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EDH Guide A: Electrical Installations for SSEN Client Systems

Guide on Standardisation of Components for SSEN Client Systems in ITER

Approval Process			
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Change Log			
EDH Guide A: Electrical Installations for SSEN Client Systems (2EB9VT)			
Version	***Latest Status***	***Issue Date***	***Description of Change***
v1.0	In Work	16 May 2008	New IDM Document Template and document split from main EDH into standardisation supplement
v1.1	In Work	07 Jan 2010	New IDM Document Template and document split from main EDH into standardisation supplement
v1.2	In Work	07 Jan 2010	Alignment of version numbers with working version in Sharepoint
v2.0	Approved	14 Mar 2011	General revision
v2.1	Approved	28 Feb 2012	The following sections have been updated in this version: - section 2.2: labelling rule for SIC components is revised. -section 4.1: Minor Changes -section 4.2: link to MV Interface document added -section 4.7: updated to reflect the changes in SRD 43
v2.2	In Work	11 Jul 2012	The following sections have been updated in this version: section 4.7.3-updated to include surge arrestors in the requirement of motors section 4.7.4 - updated performance requirement of motors section 4.7.12- updated to include " Test after connection between motor and load"

v2.3	Approved	16 Jul 2012	The following sections have been updated in this version:
			section 4.7.3-updated to include surge arrestors in the requirement of motors
			section 4.7.4 - updated performance requirement of motors
			section 4.7.12- updated to include " Test after connection between motor and load"
			
			if(typeof editorarray == 'object')
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v2.4	Approved	22 Jan 2013	Updated Section 2.3 to be inline with "ITER Site Signage & Graphics Standards (4ALJEU)".
v2.5	Approved	30 Apr 2014	Updated the EDH to be inline with the SRD 43. Added colour coding of wires and protection of nuetral inside distribution boards in accordance with the French regulations and IEC standards.
v2.6	Signed	31 Mar 2017	Earthing connection description for motors and boards included. PIC nomenclature updated and included for safety components. MV motor operation description complemented. Documentation links updated.
v2.7	Approved	31 Mar 2017	Track changes removed.

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1 Introduction

1.1 General

Electrical components and systems used in ITER must meet the required standards specified in the EDH. The general definition of a component and a system is as follows:

- A component is standalone and is connected directly to the electrical network; it is self-protecting and has no other interface. A typical component is an electrical heating element or a light bulb. Each must be correctly rated for connection to ITER power supplies. The protection of an electrical component is typically a fuse, which is rated to interrupt the supply in the event of fault.

- A system is likely to be an integrated collection of components and will normally have multiple interfaces, e.g. with other components and systems such as CODAC. A typical example is a vacuum pumping system. The overall system must be correctly rated for connection to its power supply but it can signal various systems to request response, e.g. to switch off in a controlled manner as well as directly tripping its supply in the event of serious fault.

This part of the EDH details the requirements for, and recommendations on, all electrical components and plant systems to be used or installed at ITER and to be connected to the SSEN. It applies to the standard industrial ac power distribution components and devices of the SSEN.

In general, SSEN loads are not ITER pulse related but of a continuous nature, e.g. cryogenics plant, vacuum plant, heating, cooling, ventilation and building electrical systems, etc.

This guide provides practical design guidance to Class IV power consumer. Most design guideline described in the EDH Guide A will be applicable to EPS loads as well, unless specifically described otherwise in the EDH Guide C: Electrical Installations for EPS Systems.

Cabling requirements, including cable design requirement; raceway design requirement; interface requirement for cabling and wiring, will be defined by IO cabling rules will govern ITER plant cabling engineering.

1.2 Abbreviations

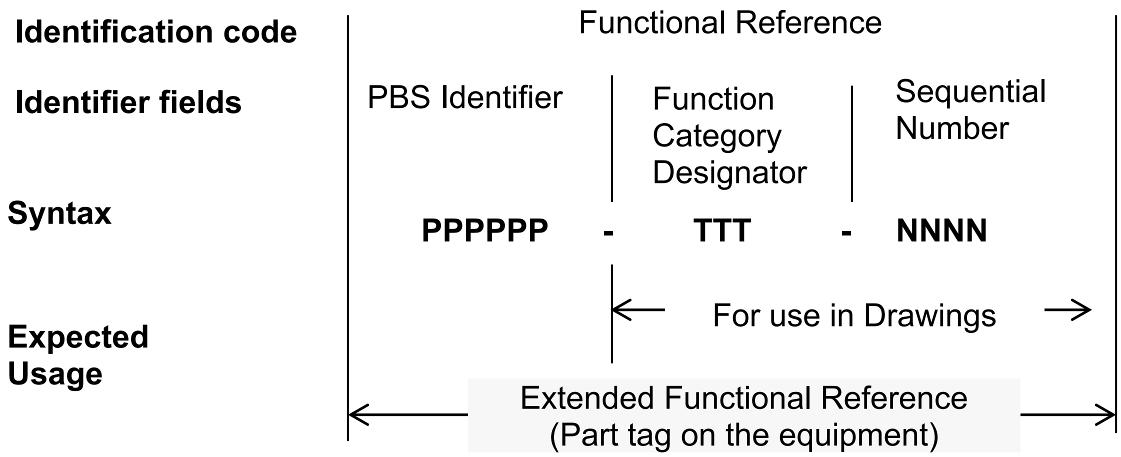
Abbreviation	Full Description
AC	Alternate Current
CB	Circuit Breaker
CIS	Central Interlock System
CODAC	Control, Data Access and communication
DC	Direct Current
EDH	Electrical Design Handbook
EMI	Electro-magnetic Interference
EMC	Electro-magnetic Compatibility
EPS	Emergency Power Supply
HCC	Hard Core Component
HVAC	Heating Ventilating and Air Conditioning
ICD	Interface Control Document
IEC	International Electrotechnical Commission
IP	Investment Protection
IO	ITER Organisation
ITER	International Thermonuclear Experimental Reactor
LC	Load-Center
LOSP	Loss of Off-site Power
LV	Low Voltage
MV	Medium Voltage
PBS	Physical Breakdown Structure
PIS	Plant Interlock System
PSH	Plant System Host
PIC	Protection Important Component
SSEN	Steady State Electrical Network
SRD	System Requirement Document
THD	Total Harmonic Distortion
TDD	Total Demand Distortion
VFD	Variable Frequency Drive

2 Identification and Labelling

2.1 ITER Numbering System

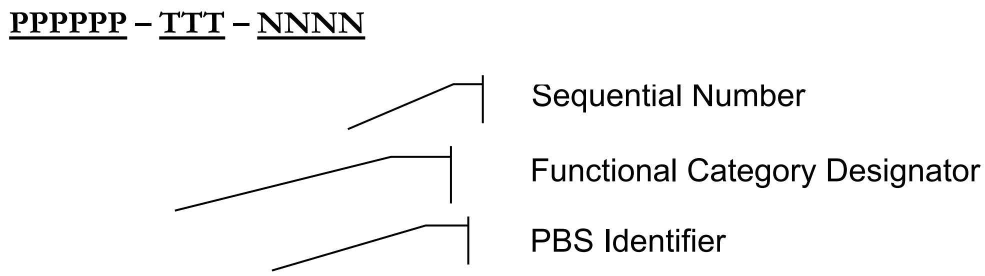
2.1.1 Syntax of Generic Component/Parts Identification

According to referenced the ITER Numbering System (ITER_D_28QDBS), complete syntax of generic component/part identification is as below.



The functional reference shall consist of three (3) identifiers separated by the separator: hyphen (-): PBS Identifier, Functional Category Designator and Sequential Number. The functional reference shall be used to provide a unique number.

2.1.2 Components/Parts Identification



- *PPPPPP*: PBS identifier field

This field indicates which part of the ITER plant (system, subsystem or loop) and the component belongs to. In general up to 3 levels of the PBS are used. However, depending on the complexity of the discipline or system, the System Responsible Officer (RO) can decide to use a lower number of PBS levels (1 or 2). In this case remaining digits out of six (6) shall be put with Zero (0).

Latest version of the ITER PBS (https://user.iter.org/?uid=2FBMWF) is stored in Configuration Management Databases.

- TTT: Function Category Designator field (2 or 3 alphabetic digits)

This is a short string identifying the function category (e.g., pump, valve, etc.). The number of the digits shall be subject to the following area. Two (2) digits are for mechanical (piping, HVAC, etc.) and electrical, and three (3) digits are for CODAC and Diagnostics and some electrical components.
Function Category Designator shall be stipulated in the ITER Function Category and Type (ITER_D_2FJMPY), and shall be maintained and updated as latest version by the IO Design Office (DO).
These tables are given in the Document ITER Function Category and Type and will be maintained updated by the IO Design Office.

- Hyphen (–): Separator

- NNNN: Sequential number field (4 digits)

This is a sequential number that can be generated by the RO/designer so as to be small and applicable to their system. The sequential number alone is not unique, many systems and different part types can have the same number. However, the combination of a PBS identifier, a function category designator and a sequential number uniquely defines the component.

2.2 Labelling

2.2.1 General

All electrical components of the ITER plant as well as components for monitoring, controlling, indicating, announcing, acting, switching, alarming, measuring and maintenance shall be provided with labels, showing the component identification including PBS(Plant Breakdown Structure), component description and other information as required per each component.
The labels shall - depending on the purpose for which they are to be used - either be made of non-transparent or translucent heat-resisting synthetic resin, stainless steel or yellow brass as appropriate.

Labels shall be mounted with double sided tape and shall not peel off for the component design life. In addition, labels on the component enclosure, local panels and cabinets shall be fastened with the rust-proof screws or otherwise agreed-upon methods.

Label shall be engraved through to core colour. Engraving shall be performed by rounded or square ended cutter. “V” type engraving is not acceptable
Lettering style shall be all capitals, gothic (san serif), condensed, and shall be consistently applied.

Label shall have a minimum of 1.5mm thickness, 25 mm width and a length required for the numbering respectively name and additionally at each side a length equal to the width, where screw holes for the stainless steel screws (minimum size M3) is located.
In case, the equipment is small relative to the label, a separate stainless steel support shall be provided and installed, holding the label in a position, which allows good reading.

Labels shall be written in English only. The letters and numbers shall have a minimum height of 8 mm and shall be engraved by professional means.
The proposed arrangement of the labels (material, colour, size and engravings) shall be submitted to the ITER Organization for approval.

2.2.2 Label Colour

Electrical equipment including electrical power supply equipment, e.g. SSEN and PPEN components, and electrical components designed, procured and maintained by other PBS' of electrical power service clients shall be marked or labelled in a distinct manner with its corresponding safety colours determined in Table 2-2-1.
The standard means of the safety colour coding for electrical equipment is coloured (foreground or background) equipment (identification) labels. Just in case coloured equipment labels are practically unachievable to apply, permanently attached colour stripe above or below label (or nameplate) might be applicable.

In order to ensure optimum visibility and to highlight equipment labels from visual environment, colour contrast must be achieved between identification itself and the label and between the label and visual environment back-grounding the label. Thus, where used in equipment labels on bright equipment surface, the distinct colour should be a background colour, and the foreground colour is white. On the contrary, where used in equipment labels on dark equipment surface, the distinct colour should be a foreground colour, and the background colour is white. Refer to Figure 2-3-1 and Figure 2-3-2 for easier understanding.

Table 2.2-1 Colour code for identification with safety classification

Safety classification	Train	Colour	RAL ID [1]	Remark
PIC	Train A	Orange	RAL2000	
PIC	Train B	Green	RAL6016	
Non-PIC	-	Black	RAL9005	

2.2.3 Electrical Boards and Cubicles

Nameplates (labels) of boards and cubicles shall designate the component identification and component description. Devices inside cubicles, panels, boxes, etc., such as instruments, meters, relays and fuses, shall be properly labelled with individual component identification number (or item number) with corresponding description. This number shall be the same as indicated in the pertaining documents (wiring diagrams, equipment lists, etc.).

Cubicles or similar units shall also bear their identification number on the rear side if rear access is allowed.

Instruction plates showing the sequence diagrams or cautions for maintenance shall be fitted on the inside of the front door of the electrical boards and cubicles.

2.2.4 Electrical Equipment

Nameplates (labels) of electrical equipment (e.g. rotating machines, transformer, etc.) nameplates shall be of non-corrosive material, covered with a transparent paint after printing, stamping or engraving.

[1] RAL IDs shown here are proposed as recommendation and subject to be changed with those more appropriate.

2.2.5 Raceway

Each cable tray and conduit is assigned with a unique identification developed according to the ITER Numbering System for Parts/Components (ITER_D_28QDBS). PBS level 2 of the identification identifies its separation group into PIC train A, PIC train B, HCC train A, HCC train B or Non-PIC.

Associating the raceway separation groups identified in PBS level 2 with its safety classification colours provides a distinguishing colour coding for PIC, non-PIC and HCC raceways as follows:

Table 2.2-2 Colour coding for Raceway

Safety classification	Train	Safety Class	Separation group colour
PIC	Train A	PIC-A	Orange
PIC	Train B	PIC-B	Green
HCC	Train A	HCC-A	Violet
HCC	Train B	HCCB	Blue
Non-PIC	-	NS	Black

The identification shall be permanently marked on the cable trays so that it is easily visible by using stencil markers, colour strip or square adjacent to raceway identification with appropriate interval in accordance with article D6240 of RCC-E (2005) and manufacturer's instructions.
Detail application guide for raceway identification will be described in IO cabling rules (https://user.iter.org/?uid=335VF9)

2.2.6 Cable

Each cable is assigned unique identification as described in section 2.1.2. Unlike cable tray identification, cable identification will not contain its safety classification necessarily in its PBS. The safety classification of each cable will be described in cabling diagram and managed by ITER cable management system to be launched in detail cabling design phase.
According to the safety classification, each cable shall be identified by permanent cable marker which contains distinguishing colours determined in table 3.2-1.
PIC cables shall be colour coded in a manner of sufficient durability and at sufficient number of point, e.g. at each ends and intermediate positions with adequate interval, to facilitate verification of its separation group.
Detail identification rule follows article D6240 of RCC-E (2005).
Associated cables to PIC circuits shall be identified and colour coded same as the PIC cables with which they are associated.
Detail application guide for cable identification will be described in IO cabling rules (https://user.iter.org/?uid=335VF9)

2.3 Colours for equipment surface

The colours shown in table 2.3-1 shall be used to identify voltage levels and functions of the electrical equipment including the Client[2]'s electrical components. These colours shall be applied on the equipment surface.

[2] Clients to SSEN(steady state electrical network)

Table 2.3-1 Colour code for voltage level and function of electrical equipment

Category	Voltage level	Colour	RAL ID[3]	Example
HV	Higher than 10kV	Yellowish orange	RAL 1003	
MV	6.6kV	Yellow	RAL 1018	
LV-AC	400V, 230V	Yellowish gray	RAL 1013	
LV-DC	48V,110V	Gray	RAL 7001	
Control Cubicle	Local control box	Dark grey	RAL 7043	
	I&C cubicles	Blue	AFNOR 2550 [4]	

Table 2.3-2 Identification Codes For Other Electrical Equipment

Component	Basic Colour			Example
	Name	RAL	Pantone	
Motors	Blue	5010	541	
Power generator	Grey	7035	421	
Transformers	Grey	7030	416	
Remaining cabinets	Lt. Beige	1015	726	
Remaining structures and electrical equipment foundations	Grey	7035	421	

2.3.1 Background of colour selection

The colours are so selected as to match well with the colours of equipment labels to be applied on the surface of equipment in terms of visibility of equipment identification.
Red colour is avoided since the colour usually used as special purpose (e.g. fire protection).
From yellowish orange to grey, they are usual finish colours for electrical equipment surface. Yellowish orange is selected for equipment of highest voltage level since the colour is felt warm by workers or operators, thereby provides cognitive notification to human's sense. As voltage level decreases, colour gets close to grey step by step such that the lowest level, low voltage dc, is assigned dark grey colour, which is felt cold.
Colours for control cubicles including plant system I&C cubicles are assigned with dark ones whereas those for electrical power equipment will be coloured with bright ones. Cubicles associated or interfaced with ITER central I&C system should be coloured with 'Blue' represented as AFNOR 2550 according to ITER I&C cubicle catalogue (35LXVZ).
Local control box or cubicles which have no physical and/or functional interface with central I&C system should be coloured with dark grey.

2.3.2 Application

[3] Same as footnote i.
[4] Electrical I&C cubicles, interfaced with ITER central I&C system, i.e. CODAC(PBS 45); CIS(PBS 46) or CSS(PBS 48), follow the colour code determined in ITER I&C cubicle catalogue (35LXVZ v2.3).
Other colours may be added for I&C cubicles for safe and interlock as determined by CODAC section.

