

ENGINEERING STANDARD

FOR

ELECTRICAL SYSTEM DESIGN

(INDUSTRIAL AND NON-INDUSTRIAL)

FIRST EDITION

FEBRUARY 2012

FOREWORD

The Iranian Petroleum Standards (IPS) reflect the views of the Iranian Ministry of Petroleum and are intended for use in the oil and gas production facilities, oil refineries, chemical and petrochemical plants, gas handling and processing installations and other such facilities.

IPS are based on internationally acceptable standards and include selections from the items stipulated in the referenced standards. They are also supplemented by additional requirements and/or modifications based on the experience acquired by the Iranian Petroleum Industry and the local market availability. The options which are not specified in the text of the standards are itemized in data sheet/s, so that, the user can select his appropriate preferences therein.

The IPS standards are therefore expected to be sufficiently flexible so that the users can adapt these standards to their requirements. However, they may not cover every requirement of each project. For such cases, an addendum to IPS Standard shall be prepared by the user which elaborates the particular requirements of the user. This addendum together with the relevant IPS shall form the job specification for the specific project or work.

The IPS is reviewed and up-dated approximately every five years. Each standards are subject to amendment or withdrawal, if required, thus the latest edition of IPS shall be applicable

The users of IPS are therefore requested to send their views and comments, including any addendum prepared for particular cases to the following address. These comments and recommendations will be reviewed by the relevant technical committee and in case of approval will be incorporated in the next revision of the standard.

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GENERAL DEFINITIONS

Throughout this Standard the following definitions shall apply.

COMPANY :

Refers to one of the related and/or affiliated companies of the Iranian Ministry of Petroleum such as National Iranian Oil Company, National Iranian Gas Company, National Petrochemical Company and National Iranian Oil Refinery And Distribution Company.

PURCHASER :

Means the "Company" where this standard is a part of direct purchaser order by the "Company", and the "Contractor" where this Standard is a part of contract document.

VENDOR AND SUPPLIER:

Refers to firm or person who will supply and/or fabricate the equipment or material.

CONTRACTOR:

Refers to the persons, firm or company whose tender has been accepted by the company.

EXECUTOR :

Executor is the party which carries out all or part of construction and/or commissioning for the project.

INSPECTOR :

The Inspector referred to in this Standard is a person/persons or a body appointed in writing by the company for the inspection of fabrication and installation work.

SHALL:

Is used where a provision is mandatory.

SHOULD:

Is used where a provision is advisory only.

WILL:

Is normally used in connection with the action by the "Company" rather than by a contractor, supplier or vendor.

MAY:

Is used where a provision is completely discretionary.

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1. SCOPE

This recommendation covers the minimum requirements which shall be considered in design of electrical systems in oil, gas, and petrochemical industries. It deals with planning, selection of equipment, economics of design and hints to be taken care in operation and maintenance. It describes criteria in selection of system voltage, fault consideration and discusses the safety and protection of electrical system.

Note:

This is a revised version of this standard, which is issued as revision (1)-2012. Revision (0)-1997 of the said standard specification is withdrawn.

2. REFERENCES

- a) This recommendation is based on IEC standards and the following standards have been referred in this document.
- b) The following IPS standards may be referred in detail design engineering when required.

IPS (IRANIAN PETROLEUM STANDARDS)

IPS-C-EL-115 (1)	“Construction Standard for Electrical Installation”
IPS-M-EL-131 (2)	“Material and Equipment Standard for Low Voltage Induction Motors”
IPS-M-EL-132 (2)	“Material and Equipment Standard for Medium and High Voltage Induction Motors”
IPS-E-EL-110 (1)	“Engineering Standard for Hazardous Area”
IPS-M-EL-138 (0)	“Materials and Equipment Standard for Synchronous Generators”
IPS-E-EL-160 (1)	“Engineering Standard for Overhead Transmission & Distribution Lines”
IPS-I-EL-215 (1)	“Procedure for Initial & Periodical Inspection in Potentially Explosive Atmospheres (Hazardous Area)”
IPS-M-EL-136 (1)	“Material and Equipment Standard for Rotating Electrical Machines Direct Current Motors”
IPS-M-EL-138 (0)	“Material and Equipment Standard for Synchronous Generators”
IPS-I-EL-217 (0)	“Inspection Standard for Pre-commissioning Electrical Tests”
IPS-M-EL-143 (2)	“Material and Equipment Standard for Low Voltage Switchgear and Control gear”
IPS-M-EL-144 (1)	“Material and Equipment Standard for Medium and High Voltage Switchgear and Controlgear”
IPS-M-EL-181 (2)	“Material and Equipment Standard for Power Factor Improvement Capacitor”
IPS-M-EL-151 (1)	“Dry Type Power Transformers”
IPS-M-EL-152 (2)	“Oil Immersed Power Transformers”
IPS-M-EL-190 (1)	“Material Standard for Electrical Heat Tracing”
IPS-M-EL-165 (0)	“Material and Equipment Standard for Low Voltage Industrial and Flameproof AC Motor Control Centers (MCC)”
IPS-M-EL-220 (1)	“Material and Equipment Standard for Current Limiting Reactors”
IPS-M-EL-174 (2)	“Material and Equipment Standard for Battery and Battery Charger (DC Power supply)”

