Short Circuit Analysis

and the

Interpretation of SKM Power*Tools Fault Study Results

Reason for short circuit analysis

A short circuit analysis models the currents that flow in a power system under fault conditions and determines the prospective fault currents in the electrical power system. These fault currents must be calculated in order to adequately specify electrical apparatus' withstand and interrupting ratings. The study results are also used to selectively coordinate time current characteristics of electrical protective devices.

Momentary and interrupting fault current

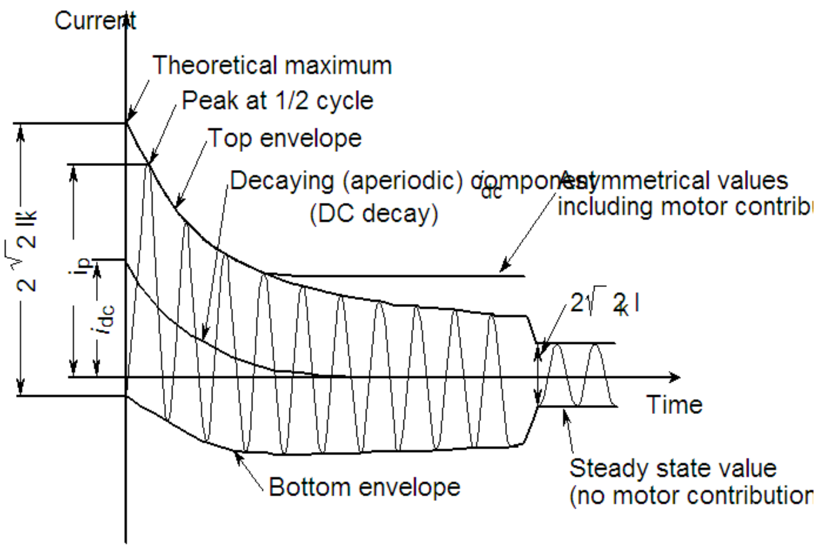
The momentary fault current is defined as the short circuit peak (equivalent RMS) current that flows at the first one-half cycle after the onset of the fault. Electrical apparatus must withstand the mechanical and thermal affects of this momentary current. Protective devices and switches must be capable of closing and latching into this momentary current. Momentary current can be highly asymmetrical (with the time axis).

The interrupting fault current is defined as the short circuit current that flows through a protective device at the time of its contact separation. The interrupting duty of a circuit breaker may be lower than its associated closing and latching (momentary) rating. The interrupting current tends to be more symmetrical with the time axis than the momentary fault current. Medium and high voltage circuit breakers in particular may have interrupting ratings based on contact parting times of 3 or 5 cycles after the onset of the fault.

The asymmetrical nature of the momentary fault current is a result of the instantaneous change in system X/R at the point of the fault prior to and immediately after the fault. Prior to the fault, the system generally operates at a very small X/R ratio (that is, a high power factor). However, after the fault when all the high power factor loads are ignored, the system X/R ratio can be quite large. This instantaneous change in system X/R ratio at the instant the fault occurs can be exacerbated depending on when, during the voltage sine wave, the fault occurs.

If the fault occurs at a positive-increasing voltage peak, then the current wave is said to have maximum asymmetry. This asymmetric condition is known as the dc component or dc decay because the asymmetric nature of the wave shape decays exponentially over time. Also, the momentary fault current and, to a lesser degree, the interrupting fault current are dependent upon the time varying collapse in machine voltages. This time varying collapse is known as the ac decrement and is most often modelled as a time varying machine reactance.

Current limiting fuses which operate within one-half cycle are subject to momentary currents and may open to clear the fault before the maximum prospective fault current occurs. Devices such as circuit breakers require the fault current to pass through a current zero before the arcing current is extinguished. Breakers may experience significant interrupting fault current for many cycles during operation.



Engineering methodology and theory

The systematic short circuit study methodology begins by creating a system one-line diagram, thus defining all electrical characteristics of the power system. If the solution is worked by hand, the engineer must define a complete Thevenin equivalent impedance diagram and place all impedances on a common base. Selected fault points are chosen and the specific Thevenin equivalent impedances are calculated. Knowing the fault impedances and the driving point voltages, the fault currents are calculated using Ohm's Law.

Power*Tools

The computer-based solution methodology is slightly different. The software calculates the currents for a fault at every bus or node bus within the system. From the one-line diagram and the associated computer database of system equipment, the computer forms an admittance matrix. An admittance matrix is a square matrix of a size equal to the number of electrical buses. The matrix is well ordered and generally symmetric about the diagonal. The well ordered and sparse matrix characteristics of the admittance matrix allow for convenient, albeit computationally intensive, matrix inversion. From the inverted admittance (impedance) matrix, the bus fault currents are calculated using Ohm's Law.