The colours determined in the diagram below should be applied to finish colours of equipment surface. Applicable equipment will be as follows:

- Electrical power distribution boards;
- Cubicles for UPS (or inverter) with or without accumulator, ac/dc converter;
- Local control box or local I&C cubicles associated or not associated with central I&C system,

These colours do not apply to cable jacket or surface of cable raceways.
Large scale outdoor equipment, e.g. UHV substation equipment, large size transformers, and equipment which are not contained in metal enclosure, e.g. station batteries, will be coloured in natural colours of manufactures' own or particular colours determined considering harmonization with colours of other equipment and structures in the area the machine situated.

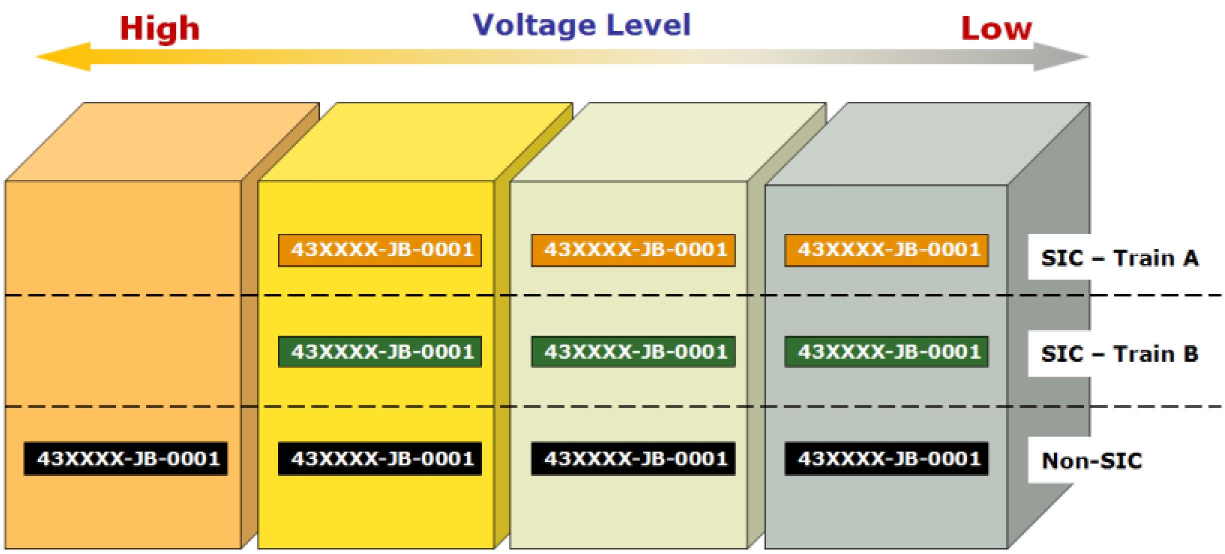


Figure 2.3-1 Examples of colour code – electrical power distribution boards

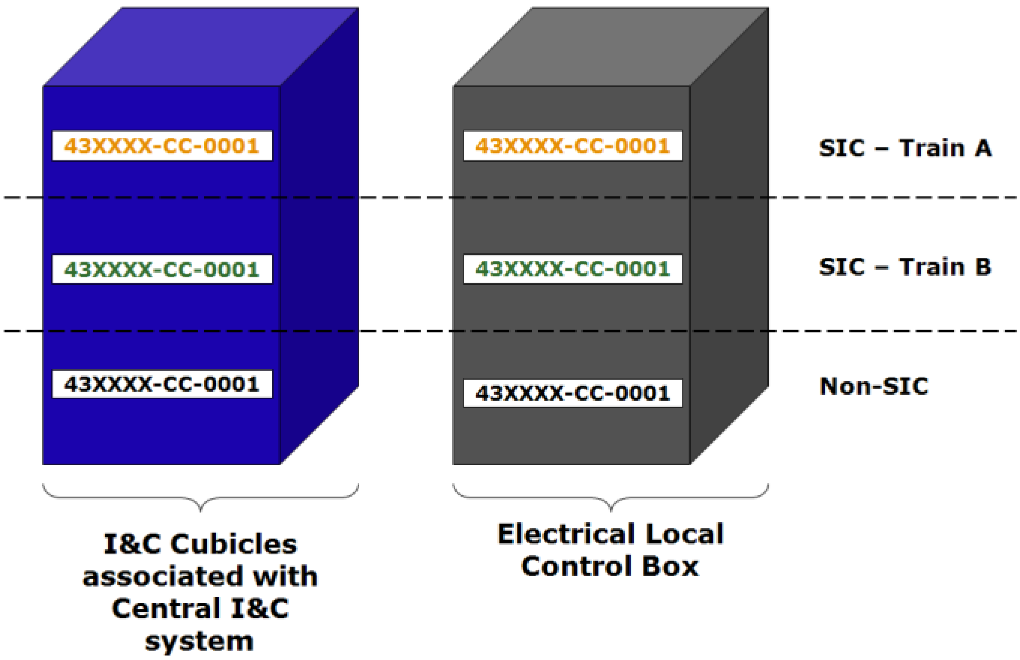


Figure 2.3-2 Examples of colour code – control cubicles

The finish colors of components shall be those defined in the figures 2.3 except for those components whose finishing color has a technical or security function (heat dissipation, warning, etc). This is only a sketch and must be highlited that PIC and non PIC devices cannot share the same board. Also, PIC components for Train A and Train B cannot share the same board.

3 Occupational Safety

Lock and tag capability of electrical components and plant systems shall be integrated into the design. The purpose of lock and tag is to prevent injury to servicing and/or maintenance personnel due to the unexpected energisation or start-up of machines, equipment or processes; or the release of stored energy.

Constructing, installing, setting up, adjusting, inspecting, modifying, maintaining and/or servicing of electrical components and plant systems, lubrication, cleaning or un-jamming of machines or equipment and making adjustments or tool changes, where personnel would be exposed to the unexpected start-up of the equipment or release of hazardous energy shall be subject to locking and tagging.

4 Components Criteria and Guideline

As defined in, in terms of the degrees of service availability, steady state power distribution system is classified into 4 power supply classes: Class I to Class IV. Class I through Class III power supplies are included in the emergency power supply (EPS) system. The SSEN consumers having power loads higher than 200kW shall be supplied at 6.6kV. The SSEN lower power (<200kW) consumers shall be supplied at 400/230V voltage level.

4.1 General Rules and Design Criteria for Low Voltage Electrical Consumers

4.1.1 Low Voltage AC Power Quality

Power quality shall be in accordance with the IEC60038 and NF EN50160.

The nominal voltage shall be equal to 230/400V. Concerning supply voltage range, under normal service conditions, it is recommended that the voltage at the supply terminals should not differ from the nominal voltage of the system by more than ±10 %.

The LV AC power distribution system shall be of TN-S earthing system in accordance with NF C15-100 (corresponding to IEC 60364).

For the utilization voltage range, in addition to the voltage variations at the supply terminals, voltage drops may occur within the consumer's installations. For low-voltage installations, this voltage drop is limited to 4 %, therefore, the utilization voltage range is +10 %, –14 %.

Limit of voltage variations, including the transients produced by motor starting: ±8%. This limit does not apply to the motor being started.

Voltage design limits during normal operation: ±6% for lighting and 10-16A socket.

Voltage design limits during normal operation: ±8% for motors.

Nominal AC voltage frequency: 50 Hz, with a daily and seasonal variation of +/-1%, corresponding to a nominal range of 49.5 to 50.5 Hz.

Total harmonic distortion shall be: < 5%.

To allow for inaccuracies in the analysis, the loads will be specified to function satisfactorily with a supply voltage of 230/400 V ±10%, and the conditions specified in the section 2.14 of SRD 43.

Environmental protection of Electrical and electronics equipment shall be in accordance with IEC 60529.

The electrical consumers shall be designed manufactured and tested to withstand power quality, according to IEC 61000-2-4, at their electrical terminal blocks as follows:

- IEC Class 2, for the electrical consumers connected to the class IV voltage;
- IEC class 3, for the electrical consumers connected to the class III voltage

These electrical consumers should be tested according the following standards:

- IEC61000-4-11 for AC power supplied components (drop voltage)
- IEC61000-4-14 for AC power supplied components (voltage fluctuations)
- IEC61000-4-17 for DC power supplied components

4.1.2 SSEN Boundaries for Low Voltage Consumers

The SSEN lower power consumers (< 200 kW) shall be supplied at 400/230 V voltage level[5]. There is exception to this criterion in case of heater loads. Heater loads in spite of having greater than 200kW shall be supplied at 400V due to technological limitations. SSEN has 14 load centers which are disseminated all over the ITER Site to provide power to low voltage class IV loads. The loads are provided power from the load center in the proximity of the building where the load is placed. The physical interface between the SSEN and the client system is at the incoming terminals of consumers' distribution board or terminal box. If the rated power of a load is greater than 70 kW, it will be supplied by a dedicated cable directly from the Main distribution board located in the LC.

4.1.2.1 Non-Nuclear building

Normally, in non-nuclear buildings SSEN does not have any sub distribution boards[6]. The main distribution boards are located in the Load Centers. The SSEN clients are expected to group loads from their operational point of view.

Main distribution boards: The main distribution boards are located within the Load Centers. They consist of incomer cabinet, outgoing cabinets and coupler circuit breakers. Outgoing cabinets consists of circuit breakers which supply power to loads ranging from 70 kW to 200 kW.

Sub-Distribution Boards: These are distribution boards which are located in the each level of Tokamak complex. They receive power from the main distribution board. The function of the 400/230V sub distribution board is to supply power to the loads with rated power <70kW.

The figure below depicts the low voltage boundaries of SSEN with Low voltage clients.

The physical interface between Plant System and PBS 43 can be defined as follows:

- LV Class IV LC circuit breakers for the Plant System Equipment[7] by PBS 43.
- Power Cables between the LV Class IV LC Circuit breakers and Plant System Equipment by PBS 43

[5] Due to technological limitations there may be exceptions. For eg. Heaters are supplied at low voltage eventhough their power > 200kW

[6] Building 71(Control Building) and 21(Hot Cell Building) are an exception to this rule. In these buildings SSEN has distribution boards as these buildings are multi-storeyed.

[7] Plant System Equipment may be a Plant System Intermediate DB, a Wall mounted panel or Load >70kW

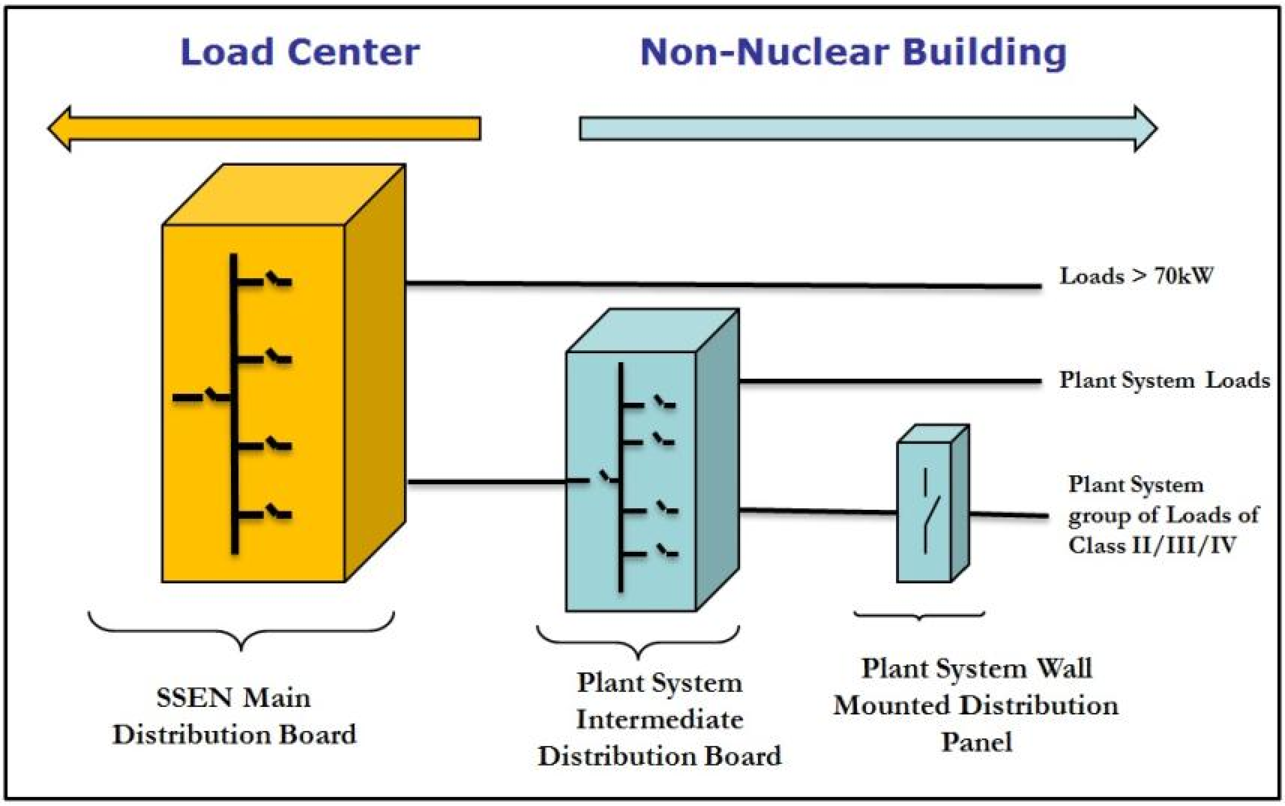


Figure 4.1-1 Low Voltage Interface of SSEN with Plant Systems - Physical and Functional

4.1.2.2 Nuclear building

In nuclear buildings SSEN has sub distribution boards. These sub distribution boards are located in the four corners at each level of the building. The SSEN Clients in the buildings are expected to group the loads.

The figure below depicts the low voltage boundaries of SSEN with Low voltage clients in Nuclear buildings.

The physical interface between Plant System and PBS 43 can be defined as follows:

- LV Class IV LC circuit breakers for the Plant System Equipment[8] by PBS 43.
- Power Cables between the LV Class IV LC Circuit breakers and Plant System Equipment by PBS 43.

[8] Plant System Equipment may be a Plant System Intermediate DB, a Wall mounted panel or Load >70kW

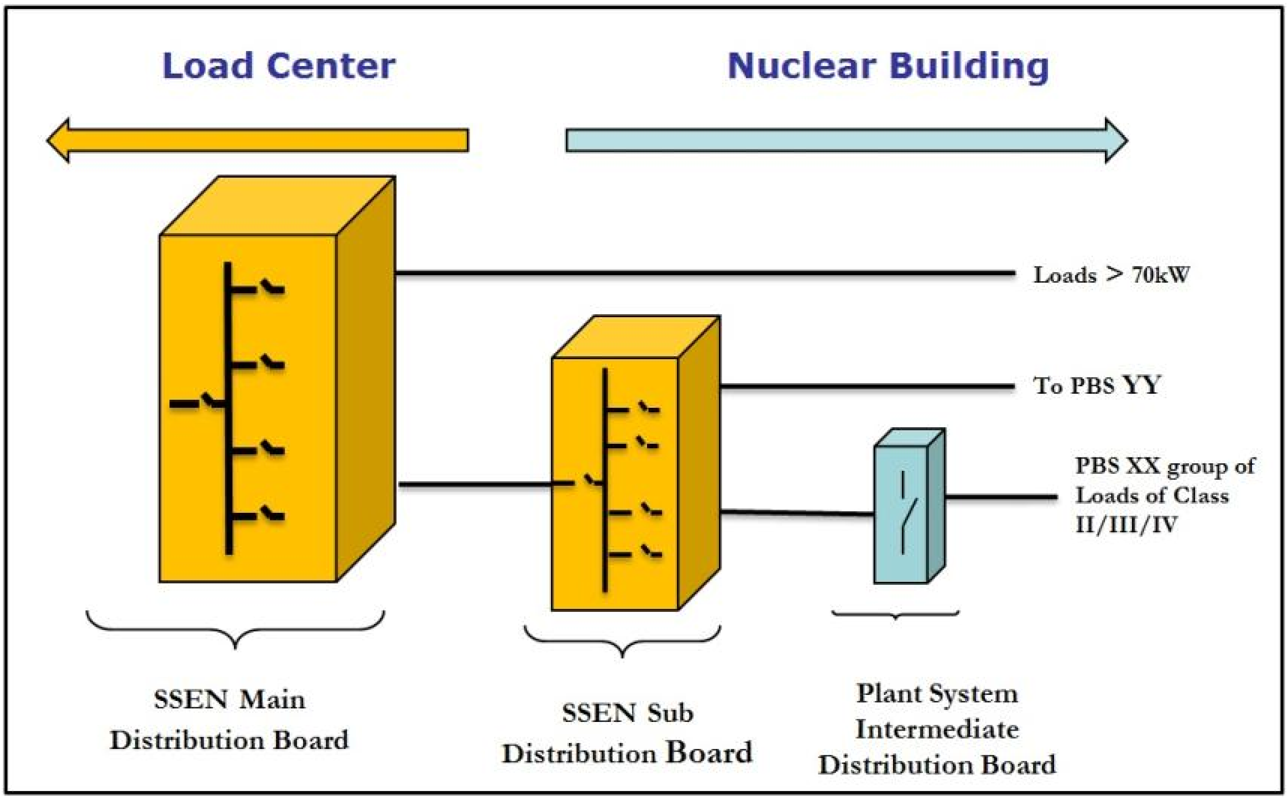


Figure 4.1-2 Low Voltage Interface of SSEN with Plant Systems - Physical and Functional

4.2 General Rules and Design Criteria for Medium Voltage Electrical Consumers

4.2.1 Medium Voltage A.C. Power Quality.

Equipment suppliers shall certify supplied equipment to be in compliance with IEC standard 61000 and European Directives on electromagnetic compatibility.

