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DESIGN ASPECTS FOR SAFETY IN ELECTRICAL SYSTEM

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Oil Industry Safety Directorate

Government of India

Ministry of Petroleum & Natural Gas

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**DESIGN ASPECTS FOR SAFETY
IN
ELECTRICAL SYSTEM**

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Preamble

Indian petroleum industry is the energy lifeline of the nation and its continuous performance is essential for sovereignty and prosperity of the country. As the industry essentially deals with inherently inflammable substances throughout its value chain – upstream, midstream and downstream – Safety is of paramount importance to this industry as only safe performance at all times can ensure optimum ROI of these national assets and resources including sustainability.

While statutory organizations were in place all along to oversee safety aspects of Indian petroleum industry, Oil Industry Safety Directorate (OISD) was set up in 1986 Ministry of Petroleum and Natural Gas, Government of India as a knowledge centre for formulation of constantly updated world-scale standards for design, layout and operation of various equipment, facility and activities involved in this industry. Moreover, OISD was also given responsibility of monitoring implementation status of these standards through safety audits.

In more than 25 years of its existence, OISD has developed a rigorous, multi-layer, iterative and participative process of development of standards – starting with research by in-house experts and iterating through seeking & validating inputs from all stake-holders – operators, designers, national level knowledge authorities and public at large – with a feedback loop of constant updation based on ground level experience obtained through audits, incident analysis and environment scanning.

The participative process followed in standard formulation has resulted in excellent level of compliance by the industry culminating in a safer environment in the industry. OISD – except in the Upstream Petroleum Sector – is still a regulatory (and not a statutory) body but that has not affected implementation of the OISD standards. It also goes to prove the old adage that self-regulation is the best regulation. The quality and relevance of OISD standards had been further endorsed by their adoption in various statutory rules of the land.

Petroleum industry in India is significantly globalized at present in terms of technology content requiring its operation to keep pace with the relevant world scale standards & practices. This matches the OISD philosophy of continuous improvement keeping pace with the global developments in its target environment. To this end, OISD keeps track of changes through participation as member in large number of International and national level Knowledge Organizations – both in the field of standard development and implementation & monitoring in addition to updation of internal knowledge base through continuous research and application surveillance, thereby ensuring that this OISD Standard, along with all other extant ones, remains relevant, updated and effective on a real time basis in the applicable areas.

Together we strive to achieve NIL incidents in the entire Hydrocarbon Value Chain. This, besides other issues, calls for total engagement from all levels of the stake holder organizations, which we, at OISD, fervently look forward to.

Jai Hind!!!

Executive Director

Oil Industry Safety Directorate

FOREWORD

Oil Industry in India is nearly 100 years old. Due to various collaboration agreements a variety of international codes, standards and practices are in vogue, Standardisation in design philosophies, operating and maintenance practices at a national level was hardly in existence. This lack of uniformity coupled with feedback from some serious accidents that occurred in the recent past in India and abroad, emphasised the need for the industry to review the existing state of art in designing, operating and maintaining oil and gas installations.

With this in view, the Ministry of Petroleum and Natural Gas in 1986 constituted a Safety Council assisted by the Oil Industry Safety Directorate (OISD) staffed from within the industry in formulating and implementing a series of self-regulatory measures aimed at removing obsolescence, standardising and upgrading the existing standards to ensure safer operations. Accordingly OISD constituted a number of functional committees comprising of experts nominated from the industry to draw up standards and guidelines on various subjects.

The present document on "Design Aspects for Safety in Electrical System" was prepared by the Functional committee on "Design Aspects for Electrical Safety". This document is based on the accumulated knowledge and experience of industry members and the various national and international codes and practices.

It is hoped that provisions of this document if implemented objectively, may go a long way to improve the safety to reduce accidents in Oil and Gas Industry. Users are cautioned that no document can be a substitute for the judgement of responsible and experienced engineer.

Suggestions are invited from the users after it is put into practice to improve the document further. Suggestions for amendments, if any, to this standard should be addressed to :

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These documents are intended to supplement rather than replace the prevailing statutory requirements.

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DESIGN ASPECTS FOR SAFETY IN ELECTRICAL SYSTEM

1.0 INTRODUCTION

Safety in electrical system draws maximum attention especially in the hydrocarbon industry, where classified hazardous atmosphere is encountered and electricity can constitute one of the sources of ignition for fire accidents and explosions. Besides equipment damage and property loss, electrical hazards can lead to injuries and fatalities to personnel due to electric shock and burns. The electrical system designer, hence, faces a challenge to provide a safe and reliable electrical system.

It is therefore imperative that safety aspects are built into the electrical system right from the design and engineering stage with the main objective of minimising equipment/system failure to prevent injury to personnel and damage to system components.

Following the guidelines and adhering to the safe practices given in this standard, would ensure adequate levels of safety in the electrical facilities of Oil Industry.

2.0 SCOPE

This document recommends minimum requirements in the design and engineering of electrical installations in Refineries, Gas Processing Plants and Cross country Pipeline Installations with or without storages.

This standard does not cover offshore installations and also the provisions of this standard do not apply to the following:

- i. Petroleum Depots, Terminals, Central Tank Farms (CTF), Lube Oil Installations, Grease Manufacturing and Filling facilities.
- ii. Onshore Drilling and Work over rigs which are covered in OISD-STD-216.
- iii. E&P onshore Production installations (GGS/OCS, GCP/GCS, EPS, QPS/WH etc).

This standard is not intended for use as a comprehensive design manual for electrical power system design. The standard in no way supersedes the statutory regulations of the Chief Electrical Inspectorate, Factory Inspectorate, Chief Controller of Explosives, Director General Mines Safety, Central Electricity Authority or other Government bodies, which shall be followed as applicable.

3.0 DEFINITIONS

i) Earth Connection

A connection to the general mass of earth by means of an earth electrode. An object is said to be 'earthed' when it is electrically connected to an earth electrode; and a conductor is said to be 'solidly earthed' when it is electrically connected to earth electrode without a fuse, switch, circuit-breaker, resistance or impedance in the earth connection.

ii) Earth Continuity Conductor

The conductor, including any clamp, connecting to the earthing lead or to each other of those parts of an installation which are required to be earthed.

iii) Earth Electrode

A metal plate, pipe or other conductor embedded in the soil that makes a direct contact to the general mass of the earth.

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iv) **Earth Fault**

Accidental connection of a conductor to earth. When the impedance is negligible, the connection is called a dead earth-fault.

v) **Earthing Lead**

The final conductor by which the connection to the earth electrode is made.

vi) **Earth Leakage Current**

The current flowing to earth on account of imperfect insulation.

vii) **Electrical Apparatus for Hazardous Areas**

Electrical apparatus which will not ignite the surrounding flammable atmosphere in which it is used.

viii) **Electrical Equipment**

The electrical machines, apparatus and circuits forming part of an electrical installation or a power system.

ix) **Electromagnetic Interference**

Degradation of the performance of an equipment, transmission channel or system caused by an electromagnetic disturbance.

x) **Encapsulation “m”**

Type of protection whereby parts that are capable of igniting an explosive atmosphere by either sparking or heating are enclosed in a compound in such a way as to avoid ignition of a dust layer or explosive atmosphere under operating or installation conditions

xi) **Equipotential Bond**

Electrical connection maintaining various exposed conductive-parts and extraneous-conductive-parts at substantially the same potential.

xii) **Fixed Equipment**

Equipment fastened to a support or otherwise secured in a specific location.

xiii) **Flameproof Enclosure “d”**

Enclosure in which the parts which can ignite an explosive gas atmosphere are placed and which can withstand the pressure developed during an internal explosion of an explosive mixture, and which prevents the transmission of the explosion to the explosive gas atmosphere surrounding the enclosure.

xiv) **Flammable Material**

A flammable material is a gas, vapour, liquid, and/or mist which can react continuously with atmospheric oxygen and which may therefore, sustain a fire or explosion when such reaction is initiated by a suitable spark, flame or hot surface.

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xv) Flammable Mixture

A mixture of flammable gas, vapour, or mist with air under atmospheric conditions, in which after ignition, combustion spreads throughout the unconsumed mixture.

xvi) Hand-Held Equipment

Portable equipment intended to be held in the hand during normal use in which the motor, if any, forms an integral part of the equipment.

xvii) Hazard

The presence or the risk of presence, of a flammable mixture.

xviii) Hazardous Area

In accordance with the petroleum rules, an area shall be deemed to be a hazardous area, where:

- a) Petroleum having flash point below 65°C or any flammable gas or vapour in a concentration capable of ignition is likely to be present;
- b) Petroleum or any flammable liquid having flash point above 65°C is likely to be refined, blended, handled or stored at or above its flash point.

Zone 0 An area in which an explosive atmosphere is present continuously, or is present for long periods or frequently.

Zone 1 An area in which an explosive atmosphere is likely to occur in normal operation occasionally.

Zone 2 An area in which an explosive atmosphere is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

xix) Hazardous (Flammable) Atmosphere

In accordance with the Petroleum Rules, an atmosphere containing any flammable gas or vapour in a concentration capable of ignition.

xx) Highest System Voltage

The highest R.M.S. phase to phase voltage, which occurs under normal operating conditions at any time and at any point in the system. It excludes voltage transients (such as those due to system switching) and temporary voltage variation due to abnormal system conditions (such as those due to fault conditions on sudden disconnection of large loads).

xxi) Impulse

A unidirectional wave of voltage or current which, without appreciable oscillations, rises rapidly to a maximum value and falls, usually less rapidly, to zero with small, if any, loops of opposite polarity.

The parameters which define a voltage or current impulse are polarity, peak value, front time, and time to half value on the tail

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xxii) **Increased Safety “e”**

Type of protection applied to electrical apparatus in which additional measures are applied so as to give increased security against the possibility of excessive temperatures and of the occurrence of arcs and sparks in normal service or under specified abnormal conditions.

NOTE 1: This type of protection is denoted by "e".

NOTE 2: Apparatus producing arcs or sparks in normal service is excluded by this definition of increased safety.

xxiii) **Insulation Fault**

An abnormal decrease in insulation resistance.

xxiv) **Intrinsic safety “i”**

Type of protection based on the restriction of electrical energy within apparatus and of interconnecting wiring exposed to the potentially explosive atmosphere to a level below that which can cause ignition by either sparking or heating effects.

An intrinsically safe apparatus is one in which all electrical circuits are intrinsically safe. It is placed in one of the following categories:

Level of protection "ia"

With U_m (maximum voltage that can be applied to the non energy-limited connection facilities of associated apparatus without invalidating the type of protection) and U_i (Maximum input voltage) applied, the intrinsically safe circuits in electrical apparatus of level of protection "ia" shall not be capable of causing ignition in each of the following circumstances:

- in normal operation and with the application of those non-countable faults which give the most onerous condition;
- in normal operation and with the application of one countable fault plus those non-countable faults which give the most onerous condition;
- in normal operation and with the application of two countable faults plus those non-countable faults which give the most onerous condition.

Level of protection “ib”

With U_m and U_i applied, the intrinsically safe circuits in electrical apparatus of level of protection “ib” shall not be capable of causing ignition in each of the following circumstances:

- In normal operation and with the application of those non-countable faults which give the most onerous condition;
- In normal operation and with the application of one countable fault plus the application of those non-countable faults which give the most onerous condition.

The non-countable fault applied may differ in each of the above circumstances.

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If no countable fault can occur the requirements of a) are considered to give a level of protection of “ib” if the test requirements for “ib” can be satisfied

Level of protection “ic”

With U_m and U_i applied, the intrinsically safe circuits in electrical apparatus of level of protection “ic” shall not be capable of causing ignition in normal operation.

xxv) Lightning Protective System

The whole system of interconnected conductors used to protect a structure from the effects of lightning.

xxvi) Nominal Voltage (of an Installation)

Voltage for which an installation or part of an installation is designated.

xxvii) Oil Immersion “o”

Type of protection in which the electrical equipment or parts of the electrical equipment are immersed in a protective liquid in such a way that an explosive gas atmosphere which may be above the liquid or outside the enclosure cannot be ignited.

xxviii) Overload

Operating conditions in an electrically undamaged circuit which cause an overcurrent.

xxix) Peak short circuit current

This is the highest instantaneous value of current after the occurrence of short circuit. It is given as a peak value. Its magnitude depends on the instant of the cycle at which the short circuit occurs.

xxx) Portable Equipment

Equipment which can be moved even while in operation or which can easily be moved from one place to another while connected to the electric supply.

xxxi) Powder filling “q”

Type of protection in which the parts capable of igniting an explosive gas atmosphere are fixed in position and completely surrounded by filling material to prevent the ignition of an external explosive gas atmosphere.

