

SHORT CIRCUIT CAPABILITY OF GENERATOR CIRCUIT BREAKER

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ABSTRACT

This paper deals with the essential function of generator circuit breaker in power plant. The aim of the paper is to analyse very demanding current and voltage required capabilities concerned with the short-circuit current which a generator circuit breaker can experience. Many of today's 1000+ MVA class generators can produce a maximum degree of asymmetry up to 130% for generator fed faults.

KEYWORDS

Generator circuit breaker, Short Circuit, Recovery voltage, Asymmetry, Generator

1. INTRODUCTION

Since the first delivery of a specific purpose generator circuit-breaker consisting of free metal-enclosed, phase-segregated units and using compressed air as operating and arc-extinguishing medium in 1970 the development of this core power plant equipment continues till today. In the 1980's the first generator circuit-breaker using SF₆ gas as arc-extinguishing medium was produced and brought to the market. Recently, a SF₆ generator circuitbreaker with a rated current of 24,000 A (naturally cooled, higher rated currents can be reached with forced air cooling) and a short-circuit breaking current of 220 kA at a maximum service voltage of 30 kV has become available. This breaking capacity corresponds to the highest short-circuit breaking current ever achieved with a single SF₆ interrupter unit. The development was rendered possible by using the most advanced SF₆ self-extinguishing technology. With this achievement modern specific purpose generator circuit-breakers using SF₆ gas as arc-extinguishing medium are now available for generating units with ratings up to 1400 MW.

2. SHORT CIRCUIT RATING OF A GCB

The rated short circuit current of a generator circuit breaker as defined in IEEE C37.013-1997 [2] is the highest RMS value of the symmetrical three phase short circuit current. This definition is based upon a system source short circuit with at least one transformation. It is assumed by the standard that the system source short circuit current is generally higher than the generator source short circuit current. It states that special consideration is required in rare cases when the generator source short circuit current is higher than system source short circuit current.

The IEEE C37.013, assigns for GCB a symmetrical interrupting rating for generator-source currents, this rating assumes a maximum DC component of 110% of that value. 110% asymmetry means that at the time of contact separation, the DC instantaneous value is 110% of the AC instantaneous peak value. The same GCB can be applied when the degree of asymmetry is higher than 110%, but the symmetrical current in such case must be lower. C37.013 defines that maximum asymmetry to be 130%, but the symmetrical current must not exceed 74% of rated.

2.1. Background of short-circuit current rating

The symmetrical short-circuit current, which a generator circuit breaker can experience, is explained by Figure 1, a general diagram of a power station, with a short-circuit shown in the following different locations:

- The system-source short-circuit current (location a, Figure 1);
 - The generator-source short-circuit current (locations b & c, Figure 1);
- (Location b has a higher short-circuit current than location c; therefore location c can be disregarded for the following considerations.)

In all practical applications, the system-source symmetrical short-circuit current is higher than that of the generator-source case because the sum of the short-circuit reactance of the transformer and the system is lower than the subtransient and transient reactances of the generator.

The generator-source short-circuit current has no direct relationship to the system-source short-circuit current. Because the system-source short-circuit current is higher than the generator-source short-circuit current, it has been specified as the rated short-circuit current of a generator circuit breaker.

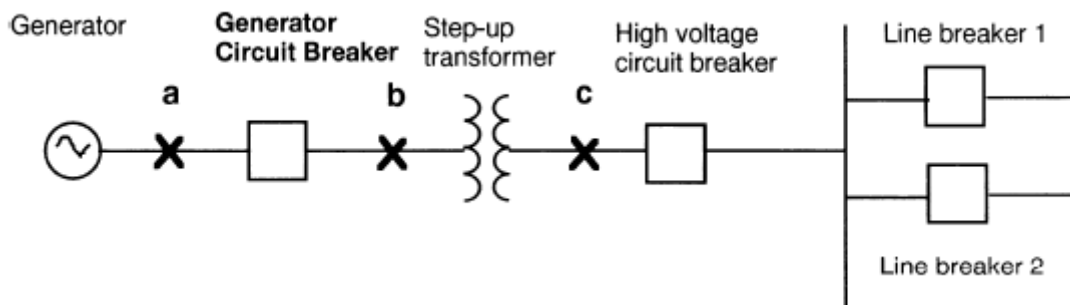


Figure 1 – General circuit diagram of a power station

The system-source short-circuit current can be very high because the full energy of the power system feeds the fault. The low impedance of the transformer and the short, very low loss buses connecting the generator, generator circuit breaker, and transformer, limit only a little the fault current because of their very low impedance. To interrupt these kinds of faults, generator circuit breakers must be tested and proven capable of interrupting not only the high symmetrical fault current, but also the higher asymmetrical fault currents resulting from extreme DC components of fault current.

