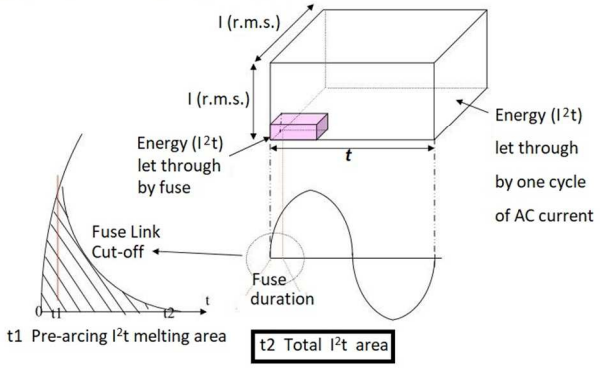
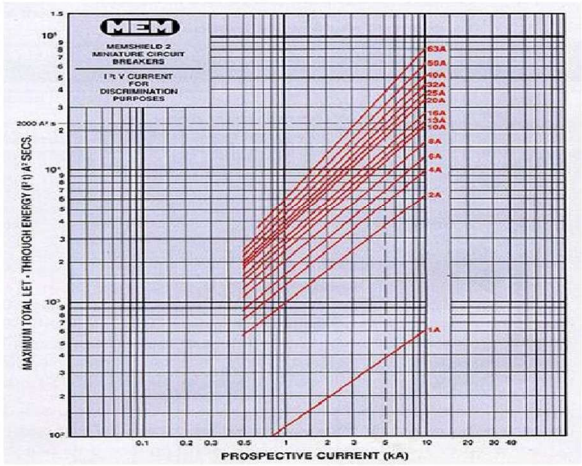
Applying Circuit Design 2

Operating Characteristics of Protective Devices

Energy Let Through (Heat) 434.5.2



Energy let-through for MEM 10kA MCBs



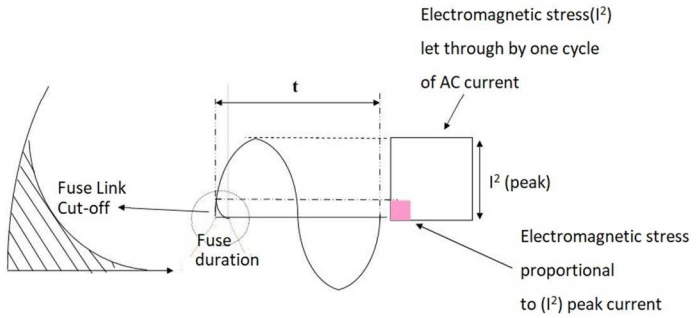
MCB Breaking Capacities

MCB to BS3871 Obsolete from 2001 (blue)		Circuit Breakers BS EN 60898 / BS EN 61009	
Category of Duty	*Prospective current (A)*	ICN (once only)	ICS (repeatable)
		kA	kA
M1	*1000*	1.5	1.5
M1.5	*1500*	3.0	3.0
M3	*3000*	6.0	6.0
M4.5	*4500*	10	7.5
M6	*6000*	15	7.5
M9	*9000*	20	10.0
		25	12.5

Applying Circuit Design 2

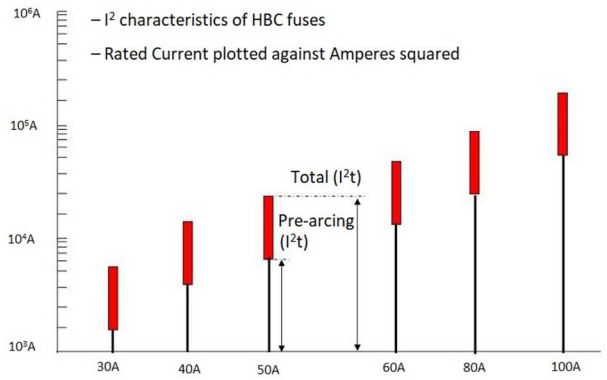
Operating Characteristics of Protective Devices

