the long-term objectives of system reliability and economy. The effectiveness of the alternative plans is determined by load flow analysis.

After determining the best system configuration from load flow studies, the power system can be tested for system behaviour under fault conditions. The main objectives of short circuit studies can be expressed as: to determine the current interrupting capacity of the circuit breaker so that the faulted equipment can be disconnected successfully, to establish the relay requirements and settings to detect the fault and cause the circuit breaker to operate when the current flowing through it exceeds the maximum allowable current, to calculate voltages during faulted conditions that affect insulation co-ordination and lightning arrester applications, and to design the grounding systems.
Stability [2] studies are performed in order to be sure that the system will remain stable following a severe fault or disturbance. Stability analysis is defined as the transient behaviour of the power system following a disturbance. The transient stability is defined as the ability of the system to maintain synchronous operation following a disturbance, usually a fault condition. Normally, the first swing of rotor angles is considered to be an adequate indicator of whether or not the power system remains stable. Therefore, generally the simulation of the first few seconds following a disturbance is sufficient for transient stability. However, there are chances of system being oscillatory and unstable in the subsequent swings. Hence on case to case basis stability study time period should be selected. Usually, the critical switching time, that is, the time during which a faulted system component must be tripped to assure stability, is used as an indicator of stability margin. Whereas steady-state stability analysis is defined as long-term fluctuations in system frequency resulting in total blackouts, in this case, the system is simulated from a few seconds to several minutes. Unless the fault condition is cleared rapidly by circuit breakers, this situation, in turn, will cause large current to flow through the network. Power system protection engineering deals with precautionary measures to be taken to safeguard the power system during abnormal operating conditions. The practice of protection engineering involves periodic fault studies followed by relay setting, checking and co-ordination studies. These studies are necessary in order to ensure that the wide variety of protective relays function correctly with proper discrimination to provide required reliable, sensitive and selective isolation of faulty power system equipment.

II. SYSTEM DESCRIPTION

In this paper a classical model of a synchronous machine (3 machine 9 bus system) [1] has been used for the study purpose. Preliminary Load Flow studies are conducted to calculate the steady state stability of the system. Analyzing the solution of load flow analysis for numerous conditions helps ensure that the power system is designed to satisfy its performance criteria while incurring the most favourable investment and operation costs. Some examples [3] of the uses of load flow studies are to determine,

- Component or circuit loading.
- Steady state bus voltages.
- Power flows.
- Transformers tap settings
- System losses
- Current

However, these small fluctuations can be ignored in calculating the steady state effects on system equipment. The load flow model is also the basis for several other types of studies such as short circuit, stability, motor starting, and harmonic studies. The load flow model supplies the network data and an initial steady state condition for these studies.

Short circuit studies were conducted to determine the fault currents and fault MVA levels in the plant for single line to ground fault and three phases to ground fault. The study is done for various types of faults at different locations throughout the system. Two factors upon which the proper selection of circuit breakers depends are the current flowing immediately after the fault occurs and the current, which the breaker must interrupt. In addition, the results of the short circuit studies are used to determine the settings of relays, which control the circuit breakers.

Voltage, Current, Kilovolt amperes and impedance are so related that selection of base values for any two of them determines the base values of the remaining two [2]. For single phase systems or a three phase systems, the term current refers to line current and the term voltage refers to voltage to neutral.

The per unit value of a line to neutral voltage on the line to neutral voltage base is equal to the per unit value of the line-to-line voltage at the same point on the line-to-line voltage base if the system is balanced. Similarly the three phase kVA is three times the kVA per phase and the three phase kVA base is three times the base kVA per phase. Therefore the per unit value of the three phase kVA on the three phase kVA base is identical to the per unit value of the kVA per phase on the kVA per phase base. Base impedance and base current can be computed directly from three phase values of base kilovolts and base kilovolt amperes. If we interpret base kilovolt amperes and base voltage in kilovolts to mean base kilovolt amperes for the total of the three phases and base voltage from line to line, we find:

\[ \text{BaseCurrent} = \frac{\text{BasekVA}_{3ph}}{3\text{BasekV}} \]

\[ \text{BaseZ} = \left( \frac{\text{BasekV}}{\text{BasekVA}} \right)^2 \]