Nominal voltage 6.6 kV

The consumers shall function satisfactorily with a supplied voltage of 6.6 kV ±10% and the power quality conditions specified in the following paragraphs.

The voltage design limits for the 6.6 kV power during normal operation are 6.6 kV±6%.

Limit of voltage variations for the 6.6 kV power, including the transients that are produced by motor starting is ±8%. This limit does not apply to the motor that is being started (Section 2.8.6 of SRD 43.)

The nominal AC voltage frequency for the 6.6 kV power is 50 Hz, with a daily and seasonal variation of +/-1%, corresponding to a nominal range of 49.5 to 50.5 Hz.

The electrical consumers shall be designed manufactured and tested to withstand power quality, according to IEC 61000-2-4, at their electrical terminal blocks as follows:

- IEC Class 2, for the electrical consumers connected to the class IV voltage;
- IEC class 3, for the electrical consumers connected to the class III voltage

These electrical consumers should be tested according the following standards:

- IEC61000-4-11 for AC power supplied components (drop voltage)
- IEC61000-4-14 for AC power supplied components (voltage fluctuations)
- IEC61000-4-17 for DC power supplied components

Nominal AC voltage frequency: 50 Hz, ±1%.

Total harmonic distortion < 5% Power factor, at nominal loading conditions better than 0.85

4.2.2 SSEN Boundaries for Medium Voltage Consumers

The SSEN consumers having power loads higher that 200kW shall be supplied at 6.6kV. Medium Voltage Switchgears prefabricated modules shall be installed close to the consumers.

The interface between the SSEN and the Client is at the outgoing terminals of the feeder Circuit breaker of the Medium Voltage Switchgear Cubicle. Therefore the Circuit breaker or Fuse and the power cable shall be incorporated within the SSEN procurement. The interface between the SSEN and the Client is at the cable terminals of the Clients equipment that is served by the circuit breaker or fuse.

Some protection functions for MV equipment are proposed in the Electrical Interface Sheet document.

The medium voltage client must specify the kind of protections required per motor.

The physical and functional interfaces are as follows:

Physical:

- MV Class IV Switchgear circuit breakers with protective devices for the Plant System Equipment by PBS 43
- Power Cables between the MV Class IV Switchgear Circuit breakers and Plant System equipment and MV Switchgear and electrical motor by PBS 43
- The control cable for emergency stop alarm between MV switchgear and Plant System Equipment as defined in the Interface Control Document.

Functional:

- Any data required from PBS 43 by the user software of the Plant System I&C to monitor MV Switchgear through CODAC.
- Any data required from PBS 43 by the user software of the Plant Interlock System (Plant Systems) for investment protection of electrical motors via CIN.

The boundaries for physical and functional interfaces of PBS 43 with Plant Systems are mentioned in the respective ICD.

The physical and functional interfaces for MV Class III IP are similar to the interfaces mentioned above for MV Class IV. The document ITER_D_6655YR - Medium Voltage (6.6kV) Class IV-OL Motor Protection Scheme illustrates the physical interfaces between PBS 43 and the Plant Systems.

4.3 Low Voltage Protective Devices

The design of electrical components and plant systems to be installed at ITER shall provide selective and coordinated protection for the ITER power distribution system by the proper application of protective devices to prevent adverse effects of over currents, under voltages and overvoltages that may cause damage to the electrical installation, supplied systems and building structures. The protection of an electrical system is typically performed by a range of devices, e.g. circuit breaker, overload relays, phase current imbalance relays, etc.

4.3.1 General

Low voltage switchgear is designed for switching and protection of electrical equipment. The selection of switching devices is based on the specific switching task, e.g. isolation, load switching; short-circuit current breaking, motor switching, protection against overcurrent and personnel hazard. Depending on the type, switching devices can be used for single or multiple switching tasks. Switching tasks can also be conducted by a combination of several switchgear units.

IEC 60947-1 contains the general stipulations for all types of low voltage switching devices. Further general stipulations for electromechanical control circuit devices and switching elements can be found in IEC 60947-5-1.

The standards set down ratings for all devices, and defined test values are assigned to these. Devices for up to 690 V, for example, have a test level of 1890 V for the rated insulation voltage. The rated impulse withstand voltage U_{imp} (stated on the switch or noted in the manufacturer's documentation) for service in power distribution is as a rule 6 kV (IEC 60947-1, Table H1).

4.3.2 ACBs (Air circuit breakers)

4.3.2.1 Codes and Standards

The design and manufacture of ACBs shall comply with the latest editions of the IEC recommendations. Particularly the following shall be applied to select the ACBs.

- *IEC 60038 IEC standard voltages*
- *IEC 60947-2 Low-voltage switchgear and controlgear – Part 2: Circuit breakers*

4.3.2.2 Technical Requirements

a. ACBs shall be three-pole/four-pole(as required), single throw, drawout type, stored energy operating mechanism type, supported on a frame, and designed to be rigidly connected to the housing in the operating position.

b. Circuit breakers shall be provided with current ratings. Static overcurrent trip device, with an individual sensing device per each pole, shall be provided for each breaker.

c. The circuit breaker operating mechanisms operated from a 48 Volts/ 110 Volts dc source shall successfully operate with a control power voltage range. The spring charging motor for the breaker shall be energized after the closing operation is performed.

d. Circuit breaker mechanisms shall absorb any shock incident to the operation of the breaker with a minimum of vibration and noise.

e. Provision shall be made for manual operation of circuit breakers from the front of the housing. An operating lever shall be provided for manual closing of the breakers during maintenance. A positive mechanical "CLOSE-OPEN" indicator shall be provided on each breaker.

f. Sufficient number of auxiliary contacts shall be provided to automatically bypass certain "b" auxiliary contacts as the breaker is withdrawn from the operating position. If "b" auxiliary contacts are mounted on the housing and their operation is not affected by the breaker in the withdrawn position, the bypass contacts may be omitted.

g. Sufficient breaker operated cell switches (N.O. & N. C.) each rated 110/48 Volts dc, minimum 5.0 amperes interrupting rating shall be furnished for each breaker. The switches shall operate when the breaker is moved between the operating and the test position.

h. All breakers shall be equipped so that the stored energy mechanism discharges when the breaker is withdrawn from the cubicle. An indicator showing when the stored energy mechanism is charged shall be provided.

i. Breakers of the same type and ratings shall be completely interchangeable. Each breaker shall be individually identified for traceability by its compartment number.

j. The fixed and movable contacts of the primary disconnecting devices shall be silver plated, sturdily constructed and arranged so as to maintain accurate alignment. The primary disconnecting devices and their supports shall not distort or fail under the mechanical stresses and heating due to the duties specified herein. The contact of the secondary fixed and movable disconnecting devices shall be also silver plated, sturdily constructed and arranged so as to maintain accurate alignment.

k. Control relays shall be so connected as to make mechanism anti-pumping. The relays shall have coils suitable for continuous operation.

l. Circuit breakers, under any conditions, shall be mechanically and electrically trip free (the breaker will trip and remain open if both "trip" and "close" commands are present).

m. Anti-pumping or tripping arrangements on "stored energy" breakers shall not prevent the immediate restoration of the "stored energy" after a closing operation. In the event that an automatic control calls for "close" at the time when a "trip" is being manually initiated, the breaker shall immediately reclose upon the release of the trip circuit.

n. Breaker direct acting overcurrent trip elements shall be adjustable with long time, short time and/or instantaneous trip characteristics. The pick-up and time delay settings shall be such as to ensure maximum system selectivity and reliability.

o. Each circuit breaker shall be furnished with a trip alarm switch which operates when the breaker is tripped by other than manual means.

p. Each circuit breaker shall be furnished with an operation counter.

4.3.2.3 Design data

The minimum requirements for ACBs are described in Table 4.1-2.

Table 4.3-1 Technical data for ACBs

Description	Data	Remark
a. System nominal voltage, V	400	
b. Rated operating voltage, V	690	
c. Rated frequency, Hz	50	
d. Control voltage, V	48V, DC	Only IP and PIC classed ACB will be supplied with 48Vdc by PBS 43
e. Recommended(preferred) rated current, A	400, 630, 800, 1000, 1250, 1600 or higher	To be determined
f. Interrupting current at rated voltage	65 kA, sym. rms.	
g. Rated insulation voltage, V	1,000	

Figure 4.3-1 Typical Air Circuit Breaker (ACB)

4.3.3 Moulded Case Circuit Breakers

4.3.3.1 Codes and Standards

The design and manufacture of MCCBs shall comply with the latest editions of the IEC recommendations. Particularly the following shall be applied to select the MCCBs.

- *IEC 60038 IEC standard voltages*
- *IEC 60947-2 Low-voltage switchgear and controlgear – Part 2: Circuit breakers*

4.3.3.2 Technical requirements

a. All MCCBs shall be 600 Volt, 50Hz, with auxiliary contact and bell alarm contact. Specialized Circuit Breakers could be used for DC applications also.

b. Circuit breakers for motor feeders shall be magnetic only type with adjustable instantaneous trip elements.

c. Circuit breakers for non-motor feeders shall be with inverse time, thermal and magnetic element overload protection.

d. The circuit breaker used in feeder with separate ground fault protection shall be provided with shunt-trip unit.

e. Short circuit protection of combination motor starters shall be provided by moulded case manually operated, trip-free magnetic-only breakers equipped with front adjustable magnetic trip.

f. Protection of feeder taps and magnetic contactors for non-motor loads shall be provided by moulded case, manually operated, trip-free thermal-magnetic breakers with inverse-time thermal overload and instantaneous magnetic-trip for short circuit protection on each pole.

g. Circuit breakers shall be fully withdrawable for isolation and maintenance purposes and shall be lockable in the isolated position.

h. Breakers shall be equipped with an external operating mechanism to allow operation from the front with the unit door closed. The operating mechanism shall clearly indicate whether breaker is ON, OFF, TRIPPED.

i. Breakers shall be chosen to be selective with the LV switchgear circuit breaker in accordance with the protection coordination. The Seller shall be required to install the additional protective relay for suitable protection coordination, if required.

j. The breaker operating mechanism and the unit door shall be interlocked to prevent opening the door when the breaker is in the ON position. Means shall be provided to bypass the interlock for maintenance.

k. Breakers shall be provided with auxiliary contacts, bell alarm switches and other accessories indicated on the referenced schematic diagram to be furnished later by the Buyer.

4.3.3.3 Design Data

The minimum requirements for MCCBs are described in Table 4.1-5.

Table 4.3-2 Technical data for MCCBs

Description	Data	Remark
a. System nominal voltage, V	400	
b. Rated operating voltage, V	600	
c. Rated frequency, Hz	50	
d. Recommended(preferred) rated current, A	2.5, 4, 6.3, 10, 16, 25, 40, 63, 100, 125, 160, 250 or higher	To be determined
e. Rated short-circuit breaking capacity at rated voltage, KA, sym, rms	65	
f. Rated insulation voltage, V	690	
g. Type of MCCB		
- For motor load	MO(Magnetic Only) type	
- For non-motor load	TM(Thermal Magnetic) type	

Figure 4.3-2 Typical Moulded Case Circuit Breaker (MCCB)

4.3.4 Fuse Protection

4.3.4.1 Codes and standards

The design and manufacture of fuses shall comply with the latest editions of the IEC recommendations. Particularly the following shall be applied to select the fuses.

- *IEC 60038 IEC standard voltages*
- *IEC 60269 Low-voltage fuses*
- *IEC 60947-3 Low-voltage Switchgear and Controlgear – Part 3: Switches, Disconnectors, Switch-Disconnectors and Fuse-Combination Units*

4.3.4.2 Technical Requirements

a. Voltage transformer high voltage windings shall be protected by current limiting fuses. Fuses sized to prevent harmful overload to the VTs shall be installed in all ungrounded phase of the low voltage circuit and shall be located to permit replacement while the switchgear is energized. Fuse holders shall be permanently labelled as to size and type fuse required.

b. The secondary of the control transformer for L.V. switchgear shall have one side grounded and the other side fused.

c. Fuse holders shall be permanently labelled as to size and type of fuse installed. Fuse size shall be noted on all electrical schematic diagrams and wiring diagrams.

d. Fuses shall be located in areas where it will not be hazardous to replace them.

e. Tripping of fuses shall be indicated by the local and remote alarm system and the event recorder. For remote alarm and event recording, group alarms may be provided.

4.3.4.3 Design Data

The minimum requirements for fuses are described in Table 4.1-7.

Table 4.3-3 Technical data for Fuses

Description	Data	Remark
a. System nominal voltage, V	230V AC;110V/48V DC	
b. Rated operating voltage, V	250, 400	
c. Rated frequency, Hz	50/DC	
d. Recommended(preferred) rated current, A	2, 4, 6, 8, 10, 12, 16, 20, 25, 32, or high	To be determined
e. Minimum interrupting rating, A	To be determined in Tender design phase	To be determined

4.3.4.4 Principal type of fuses

The application ranges of fuses are identified by two letters. The first letter identifies the breaking range:

g – General purpose fuse links

These can continuously conduct currents up to their rated current and can interrupt currents from the smallest fusing current to the rated breaking capacity.

a – Back-up fuse links

These can continuously conduct currents up to their rated current and can interrupt only currents above a specific multiple of their rated current. The second letter identifies the application, i.e. the time-current characteristic.

G – for general application

M – for the protection of motor circuits and switching devices

R – for protection of semiconductor components

Tr – transformer protection

B – mine substation protection

D – fuse links with delay

N – fuse links without delay practice

The time response of fuse links depending on the breaking current that causes the fuse to melt and interrupt as per the time/current characteristics. The interrupting behaviour of the fuse links is characterized by the small test current (I_{nf}– no interruption during the test period) and the large test current (I_f – interruption during the test period)

Figure 4.3-3 Typical aM & gG Fuses

4.3.5 MCBs(Miniature circuit breakers)

4.3.5.1 Codes and Standards

The design and manufacture of MCBs shall comply with the latest editions of the IEC recommendations. Particularly the following shall be applied to select the MCBs.

- *IEC 60038* *IEC standard voltages*
- *IEC 60898* *Electrical Accessories – Circuit-Breakers for Overcurrent Protection for Household and Similar Installations*
- *IEC 60947-2* *Low-voltage switchgear and controlgear – Part 2: Circuit breakers*

4.3.5.2 Technical Requirements

a. L.V. 400/230V AC distribution boards shall preferably be equipped with miniature circuit breakers on outgoing circuits. They shall be single, double or triple pole as appropriate to the circuit and shall have sealed operating and overload mechanisms. Specialized MCBs can be used DC applications as well.

b. MCBs protect against overload and short-circuit, warranting reliability and safety for operations.

c. Tripping of MCB shall be indicated by the local and remote alarm system and the event recorder. For remote alarm and event recording, group alarms may be provided.

d. For lighting distributions, fixed mounted incoming CB and outgoing feeders with fixed mounted miniature circuit breakers (MCB), all with thermal and magnetic over-current release, as well as pulse relays/contactors for remote control, if required, shall be provided.

e. Each lighting and socket outlet circuit shall be protected by MCB

4.3.5.3 Design Data

The minimum requirements for MCBs are described in Table 4.1-9.

Table 4.3-4 Technical data for MCBs

Description	Data	Remark
a. System nominal voltage, V	230	
b. Maximum operating voltage, V	250	
c. Rated frequency, Hz	50	
d. Recommended(preferred) rated current, A	0.5 ~ 63 or higher	To be determined
e. Rated insulation voltage, V	690	
f. Breaking capacity (kA)	10	

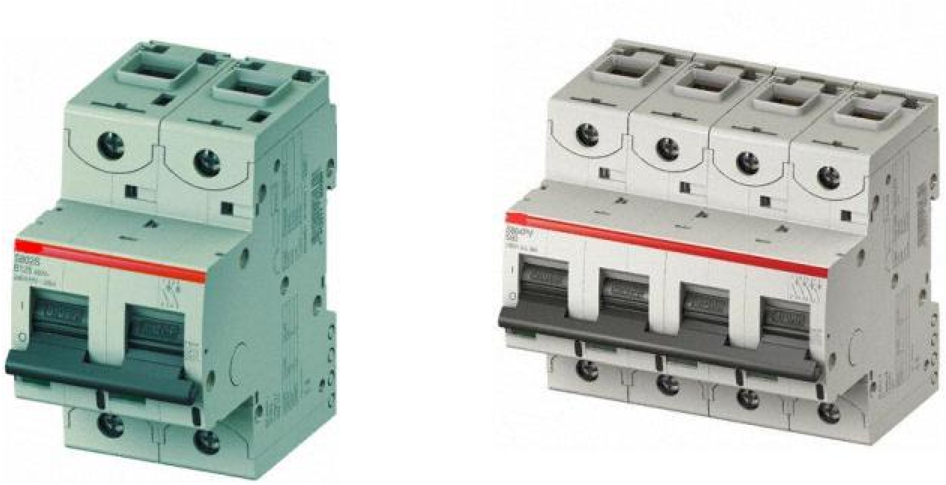


Figure 4.3-4 Typical 2-Pole and 4-Pole Miniature Circuit Breaker (MCB)

4.3.5.4 Tripping Characteristics

When choosing an MCB for a particular application, four major factors need to be considered. These are the standard to which the MCB conforms, its current rating, the type of trip characteristic and its breaking capacity.

