Short circuit interrupting ratings of the Low Voltage Generator Circuit Breakers.

Low voltage circuit breakers are rated on symmetrical basis. Therefore the interrupting ratings (or interrupting capacity) of the low voltage circuit breakers, published by manufacturers, are expressed in RMS symmetrical current.

The instantaneous function of the circuit breaker trip unit is designed to react to the peak value of the phase current. Since circuit breakers are capable of parting their main contacts during first 1-3 cycles of the fault, their short circuit ratings should be higher than the maximum available symmetrical fault current during the 1st cycle of a fault.

Generator direct axis subtransient reactance (X"d) is the reactance of the stator winding at the instance of fault. RMS symmetrical values of the fault current at the generator terminals can be calculated as follows:

Three phase fault: $Isc = \frac{E}{\sqrt{3}} \frac{}{X''d}$

Line to Neutral fault: $Isc = \frac{E\sqrt{3}}{X''d + X_2 + X_0}$

Where:
E – generator line to line voltage before fault, Volts
X"d -- generator direct axis subtransient reactance, Ohms
X_2 -- generator negative sequence reactance, Ohms
X_0 -- generator zero sequence reactance, Ohms

Note: all reactance values should be used as the "worst case values". Example: if X"d value is specified by the generator as 20% +/- 15%, that the "worst case value" of X"d should be calculated as 20%* 0.85 = 17%.

Typical values for a 2.25 MW, 480 V generator are: X"d= 0.013 Ohms (15.9%), X_2= 0.012 Ohms (14.6%), X_0= 0.003 Ohms (3.7%).

As can be seen if the generator neutral is solidly grounded, the ground fault current will exceed the value of the three phase fault current.

Let's assume that two (2) of the above generators are operated in parallel with high impedance grounded neutral. In this case, three phase bolted fault will produce the highest fault current, since line to ground fault will be limited by the neutral grounding resistor(s). Than the highest fault current they can produce is approximately 42,615 Amperes of RMS symmetrical current. For the "worst case scenario" we will assume close proximity of the switchgear to the generator sets and therefore ignore the values of X and R of the connecting cables as negligible. In this case, as a rule of thumb, if the 80% of nameplate interrupting capacity of the feeder circuit breakers connected to this generator bus is above 42.615 kA, no further calculations are generally required.

If the 80% of nameplate interrupting capacity of the feeder circuit breakers connected to this generator bus is not above 42.615 kA, than further evaluation is required as outlined below.

1. <u>Type of low voltage circuit breaker</u>. Most low voltage circuit breaker used in North American power systems are rated to ether ANSI C37 standards or UL 489. ANSI rated circuit breakers are tested at 15% Power Factor (P.F.) UL 489 rated breakers are tested at 20% Power Factor.
2. <u>Calculate short circuit Power Factor or Power System X/R ratio</u>. System Power Factor and X/R ratio are both indicators of the mathematical relationship between system reactance and resistance. They are related by the following formula: $P.F. = \cos(\tan^{-1}(X/R))$. For example 15% Power Factor corresponds to 6.59 X/R ratio and 20% Power Factor corresponds to 4.9 X/R ratio. If actual system fault X/R ratio higher than the X/R ratio the circuit breaker was tested to, than the fault interrupting rating of the circuit breaker needs to be adjusted by applying a derating multiplier further called “Derating Factor”. To determine required interrupting rating of the circuit breaker, value of the available fault current needs to be multiplied by a “Isc Multiplying Factor” as outlined in Table 1.

The reason the system X/R ratio needs to be considered is that the actual generator fault current is not symmetrical. It consists from the symmetrical AC component and a DC component sometimes called DC offset. A typical asymmetrical current wave is shown in Figure 1. The actual degree of asymmetry and therefore the actual magnitude of current the circuit breaker will need to interrupt, depends on the system X/R ratio and when in the power cycle the fault occurs. The higher the system X/R ratio, the greater the potential for the instantaneous peak value of the fault current to reach its maximum theoretical instantaneous peak value. The initially asymmetrical fault current becomes symmetrical as the DC component of the fault current decays.