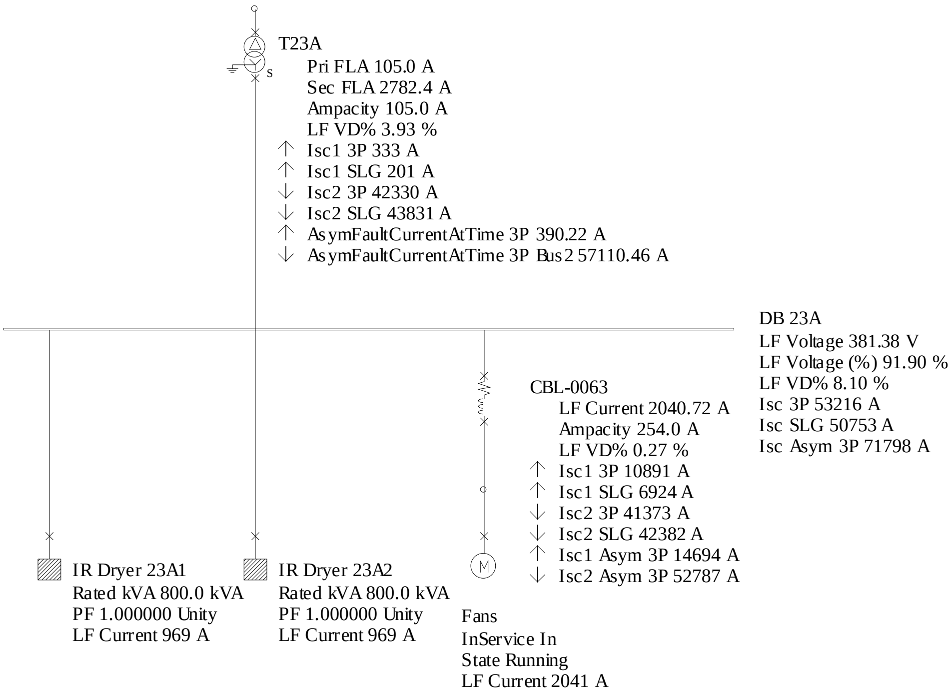
Types of fault

The fault currents in a three-phase power system may be either equal (balanced across all three phases) or unbalanced. An unbalanced fault involves one or two phases, but not all three. The three-phase symmetrical RMS fault current (balanced fault) is often considered the maximum fault current at the bus. However, in certain situations an unbalanced fault may be larger.

How the information is displayed

When a short circuit study is run in Power*Tools, fault currents are calculated for each component within the system, as detailed above. The information is displayed on the single line diagram alongside the relevant component. Each component type will have the information displayed slightly differently. Bus bars for example will have short circuit currents displayed for a fault occurring at the bus bar. Cables and transformers will have two sets of short circuit currents displayed; one set for a fault at the nearest “upstream” bus and one set for a fault at the nearest “downstream” bus. The upstream or downstream fault is identified by a 1 or a 2 in the descriptor and directional arrows next to the value indicate the direction of current flow.

Take the SLD below for example. The diagram shows a modified portion of the circuit at substation 23. The fan motor output rating has been increased to 1MW and a short (1m) length of cable added to illustrate motor fault contribution.



Transformer “T23A”:

- Isc1 3P – is the three phase symmetrical RMS short circuit current referred to the HV side of the transformer (due to motor contribution) which would flow from the transformer for a fault upstream at the HV side terminals of the transformer
- Isc1 SLG – is the single line to ground symmetrical RMS short circuit current referred to the HV side of the transformer which would flow from the transformer for a fault upstream at the HV side terminals of the transformer
- Isc2 3P – is the three phase symmetrical RMS short circuit current referred to the LV side of the transformer which would flow from the transformer for a fault at bus bar “DB 23A”

- Isc2 SLG – is the single line to ground symmetrical RMS short circuit current referred to the LV side of the transformer which would flow from the transformer for a fault at bus bar “DB 23A”

- AsymFaultCurrentAtTime3P – is the RMS equivalent of the three phase asymmetrical short circuit current for a fault upstream at the HV side terminals of the transformer

- AsymFaultCurrentAtTime3P Bus 2 – is the RMS equivalent of the three phase asymmetrical short circuit current for a fault at bus bar “DB 23A”

Cable “CBL-0063”:

- Isc1 3P – is the three phase symmetrical RMS short circuit current (due to motor contribution) flowing through the cable for a fault at bus bar “DB 23A” This current (10891Amp) is referred to 415V. Isc1 SLG – is the single line to ground symmetrical RMS short circuit current for a fault at bus bar “DB 23A”

- Isc2 3P – is the three phase symmetrical RMS short circuit current for a fault at the terminals of the fan motor

- Isc2 SLG – is the single line to ground symmetrical RMS short circuit current for a fault at the terminals of the fan motor

- Isc1 Asym 3P – is the RMS equivalent of the three phase asymmetrical short circuit current for a fault upstream at bus bar “DB 23A”

- Isc2 Asym 3P – is the RMS equivalent of the three phase asymmetrical short circuit current for a fault at the fan motor terminals

Bus bar “DB 23A”:

- Isc 3P – is the three phase symmetrical RMS short circuit current for a fault at the bus bar. It is equal to the vector sum of the incoming fault contributions, i.e. 42,330A (T23A Isc2 3P) + 10,891A (CBL-0063 Isc1 3P) = 53,221A ≈ 53,216A.

- Isc SLG – is the single line to ground symmetrical RMS short circuit current for a fault at the bus bar. It is equal to the vector sum of the incoming fault contributions, i.e. 43,831A (T23A Isc2 SLG) + 6,924A (CBL-0063 Isc1 SLG) = 50,755A ≈ 50,753A.

- Isc Asym 3P – is the RMS value of the asymmetrical three phase short circuit current for a fault at the bus bar. It is equal to the vector sum of the incoming fault contributions, i.e. 57,110A (T23A AsymFaultCurrentAtTime3P Bus 2) + 14,694A (CBL-0063 Isc1 Asym 3P) = 71,804A ≈ 71,798A.

- Note the small differences in the calculations above are due to phase differences in the fault currents flowing into the busbar resulting in a difference between the scalar and vector additions.