NOTE : The type of protection may not prevent the surrounding explosive gas atmosphere from penetrating into the equipment and components and being ignited by the circuits. However, due to the small free volumes in the filling material and due to the quenching of a flame which may propagate through the paths in the filling material, an external explosion is prevented.

xxxii) Pressurised Enclosure

Enclosure in which a protective gas is maintained at a pressure greater than that of the external atmosphere.

xxxiii) Protective gas

Air or inert gas used for purging and maintaining an overpressure and, if required, dilution

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NOTE: For the purposes of this standard, inert gas means nitrogen, carbon dioxide, argon or any gas which, when mixed with oxygen in the ratio 4 parts inert to 1 part oxygen as found in air, does not make the ignition and flammability properties, such as explosive limits, more onerous.

xxxiv) Redundancy

Duplication of elements in a system or installation, for the purpose of enhancing the reliability or continuity of operation of the system or installation.

xxxv) Self Powered Vehicle

A vehicle used for the conveyance of stationary equipment (e.g. compressors), personnel or goods in which petroleum or storage battery is used to generate the motive power.

xxxvi) Short-Circuit

The intentional or accidental connection of two points of a circuit.

The term is often applied to the group of phenomena which accompany a short circuit between points at different potentials.

xxxvii) Special Protection ‘S’

A kind of protection which does not fall into any of the recognised techniques, but which may be demonstrated to afford equivalent levels of protection to equipment intended for use in classified hazardous areas. This is to develop new ideas before standard specifications are available.

The certificate will normally describe the techniques and conditions of use.

xxxviii) Stationary Equipment

Either fixed equipment or equipment not provided with a carrying handle and having such a mass that it cannot easily be moved.

xxxix) Switchgear and Controlgear

A general term covering switching devices and their combinations with associated control, measuring, protective and regulating equipment; also assemblies of such devices and equipment with associated inter-connections, accessories, enclosures and supporting structures intended in principle for use in connection with generation, transmission, distribution and conversion of electrical energy. Controlgear are switching devices intended in principle for the control of electrical energy consuming equipment.

xl) Symmetrical breaking current

The symmetrical breaking current, during opening of a circuit breaker in the event of a short circuit, is the r.m.s. value of the symmetrical short circuit current flowing through the first phase to open at the instant of contact separation.

xli) Type of protection “n”

Type of protection applied to electrical equipment such that, in normal operation and in certain specified regular expected occurrences, it is not capable of igniting a surrounding explosive gas atmosphere

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NOTE 1: Additionally, it is intended to ensure that a malfunction capable of causing ignition is not likely to occur.

NOTE 2: An example of a specified regular expected occurrence is a luminaire with failed lamp.

xlii) **Voltage, Low - (LV)**

The voltage which does not normally exceed 250 volts.

xliii) **Voltage, Medium - (MV)**

The voltage which normally exceeds 250 volts but does not exceed 650 volts.

xliv) **Voltage High - (HV)**

The voltage which normally exceeds 650 volts but does not exceed 33 kV

xlvi) **Voltage, Extra-High-(EHV)**

The voltage which exceeds 33 kV under normal conditions.

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4.0 Power System Design

- i) The design of electrical installation shall ensure provision of a safe and reliable supply of electricity at all times. Safe conditions shall be ensured under all operating conditions including those associated with start-up and shut down of plant, as well as those arising out of failure of electrical equipment. The isolation of a part of system of electrical equipment due to either maintenance or shutdown shall not compromise safety. Power distribution system shall constitute sub-stations located near load centres as far as practical.
- ii) The design shall be broadly based upon the following factors:
 - Safety to personnel and equipment during operation and maintenance,
 - Reliability of service,
 - Ease of maintenance,
 - Convenience of operation,
 - Maximum interchangeability of equipment,
 - Elimination of fire risk,
 - Facility for ready addition of future loads.
 - Suitability for applicable environmental factors.
- iii) Special attention is drawn to Chapter IX of CEA Regulations 2010(Measures relating to safety & electric supply) which include requirements for design of electrical system as applicable to oil mines and oil fields.

4.1 Capacity of Electrical Plant

- i) All the components of the electrical system shall be sized to suit the maximum load, under the most severe operating conditions. The amount of electrical power consumed by each process unit shall be calculated for its operation at the design capacity. Accordingly, the maximum simultaneous consumption of power, required by continuously operating loads shall be considered and additional margin shall be taken into account for intermittent service loads and stand-by loads, if any.
- ii) While carrying out load analysis, loads shall be characterised under different heads as under:
 - Normal loads (continuous/intermittent loads)
 - Essential loads (Emergency loads)
 - Critical loads (e.g. computer, fire water pumps, communication, instrumentation controls, load for safe shutdown of plant including lighting in critical areas etc.
- iii) Required redundancy (based on specific process/operating needs) shall be built in the substation which feeds power supply to the process units/important facilities so that in case of tripping or scheduled outage of one feeder, the unit/facility does not get adversely affected.
- iv) The power system design shall ensure system reliability. This assumes particular significance where in-plant generation supplements the external power supply. For this,

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quick isolation of in-plant system from faulty grid, in-plant load shedding etc. requires detailed consideration.

- v) Before carrying out system design, it is recommended that the following minimum information/data be obtained, from the power supply authorities:
 - a) Incoming grid voltage and frequency, actual variation limits, guaranteed power availability.
 - b) Existing fault level of feeding bus and system expansion factor for fault level.
 - c) Location of feeding substation and routing of supply lines/feeder and the reliability of power supply, specifying power outages per year if any.
 - d) Size of conductor and current carrying capacity.
 - e) Supply system neutral earthing.
 - f) Details of protection relays and their settings at sending end breaker side.
 - g) Required metering arrangements at receiving end.
- vi) When capacitors are added to the system for power factor improvement, necessary system study should be carried out to decide measures for avoiding problems due to harmonics, system resonance, oscillatory torques in rotating equipment, in rush current, increase in voltage across capacitors due to use of series reactor, harmonic loading of capacitor, etc. The above assumes particular significance where there is captive generation.

4.2 Neutral Earthing

4.2.1 Earthed System^{Note-1}

- i) Power system neutral shall be earthed:
 - a) To limit the difference of electric potential between all uninsulated conducting objects in a local area.
 - b) To provide for isolation of faulty equipment and circuits when a fault occurs.
 - c) To limit over voltages appearing on the system under various conditions.

Note-1: In oil mines& oil fields, earth fault currents shall be limited to not more than 750 mA in installations of voltages exceeding 250 V and up to 1000 V. (Rule 100 of CEA regulations 2010).

- ii) The neutral earthing system employs one of the following methods:
 - a) Solid earthing for low, medium voltage system (upto 650V) and for high voltage above 11 kV.
 - b) Resistance / Impedance earthing for 3.3 kV to 11 kV system.
 - c) Resistance/Neutral Grounding Transformer earthing for Generators.
- iii) The values of neutral earthing resistors normally applied in industrial power system are selected to meet the governing criteria for limiting transient over-voltages, i.e. earth fault current should not be less than the system charging current. Besides, the value of neutral earthing resistor selected shall limit the earth fault current to a value, which shall be sufficient for selective and reliable operation of earth fault protection system.

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However, where an earthing transformer is used for obtaining the system neutral, the zero sequence reactance limit (i.e. $R_0 > 2 X_0$) should also be considered. (R_0 - zero sequence resistance of the circuit including neutral resistor and X_0 zero sequence inductive reactance of the circuit).

- iv) The neutral earthing resistor shall be able to carry at least 10% of its rated current continuously, unless otherwise required, and full rated current (100%) for a minimum duration of 10 seconds.

4.2.2 Unearthed System

- i) Use of unearthed system should be avoided since arcing ground faults can result in severe over voltages.
- ii) Where unavoidable (such as expansion projects where existing systems have unearthed system) unearthed system shall have provision for detecting earth fault and for isolation of faulty section through the use of core balance current transformers. The current transformers (CTs) shall be sized in relation to the system capacitive currents arising due to distributed capacitance of the entire network. The system shall also include alarm/tripping provision using unbalance voltage sensing through open delta potential transformers (PTs) under earth fault conditions. Provision of 'on line insulation monitoring facilities' may be considered.

4.3 Short Circuit Capacities

- i) Each short-circuit interrupting device shall have fault duty higher than the maximum value of short circuit current calculated at its location. The related switchgear and bus ducts shall withstand the above maximum fault current (mechanical and thermal stresses) for a minimum duration of one second.)
- ii) The sizing of high voltage cables shall be based on the short circuit withstand capacity for a minimum time period as dictated by the protection system in addition to the maximum anticipated load current carrying capacity.
- iii) It is to be noted that in the case of generators, whose excitation power is terminal dependent, short circuit in the system will result in drop of the terminal voltage and consequently the over-current protective devices may not get adequate current for operation. To avoid such a situation, necessary excitation support shall be provided unless otherwise required.
- iv) While sizing, the system necessary consideration shall be given to restrict the system voltage drop within permissible limits during starting of large rated motor or group of motors. At the same time, the short circuit current shall be kept within limits keeping in view of the market availability of switchgears. Reduced voltage starting (soft start feature, Auto transformer, star-delta starter etc.) for motors may be considered as per system requirements.

4.4 Insulation coordination

- i) The insulation of electrical facilities shall be designed considering the system voltage, the system neutral earthing, and the over-voltages resulting due to system fault, switching or lightning surges. The insulation co-ordination between the electrical equipment and the protective devices shall be done in line with IS: 3716 and IS: 2165.
- ii) Insulation coordination is a correlation of insulation of equipment and circuit with the characteristic of protective devices such that the insulation is protected from over voltages.

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- iii) The rated insulation level of equipment shall refer to the maximum system voltage, power frequency withstand voltage and impulse voltage withstand values which characterise the insulation. In respect of systems with nominal voltage of 132 kV and above, full insulation values shall be considered for non-effectively earthed system, and reduced insulation values should be used for effectively earthed system.

4.5 Protection and Metering

- i) The protective system shall be selected and coordinated to ensure the following:
- a) Protection of equipment against damage which can occur due to internal or external short circuits, overloading, abnormal operating conditions, switching, lightning surges, etc.
 - b) The continuity of operation of those parts of the system not affected by the fault, is maintained.
- and
- c) Personnel and plant safety.
- ii) Accordingly, relays and protective devices shall be suitably selected and coordinated. As a minimum, differential protection shall be provided for the following:
- a. Transformers rated 5 MVA and above,
 - b. Induction and synchronous motors rated 1500 kW above,
 - c. Generators rated 2 MVA and above.
 - d. Bus differential shall be provided for all HV switchgear having direct connection with the in plant generators and other vital HV switchgear.
- iii) Longitudinal differential protection shall be provided for important plant feeders in general, and plant feeders connected to a captive power plant bus in particular. Wherever the system is resistance earthed, restricted earth fault protection should be provided for transformer secondary.
- iv) Particular care should be taken in the selection of protective devices for machines and equipment operating in hazardous areas, so as to isolate the faulty section in the shortest time possible. For high voltage system, protective relays shall be used. For medium voltage systems, direct acting releases and/or protective relays and fuses may be employed.

In general, quick acting relays (with time delays if necessary) shall be used and all fault tripping shall be done through high speed tripping relays.

- v) The supply of Energy to every electrical installation other than low voltage installations below 5 kW and those low voltage installations which do not attract provisions of Section 54 of Indian Electricity Act, 2003 shall be controlled by an earth leakage protective device so as to disconnect the supply instantly on the occurrence of earth fault or leakage of current (Regulation 42 of CEA regulations 2010).

Provided that the above shall not apply to overhead supply lines having protective devices which are effectively bonded to the neutral of supply transformers and conforming to Regulation 73 of CEA regulations 2010.