Electromagnetic Energy

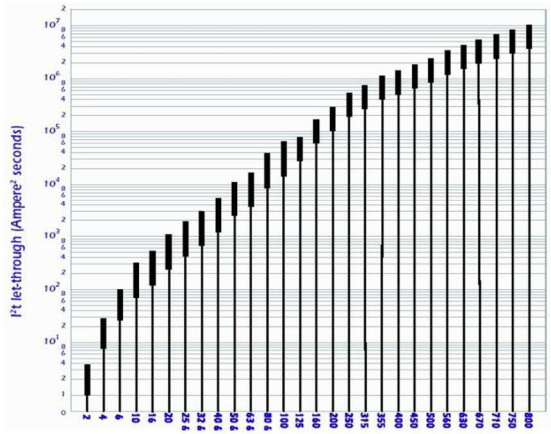


Discrimination of OPD

435.2 Discrimination of Protective Devices



Ferraz Shawmut BS88 cartridge fuses



I²t Characteristics

Discrimination achieved when downstream fuse when downstream fuse is ½ the size of the size of the upstream OPD

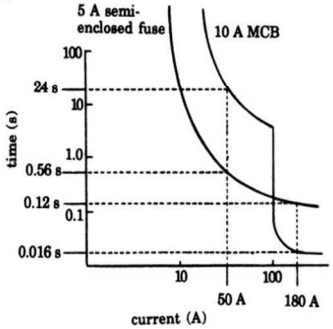
Ampere Fuse rating

Coordination of OPD

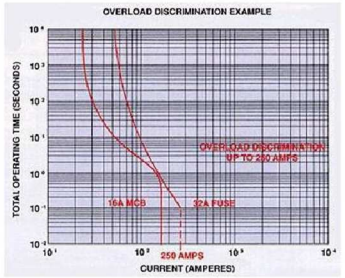
The example, shows the superimposed characteristics of a **5 A semi-enclosed fuse** and a **10 A miniature circuit breaker** which we shall assume are connected in series.

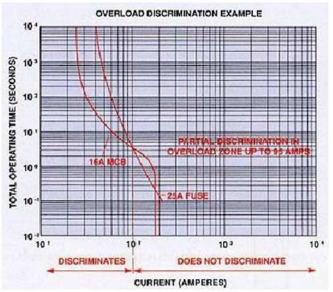
*If a fault current of 50 A flows, **the fuse will operate in 0.56 s** whilst the **circuit breaker would take 24 s** to open. Clearly the **fuse will operate first** and the devices have discriminated.*

However, if the **fault current is 180 A**, the **circuit breaker will open in 0.016 s**, well before the fuse would operate, which would take 0.12 s. In this case, **there has been no discrimination.**



Coordination of OPD



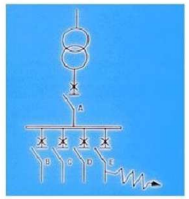


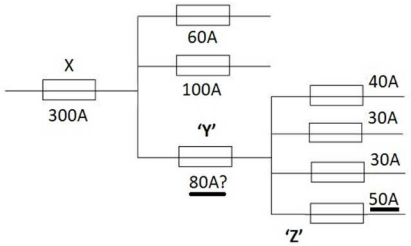
Graph A shows discrimination from instantaneous disconnection of the **16A MCB** from the **32A fuse** at 180A

Graph B shows poor discrimination between **16A MCB** and **25A fuse** starting at 100A+ in an overload condition but none for short circuit

Protection against Fault Currents

Discrimination of Protective Devices - 434.1 to 434.5.3





Discrimination of devices must take place to reduce danger and inconvenience 314.1; and

If **fuse 'Z'** blows then **fuse 'Y'** should be of such size that it can **withstand the energy let through without disconnecting**

Protection against overcurrents

Positioning of Device – 433.2 and 434

Where a conductors diameter reduces along the line of a cable run a method of protection is required for that part of the cable which has a reduced cross sectional area 434.1.1