IPS-M-EL-176	“Material and Equipment Standard for Uninterruptible Power Supply (UPS)”
IPS-M-EL-240 (0)	“Material and Equipment Standard for Low Voltage Industrial and Flameproof AC Switch-Fuse Assembly”
IPS-M-EL-271 (1)	“Material Standard for Low Voltage Cables & Wires”
IPS-M-EL-272 (1)	“Material Standard for Medium and High Voltage Power Cables”
IPS-M-EL-273 (1)	“Material Standard for Sub Marine Power Cables with Inherent Optical Fibers”

ISO (INTERNATIONAL ORGANIZATION FOR STANDARDIZATION)

ISO 12332	“Code of practice for Ventilation in Petrochemical Plants and Refineries”
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NFPA (NATIONAL FIRE PROTECTION ASSOCIATION)

NFPA 76	“Fire Protection for Telecommunication facilities”
NFPA 70	“Electrical Safety Requirements for Employee Workplaces”

ASHRAE (AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS)

ASHRAE 62	“Ventilation for Acceptable Indoor Air Quality”
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BSI (BRITISH STANDARDS INSTITUTION)

EN 50272-2	“Safety requirements for Secondary Batteries and Battery Installations”
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IEEE (INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS)

IEEE Guide for Substation Fire Protection IEEE Std 979-1994

3. UNITS

This Standard is based on International System of Units (SI), as per [IPS-E-GN-100](#) except where otherwise specified.

4. ENVIRONMENTAL AND SITE CONDITIONS

The following are the minimum typical information that shall be completed in conjunction with the environmental conditions before engineering work proceeds on:

- 1) Site elevation m above sea level
- 2) Maximum ambient temperature..... °C
- 3) Minimum ambient temperature..... °C
- 4) Minimum relative humidity..... %
- 5) Atmosphere: Saliferous, dust corrosive and subject to dust storms with concentration of 70-1412 mg/m³, H₂S may be present unless otherwise specified.
- 6) Lightning storms: Isoceraunic level..... storm-day/year
- 7) Earthquake zone.....
- 8) Wind direction (where relevant).....
- 9) Area classification (where applicable).....

5. GENERAL

5.1 Definitions

For the purpose of this standard, the following definitions apply:

Autonomy time (of a battery)

The autonomy time is the duration for which the battery can supply its rated load within its specified voltage limits, following a prolonged period (i.e. not less than one year) of battery float-charge operation.

Certificate

Document issued by a recognized authority certifying that it has examined a certain type of apparatus and, if necessary, has tested it and concluded that the apparatus complies with the relevant standard for such apparatus.

Certificate of conformity

Certificate stating that the electrical apparatus complies with the relevant standards for apparatus for potentially explosive atmospheres.

Declaration of compliance

Document issued by the manufacturer declaring that the electrical apparatus complies with the requirements of IEC 60079-15.

Distribution of electricity

The transfer of electricity to consumers within an area of consumption.

Electrical installation

Civil engineering works, buildings, machines, apparatus, lines and associated equipment used for the generation, conversion, transformation, transmission, distribution and utilization of electricity:

Electrical power system

All installations and plants provided for the purpose of generating, transmitting and distributing electricity.

Emergency Lighting

Lighting provided for use when the supply to the normal lighting fails.

Escape Lighting

That part of the emergency lighting which is provided to ensure that the escape route is illuminated at all material times.

Essential service

A service, which, when failing in operation or when failing if called upon, will affect the continuity, the quality or the quantity of the product.

Firm capacity

The installed capacity less than stand-by capacity.

Frequency deviation

The difference between the system frequency at a given instant and the nominal value.

Hazardous area

An area in which an explosive gas atmosphere is or may be expected to be present in quantities such as to require special precautions for the construction, installation and use of electrical apparatus.