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- vi) Metering instruments shall be provided on plant Main Switch Board to monitor the power consumption and supervision of all concerned parameters like current, voltage, power, frequency, power factor etc. Ammeters in the field for monitoring motor current shall be provided as per process requirements. Metering and protection current transformers shall be preferably kept separate. However, numerical relays may be fed from a single set of CTs for both metering and protection. In the case of control cables having long length (more than 800 m or so) due consideration shall be given to the effect of capacitance.
- vii) Annunciation for trip circuit supervision relay shall be provided in control room / operator room for immediate attention of abnormality in tripping circuits.
- viii) Recommended relay protections for Transformers, motors and feeders which are generally encountered in distributing network are given below :

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TABLE-I
Relay protection system

Protection devices for power distribution system shall be as indicated below
(Figure inside bracket refers to note below) √ Applicable

RELAY DESCRIPTION	RELAY NUMBER	HV TRANSFORMER FEEDER		HV MOTOR FEEDER	OUTGOING BREAKER FEEDER		INCOMER	
		(SECONDARY WINDING VOLTAGE ≥ 3.3 KV)	(SECONDARY WINDING VOLTAGE ≤ 0.433 KV)		HV PLANT FEEDER	MV PCC/ PMCC	HV	MV PCC/ PMCC
IDMTL over-current relay	51	√	√	-	√	√	√ (1)	√
IDMTL earth-fault relay	51N	√ (2)	√	-	√	√	√ (1)	√
51G backup earth-fault relay (earthed neutral)	51G (11)	√	√	-	-	-	-	-
Motor protection relay with (50, 50N, 46, 49, 50L/R, 86, 95)	99	-	-	√ (3)	-	√ (3)	-	-
Instantaneous restricted earth-fault relay (earthed side)	64R (11)	-	-	-	-	-	√	√
Instantaneous over-current relay	50	√	√	-	-	-	-	-
Instantaneous earth-fault relay	50N	√ (4)	√	-	-	-	-	-
Differential protection relay	87	√ (5)	-	√ (6)	√ (7)	-	-	-
High speed tripping relay	86 (20)	√	√	√	√	√	√	√
Trip circuit supervision relay	95 (20)	√	√	√	√	-	√	√
Transformer auxiliary relay	63	√	√	-	-	-	-	-
Under-voltage relay with timer	27/2	-	-	√	-	-	√ (9)	√ (9)
Check synchronisation relay	25	-	-	-	-	-	√ (10)	√ (10)

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TABLE -II
Power generation and External power supply

Minimum protection relays for Synchronous generator (GTG/STG), generator transformer
National power supply incomer and Synchronous motors shall be as follows

(Figure inside bracket refers to note below) ✓ Applicable

RELAY DESCRIPTION	NEMA CODE	GENERATOR	GENERATOR TRANSFORMER	EHV INCOMER	EHV TRANSFORMER	SYN MOTOR
Distance protection	21	-	-	✓	-	-
Synchronous check	25	✓(27)	✓	✓	-	-
Under voltage with timer	27	✓	-	✓	-	✓
Reverse power	32	✓	-	-	-	✓
Low power flow	37	✓	-	-	-	-
Loss of excitation	40	✓	-	-	-	✓
Negative sequence	46	✓	-	-	-	✓
Over current	50	-	-	-	✓	✓
Earth fault relay	50N	-	-	-	✓	✓
Over current	51	-	-	✓	✓	-
Voltage restrained	51V	✓	✓			-
Earth Fault back up	51G	✓	✓		✓	-
Over current E/F	51N	-	✓	✓	✓	-
Over voltage with timer	59	✓	-	✓	-	✓
VT failure	60	✓	-	-	-	✓
Auxiliary relay for transformer	63TX	-	✓	-	✓	-
Restricted Earth Fault	64R	✓(26)	✓	-	✓	-
Stator back up earth fault	64G	✓	-	-	-	-
Rotor Earth fault	64R	✓	-	-	-	✓
Directional O/C	67	-	-	✓	-	-
Directional E/F	67N	-	-	✓	-	-
Under frequency/df/dt	81	✓	-	✓	-	✓
Tripping relay	86	✓	✓	✓	✓	✓
Gen differential	87G	✓	-	-	-	-
Gen and Transformer differential	87GT	-	✓	-	-	-
Transformer differential	87T	-	✓	-	✓	-
Feeder differential	87F	-	-	-	✓	-
Bus bar differential and check	87B/87CH	-	✓	-	-	-
Trip circuit supervision	95	✓	✓	✓	✓	-
Dead bus charging relay	98	✓ (27)	✓	✓	-	-

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RELAY DESCRIPTION	NEMA CODE	GENERATOR	GENERATOR TRANSFORMER	EHV INCOMER	EHV TRANSFORMER	SYN MOTOR
Over fluxing	99	√	√ (28)	-	-	-
OUT OF STEP	78	√	-	-	-	√

Notes:

1. In case of HV switchboards with continuous parallel operation of incomers, following additional relays shall be provided:
 - a. One set of 87B (Bus differential) and 95 B (Bus wire supervision) for each bus section.
 - b. 67 and 67N (Directional IDMTL over current and earth fault) relays for the incomers.
2. Instantaneous earth fault (50N) shall be provided only for transformer with delta primary.
3. For breaker fed motor feeders. Relay 50 shall not be provided for contactor controlled feeders.
4. Directional IDMTL earth fault (67N) shall be provided for transformer with star primary.
5. For transformers rated 5 MVA and above.
6. For motors rated 1500 kW and above.
7. For critical/long feeders and plant feeders connected to main power generation and distribution bus. A plant feeder implies outgoing feeders from one switchboard to another switchboard of same voltage level.
8. Intentionally left blank.
9. Wherever auto-transfer feature is provided
10. For switchgears where continuous or momentary paralleling of Incomers is envisaged, check synchronising relay shall be provided
11. 51G and 64R relays shall not be provided for input transformer of VFD system.
12. The bus tie feeders in HV switchboards shall be provided with 51, 51N, 86 and 95 relays.
13. HV capacitor bank feeders shall be provided with 51, 51N, 59 (over voltage), 60 (Neutral displacement), 86 and 95 relays.
14. The following feeders shall be provided with timers for delayed tripping on bus under voltage while the under voltage relay shall be common for the bus
 - a. HV and MV capacitor feeders
 - b. HV and MV breaker controlled motor feeders
 - c. Contactor controlled motor feeders with DC control supply.

Numerical relays where ever provided for motor and capacitor feeders shall use in built under voltage relay and timer for delayed tripping on bus under voltage.
15. One no. DC supply supervision relay (80) shall be provided for each incoming DC supply to the switchboard.
16. One set of bus differential relays (87B) and bus wire supervision relay (95 B) for each bus section shall be provided for HV switchboards connected directly to generation buses
17. In case of numerical relays, all relays shall be comprehensive units including protection and metering.
18. Wherever numerical relays are used, under voltage and over voltage functions alongwith associated timer may be part of the numerical relays.
19. Wherever numerical relays are used, Auto changeover logic between Incomers and bus coupler(s) may be built in the numerical relay.
20. Wherever numerical relays are used, Tripping relays (86) & Trip Circuit supervision relay (95) may be part of the numerical relay.

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21. 2Nos of 86 relays shall be considered for HV and MV breaker fed motors, for ease of differentiating between Process and Electrical trips.
22. Breaker control switch shall be hardwired type.
23. Stand by earth fault relay 51G shall be provided in the incomer of switchboard fed from transformers and transformer and switchboard located remotely from HV substation.
24. Restricted earth fault relay 64R shall be provided for Transformer rating ≥ 2.5 MVA in the incomer of switchboard fed from transformers having secondary voltage greater than 3.3KV and secondary winding is star connected.
25. Relay 51V voltage controlled over current relay shall be provided on specific requirement considering the rating of the outgoing feeders with respect to the Incomer rating. Generally this relay shall be provided wherever CT primary current of outgoing feeders is exceeding 40% of the CT primary current of the Incomer.
26. 415V DG set shall be provided with protection but not limited to 51V, 51G, 40, 46, 86, 95, 80, 64R etc. for generator rated above 500 KVA and Generator rated less than 500 KVA shall have 51V, 51G, 40, 46, 86, 95, 80 unless otherwise agreed with the owner.
27. For directly connected Generator.
28. For large transformers as per manufacturer's standard.

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ix) Medium Voltage Motor Protection:

- The minimum protection requirement shall include fuses and thermal overload relay suitably co-ordinated with contactor characteristics as per applicable Indian Standards (BIS). However MV Motors controlled by circuit breakers should have either releases or relays for Motor Protection.
- Large rating motors which are contactor fed (55 KW and Above) should have core balance earth fault protection in addition to bimetal and fuse coordination or composite motor protection relay.
- Bimetal relays shall be preferably with inherent protection against single phasing.

4.6 Emergency Power Supply

- i) This is an independent back-up source of electric energy that upon failure or outage of normal source, automatically provides reliable electric power within specified time to critical devices and equipment whose failure to operate satisfactorily may jeopardise the health and safety of personnel or result in damage to property.
- ii) The emergency power supply system shall feed the following loads to enable continuity of supply in the event of failure of MAIN SUPPLY.
 - Electrical loads essential for the safe shutdown of the plant.
 - Emergency lighting, security lighting, obstruction lights.
 - Process plant instruments as required
 - Communication equipment, Fire Alarm control panels.
 - D.C. Supply system, UPS system
 - Auxiliaries of emergency set as applicable
 - Fire fighting equipment excluding main fire water pumps
 - Essential ventilation loads, and
 - Loads critical for process, plant and personnel safety.
- iii) Emergency power supply shall be available as per process/equipment requirements, but within a period not exceeding 30 seconds from the instant of failure of normal supply. Emergency Power shall be supplied from suitably rated diesel generator set conforming to CPCB/MOEF guidelines.
- iv) Unless otherwise required, the emergency generator in general should not run continuously in parallel with the normal power supply system. However, to facilitate periodic testing and maintenance it is preferable to include synchronising facilities for short time parallel operation of D.G. set with approval from electrical supply authorities.
- v) Upon restoration of normal power supply, it is preferable to synchronize the DG supply with the normal supply and only then switch-off the DG set. This will avoid unnecessary tripping of the emergency loads upon restoration of normal power supply.

4.7 Critical Power Supply Systems

- i) These systems shall have inherent independent battery backup to maintain continuity of supply to critical loads (e.g. process control, communication, fire alarm systems etc.) in the event of normal/emergency supply failure.

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4.7.1 Un-interrupted Power Supply(UPS)

- i) An un-interrupted power supply shall be provided, as required for meeting critical loads that cannot withstand a momentary interruption/other A.C. mains disturbance in supply voltage. A separate battery shall be provided for UPS system.
- ii) UPS supply should be provided for control circuit of all the critical variable speed drives.
- iii) It is desirable that a 2 x 50% battery bank configuration be provided.
- iv) Following loads shall be connected to the UPS system:

- Critical instrumentation and process control,
- Critical communication equipment,
- Microprocessor based Digital Control System.

Incoming power to the UPS system shall be fed from the emergency system, wherever provided.

- v) In case of total power failure, un-interrupted power supply shall be available for at least 30 minutes or as determined by the process considerations.
- vi) Each branch circuit of the UPS distribution system shall have a fused disconnect switch. The fuse shall be fast clearing type and the fuse rating shall be coordinated with the rating of the UPS system.

4.7.2 DC Power Supply

- i) Unless otherwise specified, independent DC power supply systems shall be provided for the following:
 - Plant shut-down system and DC instrumentation.
 - Electrical switchgear controls and critical (escape) lighting, critical D.C. drives viz. Lube Oil pumps etc.
- ii) Each DC power supply system shall include charger-cum-rectifier, battery and DC distribution board. DC link in the UPS system shall generally not be tapped for DC instrumentation power supply except in rare circumstances.
- iii) It is desirable that a 2 x 50% battery bank configuration be provided.
- iv) Fire alarm system shall have a dedicated DC battery backup system.
- v) DC supply for electrical controls, instrumentation, UPS etc. shall have separate independent battery banks. The DC bus for electrical controls and DC lighting should preferably be distinct to avoid switchgear control supply being affected by faults in DC lighting circuits.

4.7.3 Battery Sizing for DC systems

i) Electrical Switchgear and Controls

Battery shall normally be sized for a load cycle having a minimum duration of one hour. While deciding the load cycle, consideration shall be given to the specific operating/safety requirements of plant & equipment e.g. lube oil pump of STG for bearing oil flushing. The duration for battery sizing hence shall vary accordingly as per specific operational requirements.

ii) DC Instrumentation Shutdown System

This shall in general be sized for 30 minutes, unless otherwise required.

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iii) Fire Alarm System

The battery shall be sized for the duration and load in line with the guidelines given in NFPA 72 guidelines as under:

The secondary power supply (battery shall have sufficient capacity to operate the fire alarm system under quiescent load (system operating in a non alarm condition) for a minimum of 24 hours and at the end of that period, shall be capable of operating all appliances used for evacuation or to direct aid to the location of an emergency for 5 minutes.

- (A) The secondary power supply for emergency voice/alarm communications service shall be capable of operating the system under quiescent load for a minimum of 24 hours and then shall be capable of operating the system during a fire or other emergency condition for a period of 15 minutes at maximum connected load.
- (B) The secondary power supply capacity for supervising station facilities and equipment shall be capable of supporting operations for a minimum of 24 hours. “

iv) EPABX (Telephone System)

This will have an independent battery backup system.

4.7.4 Annunciation

For plant DC systems Sensitive earth fault detectors along with Earth leakage current ammeter having centre zero shall be provided in DC system to annunciate earth faults.

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5.0 Electrical Equipment for Classified Areas

- i) All the areas within the Battery limits shall be classified for degree and extent of hazard from flammable materials. The basis for hazardous area classification recognises the differing degrees of probability with which flammable atmosphere may arise in the installation, in terms of the frequency of occurrence and the probable duration of existence on each occasion.
- ii) Following factors shall be considered for proper selection of electrical apparatus and equipment for areas where flammable gas or vapour risks may arise:
 - a) Area classification, i.e. Zone 0, 1 or 2
 - b) Gas group classification, i.e. gas groups IIA, IIB or IIC.
 - c) Temperature classification i.e. T-Rating.
 - d) Environmental conditions in which apparatus is to be installed.

Wherever practicable, electrical apparatus in general and switch and control apparatus in particular shall be installed in safe area. Substation and control room shall be located in safe area. While deciding the route of overhead power lines, necessary considerations shall be given to avoid overhead lines passing through hazardous areas.