– Examples of reduced cable conductors are:

- Fused spur on a ring final circuit
- Installation method changed (overhead to underground)
- Type of cable has changed (PVC in conduit to MIMS)
- Ambient change in temperature (Boiler house to outside)

– Rules for termination between reduction in current carrying capacity and Protective Device 434.2.1

1. Not Exceed 3m in length
2. Be erected to minimise risk of fault current
3. Be erected to minimise fire and danger to persons

Protection against Overcurrent

Omission of protective devices for safety reasons 433.3.3

Used where unexpected disconnection would cause a dangerous situation

1. The **exciter circuit** of a **rotating machine**
2. The **supply circuit** of a **lifting magnet**
3. The **secondary circuit** of a **current transformer**
4. A **circuit** supplying a **fire extinguishing device**
5. A **circuit** supplying a **safety circuit (fire or gas alarm)**
6. A **circuit** supplying **medical equipment in IT systems**

Voltage and Electromagnetic disturbances

441 Overvoltages due to HV and LV faults

HV faults to earth at the substation 442.2

Loss of supply neutral on LV systems 442.3

Line to Neutral Short Circuit in LV systems 442.5

Accidental earthing of a line conductor to earth in IT systems 442.4

Stress Voltages created by HV currents circulating around exposed conductive parts producing an electromagnetic effect thus producing a secondary fault voltage (stress voltage U1 and U2)

442.1 rules for designers and installers of substations

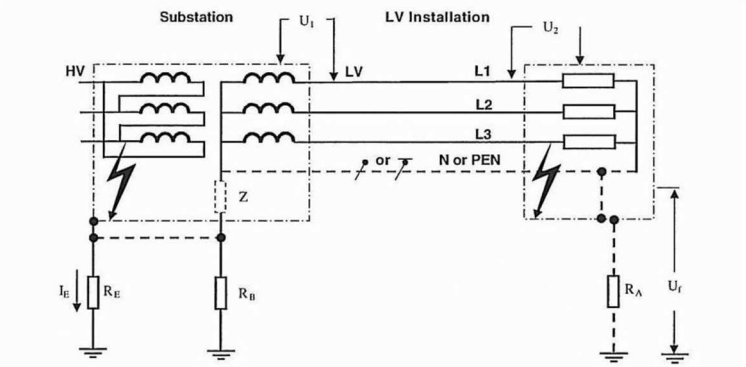
Quality of system earth

Maximum level of earth fault current

Resistance of earthing arrangements

Voltage and Electromagnetic disturbances

Fig 44.1 - Representative diagram for connections to Earth in the substation and the LV installation and the overvoltages occuring in case of faults.



HV fault conditions affecting LV systems

In Section 442 the following symbols are used (see Figure 44.1):

- I_E part of the earth fault current in the high voltage system that flows through the earthing arrangement of the transformer substation
- R_E resistance of the earthing arrangement of the transformer substation
- R_A resistance of the earthing arrangement of the exposed-conductive-parts of the equipment of the low voltage installation
- R_B resistance of the earthing arrangement of the low voltage system neutral, for low voltage systems in which the earthing arrangements of the transformer substation and of the low voltage system neutral are electrically independent
- U_o nominal phase voltage (to earth for TN systems)
- U_f power frequency fault voltage that appears in the low voltage system between exposed-conductive-parts and earth for the duration of the fault
- U_1 power frequency stress voltage between the line conductor and the exposed-conductive-parts of the low voltage equipment of the transformer substation during the fault
- U_2 power frequency stress voltage between the line conductor and the exposed-conductive-parts of the low voltage equipment of the low voltage installation during the fault.

NOTE 1: The power frequency stress voltage (U_1 and U_2) is the voltage that appears across the insulation of low voltage equipment and across surge protective devices connected to the low voltage system.

HV fault conditions affecting LV systems

442.2.1 The size of calculated Fault voltages from table 44.1 must not exceed a dangerous level across exposed conductive parts and earth.

