Contents

1. Introduction

This topic gives general information about prospective fault current and the related requirements of *BS 7671*. Information on determination of prospective fault current by calculation, by measurement and by enquiry is given in Topic ***F13-17***, the NICEIC book entitled *Inspection, Testing and Certification* and Topic ***F13-21***, respectively.

Prospective fault current is the value of overcurrent that would flow at a given point in a circuit if a fault (that is, a short-circuit or an earth fault) were to occur at that point. Conventionally, the impedance of the fault is taken to be negligible, although there is always some finite value of fault impedance in practice. The prospective fault current therefore tends to be higher than the fault current likely to occur in practice.

The design of an electrical installation must take account of prospective fault current in order to avoid danger or damage arising under fault conditions, due to causes such as:

- Live conductors or protective conductors experiencing a temperature rise due to fault current, sufficient to damage insulation, joints, terminations or the surroundings of the conductors (e.g. building surfaces with which the conductors may be in contact).
- Busbars or other conductors not being arranged to safely withstand the strong electromechanical forces which can occur between them when they carry fault current.
- Fault current protective devices, such as fuses and circuit-breakers, not having sufficient capacity to break the fault current safely (an adequate making capacity is also necessary for a circuit-breaker).

2. Types of fault conditions

When a fault occurs in a circuit, the magnitude of the current which flows depends upon the type of fault (that is, which conductors are involved), the internal electromotive force (emf) of the source (equivalent to the source open circuit voltage), and the impedance of both the supply network and the installation up to the point of fault. The internal emf of the source is normally considered to remain constant under fault conditions.

Fig 1 shows a TN-S system and gives examples of the various types of short-circuit and earth fault conditions. A short-circuit is any fault between live conductors (i.e. phase-to-phase or phase-to-neutral), and an earth fault is a fault between a phase conductor and either an exposed-conductive-part or the protective conductor of the circuit. Equivalent circuits for short-circuit conditions are the same irrespective of the type of electrical system, whereas equivalent circuits for an earth fault do differ. This is because of differences in the constitution of the part of the fault current path between the main earthing terminal of the installation and the earthed point of the source. (An explanation of the various types of electrical system is given in Topic ***E93-1***.)

TN-S system, giving examples of the various fault conditions

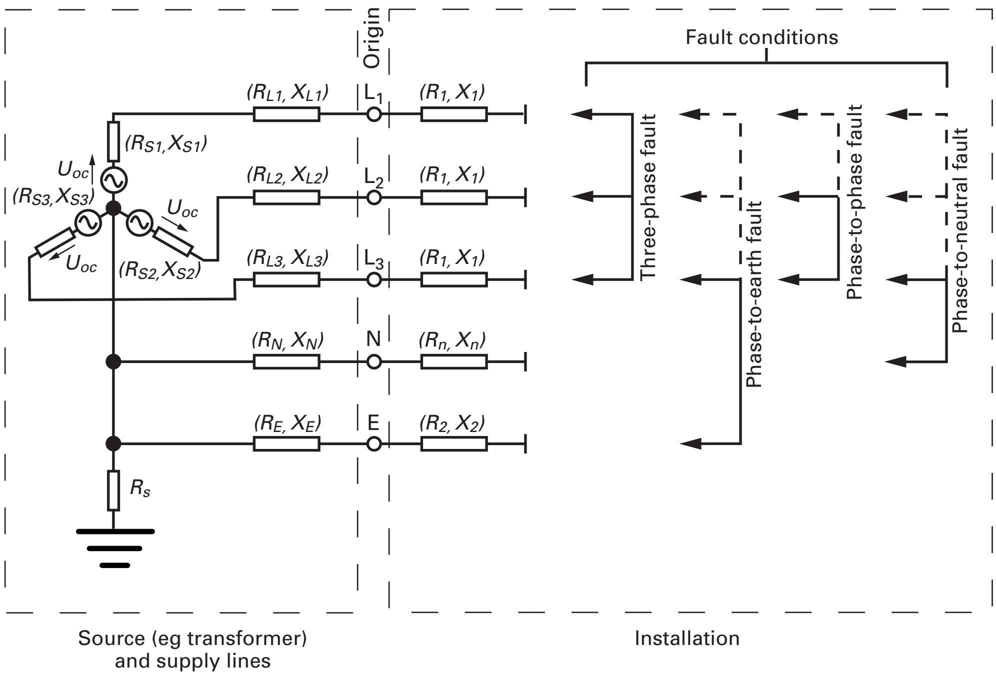

Fig 1

The symbols in Fig 1 have the following meanings:

U_{oc} : The open-circuit voltage (or internal emf) at the distribution transformer or other source of supply (generally presumed to be 240 V for a nominal voltage (U_0) of 230 V.