Sometimes the per unit impedance of a component of a system is expressed on a base other than the one selected as base for the part of the system in which the component is located. Since all impedances in any one part of a system must be expressed on the same impedance base when making computations, it is necessary to have a means of converting per unit impedances from one base to another. The per unit impedance is given by equation

\[ \text{per unit Z} = \frac{\text{Actual Z in volts - baseMVA}}{\text{BaseMVA}} \times \left( \frac{\text{BasekV}}{\text{BasekVA}_{3ph}} \right)^2 \times 1600 \]

which shows that per unit impedance is directly proportional to base megavolt amperes and inversely proportional to the square of the base voltage. Therefore to change from per unit impedance on a given base to per unit impedance on a new base, the following equation is used:
The ohmic value of resistance and leakage reactance of a transformer depends on whether they are measured from the LT side or HT side of a transformer. If they are expressed in pu, the base MVA is the MVA rating of the transformer which is same as referred from HT side or LT side. The base kV is selected as the voltage of LT winding, if the ohmic values are referring to LT side, else it is selected as voltage of HT winding, if the ohmic values are referring to HT side of transformer. Whereas the PU values remains same regardless of whether they are determined from HT side or LT side.

1.1 3 phase fault is created at Bus 1

In the first case we study the effect of generator towards the 3 phase fault side. Generally there might arise a fault: Near-To-Generator Short-Circuit or Far-From-Generator Short-Circuit.

As we can see the simulation results show the 3 phase fault is created at Bus 1 near to the generator. The voltage at bus 1 goes to 0 and at other buses dip due to the effect of fault. The breakers inserted in the single line diagram are exceeding the given limits. This situation shows that the existing breakers are improved correspondingly. The table below the breaker settings before and after improvements:

1.2 Load flow analysis and short circuit analysis

A load flow calculation determines the state of the power system for a given load and generation distribution. It represents a steady state condition as if that condition had fixed for some time. In reality, line flows and bus voltages fluctuate constantly by small amounts because load changes constantly as lights, motors, and other loads are turned on and off.

1.2.1 Near-To-Generator Short-Circuit

This is a short-circuit condition to which at least one synchronous machine contributes a prospective initial short-circuit current which is more than twice the generator’s rated current, or a short-circuit condition to which synchronous and asynchronous motors contribute more than 5% of the initial symmetrical short-circuit current (I’s).

1.2.2 Far-From-Generator Short-Circuit

This is a short-circuit condition during which the magnitude of the symmetrical ac component of available short-circuit current remains essentially constant.
III. SIMULATION RESULTS AND DESCRIPTION

![Graph showing current levels after three phase short circuit](image)

This graph \(^1\) is obtained through MiPower software based on the simulation values entered and the short circuit fault created at bus 1.

The table below shows the improvements needed in resizing \(^8\) the circuit breaker so that it can be used for the above system of 9 bus.

<table>
<thead>
<tr>
<th>Generator Fault at Bus 1</th>
<th>Fault Level in MiPower in kA</th>
<th>Breaker Selected/Interrupting Current in kA</th>
<th>Making/Peak Current in kA</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.8</td>
<td>6.26</td>
<td>20</td>
<td>50</td>
</tr>
<tr>
<td>16.5</td>
<td>29.11</td>
<td>31.5</td>
<td>78.75</td>
</tr>
<tr>
<td>18</td>
<td>6.03</td>
<td>12.5</td>
<td>31.25</td>
</tr>
<tr>
<td>230</td>
<td>0.54</td>
<td>25</td>
<td>62.5</td>
</tr>
</tbody>
</table>

Using the software we were able to do the fault analysis and corrections were made in the respective CB’s. The network in this report is enclosed in the result section along with the breaker improvements and graphs for creating such faults.

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CONCLUSION

In this project, 3 phase fault analysis was done for an IEEE 9-bus \(^7\) system where bus number 1 was the main focus of this report. In three-phase fault, the voltages at faulted bus phases dropped to zero during the fault. The faulted bus is bus number 1 where Phase A, B and C has a zero voltage potential. The main intention to do a 3phase fault is to calculate the fault at various bus levels and see the contribution from other elements so as to size the switchgear \(^9\) with respective to their interrupting capability.