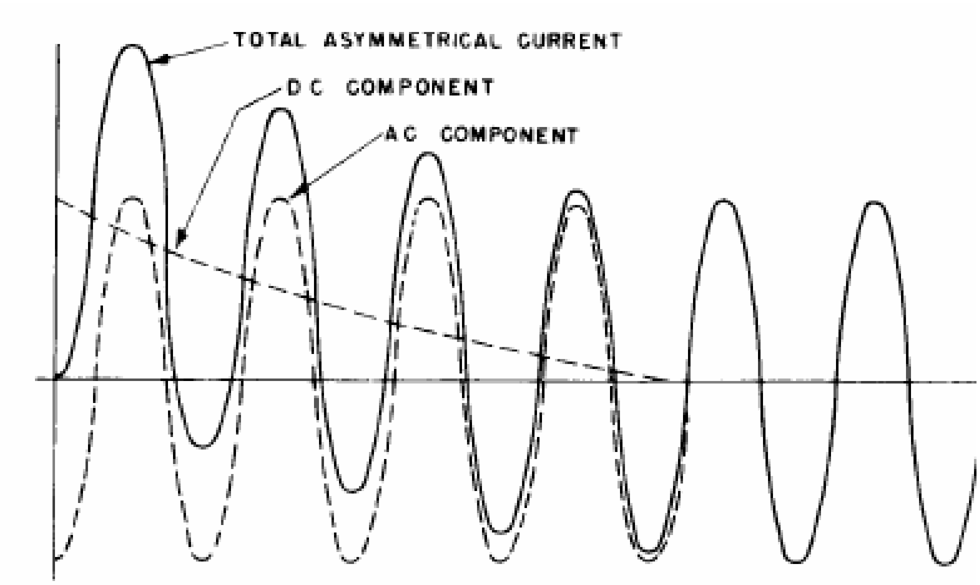

Figure 1

For a typical 2.25 MW, 480 V generator system described above the "worst case" X/R = 0.013/0.0015, which corresponds to an X/R ratio of 8.67 or system Power Factor of approximately 11%.

The Table 1 below can be used to determine the required derating of the circuit breakers interrupting ratings. In our example the required feeder circuit breaker interrupting ratings will be:

1. For an ANSI rated circuit breakers: 42.615 kA * 1.049 = 44.7 kA
2. For a UL 489 rated circuit breakers: 42.615 kA *1.11 = 47.3 kA

Table 1

Short-circuit power factor percent	Short-circuit X/R ratio	Ratio of phase instantaneous peak amperes to symmetrical RMS amperes, Mp	Isc Multiplying Factor for ANSI CB, MF1, (tested at 15% P.F)	Isc Multiplying Factor for UL489 CB, MF2, (tested at 20% P.F)	ANSI CB Interruptin g Rating Derating Factors, DF1, (tested at 15% P.F)	UL489 CB Interruptin g Rating Derating Factors, DF2, (tested at 20% P.F)
0	Infinity	2.828	1.225	1.295	0.816	0.772
1	99.995	2.785	1.206	1.276	0.829	0.784
2	49.990	2.743	1.188	1.257	0.842	0.796
3	33.318	2.702	1.170	1.238	0.855	0.808
4	24.980	2.663	1.153	1.220	0.867	0.820

5	19.975	2.625	1.137	1.202	0.880	0.832
6	16.637	2.589	1.121	1.186	0.892	0.843
7	14.251	2.554	1.106	1.170	0.904	0.855
8	12.460	2.52	1.091	1.154	0.916	0.866
9	11.066	2.486	1.077	1.139	0.929	0.878
10	9.950	2.455	1.063	1.125	0.941	0.889
11	9.036	2.423	1.049	1.110	0.953	0.901
12	8.273	2.394	1.037	1.097	0.964	0.912
13	7.627	2.364	1.024	1.083	0.977	0.923
14	7.073	2.336	1.012	1.070	0.988	0.935
15	6.591	2.309	1.000	1.058	1.000	0.945
16	6.170	2.282	0.988	1.045	1.012	0.957
17	5.797	2.256	0.977	1.033	1.023	0.968
18	5.465	2.231	0.966	1.022	1.035	0.978
19	5.167	2.207	0.956	1.011	1.046	0.989
20	4.899	2.183	0.945	1.000	1.058	1.000
21	4.656	2.16	0.935	0.989	1.069	1.011
22	4.434	2.138	0.926	0.979	1.080	1.021
23	4.231	2.116	0.916	0.969	1.091	1.032
24	4.045	2.095	0.907	0.960	1.102	1.042
25	3.873	2.074	0.898	0.950	1.113	1.053