Electrical equipment intended for service in hazardous area shall be selected in accordance with IS : 5571 and these shall be certified by recognised testing/certifying authorities of country of origin (e.g. CIMFR, LCIE, UL, FM, PTB, Baseefa etc.) and approving authorities i.e. CCoE or DGMS or DGFASLI as applicable.

For details on hazardous area classification, enclosure protection etc. OISD standard 113, National Electric Code IS 5571, 5572, Petroleum Rules and Oil Mines Regulations shall be referred.

General guidelines for type of protection for electrical equipment in hazardous areas are enumerated in Table-III.

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**TABLE-III
TYPES OF PROTECTION**

Area Classification	Description	Symbol
Zone 0	Intrinsic safety category 'ia'	'i _a '
	Encapsulation	'm _a '
	Other electrical apparatus, specifically designed for Zone 0. (See Note 1)	's'
Zone 1	Any type of protection adequate for Zone 0.	
	Intrinsic safety category 'ib'	'ib'
	Flame proof enclosure (See Note 6)	'd'
	Pressurisation (See Table IV)	'p', 'p _x , p _v '
	Powder filling	'q'
	Encapsulation	'm', 'm _a ', 'm _b '
	Other electrical apparatus specifically designed for Zone 1	's'
	Oil Immersion (see note 4)	'o'
Zone 2	Any type of protection adequate for Zone 0 or Zone 1	
	Intrinsic safety category 'ic'	'ic'
	Increased safety (See Note 2)	'e'
	Non-sparking apparatus (See Note 2)	'n'
	Pressurisation (See table IV)	'p _z '
	Encapsulation	'm', 'm _a ', 'm _b '

Note 1 It may be noted that as per petroleum rules the use of intrinsically safe electricity apparatus in zone '0' area is permitted only when the use of such apparatus cannot be completely excluded, whereas the Oil Mines regulations prohibit use of any electrical equipment in zone '0' areas.

Note 2 The apparatus with type of protection 'e' and type of protection 'n' when installed outdoors shall have enclosures having the ingress protection as recommended in IS/IEC-60529..

- a. IP 55 where there are uninsulated conducting parts internally, and
- b. IP 44 for insulated parts.

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In case of usage of Ex-nA type of motors the requirement of pre-start purging shall be verified based on requirements of IEC-60079-15.

Note 3 Name plate details of equipment intended for use in hazardous area shall include relevant marking of hazardous protection as per applicable codes.

Note 4 Oil-immersed apparatus may be used only in case its security will not be impaired by tilting or vibration of the apparatus.

Note 5 Flameproof enclosures are covered under compulsory certification.

Note 6 : In Zone '1' areas, Ex d/e equipment i.e. Ex 'd' equipment with Ex 'e' terminal boxes is also permissible.

TABLE-IV
MINIMUM ACTIONS ON FAILURE OF PROTECTIVE GAS FOR TYPE OF PROTECTION 'P'

Area Classification	Enclosure does not contain ignition capable apparatus	Enclosure contains ignition capable apparatus
Zone 1	Alarm	Alarm and switch off
Zone 2	No action required	Alarm

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6.0 SUBSTATION LOCATION / LAYOUT

The sub-station shall be located in a safe area. Consideration shall be given to cooling tower sprays, vapours contributing to insulation break down, vehicular traffic, accessibility for installation of equipment or any other factor that might affect the safe operation of the sub-station. (Refer also OISD Standard 118 'Layout for Oil and Gas Installations')

- i) In large plants, the main sub-station floor shall be raised above grade level and the space below the sub-station floor shall be utilised for installation of cable trays. The substation cellar shall preferably have a clear height of at least 2 meters. The cable cellar floor shall preferably be at least 300 mm above the approach road level. The switchgear rooms shall preferably be pressurised to prevent ingress of dust. Large substation (length greater than 60 meters) shall have three entries, one for equipment entry, second for normal entry and the third emergency exit. Whereas required normal and equipment entries can be combined.

Pressurised substation shall have necessary airlock lobby for the normal entry.

Small and medium size substations shall have one equipment cum normal entry and the second for emergency exit. Emergency exit door in substation shall open outwards. The main entry for operating personnel shall preferably be provided with double door system. Operator cabin may be separately located to avoid repeated opening of doors and dust entry to substation. Pressurised substation building shall have fixed glazing with minimum number of openable windows. All openings shall be kept properly closed to maintain sufficient pressure inside to prevent dust entry.

- ii) Non pressurised remote switch room/offsite substation shall have fixed glazing with suitable exhaust fans with louvers to meet the ventilation requirements. Proper maintenance and care shall be taken to keep the room free from dust.
- iii) The building shall be sized to take care of present/future needs and to maintain adequate clearances between equipment, and equipment and wall for ease of operation and maintenance. Small sub-stations shall be suitably elevated by compacting the soil so that the bottom of the cable trench within substation is above the surrounding grade level.
- iv) Normally transformers, reactors, neutral earthing resistors etc. shall be installed outdoor. Equipment like UPS system and Variable frequency drives shall be installed in a separate air-conditioned room. The battery banks shall be located in a separate, freely ventilated room in the substation building along with the necessary fresh air inlet and exhaust system considering required number of air changes and water connection. Battery room door shall be provided with louvers at the bottom to aid cross-ventilation. Floor of the battery room and the walls up to height of one metre shall have acid resisting material/coating/be painted with acid/alkali resistive paint or otherwise protected. In case of VRLA & Gel type Batteries air conditioned environment is recommended to get the desired battery life span.
- v) Necessary space to keep equipment under repair such as breakers, switch control gear items, spares/consumables like fuses etc. shall also be identified in building layout.
- vi) It is recommended to locate DG sets in a separate house/shed away from Substation in a safe area to reduce noise level in substation. If required DG set of smaller rating can be located in substation building provided the substation is located in a safe area. However in such cases, the foundation of such D.G. sets shall be structurally delinked from the slab or floor of the rest of the substation building. Exhaust of Diesel Engine shall be kept away from Process/Hydrocarbon area.
- vii) Transformer yard/bay shall be provided with fencing and gate and shall have fire isolation walls for individual transformers. Oil immersed equipment involving use of large quantity of oil shall have oil soak pit and drain arrangement as per CEA Regulations 2010 . Fire fighting

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equipment, first-aid boxes, etc. shall also be provided as required. (Further guidelines on this can be had from OISD standard 116 - 'Fire Protection facilities for Petroleum Refineries and Oil/Gas Processing Plants' and OISD standard 117 'Fire Protection Facilities for Petroleum Depots and Terminals.)

- viii) The substation equipment layout and the clearances between different equipment shall be planned to ensure ease of operation and maintenance and meet all requirements from the point of view of safety of the operating personnel.
- ix) Clearance between various equipment shall also satisfy respective equipment manufacturer's requirements and CEA Regulations 2010. Where these are not specified the following minimum clearances are recommended as general guidelines.

Description	Distance
a) At the rear of HV Switchboard	1500mm
b) At the front HV Switchboard	2000mm
c) At the side of various Switch boards and from wall	1000mm (Otherwise less than 200 mm)
d) At the front of various Switchboards	1500mm
e) Between front to front of two Switchboards. (Say DRAWOUT MCCS) facing each other.	2000 mm
f) At the rear of MV Switchboards requiring rear access	1000mm
g) Rear clearance in other cases	More than 750mm otherwise less than 200mm.
h) Transformers with wall on one side	As per IS 10028
i) Transformers with walls on three sides	As per IS 10028
j) Clear height of bus-duct from finished floor level	2000mm
k) Clear space between Switchboard top and beam soffit	1000mm

Note: The maximum length of switchgear line-up may preferably be limited to 15-20 metres considering operation and maintenance requirements.

- x) It is recommended that battery room, UPS room, process shut-down DC system room, operator's room of large sub stations, located close to process units should have blast resistant walls, if required as per Safety Study. This is to protect vital control power sources from any external damage, thus ensuring availability of control power for safe shutdown in disastrous conditions.

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7.0 ELECTRICAL EQUIPMENT

Electrical equipment shall be selected, sized and installed so as to ensure adequacy of performance, safety and reliability. The equipment in general shall conform to relevant Indian Standards and shall be suitable for installation and satisfactory operation in the service conditions envisaged. Specific attention is drawn to IS:9676 for deciding the design ambient temperature of electrical equipment.

7.1 CHARACTERISTICS

Every item of electrical equipment selected shall have suitable characteristics appropriate to the values and conditions on which the design of the electrical installation is based and shall in particular, fulfil the requirements given in Clause i) to vii) below.

i) Voltage

Electrical equipment shall be suitable with respect to the maximum steady voltage (rms value for AC) likely to be applied, as well as over voltages likely to occur.

Note: For certain equipment, it may be necessary to take account of the lowest voltage likely to occur.

Considerations shall also be given to the protective measures inherent in the systems and the method of neutral earthing viz. earthed or unearthed system.

ii) Current

All electrical equipment shall be selected with respect to the maximum steady state current (rms value for AC) which it has to carry in normal service, and with respect to the currents (prospective, short circuit currents) likely to be carried under abnormal conditions and the period (for example, operating time of protective devices, if any) during which it may be expected to flow.

iii) Frequency

Electrical equipment shall be suitable for continuous operation with respect to the system rated frequency with variation limits likely to occur.

iv) Power

All electrical equipment to be selected on the basis of their power characteristics shall be suitable for the duty demanded from the equipment, taking into account the load factor and the service conditions. Each equipment shall be able to deliver its rated power for specified supply and site conditions with temperature rise remaining well within the design limits as per applicable IS codes.

v) System earthing

All electrical equipment shall be selected considering the system neutral earthing particularly in high voltage systems where resistance earthing is commonly employed.

vi) Conditions of Installation

- a) All the electrical equipment selected shall have proper protection against corrosive and solvent agents, water ingress, thermal and mechanical stresses as determined by the environmental factors. If, however, an item of equipment does not have by design, the properties corresponding to its location, it should be used on condition that adequate additional protection is provided as part of the completed electrical

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installation. In addition to the above, noise level and cooling/ventilation shall also be considered.

PAINTING

a) Rotating Machinery

Internal and external parts of the casing and all metal parts likely to come in contact with the surrounding air should be protected with epoxy paint that will resist corrosion under the particular atmospheric conditions.

b) Switchgear panels and service boards

Painting of the switch gear panels should be as per manufacturer's standard.

All unpainted steel parts should be zinc passivated or suitably treated to prevent corrosion. If these parts are moving elements, then these should be greased.

c) Outdoor electrical equipment

Painting of the outdoor equipment should be as per manufacturer's standard and site environmental conditions. All metal parts likely to come in contact with the surrounding air should be protected with epoxy paint that will resist corrosion under the particular atmospheric conditions.

vii) Prevention of Harmful effects

a) All electrical equipment shall be selected so that it will not cause harmful effects on other equipment or impair the supply during normal service including switchgear operations. In this context, the factors which may have an influence include:

- Power factor
- Inrush current
- Asymmetrical load
- Harmonics
- Transient voltage dips/overshoots.

b) Energised parts shall be sufficiently enclosed or isolated so as not to expose personnel to explosion, fire, arcing, or shock hazards. Adequate safety features shall be incorporated in equipment design for the safety of operating personnel.

7.2 EQUIPMENT FEATURES

Certain essential safety features in design to be considered in specifying and sizing of commonly encountered equipment such as Transformer, Switchgear, Motors, Cables, Battery charger, Battery, and UPS etc. are enumerated below.

7.2.1 Transformers

i) The kVA rating shall depend upon the maximum simultaneous continuous load and probable system expansion loads. In general, the rating and the percentage impedance of each transformer shall be selected to limit the continuous current rating and short circuit current to values within the ratings of available switchgear. The transformer impedances shall generally be as per Indian standards unless otherwise required. The rating and the percentage impedance of transformer shall be compatible to permit start

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of highest rated motor while the transformer is preloaded with maximum operating base load.

- ii) Transformers connected to Grid supply may have ON LOAD TAP CHANGERS for in-plant control of secondary voltage. Plant distribution transformers may have OFF CIRCUIT TAP changers.
- iii) In addition to standard accessories, the transformer shall be provided with auxiliary devices/protective devices such as Buchholz relay, pressure release valve, oil level and oil temperature indicator with alarm/ trip output contacts and current transformers for the secondary side neutral for Protection. Transformers of rating above 2000 kVA should have winding temperature indicators with Alarm/Trip provisions. Stay put type emergency stop push button shall be provided to trip the transformer in case of emergency.