The current rating of an MCB is the maximum current that it will carry continuously without tripping. MCBs should always be chosen so that their current rating matches, as closely as possible, the maximum load current of the circuit they are protecting.

An MCB that trips as quickly as possible under fault conditions is ideal. This is what is required for short-circuit faults but, for overload protection, the situation is more complicated. Many items of equipment, such as fluorescent lights, transformers and motors, draw a high peak current for a short period when they are switched on.

An MCB, which reacts instantaneously, would trip every time such a peak occurred, which would make it unusable. The thermal element in MCBs does not react instantaneously, as the bi-metal strip takes time to heat up. It is, therefore, hardly affected by short-term current peaks. By changing the design of the bimetal elements, MCB manufacturers can determine what size of peak current a particular MCB will ignore, and for what length of time. This relationship between current and tripping time is usually shown as a curve, known as the MCB's trip characteristic.

To avoid the need for users to work with the curves, IEC 60898 defines several types of standard characteristic, the most important of which are Types B, C and D.

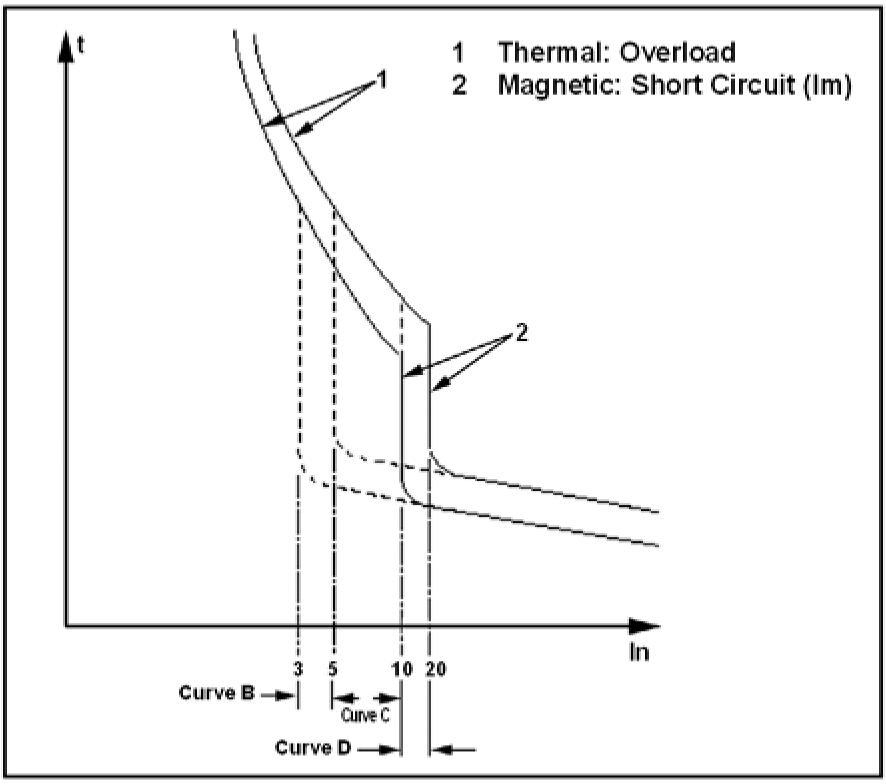


Figure 4.3-5 Tripping Characteristics of an MCB

- **Type B**

Type B MCBs react quickly to overloads, and are set to trip when the current passing through them is between 3 and 4.5 times the normal full load current. They are suitable for protecting incandescent lighting and socket-outlet circuits in domestic and commercial environments, where there is little risk of surges that could cause the MCB to trip.

- **Overloads**: Standard thermal protection.
- **Short Circuits**: Fixed magnetic curve B (I_m between 3 and 5 I_n)

- **Type C**

Type C MCBs react more slowly, and are recommended for applications involving inductive loads with high inrush currents, such as fluorescent lighting installations. Type C MCBs are set to trip at between 5 and 10 times the normal full load current.

- **Overloads**: Standard thermal protection.
- **Short Circuits**: Fixed magnetic curve C (I_m between 5 and 10 I_n)

- **Type D**

Type D MCBs are slower still, and are set to trip at between 10 and 20 times the normal full load current. They are recommended only for circuits with very high inrush currents, such as those feeding transformers and welding machines.

- **Overloads**: Standard thermal protection.
- **Short Circuits**: Fixed magnetic curve D (I_m between 10 and 20 I_n)

4.3.6 Relays

4.3.6.1 Codes and Standards

The design and manufacture of relays shall comply with the latest editions of the IEC recommendations. Particularly the following shall be applied to select the relays.

- *IEC 60038 IEC standard voltages*
- *IEC 60255 Electrical relays*
- *IEC 60947 Low-voltage switchgear and controlgear*

4.3.6.2 Technical requirements

a. If not specified otherwise in the particular specifications, all protective relays shall be mounted with the related feeder panels.

b. The protective relays shall be dust proof with removable transparent covers and external resetting devices. Unless otherwise specified, the relays shall be of the hand resetable type with start/trip indication. The relays shall be provided with test sockets and shall be easy accessible for testing and setting purposes.

c. Tripping of any protective relay shall be indicated by the local and the remote alarm system and the event recorder. Remote alarms may be grouped.

d. The protective relays shall have sufficient contacts and/or auxiliary relay contacts (including spare) to perform all required tripping, interlocking, indication and alarm functions.

4.3.7 Contactors

4.3.7.1 Codes and Standards

The design and manufacture of contactors shall comply with the latest editions of the IEC recommendations. Particularly the following shall be applied to select the contactors.

- *IEC 60038 IEC standard voltages*
- *IEC 60947-4-2 Low-voltage switchgear and controlgear – Part 4-2:Contactors and motor-starters*

4.3.7.2 Technical requirements

a. L.V. contactors shall be selected by utilization categories as shown in the table below. In addition, the ratings (voltage, current, ambient temperature and control voltage) are to be considered. Background conditions such as switching frequency, number of poles, type of coordination, short circuit level, start up conditions and contact life are also to be taken into account.

b. The contactor must be capable to operate satisfactorily with the following voltage limit values.

- Pick up: between 80% and 110%
- Drop off: below 70%

c. Contactors shall be capable of closing when a minimum transient voltage of 80% of the rated voltage is applied to the primary of the control transformers. Means shall be provided to prevent pumping.

d. When closed, the contactors shall withstand the system prospective fault current determined by the next co-ordinated short circuit tripping device. The associated thermal over-current releases shall either correspond to the primary current, or be fed via current transformer(s), as specified. They shall be adjustable in order to fit the motor requirements and be temperature compensated up to 70°C ambient temperature.

e. Suitable means shall be provided to prevent core vibration and noise. Contactors for motor control shall be suitable for direct-on-line motor starting and shall be capable of withstanding without damage the motor stalled current until the associated protective device operates. Contactors shall be designed for Type '2' co-ordination to IEC 60947-4.

f. Important accessories for the contactors include for example clip-on auxiliary contact blocks and overload relays for fitting to the contactor output terminals.

Table 4.3-5 Utilization categories for contactors as per IEC 60947-4-1

Current type	Utilization Category	Typical application
Alternating current	AC-1	Non-inductive or weak inductive load, resistance furnaces
	AC-2	Slip-ring motors: starting, disconnecting
	AC-3	Squirrel-cage motors: starting, disconnecting while running[9]
	AC-4	Squirrel-cage motors: starting, plug braking, reversing, jogging
	AC-5a	Switching gas-discharge lights
	AC-5b	Switching incandescent lights
	AC-6a	Switching transformers
	AC-6b	Switching capacitor banks
	AC-7a	Weakly inductive load in household appliances and similar applications
	AC-7b	Motor load for household devices
	AC-8a	Switching hermetically sealed refrigerant compressor motors with manual reset of the overload release[7]
	AC-8b	Switching hermetically sealed refrigerant compressor motors with

[9] Devices for utilization category AC-3 may be used for occasional jogging or plug-breaking for a limited period, such as setting up a machine; the number of actuations in these circumstances shall not exceed five per minute and ten per ten minutes.

		automatic reset of the overload release[10]
Direct Current	DC-1	Non-inductive or weakly inductive load, resistance furnaces
	DC-3	Shunt motors: starting, plug braking, reversing, jogging, resistance braking
	DC-5	Series motors: starting, plug braking, reversing, jogging, resistance braking
	DC-6	Switching incandescent lights

4.3.7.3 Design Data

The minimum requirements for contactors are described in Table below.

Table 4.3-6 Technical data for Contactors

Description	Data	Remark
a. Rated operating voltage, V	690	
b. Rated insulation voltage, V	750	
c. Rated frequency, Hz	50	
d. Recommended(preferred) rated current, A	-	To be determined

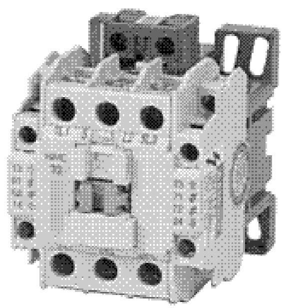


Figure 4.3-6 Typical Contactor

4.3.8 Motor Starters

4.3.8.1 Codes and Standards

The design and manufacture of motor starters shall comply with the latest editions of the IEC recommendations. Particularly the following shall be applied to select Motor Starters.

- *IEC 60038 IEC standard voltages*
- *IEC 60947-4-2 Low-voltage switchgear and controlgear – Part 4-2:Contactors and motor-starters*

[10] In the case of hermetically sealed refrigerant compressor motors, compressor and motor are sealed in the same housing without an external shaft or with the shaft sealed, and the motor operates in the refrigerant.

4.3.8.2 Technical requirements

a. Motor starter based on electromechanical switching devices are also defined in IEC 60947-4-2. Accordingly, motor starters are used to start motors, accelerate them to normal speed, ensure motor operation, disconnect the motor from the power supply and, by means of suitable protection system, protect the motor and the corresponding circuit in the case of overload.

b. The starter may function as a direct-on-line starter (DOL), reversing starter(REV), star-delta starter(YD), heavy starter (HD) or soft starter. Short circuit protection, overload protection and in many cases also an isolation device are required. Circuit-breakers are preferred for short circuit protection.

c. The components must be designed for a rated impulse withstand voltage $U_{imp.}$

d. Short circuit protection is to be provided depending on the voltage level and the rated short circuit breaking capacity of the motor starter.

e. For the design of the motor control unit, assignment to a type class in accordance with IEC 60947-4-1 which indicates the level of service continuity to be achieved with the equipment is also necessary. Two type classes are defined. The maximum permissible limits for damage are stated for both types. Machine operators must on no account be exposed to hazards.

f. All components and wiring shall be readily accessible for ease of maintenance. Connection to the bus for the starter units shall be by means of self-aligning plated connectors having free floating spring construction so as to ensure a positive pressure contact with both sides of the bus.

g. The design of the starter units and their associated connectors shall include provisions for accurately guiding the units from the disconnected or withdrawn position to the connected position and positively prevent miss stabbing.

h. The design of the starter units shall be such that combination starters of the same starter size and type shall be interchangeable.

i. All similar devices and components shall be of one manufacturer to facilitate maintenance and repair.

j. Contactors for all motor starter units shall be equipped sufficient number auxiliary contacts. Main and auxiliary contacts shall be silver plated.

k. Overload relay shall be possible to reset trip relays from outside the cubicles.

4.3.9 Disconnectors, load-break switches and switch disconnectors

4.3.9.1 Codes and Standards

The design and manufacture of disconnectors, load-break switches and switch disconnectors shall comply with the latest editions of the IEC recommendations.

- *IEC 60038 IEC standard voltages*
- *IEC 60947-3 Low-voltage switchgear and controlgear Part 3 : switches, disconnectors, switch-disconnectors and fuse- combination units*

4.3.9.2 Technical requirements

a. The isolating function of the disconnector in the open position is characterized by the following features:
   - Increased dielectric strength of the contact gap (demonstrated by a test at impulse voltage)
   - Low leakage current across the isolating distance
   - Clear indication of the OFF position of the contacts
   - No inadvertent closing (e.g. by vibration)
   - Facilities for actions to prevent impermissible reclosing

b. A disconnector can only open and close a circuit if either a current of negligible quantity is switched off or on, or if there is no significant voltage difference between the two contacts of each pole.

c. A load break switch can, under normal conditions in the circuit, if applicable with specified overload conditions, make, conduct and break currents and under specified abnormal conditions such as a short-circuit, conduct these short circuit currents for a specified period.

d. A switch-disconnector is a load-break switch that meets the requirements specified for an isolating distance in the open position.

e. Unit comprising switch-disconnector and fuses, in which one fuse is connected in series with the switch-disconnector in one or more phases.

f. A fuse switch-disconnector is a switch-disconnector in which a fuse link or a fuse holder with fuse link forms the movable contact.

g. The utilization categories define the intended applications and are given in IEC 60947-3. Each utilization category is characterized by the values of the currents and voltages, expressed as multiples of the rated operational current and the rated operational voltage, as well as the power-factors or time-constants of the circuit.

i The distinction between frequent and infrequent operation is based on the manufacturer's rated operation and the number of operating cycles used as a test criterion.

Figure 4.3-7 Typical Switch disconnectors

4.4 Low Voltage Sockets

4.4.1 Codes and standards

The design and manufacture of Low voltage sockets shall comply with the latest editions of the IEC recommendations and local standards. Particularly the following shall be applied to select the Low voltage sockets.

- *IEC 60038 IEC standard voltages*
- *IEC 60309 Plugs, socket-outlets and couplers for industrial purpose*
- *IEC 60320 Appliances couplers for household and similar general purposes*

4.4.2 Technical requirements

AC power plugs and sockets are devices for removably connecting electrically operated devices to the power supply. An electric plug connects mechanically to a matching socket. Usually plugs are movable connectors, and sockets are fixed to equipment.

Wall sockets (sometimes also known as power points, power sockets, electric receptacles, plug sockets, electrical outlets or just sockets) are mostly or completely female electrical connectors that have slots or holes which accept and deliver current to the prongs of inserted plugs.

To reduce the risk of injury or death by electric shock, some plug and socket systems incorporate various safety features. Sockets can be designed to accept only matching plugs and reject all others.

Electrical plugs and their sockets differ by country in shape, size and type of connectors. The type used in each country is set by national standards legislation. Sockets and outlets for building services shall be designed to comply with the local standards.

4.4.2.1 Single Phase Sockets and Plugs

France has standardized on a round plug with two round pins measuring 4.8 by 19 mm (0.189 by 0.748 in), spaced 19 mm (0.748 in) apart and with a hole for the socket's ground pin. This standard will also accept Europlug and CEE 7/17 plugs. Sockets are installed with the earth pin upwards.

Figure 4.4-1 Typical configuration of French socket

Figure 4.4-2 Typical configuration of French Plug

This two-prong plug is popularly known as the Europlug. The plug is ungrounded and has two round 4 mm (0.157 in) pins, which usually converge slightly towards their free ends. It is described in CEE 7/16. This plug is intended for use with devices that require 2.5 amperes or less. Because it is unpolarised, it can be inserted in either direction into the socket, so live and neutral are connected arbitrarily. The separation and length of the pins allow its safe insertion in most French outlets.

Figure 4.4-3 CEE 7/16 plug

CEE 7/17 plugs also has two round pins but the pins are 4.8 mm (0.189 in) in diameter like types E and F and the plug has a round plastic or rubber base that stops it being inserted into small sockets intended for the Europlug. Instead, it fits only into large round sockets intended for types E and F.

Figure 4.4-4 CEE 7/17 plug

4.4.2.2 Industrial and Multiphase Power Outlets

The most common range of heavy commercial and industrial plugs comply to IEC 60309. IEC 60309-2 connectors are produced in many variants, designed so that a plug of one type can only be inserted into a socket of the same type.

Different current ratings (such as 16 A, 32 A, 63 A and 125 A) are distinguished by different diameters of the circular housing.