442.2 HV fault voltages U1 and U2 as specified in table 44.1 appearing across LV installations should not exceed the values given in table 44.2

Table 44.2 – Permissible power frequency stress voltage

Duration of the earth fault in the high voltage system t	Permissible power frequency stress voltage on equipment in low voltage installations U
>5 s	U_o + 250 V
≤5 s	U_o + 1200 V

Voltage and Electromagnetic disturbances

443 Overvoltage requirements

TABLE 44.3 – Required minimum impulse withstand voltage

Nominal voltage of the installation V	Required minimum impulse withstand voltage kV[1]			
	Category IV (equipment with very high impulse voltage)	Category III (equipment with high impulse voltage)	Category II (equipment with normal impulse voltage)	Category I (equipment with reduced impulse voltage)
230/240 277/480	6	4	2.5	1.5
400/690	8	6	4	2.5
1000	12	8	6	4

[1] This impulse withstand voltage is applied between live conductors and PE.

TABLE 44.4 – Examples of various impulse category equipment

Category	Example
I	Equipment intended to be connected to the fixed electrical installation where protection against transient overvoltage is external to the equipment, either in the fixed installation or between the fixed installation and the equipment. Examples of equipment are household appliances, portable tools and similar loads intended to be connected to circuits in which measures have been taken to limit transient overvoltages.
II	Equipment intended to be connected to the fixed electrical installation e.g. household appliances, portable tools and similar loads, the protective means being either within or external to the equipment.
III	Equipment which is part of the fixed electrical installation and other equipment where a high degree of availability is expected, e.g. distribution boards, circuit-breakers, wiring systems, and equipment for industrial uses, stationary motors with permanent connection to the fixed installation.
IV	Equipment to be used at or in the proximity of the origin of the electrical installation upstream of the main distribution board, e.g. electricity meter, primary overcurrent device, ripple control unit.

Electromagnetic Disturbances

444.1 electromagnetic disturbances caused by fast changes in current in power cables can affect auxilliary circuits

See Appendix 1: BS 6701, 50310,50174, 610000-5-2

444.4.1 typical sources of interference are:

Inductive loads electric motors fluorescent lights

welding machines rectifiers choppers

VSD lifts transformers switchgear

large power distribution busbars

Electromagnetic Disturbances

444.4.2.1 measures for protection

(i) Bypass conductors for screen control cables

(ii) Surge protective device (SPD)

(iii) reduce cable loop areas

(keep power cables and earthing conductors together)

(iv) Keep power and signal cables separate

(v) Equipotential bonding networks

HV fault conditions affecting LV systems

Table 44.1 – Power frequency stress voltages and power frequency fault voltage in the low voltage system

Types of system earthing	Types of earth connections	U_1	U_2	U_f
TT	R_E and R_B connected	U_o	$R_E.I_E + U_o$	0
	R_E and R_B separated	$R_E.I_E + U_o$	U_o	0
TN	R_E and R_B connected	U_o	U_o	$R_E.I_E$
	R_E and R_B separated	$R_E.I_E + U_o$	U_o	0
IT	R_E and Z connected R_E and R_A separated	U_o	$R_E.I_E + U_o$	0
		$U_o.\sqrt{3}$	$R_E.I_E + U_o.\sqrt{3}$	$R_A.I_h$
	R_E and Z connected R_E and R_A interconnected	U_o	U_o	$R_E.I_E$
		$U_o.\sqrt{3}$	$U_o.\sqrt{3}$	$R_E.I_E$
	R_E and Z separated R_E and R_A separated	$R_E.I_E + U_o$	U_o	0
		$R_E.I_E + U_o.\sqrt{3}$	$U_o.\sqrt{3}$	$R_A.I_d$

Problem Voltages

445 Undervoltages

445.1.1 Suitable precautions shall be taken to provide protection when the voltage dips or is reduced see 552.1.3

445.1.5 No automatic restarting of rotating machinery

(Note: see external classifications appendix 5)