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(Supplement to IEEE Std C37.081-1981)

Supplement to IEEE Guide for Synthetic Fault Testing of AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis

8.3.2: Recovery Voltage for Terminal Faults; Asymmetrical Short-Circuit Current

Sponsor
Switchgear Committee
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Abstract: The transient recovery voltage needs to be modified when interrupting asymmetrical currents. The voltage rate R, the peak voltage E2 and the rate of change of current di/dt all change with the asymmetrical current zero. Guidance is provided on how to make these corrections when compared to the symmetrical case.
Keywords: asymmetrical current, correction factors, major current zeros, minor current zeros, X/R ratio

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Introduction

(This introduction is not part of IEEE Std C37.081a-1997, Supplement to IEEE Guide for Synthetic Fault Testing of AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis—8.3.2: Recovery Voltage for Terminal Faults; Asymmetrical Short-Circuit Current.)

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CLAUSE PAGE

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Supplement to IEEE Guide for Synthetic Fault Testing of AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis

8.3.2: Recovery Voltage for Terminal Faults; Asymmetrical Short-Circuit Current

Revisions to IEEE Std C37.081-1981

The contents of this supplement will be incorporated into IEEE Std C37.081 in a future edition. At that time figures and tables will be labeled sequentially. This supplement is intended to be used in conjunction with IEEE Std C37.081-1981. Editing instructions necessary to incorporate this supplement into IEEE Std C37.081 are provided in ***bold italics.***

8.3.2 Recovery voltage for terminal faults; asymmetrical short-circuit current

Replace subclause 8.3.2 with the following:

The transient recovery voltage rate R and peak E_2, together with the *di/dt* of the current at current zero for asymmetrical faults needs to be modified in accordance with the degree of asymmetry of the fault current. The normal power frequency recovery voltage is sinusoidal with a value equal to that of the symmetrical fault current case.

The basis of rating for asymmetrical faults is a fully offset current with a decrement based on an *X/R* of 17. The total current dc component and voltage are shown in Figure 8.3.2-1 for this condition. From this it can be seen that current zeros occur at the times shown in Table 8.3.2-1 with the corresponding degree of asymmetry *D*.

For circuit breakers with rated maximum voltages of 121 kV to 242 kV and for 362 kV test duties 1 to 3 as listed in C37.09-1979 Table 2, the *di/dt* rated rate R and E_2 values are adjusted using the correction factor F_1 in Table 8.3.2-1

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for the current zero at which interruption is attempted. For TRVs with T_2 not exceeding 500 μs, the reduction of *di/dt* for current injection methods may be obtained by reducing the charging voltage of the voltage circuit.

For the other rated maximum design voltages listed, the *di/dt* and the rated rate *R* are also adjusted by the same factor F_1. During the relatively long T_2 times for these ratings there is a significant change in the power frequency voltage, and the peak E_2 needs to be further modified because of this. The correction factor F_E for the adjustment of the peak voltage E_2 is listed in Table 8.3.2-1. The correction factor F_E is calculated using the equations of Annex B.

When the test is made for clearance at the end of a major loop, the dc form of the recovery voltage will adequately cover the first quarter loop of the recovery voltage (of an equivalent direct test). For clearance at the end of a minor loop of current, the dc form of the reduced recovery voltage will not cover the basis of rating condition since, in this case, the power-frequency recovery voltage continues to rise after the onset of the TRV.