Different voltage and frequency combinations are distinguished by the location of the ground pin .

The following types of industrial and multiphase power outlets shall be provided at locations to be approved by the Architect Engineer:

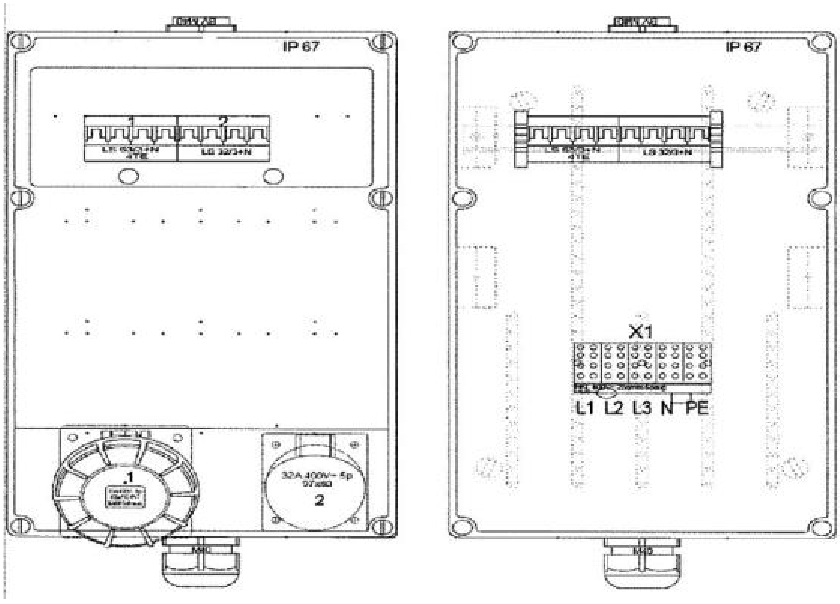
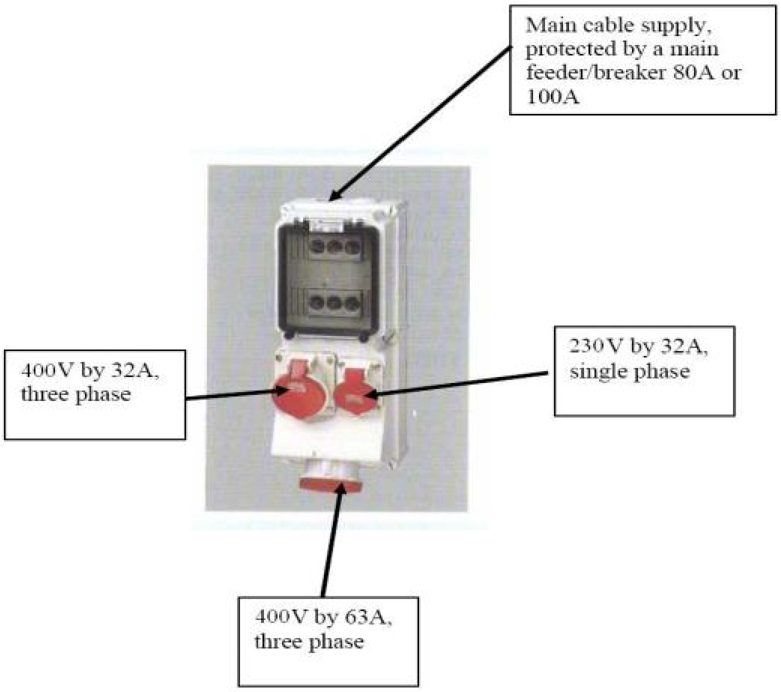


Figure 4.4-5 Typical configuration of power socket outlet



[b]

Figure 4.4-6 Typical configuration of power outlet socket

4.5 Low Voltage Distribution Boards

4.5.1 Codes and Standards

The design and manufacture of 400/230V Sub-Distribution Board or Intermediate Distribution Board shall comply with the latest editions of the IEC recommendations. Particularly the following shall be applied to select the 400/230V sub distribution panel.

IEC 60038 IEC standard voltages

IEC 60228 Conductors of insulated cables

IEC 60269 Low-voltage fuses

IEC 60439 Low-voltage switchgear and controlgear assemblies

IEC 60529 Degree of protection provided by enclosures

IEC 60947 Low-voltage switchgear and controlgear

IEC 60073 Coding principles for indicators and actuators

IEC 60364 Low-voltage electrical installations

NF C 15-100 Electrical installations in low voltage

4.5.2 Design and Construction

4.5.2.1 Enclosures

a) The 400/230V Distribution Board[11] shall be of the metal enclosed type. Furthermore, they shall be of type tested design.

b) 400/230V sub distribution panel of 200 A rating and below and having fuse/ MCB/ MCCB outgoing feeders only shall be of the conventional, fixed mounted technique.

c) All other L.V. distribution boards shall be of the module technique with withdrawable incoming and sectionalizer feeders as specified and either removable (according to IEC 60439-1) or withdrawable type outgoing feeder switchgear.

d) The construction shall be such that the individual feeders of the board are mechanically segregated from each other.

e) All faults occurring in any of the segregated sections are to be restricted to that area and, except for bus bar faults, shall not cause shut-down of any other feeder of the board other than the faulty one itself.

[11] Hereafter in this section the term Distribution Board also refers to Sub-Distribution Board or Intermediate Distribution Board.

f) If it is necessary to make provision for removal of barriers, opening of enclosures or withdrawal of parts of enclosures, one of the following protective measures must be used to guard against direct contact with live parts.
   - Removal, opening, or withdrawal must necessitate the use of a key or tool.
   - All live parts that can unintentionally be touched after the door has been opened shall be disconnected before the door can be opened.
   - An internal obstacle or shutter shielding all live parts shall exist which provides protection against unintentional contact when the door is open.

g) Opening the back or front door of any cubicle shall not expose the busbars but access to the busbars shall be possible only by removing bolted covers.

h) Those connections of the bus bars laying outside the busbar compartment shall be insulated or shrouded to minimize the risk for hazardous accidental contact while working on other parts of the switchgear.

i) Bus bars shall be capable of withstanding all electrical and thermal stresses which may occur at the point of installation. Provision shall be made for expansion and contraction of the bus bars resulting from temperature variations.

j) Clearances between live parts and to earth shall be in accordance with the relevant standard specifications.

k) Electrical cubicles shall be rigid, constructed of braced rolled steel sections with recessed panels and substantial mounting frames for mounting of power and control cables.

l) All terminal blocks/ points, relays and instruments, etc., shall be located so as to be safely accessible while the equipment is in service. Suitable touch protection shall be provided to prevent access to live parts whilst a cubicle door is open.

m) All cubicles shall be complete with all locks, lighting, socket outlet, cable end boxes, etc., colour coded busbars, internal wiring, terminal boards and accessories, as required.

n) All cubicles shall have front access and – if not designed for erection at the wall - rear access for easy cable connection works as well as maintenance and repair of the main and auxiliary equipment as applicable.

o) Busbars shall be made of high conductive electrolytic copper conductors with the connection points suitably protected against corrosion. They shall be colour coded, rigidly supported on cast resin insulators and shall comply with the requirements of the relevant standard Specifications.

4.5.2.2 Degree of Protection

Degrees of protection shall be applied in accordance with IEC 60529. A brief description of the IP Code elements is given in the following Table

Table 4.5-1 Elements of IP Code

Element	*Numerals or letters*	*Meaning for the protection of equipment*	*Meaning for the protection of persons*
Code letters	*IP*		
First characteristic numeral		*Against ingress of solid foreign objects*	*Against access to hazardous parts with*
	0	(non-protected)	(non-protected)
	1	≥50 mm diameter	Back of hand
	2	≥12.5 mm diameter	Finger
	3	≥2.5 mm diameter	Tool
	4	≥1.0 mm diameter	Wire
	5	Dust-protected	Wire
	6	Dust-tight	Wire

Second characteristic numeral		*Against ingress of water with harmful effects*	
	0	(non-protected)	
	1	Vertically dripping	
	2	Dripping(15 degree tilted)	
	3	Spraying	
	4	Splashing	
	5	Jetting	
	6	Powerful jetting	
	7	Temporary immersion	
	8	Continuous immersion	

Additional letter (optional)			*Against access to hazardous parts with*
	A		Back of hand
	B		Finger
	C		Tool
	D		Wire

Supplementary letter (optional)		*Supplementary information specific to:*	
	H	High-voltage apparatus	
	M	Motion during water test	
	S	Stationary during water test	
	W	Weather conditions	

4.5.2.3 Internal Power Distribution (Auxiliary Equipment)

4.5.2.3.1 General guidelines for internal wiring

The guidelines for wiring inside the distribution board are based on best engineering practices and should facilitate consistency across all distribution boards. The overall guidelines for wiring are as follows:

a) Electrical wiring systems shall be so arranged or marked that it can be identified for inspection, testing, repairs or alteration of the installation.

b) Where the circuit contains a protective conductor, this conductor shall be identified by bicolour green-and-yellow marking. Were the circuit does not contain a protective conductor cables containing a conductor identified by bicolour green-and-yellow marking shall not be used.

c) Where the circuit contains a neutral conductor, this conductor shall be identified by light blue colouring. Where the circuit does not contain a neurtral conductor, the conductor identified by light blue colouring may be used for other purposes, except as a protective conductor.

d) Conductors identified by colors other than green-and-yellow and light blue, or by other means, may be used for all purposes except as a protective conductors or neutral conductors.

e) If single-core cables are used, continuous colour identification of the insulation is not necessary. The ends of the conductors shall be permanently identified upon installation with the colour mention in bullets (b) and (c) above.

f) Where necessary, conductors inside cubicles should be supported to keep them in place. Nonmetallic ducts are only permitted when they are made from a flame-retardant insulating material (see the IEC 60332 series).

g) It is recommended that electrical equipment mounted inside board be designed and constructed in such a way as to permit modification of the wiring from the front or the rear of the cubicle.

h) Connections to devices installed on doors or other movable parts should be made using flexible conductors which are suitable for frequent movement. The flexible conductors should be anchored to the fixed and movable parts independently from the electrical connection.

i) The selection of conductor sizes will be in accordance with the operational conditions, see IEC-60204-1 Annex-D for more details.

j) As per NF C-15-100, a live conductor is a conductor that transmits electrical energy, including the a.c. neutral conductor and d.c.compensator. A device provided for isolation and a device provided for switching shall be placed at the origin of any installation these devices disconnecting all live conductors of the entire installation. In TN-C systems, the PEN conductor shall not be isolated or switched. In TN-S systems, it shall be possible to isolate and switch the neutral conductor. A PEN conductor, is a conductor combining the functions of both protective conductor and neutral conductor.

4.5.2.3.2 Space Heaters

a) Each individual enclosure located outside air- conditioned rooms shall be fitted with heating devices suitable for electrical operation at A.C. single phase, of sufficient capacity to raise the internal temperature by about 5°C above the ambient temperature.

b) Heaters shall be controlled automatically by adjustable hygrostats (setting range about 50-100% relative humidity).

c) The boards so protected shall be designed so that the maximum permitted rise in temperature is not exceeded if the heaters are energized while the apparatus is in operation.

d) If applicable, heating elements shall be suitably screened to avoid burns due to accidental contact.

e) Heaters shall be connected to a suitable terminal box with main switch and indicating lamp. They shall be placed in an accessible position.

f) All equipment, whether fitted with a heating device or not, shall be provided with suitable drainage and be free from pockets in which moisture can collect.

4.5.2.3.3 Indication Lamps

The terms "indication lamps, lights," etc., does not necessarily require for incandescent type bulbs. The use of LED or glow type bulbs would be acceptable as long as adequate brightness is ensured.

In any case, the lifetime of bulbs operating at rated feeding voltage plus max. positive tolerance shall not be below 2000 hrs.

Indication Lamps shall be colour-coded with respect to the condition (status) of the distribution board in accordance with Table 2.2-1.

Table 2 – Colours for indicator lights with respect to the status of the board

Colour	**Meaning**	
	Safety of persons or environment	**State of equipment**
Red	Danger	Faulty
Yellow	Warning/Caution	Abnormal
Blue	Mandatory significance	
Green	Safe	Normal
White Grey Black	No Specific meaning assigned	

4.5.2.4 Design Data

The minimum requirements of 400/230V sub distribution panels are described in Table below.

Table 4.5-3 Technical data for 400/230V sub distribution board

Description	Data	Remark
a. Input power	400/230V AC, 3 phases 4wires	
b. Interruption capacity, kA	25	
c. Rated frequency, Hz	50	
d. Busbar capacity, A	200	To be determined
e. Method of installation	Self-standing	

4.5.2.5 Earthing

a. Distribution boards earthing shall be in compliance with EDH Part 5: Earthing and Lightning Protection. In particular, chapter 7.3 and 7.4 for LV cubicles.

b. For earthing purpose, each cubicle shall be equipped with earthing bonding bar at the lower part of the frame.

c. Equipotencial bonding conductors must be calculated according to NF C15-100 chapter 544.1. All movile part shall be connected equipotencily between them, in particular main doors.

d. Earthing bonding bar shall be connected to the earthing network throughout the closer earthing bar. A disconnecting link between earthing network and bonding conductor should be also envisaged.

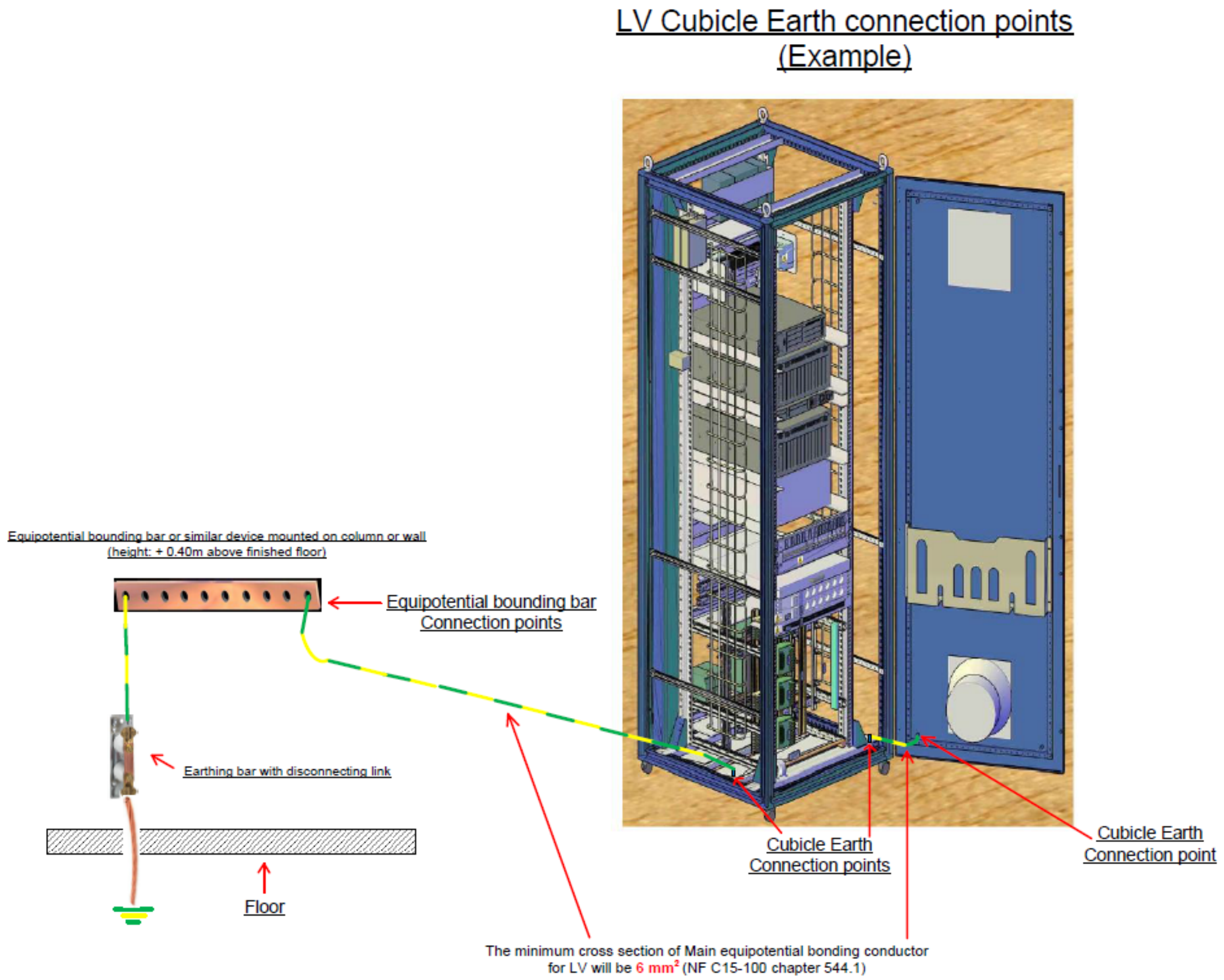


Figure 4.5-1 Example of earthing bonding connections for LV distribution boards.