R_{S1} and X_{S1},
R_{S2} and X_{S2},
R_{S3} and X_{S3} : The resistive and reactive components, respectively, of the impedance of the supply source (1 = red phase, 2 = yellow phase, 3 = blue phase).

R_S : The resistance of the source earth electrode.

R_{L1} and X_{L1},
R_{L2} and X_{L2},
R_{L3} and X_{L3} : The resistive and reactive components, respectively, of the impedance of the low voltage supply phase conductors up to the origin of the installation (1 = red phase, 2 = yellow phase, 3 = blue phase).

R_N and X_N : The resistive and reactive components, respectively, of the low voltage supply neutral conductor up to the origin of the installation.

R_E and X_E : The resistive and reactive components, respectively, of the supply earthing conductor from the source of supply to the main earthing terminal of the installation.

R_1 and X_1 : The resistive and reactive components, respectively, of the installation phase conductor(s).

R_n and X_n : The resistive and reactive components, respectively, of the installation neutral conductor(s).

R_2 and X_2 : The resistive and reactive components, respectively, of the installation circuit protective conductor(s).

The resistive (R) and reactive (X) components of impedance, referred to above, cannot be added together arithmetically as they are in quadrature (i.e. displaced by 90 °). The addition must be made vectorially. This is explained in Topic ***F13-17***.

3. Prospective fault current must be determined

Regulation 313-01-01 of *BS 7671* requires the prospective short-circuit current at the origin of an installation to be determined (amongst other characteristics of the supply or supplies). The determination may be carried out by calculation, measurement or enquiry.

In addition, Regulation 434-02-01 requires the prospective short-circuit and prospective earth fault currents to be determined at every relevant point of the complete installation. Again, calculation, measurement or enquiry may be used as the means of determination.

3.1 Purposes for which prospective fault current magnitudes are used

Prospective fault current magnitudes are needed in connection with satisfying a number of requirements of *BS 7671*, including the following:

- **Breaking capacity rating of protective devices.** It must be ensured that the breaking capacity rating of each disconnecting device (such as a fuse or circuit-breaker) for protection against fault current is not less than the prospective short-circuit current or prospective earth fault current at the point at which the device is installed, as required by Regulation 434-03-01. The regulation permits a lower breaking capacity only where appropriate back-up protection is provided by another device or devices, on the supply side. Information on back-up protection will be found in Topic ***F13-25***.

- **Protection against excessive rise in conductor temperature.** Where a protective device is provided for fault current protection only*, the device must be so selected that, under both short-circuit and earth fault conditions, it will operate sufficiently quickly to prevent the temperature of the circuit conductors being raised above the highest permissible value by the fault current (Regulation 434-03-03 refers).
- **Co-ordination of overload current and fault current protection.** Where overload current protection and fault current protection are provided by separate devices (such as often applies in a circuit supplying an electric motor), the characteristics of the devices have to be co-ordinated so that the energy let through by the fault current protective device does not exceed that which can be withstood without damage by the overload protective device under fault conditions (Regulation 435-01-01 refers).
- **Fault current protection of conductors in parallel.** Careful analysis of the prospective fault currents in each conductor will be required in order to provide protection to conductors connected in parallel (Regulation 473-02-05 refers).
- **Capacity of equipment to withstand fault current.** Regulation 512-02-01 requires every item of equipment to be suitably selected and erected for not only the design current but also the current likely to flow under abnormal conditions (including fault conditions) for such periods of time as determined by the characteristics of the protective devices concerned. For example:
  - — The making capacity rating of switchgear and circuit-breakers (as well as the breaking capacity of circuit-breakers and fuses) must be adequate for the prospective fault current.
  - — Busbars, such as in switchboards and busbar trunking, must be suitably ‘fault rated’ to safely withstand the strong electromechanical forces likely to occur between them under fault conditions. This means, for example, that the bars must be adequately supported at appropriate intervals. Similar considerations of support can apply where a group of single-core cables is used in a situation of high prospective fault current, such as for the low voltage ‘tails’ of a distribution transformer.

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* Such as sometimes applies to the protective device at the origin of a circuit in which overload protection is provided along the run of the circuit conductors as permitted by Regulation 473-01-02. For example, this may be the case in a circuit supplying an electric motor (with a starter incorporating overload protection, positioned near the motor), or in a circuit in which, for operational reasons, it is desired to have a circuit-breaker or switch-and-fuse unit at the load end of the circuit.

