SIEMENS

TechTopics No. 71

Generator circuit breakers

This is the first in a series of TechTopics dealing with generator circuit breakers. It includes a general introduction to the subject as well as a table of ratings and related capabilities for the Siemens type GMSG-GCB generator circuit breakers. These circuit breakers have been designed and tested in accordance with IEEE standard C37.013-1997, along with the amendment C37.013a-2007.

IEEE C37.013 was first issued in 1989 and was revised in 1997. These editions both covered generator circuit breakers for large machines (for example, over 100 MVA) as reflected in the listing of continuous current ratings (from 6.3 kA to 20 kA and beyond) and short-circuit ratings (from 63 kA to 160 kA and beyond). As experience grew with the use of the standard, a movement developed to extend the applicability of C37.013 to smaller machines. This led to the creation of amendment C37.013a-2007 that extended the machines covered by the document down to 10 MVA and broadened the range of continuous currents (down to 1,200 A) and short-circuit ratings (down to 20 kA).

A new revision is anticipated in 2015, which will be redesigned as ANSI/IEEE 62271-37-013, a dual-logo IEEE and IEC document.

Circuit breakers applied to generator switching applications are subject to conditions quite different from those of a normal distribution circuit breaker used in industrial, commercial and utility systems. Distribution circuit breakers, whether of the outdoor substation type or of the drawout type for use in metal-clad switchgear, conform to IEEE C37.04 (basis of ratings), IEEE C37.06 (preferred ratings), IEEE C37.09 (testing) and IEEE C37.010 (application).

A short-circuit fault current is composed of a decaying dc component superimposed on an alternating component (the symmetrical current), with the dc component having an exponential decay and the ac component having a constant rms value over the entire fault (no ac component decay). The dc component has an initial value determined by the instantaneous ac component current at the instant of fault initiation and this then decays exponentially with a time constant that is a function of the system parameters (X and R or X/R ratio). Thus, the dc component decays and the short-circuit waveform always includes current zeroes at each (offset) half-cycle. The nature of this fault current is discussed in some detail in TechTopics No. 44 - Anatomy of a short-circuit.

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Table 1: Rated values and related capabilities	IEEE C37.013 clause	Units	Circuit breaker type[1]		
			15-GMSG-GCB-40-XXXX-110	15-GMSG-GCB-50-XXXX-137	15-GMSG-GCB-63-XXXX-173
Rated maximum voltage (V)	5.1	kV	15.0	15.0	15.0
Power frequency	5.2	Hz	60	60	60
Rated continuous current	5.3	A	1,200, 2,000, 3,000, 4,000 FC	1,200, 2,000, 3,000, 4,000 FC	1,200, 2,000, 3,000, 4,000 FC
Rated dielectric strength (withstand voltage) 1. Power frequency, one minute 2. Impulse	5.4.2 C37.013a, Table 4	kV kV peak	38 95	38 95	38 95
Rated short-circuit duty cycle	5.5		CO-30 min-CO	CO-30 min-CO	CO-30 min-CO
Rated interrupting time[2]	5.6	ms	< 80 ms	< 80 ms	< 80 ms
Rated short-circuit current 1. System source (100%) (I) 2. Generator source (50%)	5.8.1 5.8.2.3	kA sym kA sym	40 20	50 25	63 31.5
dc component		%	75	64	61
Asymmetry ratio (historical "S" factor)		----	1.46	1.35	1.32
Asymmetrical interrupting (ref)		kA rms	57.9	67.5	83
Delayed current zero capability		ms	40	30	30
Closing and latching capability (274% I)		kA peak	110	137	173
Short-time current carrying capability (100% I)	5.8.2.7	kA sym	40	50	63
Short-time current duration	5.8.2.7	s	3	3	3
Transient recovery voltage (TRV) rating System source 1. E_2 peak voltage 2. RRRV (TRV rate) 3. T_2 time-to-peak Generator source 1. E_2 crest voltage 2. RRRV (TRV rate) 3. T_2 time-to-peak Out-of-phase sources 1. E_2 crest voltage 2. RRRV (TRV rate) 3. T_2 time-to-peak	5.9 C37.013a, Table 5 C37.013a, Table 6 C37.013a, Table 9	kV kV / μs μs kV kV / μs μs kV kV / μs μs	27.6 (1.84 V) 3.5 9.3 (0.62 V) 27.6 (1.84 V) 1.6 20.25 (1.35 V) 39.0 (2.6 V) 3.3 13.4 (0.89 V)	27.6 (1.84 V) 4.5 7.2 (0.48 V) 27.6 (1.84 V) 1.8 18.0 (1.20 V) 39.0 (2.6 V) 4.1 10.8 (0.72 V)	27.6 (1.84 V) 4.5 7.2 (0.48 V) 27.6 (1.84 V) 1.8 18.0 (1.20 V) 39.0 (2.6 V) 4.1 10.8 (0.72 V)
Rated load-current switching capability	5.10	A	1,200, 2,000, 3,000	1,200, 2,000, 3,000, 4,000	1,200, 2,000, 3,000, 4,000
Out-of-phase current switching capability	5.12	kA	20	25	31.5
Mechanical endurance		operations	10,000	10,000	10,000