4.5.3 Drawing and Documentation Requirements

The Supplier shall furnish to the Client with complete technical data and the following drawings and documents:

- Outline and general arrangement drawings including grounding locations, mounting method and accessories location etc.
- List of all devices in the Distribution Board and their specifications.
- The wiring diagram of the Distribution board.
- List of recommended spare parts / special tools.
- Test procedures and test reports
- Operation and instruction manual.

- Reproducible for all the drawing and manuals

4.5.4 Tests and Inspections

Tests and inspections shall be made in accordance with applicable code and standard. Written documentation and/or certified test reports shall be submitted in accordance with the packaged submittal schedule.

4.5.4.1 Routine Tests

Routine tests are intended to detect faults in materials and workmanship and to ascertain proper functioning of the equipment. They shall be made on each individual Distribution Board. All Distribution Boards after completely assembled shall be tested and inspected, not limited to the following;

- Visual and dimensional check
- Functional tests
- Dielectric tests

4.5.4.2 Type tests

Type tests are intended to verify compliance of the design of a given equipment with this standard, where applicable, and the relevant product standard. They may comprise, as appropriate, the verification of:

- constructional requirements;
- temperature-rise;
- dielectric properties;
- making and breaking capacities;
- short-circuit making and breaking capacities;
- operating limits;
- operational performance;
- degree of protection of enclosed equipment;
- tests for EMC.

NOTE: The above list is not exhaustive.

The type tests to which the equipment shall be submitted, the results to be obtained, and, if relevant, the test sequences and the number of samples, shall be specified in the relevant product standard.

4.5.4.3 Compliance with constructional requirements

The verification of compliance with the constructional requirements , for example

- the materials;

- the equipment;
- the degrees of protection of enclosed equipment;

4.5.4.4 Site Acceptance tests

On completion of installations the following tests shall be carried out and the Test procedures shall be submitted to the client for Approval.

- Insulation Resistance Test;
- Polarity Test of Switch;
- Earth Continuity Test.

4.5.5 Qualification Requirements

Refer to Section 5.1 in EDH Guide C: Electrical Installations for EPS Systems.

4.6 Dry Type Transformers

4.6.1 Codes and standards

The design and manufacture of dry transformers shall comply with the latest editions of the IEC recommendations; particularly the following shall be applied to select the dry transformers.

IEC 60038	*IEC standard voltages*
IEC 60071	*Insulation co-ordination*
IEC 60076	*Recommendations for power transformers*
IEC 60076-11	*Recommendations for power transformers*
IEC 60216	*Determination of thermal properties of insulating material*
IEC 60529	*Degree of protection provided by enclosure*
IEC 60664	*Insulation co-ordination within L.V. systems*

4.6.2 Design and Construction

a. The mechanical and electrical design of the transformers and their accessories shall strictly follow the IEC recommendations.

b. The transformers shall meet the short circuit withstand requirements of IEC 60076-5.

c. Class F insulation material shall be used with the windings impregnated and cast under vacuum into moulds for glass fibre reinforced epoxy resin. The windings shall not absorb any humidity. The insulation material shall be barely inflammable and self-extinguishing.

d. All iron parts, except the core, shall be hot dip galvanized. The core shall be protected by a resin coat. The transformer shall be free of partial discharge up to at least 120% rated voltage and shall be short circuit proof.

e. For mould type indoor transformers the respective maximum room temperature and enclosure protection class have to be considered.

f. The maximum permissible temperature rise of mould type transformer (insulation class F) shall be:

   Windings : 80K (above switchgear room temperature 40°C., i.e., maximum permissible temperature is 120°C)

   Other parts : 80K (above switchgear room temperature 40°C., i.e., maximum permissible temperature is 120°C)

g. The transformer shall be able to operate safely for 30 seconds with a voltage of 1.3 times rated voltage imposed to the feeder winding. Further they shall be able to operate continuously at their nominal ratings within the limits of temperature rises, at voltage variations of ±10% at their feeder windings, at any frequency variation between -5% and +5% and at any combination of voltage and frequency variation of total ±10% together with any voltage ratio to be adjusted by the tap changer.

h. The short circuit capability of the transformers shall be such that they can withstand for 2 seconds without damage or deterioration secondary short circuits when fed from the primary side with the maximum possible fault current.

i. The seller shall provide a 3-phase, phase sequence diagram to ensure identical phase relationship of all systems which might be interconnected and correct cable/ busbar connections.

Figure 4.6-1 Typical Dry-Type Transformer

4.6.2.1 Windings

a) The transformer shall be provided with high conductive electrolytic copper windings. Aluminium windings could be considered only after proper justification about its advantage face to copper windings. Insulation material of mould type transformers shall be of class F (IEC 60076-2).

b) The insulation of windings and connections shall be free from insulation compositions likely to soften, to shrink or to collapse during service. None of the materials used shall shrink, disintegrate, carbonize or become brittle under the action of oil at any load condition.

c) All windings including neutral ends shall be fully and uniformly insulated.

d) The insulation levels shall be complied with more severe requirement of the relevant standards.

4.6.2.2 Magnetic core

a) The core and its clamping plates shall form a rigid unit structure which shall maintain its form and position under the severe stresses encountered during shipment, installation and short circuits.

b) Core shall be taken to secure evenly distributed mechanical pressure over the whole laminations to prevent settling of the core and to eliminate noise and vibrations when the transformer is in operation.

c) The core construction shall be such that removal and replacement of windings will require removing of core laminations to a minimum extent.

d) Core laminations shall be made from cold rolled grain orientated, high permeability silicon steel free from burrs. The core joints shall be interleaved. Each lamination shall be insulated with a material that will not deteriorate due to pressure.

e) The maximum flux density shall not exceed 1.7 Tesla at rated feeder voltage and 1.9 Tesla at feeder voltage 1.1 times the rated voltage and under the condition that higher harmonics are suppressed to the maximum possible extent.

4.6.2.3 Voltage adjustment

a) Ratio adjusters shall be provided for voltage adjustment which shall be electrically and mechanically robust and arranged to ensure convenient inspection and maintenance.

b) Design, arrangement of lead and connection thereto shall withstand voltage surges, a continuous load current corresponding to 125% rated capacity of the winding without excessive heating and full short circuits without injury.

c) The transformers shall be equipped with manual no-load tap changers with 2 x ±2.5% taps on HV side. The tap changing may be gang operated by wheel or handle, or performed by changing the respective bolted link connections.

4.6.2.4 Cooling

The transformer shall be designed for natural air cooling (AN) and be housed in a steel sheet enclosure of adequate mechanical strength and protection class IP41. (refer to IEC 60529)

4.6.2.5 Measuring and monitoring

All equipment shall be wired up to terminal blocks inside the marshalling kiosk. The dial type reading thermometers and thermostats shall be provided with contact units of the snap action type rated for 110V/48V DC. All contacts shall be adjustable to scale and shall be easily accessible on removal of the cover. Reading thermometers shall be arranged on enclosure. Alarm and tripping signals shall be announced in the control room.

The following measuring and monitoring devices shall be provided:

Three (3) resistance type temperature detectors (Pt 100) inserted in the L.V. winding, for local temperature measuring (i.e., one RTD per phase)

L.V. temperature monitoring by two (2) thermistor systems, one for warning and one for tripping.

4.6.2.6 Terminals

a) The secondary terminals of transformer shall be connected to the busbars of switchgear via flexible links in such a manner that any mechanical stresses on the bushings will be avoided.

b) Air-filled high voltage cable entrance compartments shall be furnished for each transformer. Holding brackets shall be provided so that cables can be disconnected from their terminals and securely fastened to the brackets for inspection and maintenance. Brackets shall be located in such a manner that the minimum bending radius will not be compromised.

c) An appropriate earthing bar for cable screens shall also be provided.

d) Neutrals: The transformer neutrals shall be equipped with current transformers for inputs to protective relays.

4.6.2.7 Earthing

a) Two earthing terminals of adequate size shall be provided and installed diagonally at the bottom of each transformer. Earthing continuity of the bolted parts shall be ensured by approved means (earthing leads, etc.).

b) Transformer neutrals shall be connected directly to the subsoil earthing system by a separate earthing cable via a screwed link.

c) Proper connection of the auxiliary equipment like instruments, control cubicles, pipes, etc., to the earthing bar, respectively, shall be ensured.

4.6.3 Name plates and other designation plates

The following plates made of material as specified in the specification shall be supplied:

a) A rating plated according to IEC 60076

b) A diagram plate showing in an the internal connections and the voltage vector relationship of the several windings in accordance with IEC 60076, and in addition a plan view of the transformer giving the correct physical relationship of the terminals.

c) Numbered plates for all instruments, devices, etc

d) A plate showing all electrical circuits and terminal blocks shall be located at the inner side of the hinged door of enclosure.

4.6.4 Drawing and Documentation Requirements

a. The supplier shall furnish to the client with complete technical data and the following drawings and documents for each type of motor to be supplied.

- Dimensions.
- Tolerances on dimensions.
- Material designation used for different components with reference to standards.
- Fabrication details such as welds, finishes and coatings.
- Catalogue or part members for each component
- Identification marking.
- Weight of individual components and total assembled weight
- Schematic control and wiring diagram for all auxiliary equipment
- Operation and Maintenance Manual

b. Certified test reports and oscillograms shall be submitted for approval prior to the despatch of the equipment. The equipment shall be despatched only when all the required type and routine tests have been carried out and test reports have been approved by the Client. Each test report shall contain the following information;

- Complete identification, date, including serial number of the transformer.
- Method of application, where applied, duration and interpretation of test results for each test.

4.6.5 Tests and Inspection

Tests shall be made by the manufacturer or at an approved laboratory, unless otherwise agreed between the supplier and the purchaser at the tender stage. The test basis for all characteristics other than insulation is the rated condition, unless the test Clause states otherwise.

Tests and inspections shall be made in accordance with applicable code and standard. Written documentation and/or certified test reports shall be submitted in accordance with the packaged mechanical submittal schedule.

All Transformers after being completely assembled shall be tested and inspected, but not be limited to the following test;

4.6.5.1 Routine Test

- Measurement of winding resistance
- Measurement of voltage ratio and check of phase displacement
- Measurement of short-circuit impedance and load loss
- Measurement of no-load loss and current
- Separate-source AC withstand voltage test
- Induced AC withstand voltage test

4.6.5.2 Type Test

- Lightning impulse test
- Partial discharge measurement
- Temperature-rise test

4.6.5.3 Field Test

The following field tests will be performed after installation. Test procedures shall be submitted to the client for approval.

- General mechanical checks.
- Core and winding insulation tests (Earth fault check on arrival at site).
- Vector group check.
- On-load tests

4.6.6 Qualification Requirements

Refer to Section 5.1 in EDH Guide C: Electrical Installations for EPS Systems.

4.7 Motors

4.7.1 Codes and Standards

The standards specified herein define the required quality to which a particular product or scope of work shall be constructed or installed. The use of alternative standards will be considered only in the event that the Supplier offers an alternative, internationally recognized standard, of equivalent quality. The acceptance of a substitute standard shall be subject to the agreement of the Client's Engineer and shall in no respect relieve the Supplier of their general obligations under the terms of the Contract.

RCC-E	*Design and Construction rules for Electrical Equipment of Nuclear Island*
IEC 60034	*Rotating electrical machines*
IEC 60072	*Dimension and output series for rotating electrical machines*
IEC 60079	*Electrical apparatus for explosive gas atmospheres*
IEC 60085	*Electrical insulation – Thermal evaluation and designation*
IEC 60709	*Nuclear power plants – Instrumentation and controls systems important to safety – Separation*
IEC 60780	*Nuclear power plants – Electrical equipment of safety system - Qualification*

4.7.2 Ratings

4.7.2.1 General

It shall be the responsibility of the driven equipment Supplier to indicate on the Motor Data Sheet, for each motor, the type, rated output, full-load running speed, direction of rotation, flywheel effect of the load and any other details that may be required by the motor manufacturer. The rated output and motor type selected by the Supplier shall be sufficient to ensure that the motor will operate continuously at rated load, with a maximum temperature of Class B (130℃) regardless of the insulation system selected.

4.7.2.2 Ratings

a. Motors larger than 200 kW shall be rated 6,600 volts, 3 phase, 50 Hz.

b. Motors equal to and smaller than 200kW shall be rated 400 volts, 3 phase, 50Hz.

c. Motor smaller than 0.5 kW may be rated 230V, 1 phase, 50Hz. In this case, suitable motor starter shall be provided by the Supplier.

d. All motors larger than 2 MW shall be soft-started. Exception may be taken in special cases if analysis demonstrates that motor starting voltage drop criteria can be satisfied as per SRD 43.

e. All motors larger than 2 MW shall have a power factor of at least 0.87 and motors less than 2 MW shall have a power factor of at least 0.85.

4.7.3 Design and Construction

4.7.3.1 Enclosures

a. For MV motors, enclosures shall be of the type specified in the technical specification of driven equipment. (e.g. open drip proof type - IP22 and above, IC01)

b. For LV motors, enclosures shall be totally enclosed fan cooled (TEFC) type with protection class IP44 for indoor application and IP55 for outdoor application in accordance with IEC 60034-5, unless specified otherwise in the technical specification of driven equipment.

c. Motors for use in hazardous area shall be designed to meet the requirements of IEC 60079 for the particular area.

d. After proper preparation, all interior metal parts and external hardware of the motor shall be treated with a permanent protective coating to prevent corrosion and deterioration.

e. The direction of rotation shall be permanently marked on the side of driven equipment that will be clearly visible.

f. The physical characteristics of motors (e.g. frame size, dimension, etc.) shall comply with IEC 60072 as much as practical and applicable.

4.7.3.2 Insulation

g. Motor windings shall be suitably treated so that the insulation is moisture resistant and adequate for exposure to severe atmospheric conditions. Motor shall have fully encapsulated winding system as described in IEC 60034-1.

f. All motors, unless specified otherwise, shall have a premium quality of class F(155℃) insulation system with operating temperature by resistance at rated power, rated voltage, rated frequency and at the highest design cooling medium temperature limited to class B(130℃) in accordance with IEC 60085. For voltage and frequency variations, paragraph 7.3 of IEC 60034-1 shall be applied and in the cases inside zone B, the temperature limits class F (155℃) shall not be exceeded.

g. The stator winding and end turns shall be adequately braced to withstand repeated full voltage starting.

h. For MV motors, the stator insulation shall be VPI (vacuum pressure impregnated) after the stator has been wound, wedged, connected and the bracing system installed.

i. For MV motors, the strand insulation and turn insulation shall be designed to withstand excessive switching surges caused by open-close operation of vacuum contactor. If necessary, surge arresters shall be provided at the motor terminals taking into account the voltage profiles of surges, which are generated from 6.6kV switchgears, at the motor terminals. The voltage profile of surge at each motor terminal will be provided by the switchgear manufacturer.

4.7.3.3 Bearings

a. Vertical motors shall be equipped with anti-friction bearings selected to meet the requirements of the external thrust load. All motors that are supplied with ball or roller bearings shall have the appropriate relevant standard code number stamped on a corrosion proof stainless steel nameplate attached to the motor. The design of bearings shall be based on the relevant codes and standards and shall have a rating life not less than L-10 life of 100,000 hours per ISO 281 and AFBMA(Antifriction bearing manufacturing Association). Thrust bearings and guide bearings shall be capable of withstanding, without damage, any down thrust or up thrust which may occur on startup or while running.

b. Anti-friction bearings shall be grease or oil lubricated according to the bearing manufacturer's standard. Bearings shall be properly shielded to prevent leakage of lubricant or entrance of foreign matter along the shaft. Grease lubricated bearings shall be pre-lubricated and shall have provisions for in-service positive lubrication with a drain to guard against over lubrication.

c. Bearing sleeves and housing shall be of split construction to permit inspection and replacement without disassembly of the motor or removal of motor half-coupling. Sleeve bearings for horizontal motors shall be corrosion resistant solid oil-ring lubricated type unless there is a definite need for forced feed lubrication design. Forced feed lubricated bearings shall also have oil rings to supply lubrication to the bearings during starting and during possible temporary loss of lubrication. The forced feed lubrication system and accessories shall be furnished complete and ready to operate. Forced feed lubricated motors shall have "bull's-eye" glass at the input of each bearing for checking flow.

d. All oil lubricated bearings shall have a sight gauge or a sight glass for observing bearing oil level. A drain opening with pipe plug shall be provided in each bearing oil reservoir.

e. Sleeve bearing motors shall be designed such that the rotor does not ride continuously against either end bearing due to thrust developed by the motor. Limited end float couplings shall be utilized if required by the driven machine. Two pole motors shall be provided with pressurized bearing seals.

f. Where insulated bearings are required, or specified in the specification of driven equipment, one or both bearings shall be insulated to prevent flow of shaft current, unless otherwise protected by other means. The motor drawings shall clearly indicate when piping and conduit to bearings must be insulated to protect against the occurrence of shaft currents.

g. Motor construction and bearing design shall permit removal of the rotor without removing motor half-coupling.

h. Where applicable, the front end of the shaft (opposite the drive end) shall be accessible for taking speed readings with a portable tachometer.