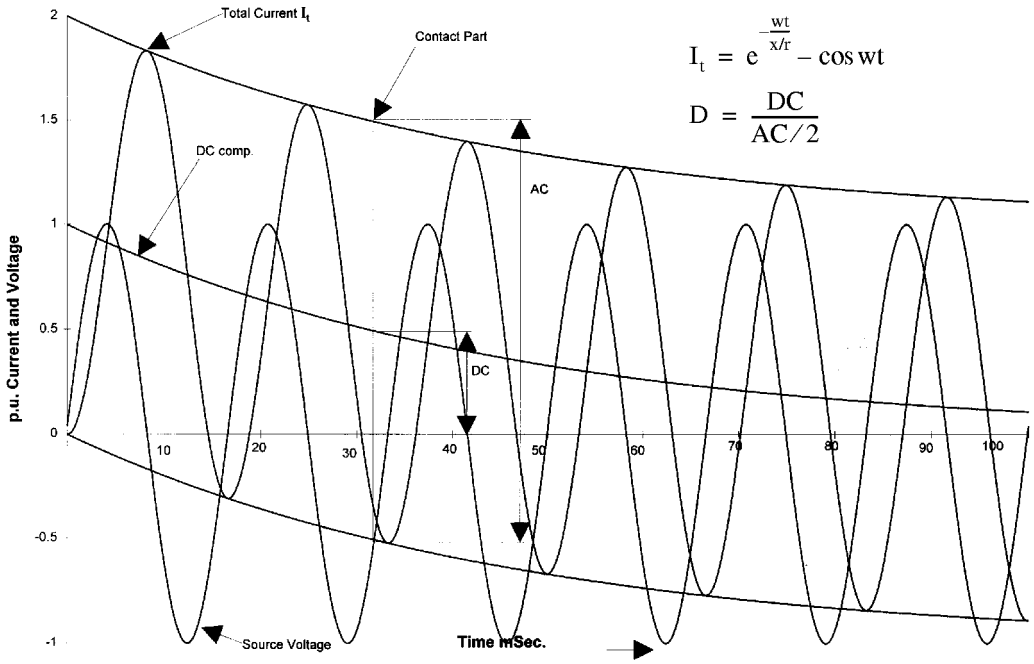


Figure 8.3.2-1 —Total current dc component and voltage

Circuit interruption after a minor loop with reduced *di/dt* and resulting TRV is assumed to be less severe than the equivalent symmetrical test. If it is required to prove this condition, there are three possibilities:

a) The test is performed with asymmetrical current conditions with the voltage source charged as for the symmetrical test. It must be recognized that this represents a considerable increase in severity above that of an equivalent direct test since both *di/dt* and the TRV are higher.
b) The test is performed as under a) except that the inductance of the injection circuit is increased in inverse proportion to *di/dt*. In this case, the *di/dt* value is correct but the TRV is higher.
c) The test is performed with an ac recovery voltage.

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Table 8.3.2-1 —Correction factors for adjustment of peak voltage

Current zero no.	Loop type	Time of zero μs	Asymmetry factor *D*	Correction factor F_1	Correction factor F_E				
					362 kV	550 kV		800 kV	
					100%	40–60%	100%	40–60%	100%
1	Major	14.64	0.723	0.733	0.573	0.594	0.475	0.575	0.442
2	Minor	18.93	0.657	0.716	0.854	0.836	0.940	0.853	0.970
3	Major	30.58	0.508	0.890	0.784	0.799	0.715	0.785	0.692
4	Minor	36.27	0.447	0.869	0.959	0.947	1.018	0.958	1.038
5	Major	46.79	0.354	0.956	0.883	0.893	0.835	0.884	0.819
6	Minor	53.34	0.306	0.934	0.995	0.987	1.036	0.995	1.049
7	Major	63.16	0.246	0.983	0.933	0.940	0.900	0.934	0.889
8	Minor	70.27	0.210	0.966	1.007	1.001	1.035	1.007	1.044

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Annex B

(Informative)

Add Appendix B as follows:

Correction factor calculation

The correction factors may be determined using the following equations:

Correction factor $F_1 = \sqrt{(1 - D^2)} - \left(\frac{D}{(X)/R}\right)$

where:

–D	is current with major loop
+D	is current with minor loop
D	is the per unit asymmetric factor
X/R	is 17
NAF	is Natural Amplitude Factor for the dependent time coordinate of the transient recovery voltage

For voltage ratings with T_2 times greater than 500 μs, the following equations were used:

$\omega = 2 \times \pi \times f$

$$NAF = AF + \left\{1 - \sin\left(\arctan\frac{X}{R} + T_2 \times \omega\right)\right\}$$

$$CF = (NAF - 1)\sin a_0 + \sin(a_0 \times T_2 + \omega)$$

$$a_0 = \arccos D - \arctan\frac{\sqrt{1 - D^2}}{X/R}$$

Where *D* is the per unit asymmetric factor, all angles are in radians, amplitude factor (*AF*) for E_2 is 1.44; assumes first pole to clear factor of 1.5.

Correction factor F_E = crest factor (*CF*)/*AF*

Substituting *NAF* in *CF*:

$$F_E = \frac{1}{AF}\left\{\left[AF - \sin\left(\arctan\frac{X}{R} + T_2 \times \omega\right)\right]\sin a_0 + \sin(a_0 + T_2 \times \omega)\right\} t$$

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