7.2.2 High Voltage (HV)/Medium Voltage (MV) Switchboards

- i) These shall be designed to ensure maximum safety during operation, inspection, connection of cables and maintenance with Switchboards energised.
- ii) The switchboard shall be totally enclosed, dust and vermin proof.
- iii) Each unit of the switchgear shall have necessary internal sheet metal barrier to form separate compartments for buses instruments/relays/cable connections etc. Compartment for cable connection shall allow cable pulling, termination and connection work with switchgear energised. Suitable arc propagation barriers shall also be provided. Independent pressure release flaps shall preferably be provided for each HV compartment of HV Switchboards. Terminal strip for outgoing control cable connections should be accessible to facilitate working and testing with breaker in test/service condition and while the switchboard is energised.
- iv) Barriers shall be provided to permit personnel to work safely within an empty compartment with the bus bars energised. The minimum clearances between live parts and between live parts to earth and neutral and creepage distance of bus bars shall conform to IS/IEC 60947.
- v) The drawout carriage on the switchboard shall have three positions viz., 'Service', 'Test' and 'drawn out'. Automatic safety shutters shall be provided to ensure the inaccessibility of all live parts after the breaker is drawn out. It shall not be possible to drawout the carriage or rack it in with circuit breaker closed. The breaker/contactor feeder trolley shall remain inside the cubicle even in the test position. There shall be distinct overall door for the breaker compartment and it should be lockable. All circuit breaker truck/trolley of the same rating shall be interchangeable.
- vi) Suitable interlocks shall be provided to prevent faulty operation such as:
 - 'Plugging in' or 'drawing out' of a closed breaker.
 - 'Plugging in' a breaker with earthing isolator closed.
 - 'Closing' of earthing isolator with the breaker 'Plugged in'.
 - Pulling out of auxiliary circuit plug with breaker in service position.
 - Pushing in breaker to service position with auxiliary circuit plug not in position.
 - Opening of compartment door with isolating switch in ON position and vice-versa for Motor Control Centres.

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- The maximum height of operating handle/switches shall not exceed 1900 mm and the minimum height not below 300 mm.
 - It shall not be possible to operate the circuit-breaker unless it is fully in service or Test or isolated position.
- vii) Suitable eye bolts for lifting of panels shall be provided. On removing the eye bolts, no holes offering access to panel shall be permitted.
- viii) Busbars and supports shall withstand specified short circuit level without permanent deformation. Busbars shall be preferably sleeved and joints shall be taped/shrouded. Switchboards shall have additional safety features such as falling tool shrouds for trapping of free fall of maintenance tools on live parts. Busbar supports shall be of synthetic material with high tracking index. The switchboard shall have earth busbar of adequate size. The switchgear drawout trolley (in case of drawout design) shall have suitable scraping earth connection. Feeder tag plates shall be provided at both front and rear side of panels. Where required, busbar routing shall be clearly marked on the back side of the H.V. Switch board panels for easy identification during maintenance.
- ix) All non-current carrying metallic parts of mounted equipment/components shall be bonded to the earth bus.
- x) Surge absorbers to limit the switching surges shall be provided as dictated by the type of arc quenching media and switching device.
- xi) Starting of motors from substation shall not be allowed and switch boards shall not have close push button at switchboard for motor starting.
- xii) In specific cases, motors requiring frequent start/stop, (e.g. product, loading pumps etc.) shall be controlled by contactor feeder appropriate to its rating.
- xiii) Switch Boards shall have anti condensation heaters.
- xiv) All HV switch gears should have provision of view glasses to take thermo graphic readings for predictive/preventive maintenance. It must be ensured that all such switch gears with view glasses windows have been duly type tested and certified for internal arc faults as per the provisions envisaged in IEC:62271 or other equivalent international standards.

7.2.3 MOTORS HIGH VOLTAGE (HV) & MEDIUM VOLTAGE (MV)

7.2.3.1 General

- i) Motors shall be totally enclosed, fan cooled type as far as practicable. As a minimum, all HV motors shall have anti condensation heaters. The minimum degree of enclosure protection for motor shall preferably be IP 44 for indoor use and IP 55 for outdoor duty motors.
- ii) Generally Motors upto and including 160 kW shall be rated for medium voltage and motors of rating above 160 kW shall be rated for high voltage. If required, the rating of medium voltage motors may be extended up to and including 200 kW. Sleeve or anti friction type bearings shall be used. Vertical motors shall have thrust bearings suitable for the load imposed by the driven machinery. Unless otherwise specified, all motors shall be designed for 'Direct ON line' starting.
- iii) High voltage DOL starting motors shall be suitable for starting under specified load conditions with 80% of the rated voltage at the terminals and medium voltage DOL starting motors shall be suitable for starting under specified load conditions with 75% of the rated voltage at the terminals.
- iv) The permissible noise level shall not exceed the stipulations laid down in IEC 60034-9.

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- v) Motor vibrations shall be within the limits of IS- 12075 unless otherwise specified for the driven equipment. Motors with sleeve bearings may require proximity probes to measure shaft vibration adjacent & relative to the bearings.
- vi) Motors shall be required for continuous, satisfactory operation at rated output under the following conditions :
 - a) The terminal voltage differing from its rated value by not more than $\pm 6\%$.
 - b) The frequency differing from its rated value by not more than $\pm 3\%$
 - c) Any combination of (a) and (b).
- vii) Motor ratings and torque characteristics shall be adequate to accelerate the load from zero to rated speed under starting requirements as stipulated by process operating conditions. Normally, the starting time shall be less than the hot withstand time of the motor.
- viii) MV Motors in general and HV Motors where required shall be suitable for restarting under full load after a momentary loss of voltage with the possibility of application of 100 percent of the rated voltage, when the residual voltage has dropped down to 50 percent and is in phase opposition to the applied voltage.
- ix) Medium voltage motors above 55 kW rating and not requiring frequent starts; should be provided with suitable type of circuit breakers and composite motor protection relays.
- x) Motor bearings shall be selected to give a minimum L-10 life rating of 5 years (40,000 hours) at rated operating condition (the L-10 rating life is the number of hours at constant speed that 90% of a group of identical bearings will complete or exceed before the first evidence of failure). The bearings shall be adequate to absorb axial thrust in either direction produced by the motor itself or due to shaft expansion. On line greasing facility should be provided on motor for all grease lubricated bearings (anti friction bearings). Wherever space heaters are provided for motors, a separate terminal box should be provided for termination of space heater cables, as far as practicable. Pre-lubricated bearings may be considered provided they have a guaranteed life of 4 to 5 years without need of re-lubrication.
- xi) Considerations should be made at the design stage for the torque values of all the Pumps / Fans requiring auto re-acceleration with discharge valve open.
- xii) The VFD driven motors shall be suitable for the associated harmonics and lesser cooling as a consequence of speed variations.

7.2.3.2 H V Motors

- i) Winding insulation shall be class F and temperature rise limited to that specified in the applicable IS for class B insulation.
- ii) Motors shall be designed to allow minimum number of consecutive hot starts as dictated by process operating requirements. Number of uniformly spaced start-ups in an hour shall be a minimum of three.
- iii) The main power Terminal Box shall preferably be phase segregated and suitable to withstand the specified fault level for a minimum duration of 0.2 sec. (Commensurate with instantaneous short circuit protection). Winding ends shall be preferably brought out and star point made in a separate terminal box. Neutral terminal box shall have

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necessary space provision to mount differential CTs for motors of rating 1500 kW & above.

- iv) Motors of rating above 1000 kW shall be provided with RTDs, BTDs and scanners. Separate terminal boxes shall be provided for space heater and RTDs, BTDs.
- v) Induced voltage at the shaft of the motor having uninsulated bearing system shall not exceed 250 mV r.m.s. for roller and ball bearings and 400 mV r.m.s. for sleeve bearings with the motor running at no load. Alternatively, the non driving end bearing shall be insulated from the motor frame to avoid circulating current.
- vi) The insulated bearing end shield or pedestal shall bear a prominent warning and manufacturer shall provide detailed drawing showing insulation arrangement.
- vii) Motors shall be designed to withstand impulse voltage of at least $(4U_n+5)$ kV with a wave front rise time of 1.2 microsecond and decay time of 50 microsecond to half the peak voltage.
- viii) The inter-turn insulation of HV motors shall be able to withstand a peak voltage of at least $0.5 (4U_n+5)$ kV with a wave front rise time between 0.5 & 1.5 μ s and a decay time to half the peak voltage of between 3 & 10 μ s.
 U_n = rated line to line voltage.
- ix) Polarisation index
Polarisation index of HV stator winding shall have a value of at least 2. If the insulation value of the motor exceeds a value of 120 (U_n+1) (where U_n is rated line - line voltage (kV) M Ω , a minimum polarisation index of 1.5 is acceptable.

7.2.3.3 M V Motors

- i) Motors shall be designed to allow three consecutive starts from cold condition, two consecutive starts from hot condition and four uniformly distributed starts in one hour.
- ii) Winding insulation shall be class B or class F and temperature rise limited to that specified in the applicable IS for class B insulation. The windings shall be tropicalised and adequately braced. The ends of the windings shall be brought out in a terminal box with six terminals with suitable links to connect them in Delta. However, motors rated up to 2.2 kW may be connected in star with three terminals.
- iii) The terminal box of motor controlled by air circuit breaker shall be capable of withstanding the full internal short circuit conditions, with the specified system fault level for a minimum duration of 0.2 second (Commensurate with instantaneous short circuit protection). Where motor control is through contactor and MCCB, or back up fuse, the terminal box shall be able to withstand the let-through energy of protective devices corresponding to maximum system fault level.
- iv) The terminal box shall be of sturdy construction and large enough to facilitate easy connection of required number of cable runs and size. (Specifically Aluminium Conductor Cables). Additional trifurcating boxes may be considered for motors requiring termination of two or more parallel runs of power cables.

7.2.4 Battery Charger and DC Distribution Board

Charger and distribution board shall be floor mounted, free standing, metal enclosed and vermin proof type having front access hinged door and suitable for indoor use.

This shall consist of battery charger/rectifier, which shall feed the load and keep the batteries under fully charged condition. Provision shall also be made for necessary boost charging/initial charging of battery. Redundancy (N+1) of the battery chargers shall also be considered for critical applications.

7.2.5 Batteries and Battery Accessories

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- i) Batteries shall be indoor stationary type with adequate capacity to meet the backup requirements as envisaged in the duty cycle. Accessories shall generally be as follows:
 - Battery stand made of solid polymer or epoxy/ powder coated mild steel (MS).
 - Inter-cell, inter row and interbank connectors and end take offs.
 - Porcelain cell insulators, stand insulators. (As applicable)
 - Hydrometers suitable for specific gravity readings.(As applicable)
 - Cell number plates as required.
 - Thermometer with specific gravity correction scale. (As applicable)
 - Cell testing voltmeter (3V-0-3V) complete with 1 m long leads.
 - Rubber gloves
 - Rubber aprons
 - Spanner Set.
- ii) While sizing the battery following factors shall be taken into consideration, in addition to envisaged duty cycle:
 - Temperature correction factor.
 - Ageing factor as applicable.

7.2.6 Equipment for Uninterrupted Power Supply System

- i) This shall be of free-standing, floor mounted, metal enclosed and vermin proof type having hinged door for front access and suitable for indoor use.
- ii) Under normal conditions, the rectifier-cum-charger shall feed the inverter and charge the battery set. In case of mains failure, the battery shall supply the necessary power to the inverter. The inverter in turn feeds the load through the static switch. If the inverter malfunctions or is overloaded, the load shall be instantaneously transferred to the by-pass line through the static switch. Normally the inverter shall be operated in synchronised mode with the by-pass line, and manual forward transfer or manual reverse transfer shall be effected without any break.

Automatic forward transfer, in case of inverter malfunction, shall be effected with a break not exceeding 5 ms.

7.2.7 Capacitor Banks

- i) The capacitor shall conform to IS 13585/ IS 13925 - specifications for shunt capacitor for power system.
- ii) HV capacitor shall comprise appropriate numbers of basic single phase units (minimum 4Nos. basic units in parallel per phase) which shall be connected in star formation.
- iii) HV Capacitor banks shall be with necessary discharge resistors to reduce the terminal voltage of each unit to a value equal to or less than 50V in 5 minutes.
- iv) Steel rack assembly suitable for outdoor installations (where outdoor location is required) to accommodate the basic capacitor units with necessary post insulators. Panel assembly (where indoor location is required) to accommodate the basic capacitor units, interconnecting busbars, insulators etc. The panel shall have minimum IP-51 protection and shall be constructed with sheet steel of minimum thickness 2.0 mm.
- v) Necessary series reactor to limit inrush current and suppress harmonics (where required)
- vi) The impregnant in the capacitors shall be non-toxic.