Footnotes:

[1] "xxxx" in type designation refers to the continuous current rating, 1,200 A, 2,000 A or 3,000 A, as appropriate. The 4,000 A fan-cooled rating is achieved using a 3,000 A circuit breaker, in combination with fan cooling in the switchgear structure.

[2] Interruption time is based on the first current zero occurring not later than 33 ms (for 50 ms interrupting) or 66 ms (for 83 ms interrupting) after fault initiation, i.e., %dc component less than 100.

One of the distinguishing characteristics of applications to generator switching is that generators have a limited rotating inertia and they slow down during short-circuits.

This introduces two problems. First, the ac component is no longer a constant rms value, but, in fact, decays. This condition is most severe with low-inertia machines, such as gas turbines, where the time constant of decay of the ac component can be faster than the corresponding dc decay. Under this condition, the superposition of the dc component on the ac component will result in a potentially long period in which the actual fault current does not pass through zero. This is a problem as circuit breakers, and especially vacuum circuit breakers, actually interrupt as the current passes through a normal current zero. This phenomenon is referred to in IEEE C37.013 as "delayed current zeroes" and is a condition for which the performance of the generator circuit breaker must be determined by testing.

This situation is exacerbated by differences in the values of the system X/R ratio between distribution applications and generator applications. The basis of interrupting ratings and testing for distribution circuit breakers is a system X/R ratio of 17 (at 60 Hz) that gives a time constant of dc decay of 45 ms. Thus, in a distribution application, the dc component is nearly completely decayed after just a few cycles. However, the basis of rating for a generator circuit breaker is a system X/R ratio of 50 (at 60 Hz), which gives a time constant of dc decay of 133 ms, and hence the dc component decays only very slowly. This means that the dc component of the current at the instant of interruption is much larger for a generator application than it would be in a distribution application.

Compounding this situation is the fact that as the machine slows down, it loses synchronism with the power system, such that there can be a significantly higher voltage across the contacts of the interrupter as the circuit breaker opens to interrupt the fault. Theoretically, this out-of-phase condition can be as great as 180 electrical degrees, but as a practical matter, is considered to be no greater than 90 electrical degrees. The out-of-phase condition is limited to 90 electrical degrees to prevent damage to the shaft of the machine if switching occurred with the generator and system more than 90 degrees out-of-phase.

The out-of-phase switching application also exists when a machine is being brought up to speed and is being synchronized with the power system. Synchronizing equipment, including a synchronism check function, is almost universally used with large machines to prevent closing of a circuit breaker while the machine is out-of-phase with the power system by more than a nominal amount. Closing under a severe out-of-phase condition would lead to very high transient currents that would cause the protective relays to initiate circuit breaker opening. However, due to the time required for interruption, damage to the machine would most likely occur before the interruption process could be completed.

Another aspect of a generator circuit breaker application is that the transient recovery voltage (TRV) across the contacts as the interrupter opens is much greater than for a distribution circuit breaker. For typical 15 kV distribution circuit breakers, the rate of rise of TRV during a symmetrical fault interruption at 100 percent of rating is 0.92 kV/μs. In contrast, for generator circuit breaker applications, the corresponding value is 3.2 to 4.5 kV/μs for systems ranging from 10 MVA up to 400 MVA (based on transformer size).

This is just a brief overview of the conditions that make a generator circuit breaker application quite different from the ordinary distribution application. These issues will be explored in more detail in subsequent TechTopics issues.

The ratings and related capabilities of the Siemens GMSG-GCB family of circuit breakers are listed in Table 1.