

Guide to the Application of Short-Circuit Parameters in Low-Voltage AC Circuits

Introduction

Low-voltage equipment standards IEC60947 and IEC60439 currently include short-circuit ratings for products and assemblies respectively, defined in terms of the ability of the equipment to operate at a level of peak current, an RMS current for a specified time and/or a level of current conditional upon a short-circuit protective device in series. In practice the correct application of the various short-circuit ratings needs to be fully understood by the circuit designer to avoid leaving a circuit or equipment with inadequate short-circuit protection. It is also useful to take full advantage of the capability of devices and systems to avoid over-engineering, with the consequent unnecessary additional cost.

This guide does not concern itself with the issue of selectivity between devices in series, which must be considered separately.

Principles of Application

The Installation

In order to ensure the capability of equipment under short-circuits conditions the circuit designer must firstly have available the prospective fault level at the point of installation of each item of equipment. This is produced by a system protection study. IEC60781 provides an application guide for calculation of short-circuit currents in low-voltage radial systems. Short-circuit parameters are defined by this guide in terms, which include the following:

- Prospective (available) short-circuit current:
The current that would flow if the short-circuit were replaced by an ideal connection of negligible impedance without any change of the supply.
- Peak short-circuit current i_p
The maximum possible instantaneous value of the prospective (available) short-circuit current.
- Symmetrical short-circuit breaking current I_b
The r.m.s. value of an integral cycle of the symmetrical a.c. component of the prospective (available) short-circuit current at the instant of contact separation of the first pole of a switching device.
- Steady-state short-circuit current I_k
The r.m.s. value of the short-circuit current which remains after the decay of the transient phenomena.
 - unlimited
 - limited by an SCPD (short-circuit protective device)

LV Assemblies (switchboard, distribution board etc.)

An assembly will have a short-circuit rating, assigned by the manufacturer, defined in terms of the maximum prospective fault level applicable at the point it is connected into the system. This will have been determined by test and/or design calculations as specified in the assembly standard, IEC60439-1, or applicable part thereof.

The terminology to define the short-circuit rating of an assembly is given in the standard as follows:

- *Rated short-time current (I_{cw}) (of a circuit of an assembly)*
Summarised as: The r.m.s value of short-time current that a circuit of an assembly can carry without damage under specified test conditions, defined in terms of a current and time e.g. 20kA, 0,2s.



TECHNICAL BULLETIN

- **Rated peak withstand current (I_{pk}) (of a circuit of an assembly)**
Summarised as: The value of peak current that a circuit can withstand satisfactorily under specified test conditions.
- **Rated conditional short-circuit current (I_{cc}) (of a circuit of an assembly)**
Summarised as: The value of prospective short-circuit current that a circuit, protected by a specified short-circuit protective device (SCPD), can withstand satisfactorily for the operating time of that device, under specified test conditions. Note: the short-circuit protective device may form an integral part of the assembly or may be a separate unit.

An assembly may be assigned a value of I_{cc} alone.

An assembly may be assigned values of I_{cw} and I_{pk} (but cannot be assigned a value of I_{cw} or I_{pk} alone).

An assembly may be assigned values of I_{cw} , I_{pk} and I_{cc} .

An assembly may be assigned different values of I_{cc} for different circuit protective devices and/or system voltages.

An assembly may be assigned different values of I_{cw} for different short-time periods e.g. 0.2s, 1s, 3 s.

Switchgear

In terms of short-circuit capability switchgear must be considered in respect of its function in the particular application. A switching device is considered in two respects, self-protection and use as a short-circuit protective device (SCPD) where applicable.

Switchgear – Self Protection Against Short Circuit

Two cases are considered: -

- a) Load and overload switching alone, without any short-circuit switching capability.
In this case the switching device will be short-circuit rated on a similar basis to a circuit of an assembly (see above), with a rating of I_{cw} and/or a conditional short-circuit rating, but will in addition have a rated short-circuit making capacity I_{cm} .
- b) Load, overload and short-circuit switching capability:
 - i) Fused switchgear – in this case the short-circuit breaking function is provided by the integral fuses and the device will have a conditional short-circuit rating.
 - ii) Circuit breakers – the circuit-breaker will be self-protecting up to its breaking capacity rating (see later). At fault levels above the breaking capacity rating a circuit-breaker may be capable of operating with 'back-up' protection by an SCPD (this is in effect a conditional rating, but the term is not generally used in this context).

Switchgear – Application as SCPD

i) Fused Switchgear and Fuses as SCPD

Since the short-circuit breaking function in fused switchgear is provided by the fuses it is the fuse characteristics that are considered. These are given in IEC60269-1 as follows:

Breaking capacity of a fuselink

- value (for a.c. the r.m.s. value of the a.c. component) of prospective current that a fuselink is capable of breaking at a stated voltage under prescribed conditions.

Cut-off current

Summarised as: maximum instantaneous value reached by the current during the breaking operation of a fuselink when it operates to prevent the current reaching the prospective peak.