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7.2.8 Emergency Generator

- i) The emergency generating sets shall form a complete package and shall be designed to start automatically on power failure and feed the selected loads. It shall be capable of taking care of the load variations (e.g. the starting of largest rated motors on a preloaded system). The unit shall be complete with necessary starting equipment, associated control panel and shall be suitable for remote starting.
- ii) The regulation of generator voltage shall be automatic and necessary instruments for metering viz. Ammeter, Voltmeter, Frequency meter, kWh meter, pf meter, Hour run counter etc. shall be included in the control panel.
- iii) Warning of abnormal conditions shall be incorporated prior to automatic trip to prevent unnecessary shutdown.
- iv) All the six stator winding ends shall be brought out to an externally mounted terminal box and shall be connected in star. Necessary temperature detectors shall be provided for the stator winding. The terminal box shall have sufficient space to receive the cables of specified size.
- v) Emergency DG set shall have Auto starting arrangement but only with manual switching off features. The rating (Ampere Hours) of battery, for cranking the engine shall be adequate to make three attempts with an interval of 5 to 10 seconds, if required. In case the engine fails to start 'FAIL TO START' annunciation shall be provided in substation or in control room.
- vi) The generator set shall be provided with complete protection against overloads, short circuits, ground faults, excitation failure, prime-mover failure and shall include other connected instrumentation interlocks.
- vii) The load shall be switched on to the generator only after the requisite voltage build-up.
- viii) Diesel Engine installation, does not call for Area Classification, provided the DG room is properly ventilated. Normally the ventilation provided to remove heat from the radiator is adequate to take care of the hazard aspect. DG sets shall comply with the latest guidelines of environment ministry with regard to noise levels.

7.2.9 Cables

- i) In order to avoid spread of fire due to cables, it is recommended that the outer PVC sheath of all cables used in industry shall be flame retardant type conforming to category AF as per IS:10810. The minimum Oxygen index shall be 29. The cables shall have a low smoke property and the minimum value of light transmittance shall be 60%.
- ii) High voltage cables may be Aluminium/Copper Conductor XLPE insulated PVC sheathed, armoured type.
- iii) The conductor screen, XLPE insulation screen shall all be extruded in one operation by 'Triple Extrusion' process.
- iv) 1.1 kV grade cables may be Aluminium/Copper Conductor PVC/XLPE insulated, PVC sheathed, armoured type.
- v) All power and control cables shall preferably have extruded inner and outer sheaths.

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- vi) Where single core cables are armoured and are meant for use on AC circuits, armouring with non-magnetic material (e.g. Aluminium) shall be employed.

The communication cables shall conform to DOT (Department of Telecom) specification. For fire alarm systems, PVC insulated, armoured and overall PVC sheathed cable with 1.5 mm² copper conductors may be used.

- vii) The power and control cables shall have the following minimum cross sectional areas:

Description	Size
a) Medium voltage power cable	4mm ² Aluminium or 2.5 mm ² Copper
b) Control cables	2.5 mm ² (Copper) (See Note 1 below)
c) Lighting	2.5 mm ² (Copper)/ 4mm ² (Aluminium) (See Note 2 below)

Note 1 In case of difficulty in connecting the cables to instrument relay terminals, the minimum cross section may be reduced to 1.5 mm² copper.

Note 2 For lighting inside the building copper conductor cables shall be used. Where conduit wiring is adopted, minimum 1.5 mm² copper conductor PVC insulated wire may be used.

Note 3 Conductor size for wiring inside the panel for electronic circuits/components shall be as per manufacturer's standard.

- viii) Cables shall be properly sized to carry without undue temperature rise the load current under site derated conditions. The derating shall take into account ambient air temperature, ground/duct temperature, grouping and proximity of cables with each other, thermal resistivity of soil, depth of cable laying etc. Cables protected by fuses shall be able to withstand the maximum I² t let through energy of fuse.

In other cases, cables shall be able to withstand the fault current for a duration as dictated by protective disconnecting device.

- ix) The type of cable selected and the insulation shall be compatible with various chemicals encountered in the plant and other environmental conditions such as dampness highly corrosive atmosphere, high/low temperature, radiation etc., bearing in mind that certain chemicals (e.g. Benzene, Ethylene Chloride) are known to be detrimental to PVC.
- x) The selection of voltage rating of HV cables shall take into account the system voltage, system earthing arrangements and type of earth fault protection schemes. (Guidelines on this can be had from IEC 60183 & IS:7098).
- xi) When feeders comprising of parallel runs of cables are envisaged, the size, length and type of individual cable shall be identical.

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7.2.10 Control Station

- i) Each Motor shall be provided with a control station in the field (systems such as skid mounted lube oil systems for compressors etc. may be accepted with integral control of lube oil motors). Motors installed at elevated platforms (such as cooling tower fan, air fin cooler etc.) shall be provided with one stop push button at ground level in addition to the one provided near the motor
- ii) The control station enclosure shall have suitable protection for site conditions such as flameproof, weather-proof, dust-proof, corrosion resistant, etc..
- iii) The control station shall include the following equipment as per individual requirements :
 - Start/stop push button/close, neutral, Trip Switch
 - Ammeter,
 - Local/Remote Selector Switch
 - Auto/Manual selector switch and
 - Cable glands.
- iv) Stop push button shall generally have stay put feature except in the case of critical drives such as lube oil pump etc.
- v) Control station shall have suitable locking facility.

7.2.11 Convenience Receptacles

- i) These shall have the necessary mechanical interlocks and earthing facilities. The enclosure shall have suitable protection for site conditions specified such as flameproof, weather-proof, dust-proof, corrosion resistant, etc.
- ii) Welding receptacles shall be provided at suitable locations to ensure accessibility with a 50 meters length of trailing cable to any point in the process area. These shall be rated for 63 A suitable for 415 V, 3-phase system with a scraping earth connection.

Adequate number of sockets for lamps and portable tools shall be provided at suitable locations to ensure accessibility with a 15 meters length of cable to any point in the process area. These shall be rated for 15 A single phase supplied at 240 V. RCCB with suitable sensitivity shall be provided at appropriate location. Hand lamps and portable tools shall be earthed through flexible cords. The flexible cable shall have 3 cores of multistrand copper conductor of minimum size equivalent to 1.5 Sq mm, with PVC insulation and metal braiding. In hazardous areas, handlamps shall be rated for 24 Volts. Accordingly 240/24 V transformers shall be provided either in the plug or in separate flameproof enclosure.

7.2.12 Actuators for Motor Operated Valves

- i) Valves with electrical actuators shall generally be provided with integral starters.
- ii) The necessary local/remote selector switch, start/stop control switches or push button, torque limit switches etc. shall be provided on actuator for local/remote control depending on mode of selection. In case of failure of torque limit switches, the mechanical design shall be adequate to stall and trip the motor without damage.

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- iii) The control circuits shall be AC operated for short distance or DC operated for extended distance. The actuator shall be provided with an anti condensation heater.

8.0 Plant Cabling

- i) Cables below ground shall be laid in concrete trench/tunnel or directly buried. Cables above ground shall be laid in cable trays/cable racks.

However, cabling for fire water system shall, as far as possible, be taken in exclusive route through underground trench.

- ii) While designing layout with single core cable installations following factors shall be considered :

- a) Cables are laid as a general practice in trefoil formation touching each other.

or

- b) Flat formation with spacing as per requirement.

- When cables are laid in a flat formation, the individual cable fixing clamps and spacers shall be of non-magnetic material.
 - As a general practice, the sheath of single core cables shall be earthed to keep sheath at earth potential. However depending on the current the cable has to carry, the feeder length and permissible sheath potential, various methods of sheath bonding are employed, viz. single point bonding, bonding at middle, bonding at two ends, cross bonding, sectionalised bonding etc., for which cable manufacturers recommendations shall be followed.
 - It should be noted here that the current rating of cables will vary depending upon laying formation, method of sheath bonding etc., apart from other derating factors normally considered e.g. ambient temperature, depth of laying etc.
- iii) All trenches shall be sized depending upon the number of cables, and their voltage grade. High voltage, medium voltage and other control cables shall be separated from each other by required spacing or running through independent pipes, trenches or cable trays as applicable. Cable trenches inside substations shall be filled with sand, pebbles or similar non-flammable, materials or covered with incombustible slabs. If a significant number of cables are taken on racks, adequate supports should be provided on the side wall of trench.
- iv) RCC covers of trenches shall be effectively sealed to avoid ingress of chemicals and oils.
- v) In unpaved areas, cables should be directly buried in ground. Where underground cables cross roadways or pipe sleepers at grade etc., they shall be protected by being drawn through sleeves/ducts to provide a permanent crossing. Sleeve/duct ends shall be effectively sealed thereafter.
- vi) Concrete lined trenches shall have suitable drainage arrangement to avoid water collection. Concrete lined cable trenches shall be sealed against ingress of liquid and gases wherever the trenches leave a hazardous area or enter control room or substation. Pipes laid for mechanical protection shall be sealed at both ends.
- vii) Above ground cable trays shall be well supported suitably at every 2 to 2.5 metres interval and protected against mechanical damage. Routing shall be decided to avoid proximity to high temperature sources (steam drains, furnaces etc.), places subject to

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undue fire risk. Cable trays, racks and trenches shall be sized to allow for 10 to 20% future cables reserve. Each cable tray tier shall accommodate the cables preferably in single layer.

Instrument and communication cables shall not be laid in the same trench/tray along with electrical power cables. The overall cable layouts shall be designed for minimum interference between signal and power cables.

Where ever there is a possibility of electromagnetic interference, shielded twisted pair and/or screened and overall shielded cables should be used for control cables/ signal cables.

- viii) Cable cellars and important cable tunnels shall be provided with fire detection and monitoring devices.
- ix) Trailing cables for equipment such as cranes and excavators shall have one additional core for earthing and the cable shall be well protected against mechanical damage.
- x) Cable straight through joints in power and control cables shall be avoided as far as possible.
- xi) Only type tested termination kits shall be used. While selecting the type of cable kit, necessary consideration should be given to the additional safety measures needed for carrying out termination with kits of type such as heat shrinkable type (particularly in hazardous areas).
- xii) Cable route markers shall be installed at every 30 metres intervals all along the directly buried cable routes and also at cable joints and locations where the direction of cable trench changes. Cable route markers shall extend 600 mm above ground.
- xiii) Cable installations shall provide for minimum cable bending radii as recommended by manufacturer.
- xiv) Cable trenches in hazardous area shall be filled with sand and covered with RCC slabs to prevent accumulation of flammable gas/vapour inside the trench.
- xv) Cables shall be identified close to their termination point by cable tag numbers as per cable schedule. Cable tag numbers shall be punched on aluminium strap 2mm thick flat or circular, securely fastened to the cable.
- xvi) Besides each underground cable shall be provided with tags of aluminium securely fastened at every 30 metres of underground length with at least one tag at each end before the cable enters the ground.

For further details, on installation practices and requirements refer OISD-RP-147 on 'Inspection and Safe Practices during Electrical Installations'.

9.0 Plant Lighting

This can be broadly classified as under:

- i) Normal lighting
- ii) Emergency lighting
- iii) Critical lighting

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- i) Normal and emergency lighting system shall be on 415/240V AC supply, whereas critical lighting will be either on 220V or 110V DC. In case of oil mines the maximum voltage of the lighting system should be 250 volts phase to phase with midpoint grounded.
- ii) Sufficient lighting shall be provided so as to enable plant operators to move safely within the accessible areas of plant and to perform routine operations. In the event of normal power failure, emergency lighting should be provided. Desired lux level shall be achieved considering that both the lighting fixtures, normal as well as emergency one are energised. In the event of normal power failure, emergency lighting shall remain energised through emergency power source.
- iii) Lighting requirements provided during the failure of power supply for Normal lighting are intended broadly,
 - a) To facilitate carrying out of specified operations, for safe shutdown of the plant.
 - b) To gain access and permit ready identification of fire fighting facilities such as fire water pumps, fire alarm stations etc.
 - c) Escape route for safe evacuation of operating personnel.
- iv) The recommended areas for critical lighting (DC) include :
 - Control rooms (Process & utility)
 - Main substations
 - DG Shed
 - Central Fire Station
 - Fire water pump house (for start-up of Diesel driven F.W. pump)
 - First Aid Centre
 - Emergency escape route
- v) The recommended areas for AC emergency lighting include :
 - Control rooms (Process & utility)
 - Fire water pump house, Fire stations
 - Main sub stations
 - Foot of stairs and ladder
 - Platforms with ladders changing direction
 - Other changes of floor level that may constitute a hazard.
 - Strategic locations in Process, utility areas where specific safety operations are to be carried out such as:
 - Areas near heat exchangers, condensers
 - Barring gears of steam turbine
 - Some portions of roads interconnecting substations and process plants.
- vi) As a good engineering practice the AC emergency load is generally considered as 20-25% of Normal Lighting load. However for small plants, where AC emergency load is not

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substantial/where there is no separate standby DG set, DC critical lighting system should take care of entire emergency lighting.