The generator-source short-circuit currents are lower in magnitude, but they are subject to another type of very demanding condition called “Delayed current zeros”. This unique characteristic of the fault current comes from the very high X/R (inductive reactance to resistance) ratio of the circuit and the operating conditions of the generator, which can combine to produce a DC component of the fault current exceeding 100%. This means the asymmetrical fault current peak becomes so high, and its decay so slow, that the first current zero can be delayed for several cycles. Since circuit breakers rely on current zero crossing in order to interrupt, generator circuit breakers must be able to withstand longer arcing times and greater electrical, thermal and mechanical stresses when interrupting this kind of fault (2.2). Analysis of coincidence of interrupting time interval focused on comparison between mechanical properties of GCB and electrical parameters in the circuit is core of my thesis.

2.2. Generator-source fault

The generator source asymmetrical current is given by the following equation:

$$I_{\text{gen source asym}} = \frac{P\sqrt{2}}{V\sqrt{3}} \left\{ \left[\left(\frac{1}{X_d''} - \frac{1}{X_d'} \right) e^{-t/T_d''} + \left(\frac{1}{X_d'} - \frac{1}{X_d} \right) e^{-t/T_d'} + \frac{1}{X_d} \right] \cos \omega t - \frac{1}{X_d''} e^{-t/T_d} \right\}$$