4.7.3.4 Terminal Leads, Connectors and Boxes

a. The design of terminal boxes shall ensure a degree of protection at least IP 54 in accordance with IEC 60034-5. Terminal boxes shall be provided with drain holes having removable threaded plugs. Terminal boxes for outdoor service shall have gasketed covers or gasketed removal plates.

b. The arrangement of terminals and cable connections shall permit the motor to be disconnected from the supply cable without damaging the seals, glands or connections. A permanently attached connection diagram shall be mounted inside the terminal box cover. If motors are suitable for only one direction of rotation, this shall be clearly indicated

c. The terminal boxes of MV motors shall be fitted with an approved cable sealing and a pressure relief diaphragm located to direct flames and/or hot gases away from personnel.

d. The terminal boxes of LV motors shall be fitted with an approved cable sealing or with suitable fittings for the cable entry.

e. The location of MV motor terminal box shall be at the right side of motor when viewing from motor driven equipment, unless otherwise agreed by client. The location of the Client’s conduit entrance will be furnished at the time of the Supplier’s drawing review.

f. The location of LV motor terminal box shall be at the right side of motor when viewing from motor driven equipment, unless otherwise agreed by client. The terminal box shall be capable of being turned to any of four position 90 degrees steps without alteration of the housing or bolting facilities, such that conduit may enter from above, below, or from either side.

g. In any case, the Supplier shall be responsible for assuring that the dimensions of the main motor leads terminal box and the size of conduits are adequate and sufficient for easy and efficient connection of the number and size of cables provided by the Client.

h. The Supplier shall submit for Client's approval the required outline and construction detail drawings, which clearly show dimensions of the terminal box, location and electrical clearances - live parts to ground and between live parts - of insulators, of the proposed terminal boxes.

i. The motor leads shall be of silicone or ozone-resistant rubber insulated cable. If braided jackets are used, the braid shall not be carried into the connections of the windings.

j. MV motor Terminal boxes shall be equipped with insulators, mounting assemblies and silver plated copper busbar for connecting terminal lugs for motor leads and feeder cables. The Supplier shall also furnish crimped type connecting lugs attached to copper busbar for the motor leads and for the Client's feeder cables. They shall be long barrel compression type for double indentation, with two-hole tongues having proper hole spacing.

k. Two sets of non-hygroscopic cable supports shall be provided in each LV motor terminal box.

l. Insulators located in each MV motor terminal box shall be high quality porcelain bus insulators and shall have a minimum of 60kV lightning impulse withstand voltage. Two or four hole insulators shall be used, and each insulator shall be affixed to both the insulator angle support and the copper busbar in at least two places, to prevent any twisting or movement of the cable lugs.

m. The motor power terminal boxes shall be designed suitably to withstand the fault currents from the associated SSEN.

n. A M10-16 machine screw or 6 × 25 mm copper earthing bus shall be provided inside each MV motor terminal box for earthing the Client’s cable shield wire(s).

4.7.4 Starting, Acceleration and Operation

4.7.4.1 Starting and Acceleration Characteristics

a. Motors shall operate satisfactorily during starting, voltage dips of short duration, and automatic transfer from a normal to a reserve power.

b. Motors designated for PIC functions shall be designed to accelerate with 75 % of rated voltage at the motor terminals throughout the starting period and shall be capable of accelerating their connected loads without exceeding the thermal limits specified by the motor manufacturer..

c. Non-PIC motors shall be capable of starting from rest and accelerating the load specified or shown on the load speed-torque curve with 80 % of motor rated voltage applied to the motor terminals without exceeding the thermal limits specified by the motor manufacturer.

d. Motors shall meet duty cycle S1 in accordance with IEC 60034-1.

e. The locked rotor current (LRC) limitation when tested at rated voltage and frequency shall be as the following ;

Rate output power of the motor	Maximum LRC (% of FLC)
$P \geq 37$ kW	500 % +20% (*)
5 kW $\leq P < 37$ kW	650 %

P < 5 kW	700 %

Note(*): 500% +20% based on the tolerance given in the IEC 60034-1, TABLE 20.

f. ~~For motors larger than 70 kW, the margin between allowable safe locked-rotor time and the time required to accelerate required mechanical load to rated speed at 80% (75% for SIC) rated voltage with hot condition shall not be less than 10 seconds.~~

g. All motors larger than 1 MW shall be equipped by a proximity sensor for measure the rotation speed. This information will be sent to the related IED The protection against motor overheating will be ensured by the detection of excessive starting time and locked rotor (Stalling time).

4.7.4.2 Operation

a. Motors shall be capable of operating satisfactorily under rated load condition within the frequency/voltage variation range of zone B per figure 12 in IEC 60034-1. A transient over-voltage of 130% of the nominal voltage shall also be sustainable. Furthermore, the motors shall be capable of delivering torque required by the driven equipment when running at 80% (75% for PIC motors) nominal voltage for a period of 10 seconds due to large motor starting in SSEN without damaging, overheating or slipping.

b. The pullout torque for continuously loaded motors shall be at least 160% of the rated motor torque and for intermittently loaded motors 200% of the rated motor torque. In case of PIC motors, the pullout torque shall be at least 200% whether the motor is loaded intermittently or continuously.

4.7.5 Vibration and Over-speed

a. Motors shall operate without undue vibration under all load conditions. The amplitude of vibration shall be limited to the values listed in IEC 60034-14, and the vibration shall be also measured in accordance with the above mentioned standard, unless a lower value is required by the driven equipment.

b. Motors shall be capable of over-speed operation, under emergency conditions, in accordance with the IEC 60034-1.

4.7.6 Sound Level

a. Motor sound level including maximum sound level and method of measurement shall be in accordance with the method described in IEC 60034-9.

b. When requested, the Supplier shall demonstrate acceptable sound level in accordance with IEC 60034-9.

4.7.7 Accessories

4.7.7.1 Lifting Device

a. Motors shall have suitable lifting devices to facilitate installation or removal. Location of lifting points shall be shown on the Supplier's drawings.

4.7.7.2 Space Heaters

a. Space heater shall be provided for motors rated 7.5 kW(10 HP) or larger, and motors rated 2 kW(3 HP) or larger installed outdoor or in damp environment. The space heater shall have sufficient capacity to keep the motor windings and internal parts dry when the motors are not running.

b. The space heaters shall have sufficient capacity to keep the motor windings and internal parts dry when the motors are not running.

c. Heating elements shall be suitable for electrical operation at 230 Vac, 1 phase or 400 Vac, 3 phases.

d. Heaters shall be placed inside the motor frame such that winding insulation and end turns are not subject to direct radiant heating.

e. The heater shall be readily accessible for inspection, maintenance, and removal without disconnecting the motor from its driven load or moving the motor from its fixed operating position.

f. Supplier shall clearly indicate that space heaters are PIC components or non-PIC components and also indicate whether space heaters are required during normal operation or only during stand-by, storage and construction.

4.7.7.3 Temperature Detectors

a. For all MV motors and for LV motors specified in the technical specification of driven equipment, resistance temperature devices (RTD's), platinum rated 100 ohms at 0℃ with temperature coefficient of 0.00385 ohms/ohms·℃, shall be provided in the motor slots of all phases.

b. For all MV motors and for LV motors specified in the technical specification of driven equipment, each sleeve or thrust bearing shall be equipped with temperature detector. The temperature detectors will be resistance temperature detectors (RTD), platinum rated 100 ohms at 0℃ with temperature coefficient of 0.00385 ohms/ohms·℃, or thermocouples. The elements shall be installed as close as possible to sleeve bearing surfaces, and shall be located preferably in the bottom half of the bearing housing. Where any bearing is insulated to prevent shaft current, thermocouple shall be ungrounded and the metallic sheath insulated from the thermocouple head to prevent bypassing the bearing insulation.

c. For MV motors, RTD's or thermocouples should be two single type or one duplex type.

4.7.7.4 Current Transformers

a. Motors situated inside Tokamak building or larger than 1,000 kW shall be equipped with three core-balance ("doughnut") or standard current transformers for the Client's self-balancing differential relaying scheme for the motor. The line and neutral leads of each phase shall be passed through its current transformer so that there is no current output from the current transformer during normal operation. The current transformers shall be located either in the main terminal box of the motor or in a separate terminal box, but not in accessory terminal boxes, and shall be accessible for replacement. The key data of current transformers such as burden, ratio, accuracy class, etc. will be informed after contract.

b. The current transformer secondary leads shall be terminated on separate, shorting-type terminal blocks located in the accessory termination box.

c. The value of all secondary side Current Transformers shall be 5A.

d. The calculation design of the primary side of Current Transformers shall include +20% of margin.

4.7.7.5 Accessory Terminal Boxes

a. All accessories such as space heater, temperature detectors, thermocouples, vibration detectors and current transformers shall be wired to separate accessory terminal boxes which shall be air insulated and shall be designed and fabricated to meet a degree of protection at least IP 54 in accordance with IEC 60034-5. The boxes shall be provided with drain hole and shall have provision for conduit connections as required. Location of each accessory terminal box and terminal markings shall be shown on the motor outline drawings.

b. Leads of accessory items normally operating at voltages of 50 volts (rms) or less shall be separated from other accessory leads by a suitable barrier or be terminated in a separate accessory terminal box. All boxes for PIC motors shall be provided with isolation means such as barriers or physical isolations between the wiring and/or components classified as PIC and the ones not classified as PIC in accordance with IEC 60709 and RCC-E. All isolation means shall be verified by the Supplier and submitted to the Client for review.

4.7.7.6 Earthing

a. Motor earthing shall be in compliance with EDH Part 5: Earthing and Lightning Protection. In particular, chapter 7.2 for MV motors and chapter 7.3 and 7.4 for LV motors.

b. For earthing purpose, each motor shall be equipped with earthing provision at the lower part of the frame.

c. For the MV motors, two copper grounding pads shall be brazed or welded at the lower part of the frame. The pads shall be located diagonally opposite one another, and each pad shall have two threaded holes for connection of an earthing conductor. Motor manufacturer shall provide suitable lugs sized for adequate connection of grounding cables specified above.

d. For the LV motors, the terminal for the earthing conductor shall be situated in the vicinity of the terminals for the line conductors, being placed in the terminal box. Motors larger than 100 kW shall have in addition an earthing terminal fitted on the frame. The earthing terminal shall be equipped with a threaded bolt, located near motor shaft end or on the same side as the terminal box, for connection of an earthing conductor.

e. In addition, each terminal box shall contain respective earthing terminal.

f. Equipotencial bonding conductors must be calculated according to NF C15-100 chapter 544.1 for LV motors and according to NF C13-200 chapter 542.3 for MV motors.

g. Earthing bonding bar shall be connected to the earthing network throughout the closer earthing point, including bonding connection with foundation rebars.

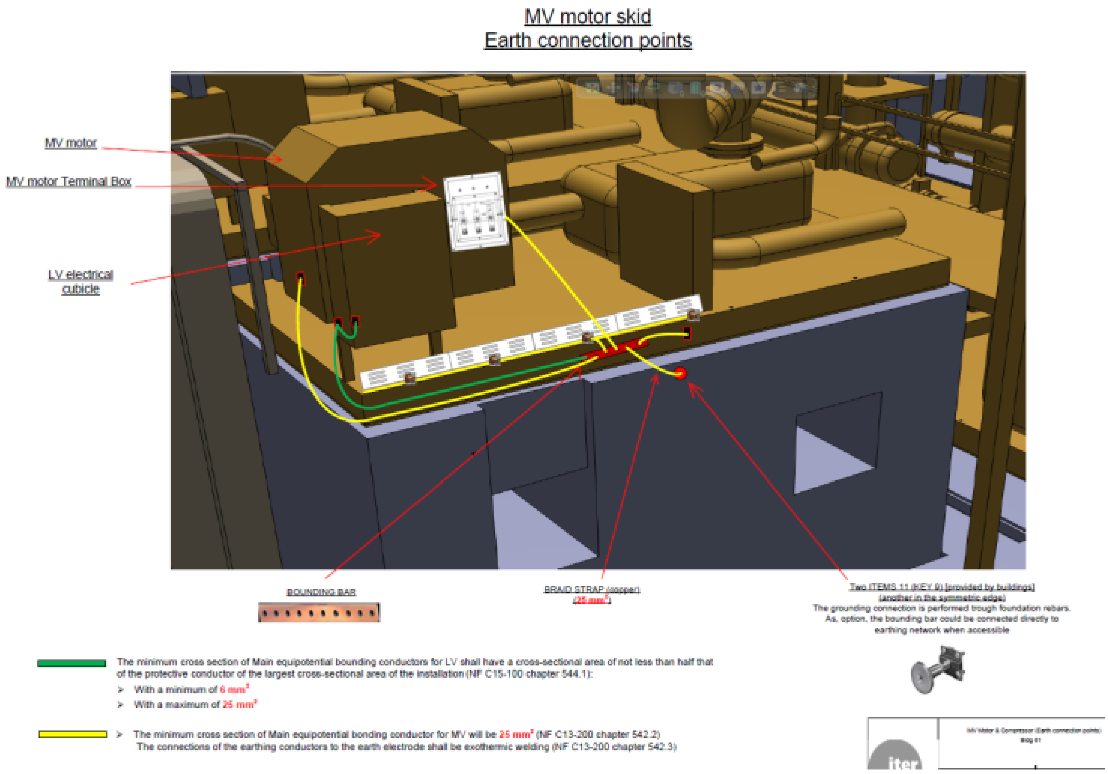


Figure 4.7-1 Example of earthing bonding connections for MV motor skid.

4.7.8 Cleaning and Painting

a. The cleaning and painting for all equipment shall be made suitably for use under the ITER site environmental condition. Unless otherwise specified, motors shall be cleaned, primed, and finish painted in accordance with the Supplier's standard specification subject to Client's approval.

b. Finish color shall be complied with the requirement of the driven equipment subject to the Client's approval, unless otherwise specified.

4.7.9 Packaging and Storage

a. Apparatus shall be substantially packaged and otherwise protected for shipment. Special care shall be taken to prevent exposure of windings and connections to weather during shipment.

b. The motors will be stored outdoors during construction of the plant and shall be suitably painted or coated to prevent corrosion. The windings, insulation, terminals, bearings, bare metal surfaces, and all other parts of the motors shall be adequately protected for outdoor storage.

c. Motors shall be prepared for extended outdoor storage by protecting the motor bearings with either a protective grease covering or liquid preservative. The motors shall be tagged to show that a preservative has been used. The procedure to be followed before motors are placed in operation shall also be indicated on the tag.

4.7.10 Nameplate

a. Nameplate(s) made from non-corrosive stainless steel shall be mounted on each motor using non-corrosive screws in a readily visible location, covered with a transparent paint after printing, stamping or engraving. The nameplate shall list all motor data required by IEC 60034-1 and the following;

- Shaft rotation corresponding to the supply voltage sequence of U-V-W
- Locked rotor current and rated voltage
- Weight of major components (i.e. total weight, rotor, stator, etc.)
- Lubricant type and lubrication instructions
- Terminal arrangements
- For MV motors, maximum permissible number of starts and the requirement cooling period when the motor is started under cold and hot motor conditions

b. Separate nameplate(s) other than main nameplate might be used to accommodate data listed above such as lubricant type and lubrication instructions, maximum permissible number of starts and the requirement cooling period, etc.

4.7.11 Drawing and Documentation Requirements

a. The Supplier shall furnish to the Client with complete technical data and the following drawings and documents for each type of motor to be supplied.

- For MV motors, the 80% (75% for PIC), 90% and 100% curves of each set shall be plotted in percent of per unit values.
  - Speed-torque curves, speed-current curves at 80% (75% for PIC), 90% and 100% rated voltage and speed-power factor curves
  - Acceleration time-current curves at 80% (75% for PIC), 90% and 100% rated voltage with thermal limit curves including cold and hot thermal limit and locked rotor thermal limit
  - Speed-load torque curves
- For LV motors, acceleration time-current curves at 80% (75% for PIC) and 100% rated voltage with thermal limit curves including cold and hot thermal limit and locked rotor thermal limit, plotted in percent of per unit values.
- Drawings and documents for each motor
  - Outline and arrangement drawings including terminal boxes location, grounding locations, mounting method, and accessories locations, etc.
  - Terminal boxes (main and auxiliary) detail drawings
  - Stator wiring diagrams and others
  - Rotor and shaft drawing including shaft end for coupling method with mechanical equipment
  - List of motor accessories and their specification
  - Space heater and thermocouple wiring diagrams

- List of recommended spare parts / special tools
- Test procedures and test reports
- Nuclear safety qualification plan, procedure and reports (for PIC motors)
- Operation and instruction manuals to be included in packaged mechanical equipment
- CT characteristic data including secondary excitation curves (current vs. voltage), if applicable
- Others for installation, test and operation

4.7.12 Tests and Inspection

Tests and inspections shall be made in accordance with applicable code and standard. Written documentation and/or certified test reports shall be submitted in accordance with the packaged mechanical submittal schedule.