- **Cross-sectional area of protective conductors.** Where the cross-sectional area of a protective conductor is calculated (Regulation 543-01-03 refers) rather than selected (Regulation 543-01-04 and Table 54G), the prospective earth fault current magnitude corresponding to the assumed point of fault is needed for use in connection with the adiabatic equation.

3.2 Highest and lowest prospective fault current magnitudes

The magnitude of the prospective fault current in a circuit reduces with increasing distance from the source of supply (due to the attenuating effect of the impedance of the circuit conductors). The relevance of this fact will be appreciated when considering the various purposes for which prospective fault current magnitudes are used (item 3.1 refers). For some of the purposes, the highest magnitude of prospective fault current is the most important, whilst for others, the lowest magnitude is the most important.

For example, consider the breaking capacity rating required for a fault current protective device. Regulation 434-03-01 requires this to be not less than the prospective short-circuit or prospective earth fault current at the point where the device is installed. In other words, the breaking capacity rating must be not less than the **highest** magnitude of prospective fault current affecting the device.

The converse is normally true when calculating the cross-sectional area required for a protective conductor in accordance with Regulation 543-01-03. The magnitude of prospective earth fault current used in connection with the adiabatic equation is normally that at the electrically furthest part of the circuit from the source (i.e. the **lowest** value of earth fault current). This is because, for the types of protective device considered in *BS 7671*, the energy let-through (I^2t) is generally, though not always, greater the lower the fault current.

3.3 The meaning of 'every relevant point', in Regulation 434-02-01

Some explanation should be given of what is meant by the words 'every relevant point' in Regulation 434-02-01 (i.e the regulation requires the prospective fault current, at **every relevant point** of the complete installation, to be determined).

> Quite simply, 'every relevant point' means:
>
> every point where, for reasons of confirming compliance with one or more of the requirements of *BS 7671*, it is necessary to determine the prospective fault current.

For example, for the installation depicted in Fig 2, suppose it is being checked whether the breaking capacity rating of each fault current protective device is at least equal to the prospective short-circuit or prospective earth fault current at the point where the device is installed. (Regulation 434-03-01 requires each device to have such a breaking capacity rating, except where appropriate back-up protection is provided by another device or devices, on the supply side).

From Fig 2, it can be seen that the maximum prospective fault current at the origin has been determined as 5.9 kA (the short-circuit current), and that this is lower than the breaking capacity rating of every fault current protective device except device No 6, which has a breaking capacity rating of 3 kA. It follows, therefore, that for the purpose of this example, the relevant points of the installation at which the prospective fault current must be determined are:

(i) **The origin**. From the knowledge that the prospective fault current at the origin is less that the breaking capacity ratings of all the fault current protective devices except device No 6, it can be deduced that the breaking capacity ratings of each of those protective devices is higher than the prospective fault current at the point where it is installed. This is because nowhere in the installation will the prospective fault current be higher than at the origin.

(ii) **The point at which fault current protective device No 6 is installed**. Without knowledge of the prospective fault current at the point where device No 6 is installed, it cannot be determined whether the breaking capacity rating of device No 6 is at least equal to that prospective fault current.

Example of an installation with fault current protective devices at a number of points