- vii) The following operational philosophy is recommended. Under normal operation, both emergency and normal lighting shall be fed by Normal power source. On failure of normal supply, emergency lighting load will be transferred to emergency source after the start of DG set within 15 seconds. Critical lighting (DC supply based) will be normally kept 'ON' and during Normal/emergency power failure, battery will provide power.
- viii) Besides, adequate number of self contained portable hand lamps and Battery emergency lighting units shall be provided for immediate use in emergency at remote stations and at other strategic places (safe areas), wherever required, for personnel safety.
- ix) HPMV/MLL / CFL / lamps shall generally be used for outdoor plant lighting. Keeping in view the re-strike time lag and to avoid complete darkness in case of a voltage dip/brown out conditions, necessary incandescent / CFL lamps should be judiciously distributed throughout the plant area. Incandescent / CFL lamps can be considered for emergency lighting to achieve this objective. Fluorescent lamps may be used for indoor lighting in non-process buildings and control rooms. Safe area street lighting and yard lighting may employ sodium vapour lamps. Low pressure sodium vapour lamps shall not be installed in hazardous areas.
- x) The illumination levels in different areas shall be as per good engineering practice. Depending on the nature of job activities to be carried out the suggested minimum illumination levels for various areas are as under:



TABLE-V

Areas	Illumination in Lux
Main roads (along process units, power houses, Workshops, etc.)	7 - 10
Secondary roads (along storage tanks settling basins etc.)	3 - 5
Tank farm	10
Pump houses, sheds	100
Main operation platforms & access stairs	60
Ordinary platforms	20
Process areas, pipe racks, heat exchanger, heater, separators, cooling tower, columns, pig launching/ receiving loading area, flare etc.	60
Switchgear building	150-200
Transformer bay	100
Battery room	150
Control room bldg./laboratory	400
Boiler house	150
Charger/UPS rooms	150-200
Cooling tower	60
Switchyard	
(i) operating area	100
(ii) other areas	50
Warehouse	100
Office	300
Compressor operating area	200
Watch room	100
Stairs	50
Corridors/ lifts	70
Tube well, gate & watchman booth	100
Fire house, garage	100-150

However, lighting levels in all areas shall take into consideration the requirements from point of view of safety, ease of operation and maintenance.

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- xi) The illumination level requirements (during normal lighting source failure) depend on the nature of activities to be carried out. The suggested minimum illumination levels are as below :

TABLE-VI

S. No.	Area	Illumination in Lux
1	Near to areas where specific safety operations (visual tasks are to be carried out (e.g. control room)	Spot lighting to be provided
2	Escape Lighting Escape way (interior) Areas at exit door and at points where it is necessary to emphasise the position of potential hazard if any.	5 30
3	Other notified general outdoor areas	1

- xii) The lighting fixtures on various circuits shall be suitably interlaced so that failure of any one circuit does not result in complete darkness.

- xiii) Taller structures shall have aviation obstruction lighting as per statutory regulations (DGCA).

- xiv) Battery room shall have fixtures mounted on wall in order to facilitate easy replacement of fused lamps. Switches controlling the lighting fixtures and exhaust fan shall be installed outside the battery room.

- xv) Switches of lighting panels installed in hazardous area, shall have a pole to break the neutral in addition to the poles for phases.

When the means of isolation is located in a non-hazardous area, the switch shall break all poles including neutral or alternatively may break only live poles, the neutral being isolated by a removable link.

- xvi) For details on installation practices refer OISD standard 147.

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10.0 Plant Earthing

- i) Earthing system in general, shall cover the following
 - Equipment earthing for personnel safety,
 - System neutral earthing, and
 - Static and lightning protection.
- ii) The earthing system envisages an earthing network with designed number of earth electrodes attached to it. The following shall be earthed :
 - System Neutral
 - Current and potential transformer secondary neutral
 - Metallic non-current carrying parts of all electrical apparatus such as transformers, switchgears, motors, lighting/power panels, terminal boxes, control stations, lighting fixtures, receptacles etc.
 - Steel structures, loading platform etc.
 - Cable trays and racks, lighting mast and poles.
 - Storage tanks, spheres, vessels, columns and all other process equipment.
 - Electrical equipment fencing (e.g. transformer, yard etc.)
 - Cable shields and armour
 - Flexible earth provision for Wagon, Truck
- iii) Plant earthing design shall generally be carried out in accordance with the requirements of CEA Regulations 2010 and code of practice for earthing IS 3043.
 - As far as possible, all earth connections shall be visible for inspection.
- iv) All connections shall be carefully made and adequately locked against loosening. Normally earthing system shall comprise of GI strip as main earth grid along with suitably located GI disconnecting plates to provide multiple earth connections between earth grid and equipment and for connections between main earth grid and electrodes. Alternatively, mild steel strip can also be used for earth grid after providing corrosion allowance.
- v) Connections between GI earth electrode and the disconnecting plates shall be done by GI strip. For highly corrosive areas, PVC insulated Aluminium / Copper Conductor cable (un-armoured) can be used. Connections between the disconnecting plate and various equipment shall be made by GI strip, GI wire or GI wire rope, size as recommended in Table VII.
- vi) In corrosive areas, aluminium disconnecting plates along with suitably sized PVC insulated aluminium conductor cable can be used for earthing grid/connections.
- vii) All utility, process pipelines and flanges shall be earthed on entering or leaving the hazardous areas, except where conflicting with the requirements of cathodic protection.

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In addition, steel pipe racks in the process units and offsite area shall be earthed at every 25 meters.

- viii) Equipment located remote from main earth network should be earthed by means of individual earth conductors and earth electrodes.
- ix) Lightning protection shall be provided for the equipment, structures and buildings which are higher than 20 metres or as per the risk index analysis worked out as per IS 2309. Inherently self protecting structures (Note:1) do not require lightning protection with aerial rod and down conductors. They shall be connected to the earthing system at a minimum of two points of the base. An independent earthing network shall be provided for lightning protection and this shall be bonded with the main earthing network below ground, minimum at two points.

Note:1 Metallic tanks with steel roofs of riveted, bolted, or welded construction, with or without supporting members that are used for the storage of liquids that give off flammable vapors at atmospheric pressure shall be considered to be protected against lightning (inherently self-protecting) if the following requirements are met:

- a. All joints between metallic plates shall be riveted, bolted, or welded.
 - b. All pipes entering the tank shall be metallically connected to the tank at the point of entrance.
 - c. All vapour or gas openings shall be closed or provided with flame protection in locations where the stored stock might produce a flammable air-vapor mixture under storage conditions.
 - d. The roof shall have a minimum thickness of 3/16 in. (4.8 mm).
- x) The resistance value of an earthing system to the general mass of earth shall be as follows :
 - For the electrical system and equipment, a value that ensures the operation of the protective device in the electrical circuit but not in excess of 4 ohms. However, for generating stations and large sub-stations this value shall not be more than 1 ohm.
 - For lightning protection, the value of 4 ohms as earth resistance shall be desirable, but in no case it shall be more than 10 ohms.
 - xi) The main earthing network shall be used for earthing of equipment to protect against static electricity.

For further details on earthing installation practices refer OISD standard 147.

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TABLE – VII

S. No.	Type of equipment	Earth conductor size
1	Motors upto 3.7 KW	No. 8 SWG Solid GI Wire
2	Motors 5.5 KW to 30 KW & welding receptacles	10 mm (3/8") dia. GI Wire Rope
3	Motors 37 KW and above including HV Motors	16 mm (5/8") GI Wire Rope/ 40 mm X 5 mm GI Strip
4	Building Columns	40 mm X 5 mm GI Strip
5	Storage Tank (Vertical & Horizontal)	40 mm X 5 mm GI Strip
6	Loading Racks	40 mm X 5 mm GI Strip
7	Pipe racks, Vessels & Heat Exchangers	40 mm X 5 mm GI Strip
8	Small Equipment & Instruments	No. 8 SWG Solid GI Wire Rope
9	Lighting, Power & Instrument Panels	10 mm (3/8") dia. GI Wire Rope
10	Main Earth Bus/MV & HV Switch Gear Interconnections/ Power Transformer	As Calculated
11	EHV & HV Sub-Stations	As Calculated
12	Push Button Stations	No. 8 SWG Solid GI Wire
13	Street Light Poles	10 mm (3/8") dia. GI Wire Rope
14	Lighting Transformer	16 mm (5/8") dia. GI Wire Rope
15	Bonding of Pipe	25 mm ² insulated flexible copper cable

1. Earth connections to individual equipment from nearest earth plate/ grid may also be done alternatively using Aluminum/ Copper conductor PVC insulated core of size not less than half the cross-section of respective power cable to the equipment (Motor, Panel etc.). Connections shall be made using crimped type of lugs.
2. Earth rods and conductors shall be designed to cope with the conditions imposed. The earth conductor shall be adequately sized to carry the applicable maximum earth fault current without undue temperature rise. All joints shall be protected against corrosion.
3. All the electrical equipment operating above 250 volts shall have two separate and distinct connections to earth grid.
4. Lighting Fixtures shall be earthed through the extra core provided in the lighting cable.

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11.0 Plant Safety and Security systems

This shall include the following systems:

11.1 Plant Fire Detection and Alarm System

- i) The purpose of a fire detection and alarm system is to detect fire at the earliest and to give an alarm so that appropriate action can be taken (e.g. evacuation of personnel summoning the fire fighting organisation, triggering of extinguishing process etc.). An alarm system can be activated by automatic detection devices viz. smoke detectors, heat detectors etc. and/or by manual operation of manual call points i.e. break glass units.
- ii) Manned locations prone to fire hazard shall have manual call points which on operation shall give audio-visual indication at the control rooms and actuate the sirens. If there are many manual call points, these should be conveniently grouped together to form various zones and zone panels to be installed in convenient places other than unit control rooms. Operation of each zone panel should be indicated by audio-visual indication in the main control panel in the unit control room as well as in the other zone panels with distinct colour indicating the zone number.
- iii) Analogue addressable fire detection and alarm systems may be considered for large oil & gas installations due to their versatility.
- iv) A fire detection and alarm system shall:
 - a) Operate quickly enough to fulfil its intended functions;
 - b) Reliably transmit the detection signal;
 - c) Translate this signal into a clear alarm indication that will attract the attention of the user in an immediate and unmistakable way and indicate the location of fire and initiate operation of ancillary service such as fire extinguishing system, etc;
 - d) Remain insensitive to phenomena other than those which its function is to detect; and
 - e) Signal immediately and clearly any supervised fault that might jeopardise the correct performance of the system. The system shall also include a FIRE SIREN with a distinct tone having a radial range of about 8kms. Audio/visual fire alarm may be required at the following locations in a large plant:
 - Control room
 - Fire station
 - First aid centre
 - Security office
 - Fire water pump house
- v) Detailed design, selection and installation of fire detection and alarm system shall be as per IS-2189.

11.2 Communication system

The plant communication system shall include some or all of the following facilities as per individual plant requirements:

- Telephone
- Public address system
- Emergency communication system

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- Radio communication system
- Fax
- Internet
- Intrinsically safe mobile phones
- CCTV

Certain requirements for each facility are given below as general recommendation.

11.2.1 Telephone System

- i) A private automatic branch exchange (PABX) system shall be provided. Trunk lines connecting with the external telephone network shall be provided and the number of trunk lines shall be decided based on plant size and requirement.
- ii) Selective telephone service control shall be arranged for all the extensions of the PABX to have one or more of the following service functions:
- iii) All phones shall have direct inter-communication between all the extensions of this exchange and all the extensions shall be able to accept any external calls handled by the exchange operators.
- iv) Non executive phones shall operate with operator assistance for connection to external lines for both local and long distance telephone service.
- v) Executive phone service shall include direct unassisted (operator bypass) communication to external lines for both local and long distance telephone service.
- vi) In areas with high ambient noise levels, intensified bell signals can be provided to produce an effective recognition sound level of 6db above anticipated ambient noise levels.

11.2.2 Public Address System

- i) A public address system shall be provided for communication within the plant area and it shall comprise master stations, central cabinet/exchange equipment (field station modules, amplifiers etc.), field stations, paging loudspeakers etc. The public address system shall provide, as a minimum, the following facilities:
 - a) Paging within the plant area over loudspeaker from the master control station located in process control room.
 - b) Call back from any of the field stations to the master control station.
 - c) Communication or call from master control station to any of the field stations and communication between field stations at the discretion of master station.
 - d) Communication between pre-designated field stations as per process operating requirements without interference of the operator manning the master station.
 - e) Operating an alarm call from master control station over all the loud speakers during an emergency.
- ii) Paging speakers provided in areas having high ambient noise levels shall produce a 6 dB paging sound level above anticipated ambient level for effective recognition of speaker's voice signals. Beacon lamps of acoustic hoods shall be provided for Public address systems in noisy areas.

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Also the field stations shall be capable of operating in areas of high noise levels without any interference.

11.2.3 Emergency Communication System

- i) The 'Hot line system' shall be designed to provide a dependable communication link between pre-designated points of operation. This system shall be completely isolated from the telephone system.
- ii) The emergency communication system shall include a 'Direct phone to phone hot line (H.L.) system' and a 'Dedicated hot line (D.H.L.) system'.

H. L. System

- iii) By removing phone from cradle switch, the corresponding phone at opposite end will ring till answered or until the phone is returned back to cradle disengaging the circuit switch.

D.H.L. System

- iv) A simplified selective dial scheme shall be provided to give selective contact between all the extensions of this system. All the telephones used for the emergency communication system shall be red in colour and shall have ringing indication lights.

11.2.4 Radio Communication System

Portable Walkie-Talkie system.