Installed capacity

The sum of the rated powers of equipment of the same kind (generators, transformers, converters, etc.) in an electrical installation.

Low voltage (LV)

A set of voltage levels used for the distribution of electricity and whose upper limit is 1000 V AC

Non-essential service

A service that is neither vital nor essential.

Non-hazardous area

An area in which an explosive gas atmosphere is not expected to be present in quantities such as to require special precautions for the construction, installation and use of electrical apparatus.

Point of common coupling (PCC)

The point of coupling at the public utility networks, to which the system under consideration is, or is to be, connected.

Rated value

A quantity value assigned, generally by the manufacturer, for a specific operating condition of a component, device or equipment.

Site conditions

The external factors, e.g. altitude, air temperature, wind velocity, vibrations, earthquakes, black body temperature, relative humidity, etc., which may influence the operation of a machine or apparatus.

Spare capacity

The difference between firm capacity and the maximum calculated (peak) load.

Stand by capacity

The capacity provided for the purpose of replacing that which may be withdrawn from service under planned or unplanned circumstances.

Test report

Document prepared by the manufacturer indicating in detail the tests and verifications to which the electrical apparatus has been subjected, and their results.

Uninterruptible power supply

A source of electrical power which is backed up by a second (emergency) source of power, such as to provide a supply of electricity that may be interrupted for no more than 0.5 ms.

Vital service

A service which, when failing in operation or when failing if called upon, can cause an unsafe condition of the process and/or electrical installation, jeopardize life, or cause major damage to the installation.

Voltage deviation

The difference, generally expressed as a percentage, between the voltage at a given instant at a point in the system, and a reference voltage such as nominal voltage, a mean value of operating voltage, or declared supply voltage.

Voltage dip

A sudden reduction of the voltage at a point in the system, followed by voltage recovery after a short period of time, from a few cycles to a few seconds.

Voltage surge

A transient voltage wave propagating along a line or a circuit and characterized by a rapid increase followed by a slower decrease of the voltage.

Zone 0 (in the classification of hazardous gas areas)

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

Zone 1 (in the classification of hazardous gas areas)

An area in which an explosive gas atmosphere is likely to occur in normal operation.

Zone 2 (in the classification of hazardous gas areas)

An area in which an explosive gas atmosphere is not likely to occur in normal operation and if it does occur it will exist for a short period only.

Zone 21 (in the classification of hazardous dust areas)

An area in which combustible dust is present or may be present as a cloud during normal processing, handling, or cleaning operations in sufficient quantity that it is capable of producing an explosive concentration of combustible or ignitable dust in mixtures with air.

Note:

A dust layer maybe present and should be taken into account.

Zone 22 (in the classification of hazardous dust areas)

Areas, not classified as Zone 21, in which ignitable dust clouds may occur infrequently and persist for only a short period, or in which accumulations or layers of combustible or ignitable dust may be present under abnormal conditions and give rise to ignitable mixtures of dust in air. Where, following an abnormal condition, the removal of dust accumulations or layers cannot be assured, the area shall be classified as Zone 21.

Note:

This zone can include areas in the vicinity of apparatus containing dust, from which, dust can escape from leaks and form dust deposits in hazardous areas.

Bus coupler circuit breaker

In a substation a circuit breaker which is located between two busbars and which permits the busbars to be coupled; it may be associated with selectors in case of more than two busbars.

Bus section circuit breaker (= switched busbar circuit breaker)

In a substation a circuit breaker, connected in series within a busbar, between two busbar sections.

Controlgear

A general term covering switching devices and their combination with associated control, measuring, protective and regulating equipment, also assemblies of such devices and equipment with associated interconnections, accessories, enclosures and supporting structures, intended in principle for the control of electric energy consuming equipment.

Converter

An operative unit for electronic power conversion comprising one or more electronic valve devices, e.g. thyristors, associated firing and control circuits and, if necessary, filters and auxiliaries.

Distribution substation/switchboard

A substation/switchboard mainly used for distributing power to several plant substations.

Generating set

A group of rotating machines transforming mechanical or thermal energy into electricity.

Generator

A machine which converts mechanical power into electrical power.

Intake substation/switchboard

A substation/switchboard at which the supply provided by the public utility is interconnected with the site's electrical distribution system.

Note:

An intake substation and a power plant substation may be combined as a single substation.

Inverter

A converter for conversion from DC to AC

Plain feeder

A feeder which consists of a cable or an overhead line only and does not have. An interconnected transformer.

Plant substation/switchboard

A substation/switchboard mainly used for feeding one process or utility plant.