TECHNICAL BULLETIN

Operating I^2t (Joule integral)

Summarised as: Integral of the square of the current over the operating time of the fuse.

Sometimes referred to as 'energy let-through'. When expressed in A^2t gives the energy dissipated per ohm and thus represents the thermal effect on the circuit.

ii) **Circuit-breakers as SCPD**

Moulded-case circuit-breakers (MCCBs) and air circuit-breakers (ACBs) are rated according to IEC60947-2 as follows:

- **Rated short-circuit making capacity (I_{cm})**

Summarised as: The maximum peak prospective current that the circuit-breaker can make on to satisfactorily.

Rated short-circuit breaking capacities:

- **Rated ultimate short-circuit breaking capacity (I_{cu})**

Summarised as: The r.m.s prospective current that the circuit breaker is capable of breaking at a specified voltage under defined test conditions, which include one break and one make/break operations.

- **Rated service short-circuit breaking capacity (I_{cs})**

Summarised as: The r.m.s prospective current that the circuit breaker is capable of breaking at a specified voltage under defined test conditions, which include one break and two make/break operations. The standard specifies fixed relationships to I_{cu} of 25, 50, 75 or 100%.

- **Rated short-time withstand current (I_{cw})**

Summarised as: The r.m.s value of short-time current assigned by the manufacturer based on specified test conditions. Minimum values are given in the standard.

A circuit-breaker can only be assigned a rated short-time withstand current I_{cw} if it is equipped with a time-delay overcurrent release.

All circuit-breakers to IEC60947-2 will have values of I_{cu} and I_{cs}

Characteristics of circuit-breakers not mandated in IEC60947-2 but having application to short-circuit protection:

Cut-off current

The maximum instantaneous value reached by the current during the breaking operation of a circuit-breaker when it operates to prevent the current reaching the prospective peak.

Operating I^2t (Joule integral)

Integral of the square of the current over the operating time of the circuit-breaker on a short-circuit.

Sometimes referred to as 'energy let-through'. When expressed in A^2t gives the energy dissipated per ohm and thus represents the thermal effect on the circuit.

Examples of the Practical Application of the Product Characteristics

In simple studies only the r.m.s value of steady-state short-circuit current (I_k) is quoted. The peak current is assumed to be in a standard relationship to the r.m.s current, determined by the overall power factor, and taken into account in the rating of SCPDs to the respective IEC standards.

Circuit Protection

The application of short-circuit protective devices (SCPD) to circuit protection i.e. the protection of cables, is detailed in the installation rules, IEC364. In general it is accepted that selection of the protective device on the basis of thermal protection of a cable automatically provides short-circuit protection up to the breaking capacity of the SCPD, in the case of non-time-delayed devices.



Short-Circuit Protection for LV assemblies

Switchboard/Motor-Control Centre

The prospective short-circuit current at the input to the switchboard is obtained from a system protection study. This will be given as an r.m.s value.

- a. If the switchboard has an I_{cw} current value higher than the prospective current level then the only requirement is to limit the time for which a short-circuit could persist to within the short-time value. This is achieved by the setting of releases upstream or at the incomer to the switchboard.
- b. If the switchboard has an I_{cc} rating higher than the prospective current level then the only requirement is to include the specified SCPD in the circuit. This may be added in the circuit upstream or may already be included as an incomer to the switchboard.

Busbar Trunking (BBT)

The prospective short-circuit current at the input to the switchboard is obtained from a system protection study. This will be given as an r.m.s value.

- a. If the BBT has an I_{cw} current value higher than the prospective short circuit current level then the only requirement is to limit the time for which a short-circuit could persist to within the short-time value. This is achieved by the time-delay setting of overcurrent releases upstream.
- b. If the BBT has an I_{cw} lower than the prospective short circuit current level I_k but has an I_{cc} rating higher than I_k then the only requirement is to include the specified SCPD in the circuit upstream or in the end-feed unit. The suitability of any given SCPD may be derived from the cut-off current and Joule-integral characteristics by comparison with proof-test parameters.

Motor Control Gear (MCG)

Motor starters and contactors are not generally self-protecting against the effects of short-circuit and therefore need to be associated with an SCPD. In this particular case test procedures to IEC60947-4-1 recognise the difficulty of protecting sensitive devices from damage under heavy short-circuit conditions. Thus a special case of conditional rating is obtained which allows two classes of co-ordination with an SCPD:

- Type 1 – in which a certain amount of damage to the MCG is accepted.
- Type 2 – in which the MCG is capable of further use.

These ratings can only be obtained by type-testing and thus the data must be obtained from the manufacturer of the SCPD or the MCG.

Miniature Circuit Breakers (MCBs)

When applied in other than domestic (household) situations the short-circuit capability of MCBs to IEC60898 is often inadequate and they need to be 'backed-up' by another SCPD. Details of how the appropriate SCPD is determined are given, for circuit-breakers, in Appendix A of IEC60947-2. Basically this shows that only testing of the required combination is satisfactory and thus the data must be obtained from the manufacturer of the SCPD or the MCB. The same applies to fuses used as SCPD.

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