- i) A walkie-talkie system shall be provided for radio communication within the plant area. The system shall operate in the simplex mode on U.H.F. and the exact frequency shall be decided in consultation with P & T DOT authorities.
- ii) The system shall consist of base station, monitoring receivers, portable stations, antennas and associated accessories. Adequate number of hand stations shall be provided.
- iii) The system shall enable communication between portable station and the base station or between any of the two portable stations. The system shall have a range of approximately 6 km.
- iv) The system shall provide excellent penetration in all operating areas of the plant with no marginal locations and extend beyond the boundaries of the plant. The system shall operate above the man-made noise spectrum to provide clear noise free communication in all areas of high electrical noise.

11.2.4.1 VHF System

Radio communication (VHF band) may be provided for communication between the plant and pre-designated points outside the plant. The system shall include necessary transmitter/receivers and associated antenna. The frequency of operation shall be decided in consultation with statutory authorities (DOT).

11.2.5 Fax System

One fax machine shall be installed in the administration building of the plant.

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12.0 MOBILE EQUIPMENT FOR HAZARDOUS AREAS

12.1 PORTABLE HAND LAMPS

- i) Hand lamps for use in hazardous area shall be flameproof with an operating voltage of 24 V. The hand lamp shall be connected to the source of supply by a flexible 3x1.5 mm² copper conductor PVC insulated metal braided cable. Glanding of these cables shall be specially addressed to ensure proper integrity of flameproof enclosure.

This cable should be protected by PVC/tough rubber sheath or similar covering. The metallic body or any other exposed metal part of the hand lamp shall be connected to earthing system.

- ii) The source of supply shall be located as near as possible to the points to be illuminated. Automatic protection employing earth leakage detection scheme (e.g. using ELCB with current sensitivity of 30 mA) shall be provided to disconnect supply on occurrence of an earth fault. Hand lamps with self contained batteries shall have type of protection appropriate to the applicable hazardous zone.

12.2 DIESEL ENGINES

- i) The use of permanently installed diesel engines in Zone-0 and zone-1 areas is unacceptable and the use of permanently installed diesel engines in Zone-2 area should be avoided wherever possible.
- ii) In the event of use of a permanently installed diesel engine, being necessary in Zone-2 it is recommended that it should have the following minimum protections to ensure safety :
 - a) The starter shall be either of a flameproof electrical type (usually operated from the mains supply or battery) or of the following non-electric types :
 - i) Pneumatic
 - ii) Hydraulic
 - iii) Spring recoil
 - iv) Inertia, or
 - v) Hand start
 - b) Any other electrical equipment associated with the engine shall be flameproof. Electrical equipment shall be effectively earthed and bonded.
 - c) Cooling fan blades shall be made from non-metallic materials which do not accumulate electro-static charge.
 - d) All belts shall be of anti-static, fire-resistant type.
 - e) In order to contain discharge of sparks or flames from the exhaust system, a gas conditioner box and a flame trap shall be installed. Alternatively, the exhaust should be designed to discharge to a location within a safe area.
 - f) To prevent flashback through induction system, wherever possible, air intakes for engines shall be located in safe area. Alternatively a flame trap should be installed.
 - g) The surface temperature of the engine and exhaust system shall not exceed 250°C when tested under full load conditions. In some situations cooling of the exhaust manifold and piping may be necessary; using water jacketing or finned coolers and/ or high temperature cut-outs or alarms should be provided.

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- h) However when either the free movement of air is restricted by thermal or acoustic shielding or the ignition temperature of the surrounding flammable atmosphere is below 200°C, no engine exposed surface temperature shall exceed the minimum ignition temperature of the gases involved.
- i) To prevent over-speeding of the engine due to induction of flammable gases or vapours, means shall be provided to stop the engine. It can be either :

A valve to close the air intake,
Or

A system to inject carbon dioxide into the air intake.

- j) Audio visual alarm for automatic shutdown of the engine in the event of excessive cooling water temperature and/or low lube oil pressure shall be provided.
- k) A system using an alarm or trip device to protect the engine from excessive vibration should be considered.
- l) An engine having a crank case volume of over 0.5 m³ shall be provided with relief devices. Relief valves or breathers on engines shall be fitted with flame traps or discharge into the induction system downstream of the flame trap, if fitted and upstream of the shut-off valve, if fitted. Dipsticks and/or filler caps should be screwed or effectively secured by other means.
- m) Intake and exhaust system design shall meet the following minimum requirements:
- The length of the flame path through or across any joint shall be not less than 13 mm.
 - Suitable metal-clad or other acceptable jointing material shall be interposed between all joint faces to ensure that leakage does not occur.
 - Where valve spindles pass through the walls of any component of the induction system, the diametrical clearance shall not exceed 0.13 mm, unless end caps are fitted.
 - No screw, stud or bolt-hole shall pass through the wall of any component of the system.
- n) Decompression systems should not normally be provided. However, if they are essential, then the decompression parts should be provided with flame traps and ducted away to safe area.
- o) The fuel injection pump and governor where fitted should be so designed that reverse running of the engine is not possible.

12.3 STORAGE BATTERIES

- i) Storage batteries shall not be installed in Zone 1 locations, except those used in portable lamps where the enclosure housing bulb, switch and battery shall be flameproof type.

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- ii) As far as practicable use of storage batteries in Zone 2 areas shall be avoided. However where unavoidable, storage batteries for use in Zone 2 areas shall be “Increased Safety” type. These shall meet the following requirements :
- a) Celluloid and similar combustibles shall not be used as constructional materials.
 - b) Battery containers as well as fittings and insulating parts outside the enclosed cells shall not consist of porous materials e.g. wood or other flammable materials and shall be resistant to flame and the action of electrolytes.
 - c) Openings of cells necessary for the escape of the gases given off shall be so constructed as to prevent splashing of the electrolyte.
 - d) The exterior of the cells shall be so constructed as to resist impact, and the cell cases shall be firmly fixed.
 - e) The cells shall be so built into the containers that connection of the cells getting loose in operation is improbable and normally, the discharge voltage exceeding 24 volts should not appear between adjacent rows of cells.
 - f) The creepage distance between two poles of adjacent cells shall not be less than 35 mm. Where the discharge voltage exceeds 24 volts, the creepage distance shall be correspondingly increased by 1mm per 2 volts.
 - g) Where voltage of batteries is not less than 50 volts, either the battery case shall be subdivided by partitions or the batteries shall be grouped into containers; such that in no grouping does a voltage exceeding 50 volts occur. In these cases, the partitions or the containers shall have heights of at least half that of the battery case.
 - h) The battery case shall be so constructed as to ensure sufficient ventilation in order to prevent accumulation of gases given off from the battery, and the free space within the case shall be as small as possible.
 - i) The metallic cover of the battery case shall be lined with materials resistant to electrolyte.
 - j) The cover of the battery case shall have special fastenings.
 - k) Exposed live parts of battery contained in a case shall be protected with rubber or equivalent insulated materials. However, the openings for checking voltage may be provided.

Note: Charging of storage batteries shall be conducted in non-hazardous locations, while the cover of the battery enclosure is kept open.

12.4 TESTING EQUIPMENT

- a. All testing equipment such as Insulation testers, continuity testers etc. shall be intrinsically safe.
- b. Terminal connections shall be made by crimp type lugs.
- c. Terminals shall be provided with rubber covers.
- d. Enclosure and other constructional features shall be suitable as per the area requirement.

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12.5 MISCELLANEOUS REQUIREMENTS

- a. The electrical equipment and the system as a part of mobile equipment shall be of intrinsically safe/flame proof design, if required to be taken in classified hazardous areas.
- b. The mobile apparatus shall be used for temporary purpose only under competent supervision.
- c. No uninsulated current carrying part shall be exposed.
- d. All components shall be accessible for maintenance/repairs.
- e. All remote control or interlock circuits associated with restrained plug and socket coupling should be intrinsically safe.
- f. All electrical circuits shall be cut off automatically in the event of :
 - The current in any circuit exceeding more than the rated value in any circuit.
 - A leakage current to earth/earth fault.
- g. Cell phones used shall be intrinsically safe type suitable to the area classification.

12.6 VEHICLES

Commercial vehicles such as jeeps, trucks, cars etc. shall not be allowed inside hazardous area unless these are specifically authorized by competent authority for use inside the hazardous areas.

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13.0 REFERENCES

The following codes, standards and publications have either been referred to or used in the preparation of this document and the same shall be read in conjunction with this document:

i) BIS (Bureau of Indian Standards) Publications

- ❖ IS 732 Code of practice for electrical wiring installations.
- ❖ IS 1646 Code of practice for fire safety of buildings (General) Electrical Installations.
- ❖ IS 1944 Code of practice for lighting of public thoroughfares
- ❖ IS 2165 Part (1 & 2) Insulation Coordination.
- ❖ IS 2189 Code of practice for selection, installation and maintenance of Automatic Fire Detection and Alarm System.
- ❖ IS 2309 Protection of buildings and allied structures against lightning.
- ❖ IS 3034 Code practice for fire safety of industrial buildings, electrical generating and distributing stations.
- ❖ IS 3043 Code of Practice for Earthing.
- ❖ IS 3646 Interior illumination : Part 1, Part 2 & Part 3.
- ❖ IS 3716 Insulation coordination application guide.
- ❖ IS 5571 Guide for selection of electrical equipment for hazardous areas.
- ❖ IS 5572 Classification of hazardous areas (other than mines) for electrical installations. Areas having flammable gases and vapour.
- ❖ IS 6665 Code of practice for industrial lighting.
- ❖ IS 7098 Specifications for cross linked polyethylene PVC sheathed cables.
- ❖ IS 7689 Guide for control of undesirable static electricity.
- ❖ IS 9676 Reference ambient temperature for electrical equipment
- ❖ IS 10028 (Part 1, 2 & 3) code of practice for selection, installation and maintenance of transformers.
- ❖ IS 10810 Method of test for cables
- ❖ IS 12075 Mechanical Vibration of Rotating Electrical Machines with Shaft Heights 56 mm and Higher-Measurement, Evaluation and Limits of Vibration Severity.
- ❖ IS 13585 Shunt capacitors of non self healing type for ac power systems having a rated voltage upto and including 650 V
- ❖ IS 13925 Shunt capacitors for ac power systems having a rated voltage above 1000 V.
- ❖ IEC 60079-0 General requirements for electrical apparatus for explosive gas atmosphere.
- ❖ IS/IEC 60079-1) Explosive atmospheres – Part 1: Equipment protection by flameproof enclosures “d”
- ❖ IS/IEC 60079-2) Explosive atmospheres – Part 2: Equipment protection by pressurized enclosure «p»
- ❖ IS/IEC 60079-5) Explosive atmospheres – Part 5: Equipment protection by powder filling «q»
- ❖ IS/IEC 60079-6) Explosive atmospheres – Part 6: Equipment protection by oil immersion «o»
- ❖ IS/IEC 60079-7) Explosive atmospheres – Part 7: Equipment protection by increased safety “e”
- ❖ IS/IEC 60079-11) Explosive atmospheres – Part 11: Equipment protection by intrinsic safety “i”
- ❖ IS/IEC 60529 Degrees of protection provided by enclosures (IP CODE)
- ❖ IEC 60947, Low-voltage switchgear and controlgear

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- ❖ IS 8289 IS/IEC 60079-15) Explosive atmospheres – Part 15: Equipment protection by type of protection "n"
- ii) C.B.I.P. (Central Board of Irrigation & Power) Technical Report No. 3 'Manual on Layout of Substations'.
- iii) IEC 60034-9 Rotating Electrical Machines - Part 9 (Noise Limit)
 - IEC 60183 Guide to the selection of high voltage cables
 - IEC 60364 Low-voltage electrical installations
 - IEC:62271 High-voltage switchgear and controlgear
 - ANSI C84.1 Standard Electrical Power System
 - IEEE Device Standard Function Numbers C37.2
- iv) Indian Electricity Act, 2003&CEA regulations 2010 (Measures relating to safety & electric supply) (Ministry of Power, Govt. of India)
- v) National Electrical Code of Bureau of Indian Standards. (SP-30 : 1984)
- vi) NFPA 72 National Fire Alarm Code
- vii) NFPA 780 Standard for the Installation of Lightning Protection Systems
- viii) Oil Mines Regulations
- ix) OISD Standards / Recommended Practices such as :
 - a) OISD – STD- 113 - Electrical Area Classification
 - b) OISD STD - 116 – Fire Protection Facilities for Petroleum Refineries & Oil/Gas Processing Plants
 - c) OISD –STD- 117 – Fire Protection Facilities for Petroleum Depots, Terminals, Pipeline Installations & Lube Oil Installations.
 - d) OISD –STD- 118 – Layout for Oil and Gas Installations
 - e) OISD –STD- 137 - Inspection of Electrical Equipment
 - f) OISD –RP- 147 – Inspection, and safe practices during Electrical Installation
 - g) OISD-RP-173 Fire Protection Systems for Electrical Installations
 - h) OISD-RP-216 Electrical Safety in Onshore Drilling And Workover RIGS
- x) The Petroleum Rules 1976 (Ministry of Industry, Government of India)

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