4.7.12.1 Shop Tests and Inspections

4.7.12.1.1 Routine Tests

All motors after completely assembled shall be tested and inspected, but not be limited to the followings, after completely assembled;

- Visual and dimensional check
- Winding resistance measurement
- No load test
- Direction of rotation versus phase sequence
- Insulation resistance measurement (stator, rotor winding and auxiliary circuits)
- Withstand voltage tests
- Shaft current and bearing insulation measurement (if required)

4.7.12.1.2 Performance Tests

The performance test to obtain motor characteristic curves and motor performance data shall be made for each motor unless each type of motor supplied must be supported by a type test certificate of the same type of motor already manufactured by the Supplier.

- Locked rotor test
- Over-speed test
- Temperature rise test. It shall be carried out at full load or in case of partial load test the contractor shall provide all information related to extrapolation.
- Determination of motor characteristic curves at full load (torque, current, slip, efficiency, power factor)

- Sound level
- Mechanical vibration
- Nuclear qualification test per IEC 60780 (for PIC motor, if required)

4.7.12.1.3 Field Tests

The following field tests will be performed after installation. Test procedures shall be submitted to the Client for approval.

- Insulation resistance measurement
- Bearing insulation resistance measurement (if required and practical)
- No load readings of current and nominal speed
- Direction of rotation
- Mechanical vibration (on motors not completely assembled in the factory)
- Measurement of starting period

Measurement at maximum speed:

- Measurements current unbalance
- Motor winding temperature rise
- Bearing temperatures

4.7.12.2.2 Test after connection between motor and load

- Functional tests at 100% supply voltage
- Loads tests

4.7.13 Qualification Requirements

Refer to Section 5.1 in EDH Guide C: Electrical Installations for EPS Systems.

4.8 Variable Frequency Drive

4.8.1 Codes and Standards

The design and manufacture of VFD shall comply with the latest editions of the IEC Standard including the following.

- *IEC 60038 IEC standard voltages*
- *IEC 61800 Adjustable speed electrical power drive systems*

4.8.2 Technical Requirements

a) The VFD shall convert incoming fixed frequency three-phase AC power into an adjustable frequency and voltage for controlling the speed of three-phase AC motors. The motor current shall closely approximate a sine wave. Motor voltage shall be varied with frequency to maintain desired motor magnetization current suitable for the driven load and to eliminate the need for motor derating.

b) When properly sized, the VFD shall allow the motor to produce full rated power at rated motor voltage, current, and speed without using the motor's service factor. VFDs utilizing sine weighted/coded modulation (with or without 3rd harmonic injection) must provide data verifying that the motors will not draw more than full load current during full load and full speed operation.

c) The VFD shall maintain a fundamental (displacement) power factor near unity regardless of speed or load.

d) The VFD shall be equipped to minimize power line harmonics and protect the VFD from power line transients. It shall provide acceptable harmonic performance at full load.

e) The VFD shall be able to provide full rated output current continuously, 110% of rated current for 60 seconds and 120% of rated torque for up to 0.5 second while starting.

f) The VFD shall provide full motor torque at any selected frequency from 20 Hz to base speed while providing a variable torque V/Hz output at reduced speed. This is to allow driving direct drive fans without high speed derating or low speed excessive magnetization, as would occur if a constant torque V/Hz curve was used at reduced speeds. Breakaway current of 160% shall be available.

g) A programmable automatic energy optimization selection feature shall be provided standard in the VFD. This feature shall automatically and continuously monitor the motor’s speed and load to adjust the applied voltage to maximize energy savings.

h) The VFD must be able to produce full torque at low speed.

i) Output power circuit switching shall be able to be accomplished without interlocks or damage to the VFD.

j) VFD shall minimize the audible motor noise through the use of an adjustable carrier frequency. The carrier frequency shall be automatically adjusted to optimize motor and VFD operation while reducing motor noise. VFDs with fixed carrier frequency are not acceptable.

k) All VFDs shall contain integral EMI filters to attenuate radio frequency interference conducted to the AC power line.

4.8.3 Drawing and Documentation Requirements

The Submittals shall include the following information:

- Dimensional Drawings
- Submittal Schedule
- Electrical schematic diagram
- Connection Drawings
- Engineering Data including Weight
- Clarifications and Exceptions
- Rating Tables
- Operation and maintenance manual
- List of the shipped material and equipment.
- Installation Instruction.
- Compliance to IEC standards - Harmonic analysis for a particular jobsite including Total Harmonic Current Distortion, (THD) Current; Total Harmonic Voltage Distortion, (THD) Voltage; and Total Demand Distortion (TDD).
- The Drive manufacturer shall provide calculations, specific to the installation, showing TDD, at the Point of Common Coupling PCC , is less than required. Input line filters shall be sized and provided as required by the Drive manufacturer to ensure compliance with IEC standards, The acceptance of this calculation must be completed prior to Drive installation.
- Prior to installation, the Drive manufacturer shall provide the estimated (THD) caused by the Drive. The results shall be based on a computer aided circuit simulation of the total actual system, with information obtained from the power provider and the user.
- If the TDD, at the PCC, exceeds required levels, the Drive manufacturer is to recommend the additional equipment required to reduce the TDD to an acceptable level.

4.8.4 Testing and Inspection

Tests and inspections shall be made in accordance with applicable code and standard. Written documentation and/or certified test reports shall be submitted in accordance with the packaged mechanical submittal schedule.

4.8.4.1 Routine test

All VFDs after completely assembled shall be tested and inspected, but not be limited to the following:

- Visual Inspection
- Insulation tests
- Light load and functional
- Checking of auxiliary devices
- Checking the properties of the control equipment
- Checking the protective devices

4.8.4.2 Performance Test

The performance test shall include but not limited to the following tests:-

- Power loss determination
- Temperature rise test

4.8.4.3 Field Tests

The following field tests will be performed after installation. Test procedures shall be submitted to the Client for approval.

- Heat run test
- Measurements like Current unbalance, motor winding temperature rise, bearing temperatures (at max. speed), shaft vibration (in case of proximity probes)
- Functional tests at 100% supply voltage
- Loads tests

4.8.5 Qualification Requirements

Refer to Section 5.1 in EDH Guide C: Electrical Installations for EPS Systems.

5 Protection Guideline

The design of electrical components and plant systems to be installed at ITER shall provide selective and coordinated protection for the ITER power distribution system by the proper application of protective devices to prevent adverse effects of over currents, under voltages and over voltages that may cause damage to the electrical installation, supplied systems and building structures.

5.1 General

Selection of protection system of the electrical installation is fundamental both to guarantee correct economical and functional service of the whole installation and to reduce the problems caused by abnormal service conditions or actual faults to a minimum.

In detail, a good protection system must be able to:

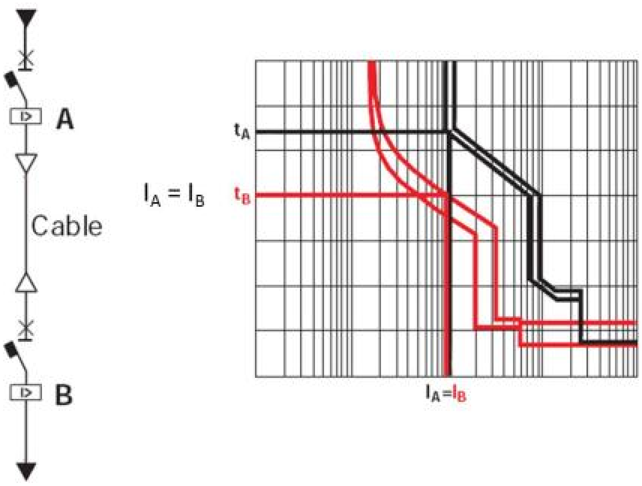
- Perceive what has happened and where, discriminating between abnormal but tolerable situations and fault situation within its zone of competence, avoiding unwanted trips which cause unjustified stoppage of a sound part of the installation;

- Act as rapidly as possible to limit the damage (destruction, accelerated ageing etc). Safe guarding power supply continuity and stability.

5.2 Protection Coordination

When two circuit-breakers placed in series, there are no other shunts, i.e. there is a single incoming and a single outgoing feeder which insist on the same node, the time-current curves of the two circuit breakers are compared as the same current passes through both of them. Hence the time current curves should line in from left to the right or bottom to the top in the sequence of load to source. There should be no overlapping of the curves nor should they cross each other. There should be sufficient space separation between the curves. Care should also be taken to ensure that the rating of Circuit breaker B is less than that of Circuit breaker A.
I_A is the overcurrent which passes through the circuit breaker A (PBS 43 CB)
I_B is the overcurrent which passes through the circuit breaker B(Plant System CB)

Figure 5.2-1 Identifying complete Selectivity-Case 1



When there is a single circuit breaker on the supply side and several circuit breakers on the load side, for the full range of overload or fault currents possible, only the nearest upstream overcurrent protective device should open in case of a downstream fault. All the other upstream overcurrent protective devices should not open. Therefore, only the circuit with the fault is removed and the remainder of the power system is unaffected. The other loads in the system continue uninterrupted.

The proper localization of a fault condition to restrict outages to the equipment affected, can be accomplished by the choice of selective fault-protective devices. It is important to note that the type of overcurrent protective device selected often determines if a system is selectively coordinated.

The figure below shows the difference between a system without selective coordination and a system with selective coordination. The figure on the left shows a system without selective coordination. In this system, unnecessary power loss to unaffected loads can occur, since the device nearest the fault cannot clear the fault before devices upstream open. The system on the right shows a selectively coordinated system. Here, the fault is cleared by the overcurrent device nearest the fault before any other upstream devices open, and unnecessary power loss to unaffected loads is avoided.

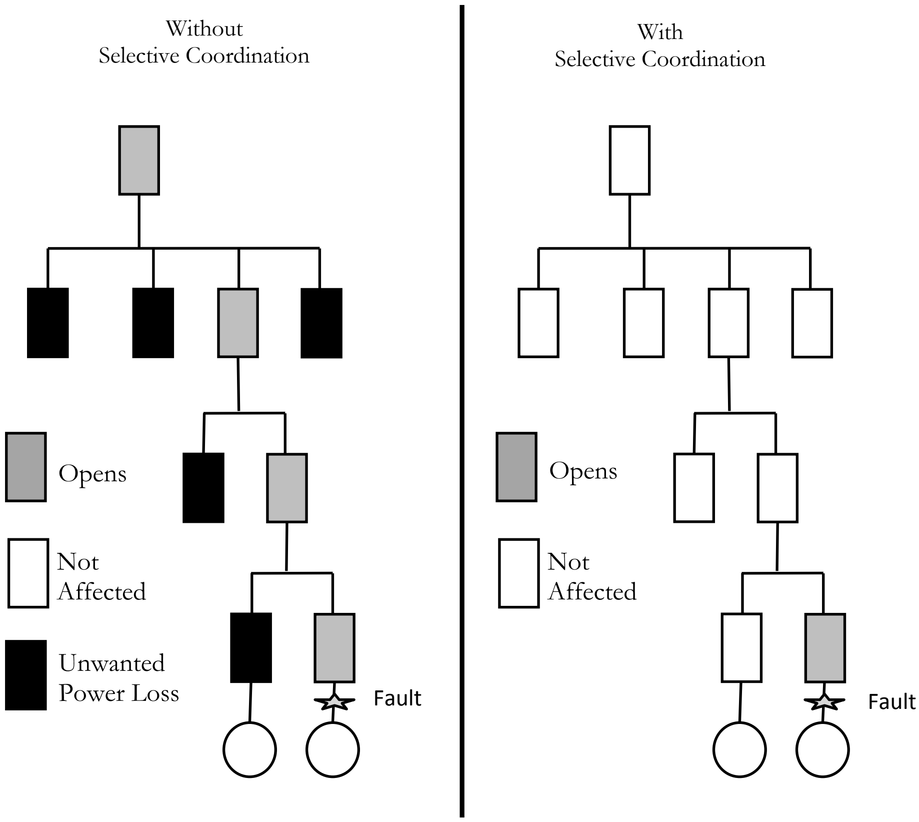


Figure 5.2-2 Protection Coordination

5.3 Motor Protection

A "motor circuit-breaker" is a thermal-magnetic circuit-breaker which provides protection against both short circuits and overloads, by rapidly opening the faulty circuit. It is a combination of a magnetic circuit-breaker and an overload relay. It conforms to IEC 60947-2 and 60947-4-1.

In these circuit-breakers, the magnetic devices (short-circuit protection) have a non-adjustable trip threshold, generally about 10 times the maximum setting current of thermal trips. Their thermal elements (overload protection) are compensated against variations in ambient temperature. The thermal protection threshold can be adjusted on the front panel of the circuit breaker. Its value must match the nominal current of the motor to be protected. In all these circuit-breakers, coordination (type II) between the thermal elements and the short circuit protection is provided by the design. Additionally, in the open position, most of these devices have a sufficient clearance distance (between their contacts) to provide an isolation function. They also incorporate a padlocking device required for logging. Any motor > 200kW connected to the LV network must be soft started.

5.3.1 Tripping curves

A motor circuit-breaker is characterized by its tripping curve, which represents the trip time of the circuit-breaker as a function of the current (multiple of I_r). This curve has four zones:

- the normal operation zone 1. Since $I < I_r$, there is no tripping.
- the thermal overload zone 2 . The thermal element trips; the trip time decreases as the overload increases. This tripping mode is therefore called "inverse time" in standards.
- the high current zone 3 , monitored by the "instantaneous magnetic element" or "short-circuit element" whose operation is instantaneous (less than 5 ms). And, in some circuit-breakers (electronic circuit breakers),
- an intermediate zone 4 monitored by a "time-delayed magnetic element" whose operation is delayed (by 0 to 300 ms). This tripping mode is called "independent delay mode" in standards. It can be used to avoid incorrect tripping when peak magnetizing current of motors is present at switch-on.

Their limits are:

I_r: setting current of the overload protection; this must match the nominal current (I_n) of the motor to be protected.

I_m: trip current of the time-delayed magnetic protection.

I_{inst}: trip current of the instantaneous magnetic protection. This can vary from 3 to 17 times I_r, but is generally close to 10 I_r.

I_{cs}: rated breaking capacity in short circuit

I_{cu}: ultimate (maximum) breaking capacity in short circuit.

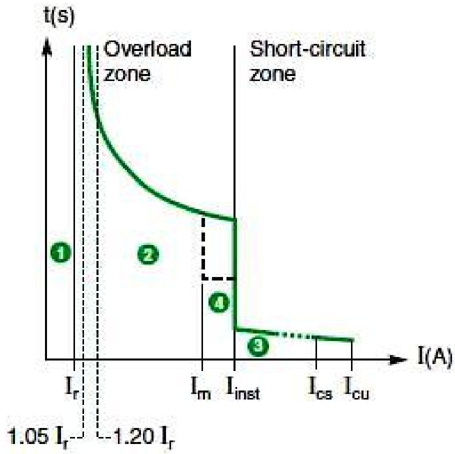


Figure 5.3-1 Operating zones of a thermal magnetic circuit breaker

The following guidelines may be followed for L.V. motor feeders;

Motors up to 10 kW capacity with

- Fuses plus adjustable thermal overload and phase failure protection or
- Circuit breaker with instantaneous over-current protection plus adjustable thermal overload and phase failure protection or
- Motor starter units including instantaneous over-current protection, thermal overload and phase failure protection

Motors above 10 kW capacity with

- Fuses or circuit breaker with instantaneous over-current protection, both with auxiliary contacts for alarm and tripping
- Starter
- C.T. operated adjustable thermal overload protection
- Phase failure protection
- Earth fault protection
- Ammeter

6 References

1) SRD (System Requirements Document) of PBS 43 : Steady State Electrical Network
2) EDH Part 1: Introduction
3) EDH Part 2: Terminology & Acronyms
4) EDH Part 3: Codes & Standards
5) EDH Part 4: Earthing, EMC and Lightning Protection
6) EDH Guide C: Electrical Installations for EPS Systems
7) Preliminary Safety Report (RPrS)
8) Colour Code for Electrical Components (ITER_D_3E5XP2)
9) RCC-E (2005), Design and construction rules for electrical equipment of nuclear islands
10) NF C15-100, Low-voltage electrical installations.
11) NF C13-200, High voltage electrical installations.
12) IEC 60038, IEC standard voltages
13) IEC 60364, Low-voltage electrical installations
14) IEC 61000-2-4, Electromagnetic compatibility (EMC) Part 2-4: Environment – Compatibility levels in industrial plants for low-frequency conducted disturbances
15) IEC 61000-4-17, Electromagnetic compatibility (EMC) Part 4-17: Testing and measure tech Ripple on DC input power port immunity test