Power plant substation/switchboard

A substation/switchboard to which generators and outgoing feeders are connected.

Note:

An intake substation and a power plant substation may be combined as a single substation.

Power station (power plant)

An installation whose purpose is to generate electricity and which includes civil engineering works, energy conversion equipment and all the necessary ancillary equipment.

Power transformer

A static piece of apparatus with two or more windings which, by electromagnetic induction, transforms a system of alternating voltage and current into another system of voltage and current usually of different values and at the same frequency for the purpose of transmitting electrical power.

Rectifier

A converter for conversion from AC to DC.

Remote control unit (RCU)

A control device in the vicinity of a consumer for operation of the remotely installed controlgear of the consumer.

Substation (of a power system)

The part of a power system, concentrated in a given place, including mainly the terminations of transmission or distribution lines, switchgear and housing and which may also include transformers. It generally includes facilities necessary for system security and control (e.g. the protective devices).

Switchgear

A general term covering switching devices and their combination with associated control, measuring, protective and regulating equipment, also assemblies of such devices and equipment with associated interconnections, accessories, enclosures and supporting structures, intended in principle for use in connection with generation, transmission, distribution and conversion of electric power.

Switch room

A room in a substation or building intended exclusively for the installation of one or more switchboards, distribution boards etc.

Variable speed drive system (VSDS)

A line-fed AC to AC conversion system consisting of all facilities required to operate its electric motor at variable speeds.

5.2 Operational Safety and Reliability

The design of the electrical installation shall be based on the 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 shutdown of plant and equipment, and throughout the intervening shutdown periods.

The design of electrical systems and equipment shall ensure that all operating and maintenance activities can be performed safely and conveniently and shall permit periods of continuous operation of at least 4 years. To fulfill the above requirements provisions may be required for alternative supply sources and supply routes, spare/stand-by capacity, load shedding and automatic restarting schemes, etc.

The simultaneous failure of two pieces of equipment shall not be catered for.

The insulating and dielectric materials used in all electrical equipment shall be non-toxic and shall not contain compounds that are persistent and/or hazardous environmental contaminants. e.g. polychlorinated biphenyls (PCBs).

The design of the electrical installation shall ensure that access is provided for all operational and maintenance purposes.

Special attention shall be paid to provisional and temporary installations required for the erection of permanent installations to ensure compliance with basic rules for good working practice and safety and to cope with increased hazards which are present in temporary installations.

5.3 Certificates, Declarations and Test Reports

For all major equipment, the Contractor shall obtain at least the manufacturer's test reports in accordance with the equipment specifications, e.g. for generators, motors, VSDS, HV ;MV; LV switchgear, UPS equipment, and transformers.

Further certificates or declarations relating to the application of equipment for use in hazardous areas may be required by local authorities, according to the following rules:

For electrical apparatus in Zone 0, Zone 1 and Zone 2 areas, a certificate of conformity shall be obtained from the Manufacturer; For electrical apparatus in Zone 2 areas, which has type of protection 'n', a declaration of compliance may be accepted instead of a certificate of conformity.

5.4 Quality Assurance and Control

Contractors and suppliers shall demonstrate to the Principal that they implement quality control and assurance systems which conform to the ISO 9001:2000 series and shall be approved by company representative.

5.5 Standards, Codes and Regulations

This recommendation is based on the publications of the International Electro technical Commission (IEC), where relevant the specific publications are referenced in this recommendation.

The design and engineering of the electrical installation shall satisfy all statutory requirements of the national and/or local authorities of the country in which the electrical installation will be located.

The electrical installation shall be suitable for the site conditions as specified by the Principal. Where necessary special attention shall be paid to the selection and installation of electrical equipment suitable for seismic conditions.

Furthermore, the contents of this recommendation and of standards and publications referred to herein shall be adhered to, except where amended by specific requirements given by the Principal relating to a particular installation, and as far as is permitted under the statutory requirements mentioned above.

Electrical equipment and materials shall comply with the relevant standard and/or MESC (Group Materials and Equipment Standards and Code) specifications, which in turn shall be considered as supplementary to IEC equipment standards.

CENELEC or national standards of the country in which the installation will be located may be used in lieu of IEC standards for the design and engineering of the electrical installation, provided they are not less stringent in their total requirement.

In the event of contradiction between the requirements of recommendation specifications and IEC. national standards, the former shall prevail, subject to satisfying statutory obligations in the country of installation.

In the event of contradiction between the requirements of this recommendation and those of specifications referenced in this recommendation, the more recently published document shall prevail, except where otherwise specified by the Principal for a particular installation.