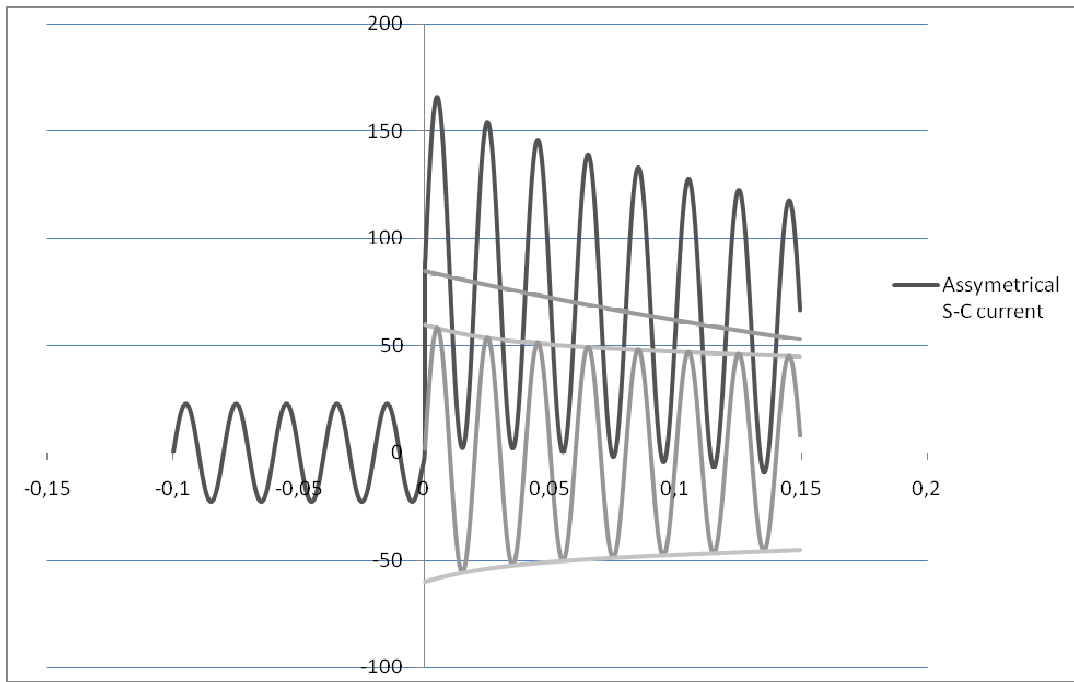


Figure 2 – DC component of generator-source short-circuit current

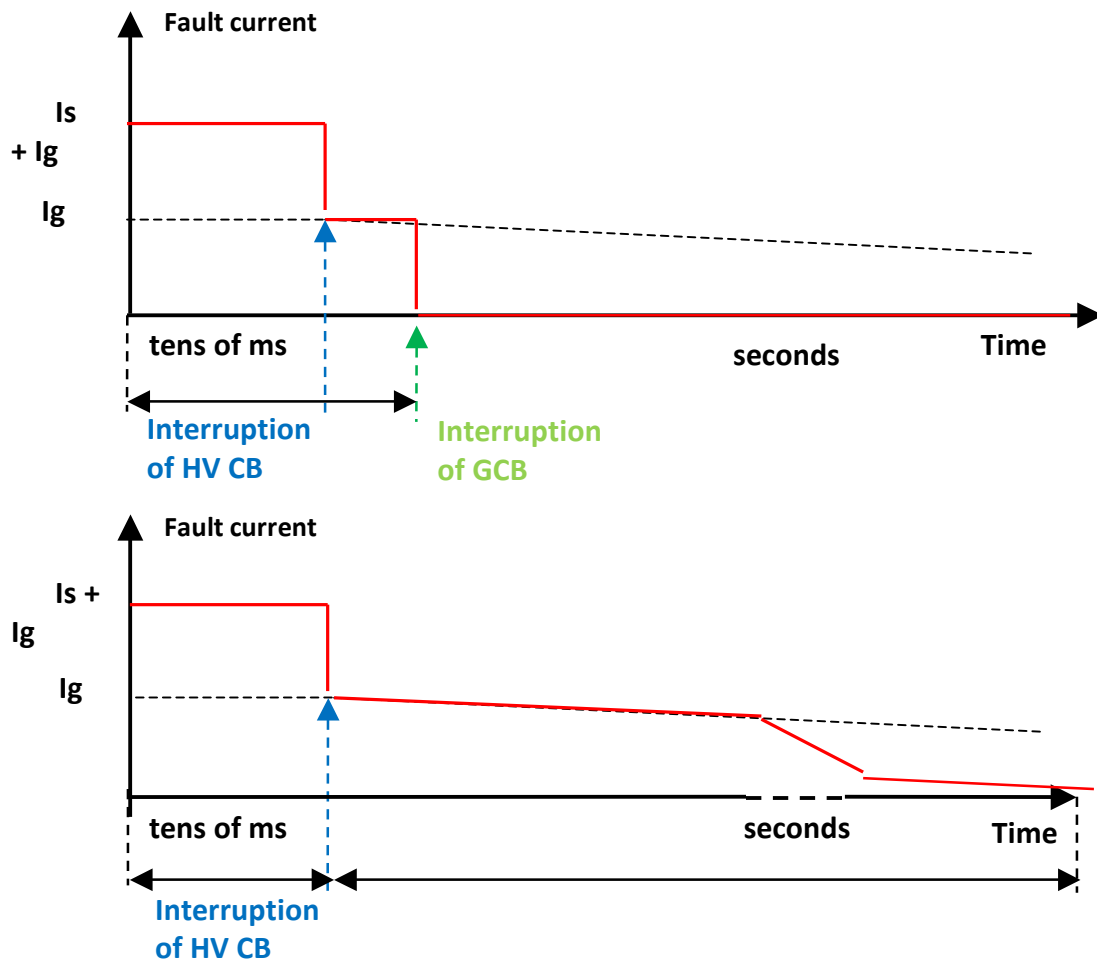


Figure 3 – Interruption of generator-source fault currents with/without GCB

3. CONCLUSIONS

The Generator Circuit Breaker (GCB) is an essential component of a power plant, protecting both the generator and the power transformers. Currently, the only standard that addresses GCB ratings is IEEE C37.013. This standard defines the primary short circuit rating of a GCB based on a system fed fault.

Common causes of main transformer internal failures are the flashover of a bushing, winding interturn faults, failures of the tap-changer and carbonisation and/or excessive moisture content of the transformer oil. Even if the system-fed component of the fault current is interrupted by the HV circuit-breaker within approximately 3 to 4 cycles, in a layout without a generator circuit breaker the generator continues to supply a fault current throughout the de-excitation time interval which may last for several seconds. The internal pressure resulting from the vaporisation of the transformer oil is a function of the product of arc current and time. This pressure stresses the transformer tank, and, if it rises above a certain value, will cause the tank to rupture, with a resulting oil spillage and possibly an oil fire. Tank rupture may occur after 4.5 to 5 cycles. The presence of a generator circuit-breaker which allows a rapid clearance also of the generator-fed component of the fault current can therefore prevent the system from event with severe or maybe catastrophic results.

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