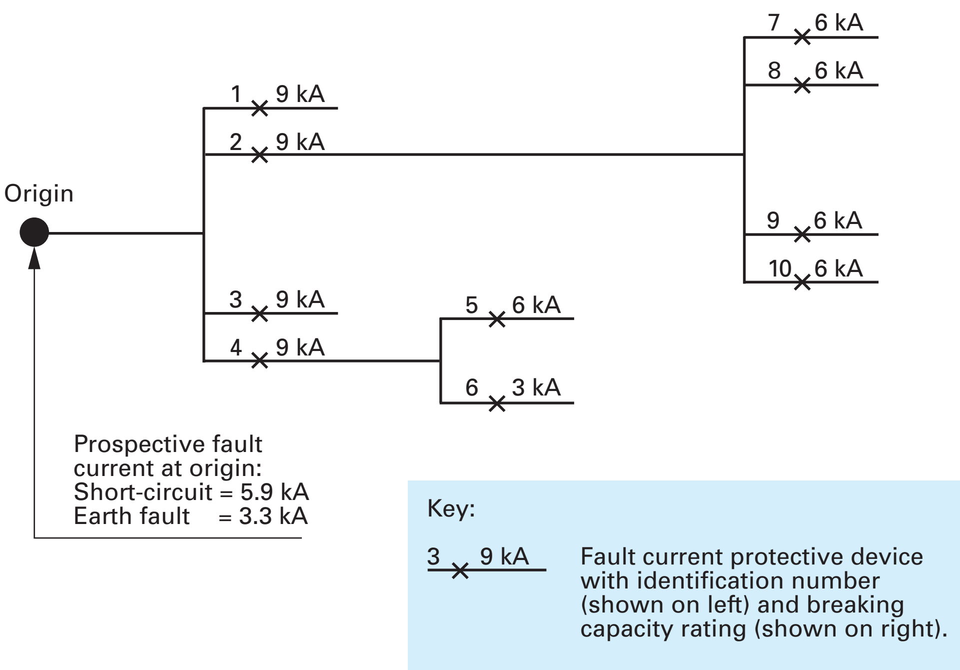

Fig 2

Note – The installation in Fig 2 is supplied from only one source and does not supply any electrical machines which might contribute to the fault current under fault conditions, such as synchronous machines.

3.4 Methods of determination

As already stated, prospective fault current may be determined by calculation, measurement or enquiry. None of these methods should be regarded as highly accurate, and a reasonable margin of error should be assumed and allowances made accordingly.

Errors are largely due to assumptions made when determining prospective fault current. For example, as mentioned in item 2, the internal emf of the source is normally considered to remain constant under fault conditions. This assumption may not be strictly true where the source is a generating set which is not operating in parallel with the public supply. The system impedances, too, are normally assumed to be constant, but are in fact subject to variation, for example with temperature change (including the temperature rise caused by fault current). In addition, account is rarely taken of the negative and zero phase sequence components – the so-called symmetrical components – of impedance which apply under unbalanced fault conditions.

Calculation, measurement and enquiry are briefly discussed in items 3.4.1, 3.4.2 and 3.4.3, respectively.

3.4.1 Calculation

For calculation of prospective fault current, information is needed on the relevant impedances of not only the installation but also the supply network and the source. Where the supply is obtained from an electricity distributor, as it is for most installations, the requisite information on the supply impedances usually has to be obtained by measurement or deduced from the results of an enquiry to the electricity distributor.

3.4.2 Measurement

Measurement of prospective fault current involves working in the proximity of live conductors, and it is therefore essential that a safe system of work is employed.

The measurement must be carried out using an appropriate, proprietary fault loop test instrument, with or without a prospective fault current range. Where the instrument does not have a prospective fault current range, the value of the supply voltage also has to be determined (normally by measurement), and used in conjunction with the measured value of fault loop impedance to give the prospective fault current.

For most installations a hand-held instrument will be sufficient. However, a more sophisticated instrument is likely to be needed in order to obtain meaningful test results at points where higher prospective fault currents are to be expected, such as at points electrically close to a distribution transformer. In some situations it may be impossible to obtain a meaningful test result at all because the impedance of the system up to the point of test is too low, and too inductive, for the instrument to function correctly.

3.4.3 Enquiry

Enquires relating to prospective fault current are normally made to an electricity distributor but in the case of a large hospital or industrial complex having its own substation(s), for example, enquiry to the maintenance manager's office may be necessary.

For a low voltage supply given in accordance with the *Electricity Supply Regulations 1988 (as amended)*, the distributor has a responsibility to provide to a person who can show reasonable cause for requiring it, a written statement of the maximum prospective short-circuit current at the supply terminals (I_{sc}) and the maximum value of earth fault loop impedance of the part of the system external to the installation (Z_e).

Further information on calculation, measurement or enquiry is given in, respectively, Topic ***F13-17***, the NICEIC book *Inspection, Testing and Certification* and Topic ***F13-21*** .

Topics referred to in this text:

E93-1	ELECTRICAL SYSTEMS: General
F13-17	FAULT CURRENT: Prospective, determination of by calculation
F13-21	FAULT CURRENT: Prospective, determination of by enquiry
F13-25	FAULT CURRENT: Protection against

Topics not referred to in this text, which are related and may be of interest:

E13-1	EARTH FAULT LOOP IMPEDANCE: Determination of external (at the origin)

BS 7671 **(Requirements for electrical installations)**

Some of the most important requirements are found in:

Assessment of general characteristics, nature of supply	313-01
Protection against overcurrent	Chapter 43
Protection against overcurrent	Section 473
Operational conditions and external influences	Section 512
Protective conductors, cross-sectional areas	543-01