In some cases, other standards except IEC standard could be used, so these standards shall be approved by company representative.

5.6 Document List

The project documents in the basic and detail design shall be included as the Appendix A.

6. BASIC ELECTRICAL SYSTEM DESIGN CONSIDERATION

6.1 Industrial Electrical System

6.1.1 Basic design consideration

6.1.1.1 General

Minimum required Documents for basic and detail design shall be accordance with "Appendix A".

6.1.1.1.1 Safety

Safety takes to form: Safety to personnel, safety to materials, building and safety to electric equipment.

Safety to personnel involves no compromise, only the safest system can be considered. Safety to materials. Buildings and electric equipment may involve some compromise when safety of personnel is not jeopardized. In general:

Safe and reliable supply of electrical supply electricity should be designed.

Safe condition for start-up and shut-down of plant shall be provided.

Safety of personnel and equipment during operation and maintenance shall be considered.

6.1.1.1.2 Continuity of service

The electrical system should be designed to isolate faults with a minimum of disturbance to the system and should feature to give the maximum dependability consistent with the plant requirements.

6.1.1.1.3 Voltage regulations

For some plant power system, voltage spread may be the determining factor of the distribution design. Poor regulation is detrimental to the life and the operation of electric equipment.

The voltage regulation of system shall not exceed $\pm 5\%$ for HV., MV. and LV. main bus bar.

6.1.1.1.4 Plant expansion

Plant load generally increase, consideration of the plant voltages, rating of equipment, space for additional equipment and capacity for increased load must be included according to client requirements.

While the power capacity of a system is increased compatibility of fault level of existing installation shall be carefully scrutinized in conjunction with new available fault level.

6.1.1.1.5 Other requirements

The following principles also shall be considered in design of electrical systems:

The insulating materials used shall be non-toxic or hazardous environmental contaminants. Use of electrical equipments in hazardous area should be minimized. Access to electrical installations for the purpose of operational and maintenance shall be ensured. Equipment of similar natures and identical construction should be of the same manufacturer. Test reports for all electrical equipments shall be provided. Certification for equipments used in hazardous areas shall be provided.

6.1.1.2 Planning guide for distribution design

With the above mentioned factors in mind, the following procedure is given to guide the engineer in the design of an electric system for any industrial plant.

6.1.1.2.1 Obtain a general layout and mark it with the major loads at various locations and determine the approximate total plant load in horsepower, kilowatts, and kilo volt-amperes.

Estimate the lighting, air-conditioning, and other loads from known data.

6.1.1.2.2 Determine the total connected load and calculate the maximum demand by using demand and diversity factors.

6.1.1.2.3 Investigate unusual loads, such as the starting of large motors, or welding machines, and operating conditions such as boiler auxiliary motors, loads that must be kept in operation under all conditions, and loads that have a special duty cycle.

6.1.1.2.4 Investigate the various types of distribution system and select the system or systems best suited to the requirements of the plant. Make a preliminary one line diagram of the power system.

6.1.1.2.5 If power is to be purchased from the utility, obtain such information concerning the supply system or systems as:

performance data, voltage available, voltage spread, type of systems available, method of system neutral grounding, and other data such as relaying, metering and the physical requirements of the equipment. The interrupting rating and momentary ratings of power circuit breakers should be obtained as well as the present and future short-circuit capabilities of the utility system at the point of service to the plant. Investigate the utility's power contract to determine if off-peak power at lower rates available, and any other requirements, such as power factor and demand clauses, that can influence power cost.

6.1.1.2.6 If considering a generating station for an industrial plant, such items should be determined as : generating KVAR required including standby loads, generating voltage, and such features as relaying, metering, voltage regulating equipment, synchronizing equipment and grounding equipment. If parallel operation is contemplated, be sure to review this with the utility and obtain its requirements.

6.1.1.2.7 A cost analysis may be required of the different voltage levels and various arrangements of equipment to justify and properly determine the voltage and equipment selected. The study should be made on the basis of installed cost including all the components in that section of the system.

6.1.1.2.8 Check the calculations of short-circuit requirements to be sure that all breakers are of the correct rating. Review the selectivity of various protective devices to assure selectivity during load or fault disturbances.

6.1.1.2.9 Calculate the voltage spread and voltage drop at various critical points.

6.1.1.2.10 Determine the requirements of the various components of the electric distribution system with special attention given to special operating and equipment conditions.

6.1.1.2.11 Review all applicable national and local codes for requirements and restrictions.

6.1.1.2.12 Check to see that the maximum safety features are incorporated in all parts of the system.

6.1.1.2.13 Write specification on the equipment and include a one-line diagram as a part of the specifications.

6.1.1.2.14 Obtain typical dimensions of equipment and make drawings of the entire system.

6.1.1.2.15 Determine if the existing equipment is adequate to meet additional load requirements. Check such ratings as voltage, interrupting capacity, and current-carrying capacity.

6.1.1.2.16 Determine the best method of connecting the new part of the power system with the existing system so as to have a minimum outage at minimum cost. Naturally the above procedure will not automatically design the electric power system in itself; it must be used with good, sound, basic engineering judgment.

6.1.1.3 General layout

A general layout of the plant should be available before the engineer can begin his study. This layout usually gives the location and the size of the proposed building or buildings in the initial particular project. The extent of the available layout gives the engineer an idea of the possible expansion of the plant in the future, and must be considered by the engineer in planning the electric distribution system.

6.1.1.4 Type of circuit arrangements

Load centers shall be employed as far as possible and the main busbars shall be fed from both sides.

6.1.1.5 Flexibility

Flexibility for expansion should be considered. In line with this, the engineer should strive for a system design that will permit reasonable expansion with minimum downtime to existing production.

6.1.1.6 System reliability

The system shall be designed so that, when one fault occurs the operation of the system will not be jeopardized.

6.1.1.7 Selection of equipment

The fundamental consideration in selecting equipment is to choose optimum equipment consistent with the requirements of the plant. Frequently it costs no more in the long run to use the best equipment available as it pays dividends in service continuity and lower maintenance. Some widely accepted principles are:

6.1.1.7.1 Use metal enclosed for 400 volt indoor switchgear and metal clad for outdoor.

6.1.1.7.2 Choose dry type transformers for indoor installations in non-process areas.

6.1.1.7.3 Use factory assembled equipment for easier field installation and better coordination as far as possible.

6.1.1.7.4 Rating and sizing

a) The rating of equipment shall be as per IEC recommendation.

b) For sizing of equipment refer to section "7. Design And Selection Requirements For Equipment"

6.1.1.7.5 Be sure equipment complies with requirement of pertinent hazard classification.

6.1.2 Load

6.1.2.1 Rating and Diversity Factors

6.1.2.1.1 Electrical equipment shall be rated to carry continuously the maximum load associated with peak design production with an additional 20% contingency.

The ambient condition at which this rating applies shall be defined in equipment specifications and unless otherwise approved by client shall not be less than 40°C maximum air temperature at an altitude not exceeding 1000 m above sea level.

6.1.2.1.2 Assessment of maximum load requirements of an installation shall allow for diversity between various loads, drives or plants. The diversity factors used shall consider the coincidentally requiring peak demands and shall be based on similar installations whenever possible. The use of diversity factors shall result in "After Diversity Maximum Demands" (ADMD) being used for design purposes.

6.1.2.2 Types of loads

6.1.2.2.1 Basic types

a) Dynamic: These are electric motors driving rotating equipment.

b) Static: These are non moving types of electrical equipment such as lighting, heating and supplies to rectifiers etc.

The bulk of the loads on the majority of installations comprise dynamic loads and the proportion of dynamic loads to static loads is generally high and varies under different circumstances.

6.1.2.2.2 Critical loads

These are loads of prime importance to the safety of the installation or the operational staff, and which require power to permit their safe shutdown in emergency. They shall have a second independent power source and be generally associated with no break supplies. In certain cases, a short supply break may be acceptable if this does not represent a hazard to safety.

6.1.2.2.3 Essential loads

These are loads whose loss would affect continuity of plant operation resulting in loss of revenue but would not result in an unsafe situation arising. Any decision to provide an alternative source of supply for these types of load shall be based on economic considerations as specified by client.

6.1.2.2.4 Non-essential loads

Non-essential loads are those which do not form an important component of a production or process plant and their disconnection is only of minimal or nuisance value. They usually form a small proportion of the total connected load and may have a single power source.

6.1.3 Power supply sources

6.1.3.1 General

The power supply system shall be designed to provide safe and economical operation. The safety aspects should cover both plant and personnel. Economic considerations shall cover capital and running costs and an assessment of the reliability and consequent availability of the system. The cost of improved power systems reliability should be weighed against the progressive potential loss incurred by loss of production. However a technical / economical study should be performed for power supply source selection.

All negotiations with public utilities shall be the sole responsibility of client.

6.1.3.1.1 Electrical import from a public utility

Where the principal sources of electrical power is selected to be from a public utility, the supply should be via duplicate feeders.

An exception to this may be permitted for economic reasons where low power loads are to be supplied from overhead lines and where a single feeder may be employed, provided that on-site standby generating equipment is available to meet the total load. Critical loads should always be provided for by on-site standby generating equipment which should only operate in the event of main supply failure.

Grid intake systems shall be controlled by circuit breakers with the protection, control, alarm, instruments and relevant meters such as KWH meters and MAX. Demand meters. The design of these systems should be performed in coordination with public utility.

6.1.3.1.2 On-site generation with no public utility connection

Where a site is offshore, or remote from a public utility network, or has a surplus of fuel or process energy, on-site generation will normally be selected as the principal source of power. The number and types of on-site generating sets shall depend on:

- i) The fuel source.
- ii) The nature of the process energy.
- iii) The process steam or other heat requirements, if any
- iv) The relationship between electric power requirements and the energy sources on any given site.
- v) Economic size
- vi) Maintenance requirements
- vii) Future development

Unless otherwise agreed by client, a minimum of 3 generating sets, which may include an emergency generator to supply the critical loads, will be required on sites where there is no alternative electricity supply. The following criteria shall be satisfied:

- There shall be sufficient generation to meet the "After Diversity Maximum Demand" (ADMD), when the largest single source of supply is out of service at peak demand times due to maintenance or any other reason.
- Generation shall be able to cater for the load requiring a supply after automatic load shedding if provided) when the largest single source of supply is out of service and the second largest single source is coincidentally shut down due to unforeseen circumstances.

6.1.3.1.3 On site generation run in parallel with a public utility

Where on-site generation is selected to be the principal source of power and where a connection to a public utility is available, the public utility connection may serve:

- i) As a standby source of electric power.
- ii) A means of export of surplus electrical power.
- iii) A combination of both.

6.1.3.2 Emergency power supply equipment

6.1.3.2.1 Critical loads by definition require a high degree of reliability of supply. This reliability may be achieved by, in order of preference:

- i) Providing another source of energy, such as batteries.
- ii) Increasing the amount of normal supply generation equipment.
- iii) Ensuring a number of alternative supply feeds is available to the loads.
- iv) Providing local standby plant.

In cases where the provision of another source of energy is not practicable, the least cost of the remaining alternatives should normally be adopted bearing in mind the additional servicing and fuel requirements associated with standby generation.

6.1.3.2.2 Critical loads shall be supplied by reliable generators or other suppliers during maintenance of the largest generator at coincidental to the unscheduled outage of the next largest generator.

6.1.3.2.3 Where increased generating plant or local standby plant is selected to provide power to critical loads, it shall be either diesel engine or gas turbine driven generator set(s) each with its own dedicated fuel supply. Secure static power supplies may be selected depending on the nature of the critical loads being supplied and on fuel availability for generator sets. The emergency equipment shall be rated to have a spare capacity of 10%. The efficiency of operation of emergency equipment is not a significant factor but its ability to start reliably and supply the loads under emergency conditions is critical.

6.1.3.2.4 Emergency generator sets shall be capable of starting and running when no alternative source of electrical AC power is available i.e., a black start capability. This shall be achieved by compressed air starting with air receivers being capable of six engine starts from one air charge, or by battery starting with a similar capability.

6.1.3.2.5 It shall not be possible to connect emergency generators to a load greater than their rated capacity. Parallel operation of emergency diesel generators with grid supply shall not be permitted and safe and reliable interlocks shall be considered for that. Manual facilities shall also be provided for regular testing purposes.

Testing facilities should permit the loading of standby generator sets.

6.1.3.3 Primary substation

6.1.3.3.1 Generator circuits other than local emergency generators and public utility power intakes shall be connected together at a common primary substation, the busbars of which are used as the main load distribution center. In certain cases, however, generators and public utility power intakes may be located at different points throughout the site, in which case there may be a number of primary substations which shall be interconnected on the site.

6.1.3.3.2 The switchgear for primary substations shall comply with the requirements of [IPS-M-EL-144](#).

6.1.3.3.3 Busbar arrangements shall be selected to be cost effective, operationally flexible and safe. The following technical points shall be taken into account:

- i) Operational flexibility to permit loads and power supplies to be effectively connected under schedule and unscheduled outages of circuits and busbar sections.
- ii) Minimal switchgear per circuit and simple control and protection.
- iii) Unscheduled loss of busbar sections shall not shut down the system beyond the level designed and provided for.
- iv) Scheduled maintenance of busbars shall be possible without system shutdowns beyond those designed and provided for.

6.1.3.3.4 The location of the primary substations shall be considered in safe areas.

6.1.3.4 Synchronizing

6.1.3.4.1 Synchronizing or check synchronizing equipment shall be provided wherever more than one source of power may be operated in parallel with another.

6.1.3.4.2 The simplest form of check synchronizing equipment shall comprise voltmeters and synchroscope to show the voltage and frequency differences between the two systems that need to be paralleled. A check synchronizing relay may be utilized to prevent operator mal-operation, but in order to allow closing a power source on to a dead system, as is required under black start conditions, the check synchronizing relay shall have a means of manual or automatic disconnection.

6.1.3.4.3 Synchronizing or check synchronizing facilities shall be fitted to busbar section and bus coupler circuit breakers only when it is possible to run the two systems feeding either section of a busbar completely segregated from the other. The numbers of circuit breakers provided with synchronizing or check synchronizing facilities shall be kept to a minimum. A similar logic shall be applied to public utility intake circuits. Alternatively, circuit breaker interlocking schemes shall be installed to preclude the possibility of paralleling two sources of power where synchronizing facilities are excluded. Synchronizing facilities shall be provided at the primary power supply voltage and avoided at other voltages by use of appropriate circuit breaker interlocking.

6.1.3.5 Secondary unit substations

6.1.3.5.1 Application

Secondary unit substations form the heart of all industrial plant electrical distribution systems. They are used to step down the primary voltage to the utilization voltage at various load centers throughout the plant. Many factors must be considered when selecting and locating substations. Most important of these are:

- i) Load grouping by KVA
- ii) Voltage rating
- iii) Service facilities
- iv) Safety
- v) Ambient conditions
- vi) Continuity of service
- vii) Aesthetic consideration
- viii) Lightning protection requirements
- ix) Space available
- x) Outdoor vs. indoor location

- xi) Plans for future expansion
- xii) Safe area location

6.1.3.5.2 Components of secondary unit substations

An articulated secondary unit substation consists of three basic components i.e.:

- Incoming line section
- Transformer section
- Outgoing section

The design principle of which is similar to load centers.

6.1.4 Load center systems

A load-center system may be defined as one in which power is transmitted at voltages above 400 volts to unit substations located close to the centers of electric load. At these substations the voltage is stepped down to the utilization level and distributed by short secondary feeders to the points of use. The trend to this type of system has become very marked in recent years. An examination of the advantages listed below for the load-center system when compared to older systems will indicate why such a trend has come about.

- i) Lower first cost.
- ii) Reduced power losses.
- iii) Improved voltage regulation.
- iv) Increased flexibility.
- v) Better continuity of service.
- vi) Simplified engineering, planning, and purchasing.
- vii) Lower field installation expense.

It should also be pointed out that a contributing factor to the increased use of load center system has been the development of air circuit breakers, metal-clad and metal-enclosed switchgear, and especially dry type transformers. These equipments have permitted the installation of the unit substations in buildings and close to the centers of loads without requiring expensive vaults to minimize fire hazards and danger to personnel.

6.1.5 Selection of system voltage

The selection of utilization distribution and transmission voltage levels is one of the most important consideration in power system design. System voltages usually affect the economics of equipment selection and plant expansion more than any other single factor; it behooves the power system engineer to consider carefully the problem when designing the distribution system.

6.1.5.1 Voltage levels

The various voltage levels may be broadly defined as follows:

Low voltage (LV): is defined as voltages below 1000 volt in a 3 phase 4 wires, 50 Hz system. 400/230 volt system is adopted as standard voltage for low voltage. However 110 volt ac for small power or control systems and 25 volt AC for inspection system are common.

Medium voltage (MV): is defined as voltages higher than 1000 volt up to 10 kV in a 3 phase, 3 wires, 50 Hz system. The following voltages may be used depending on technical and economical considerations, available utility voltages and similar equipments used indifferent locations: 3.3 KV, 6 KV

High Voltage (HV): is defined as 10 kV and higher in a 3 phase, 3 wires, 50 Hz system and it should be 10 KV, 11 KV, 20 KV, 33 KV, 63 KV, 66 KV, 132 kV and 230 KV. The low voltage is normally restricted for supplying to utilization equipment directly.

The high and medium voltage is used most frequently for distribution purposes and also is employed as utilization voltage particularly for motors rated 3.3, 6 and 11 kV.

The high voltages above 20 KV and the high voltages are mainly used for power distribution and or transmission.

The frequency of power supply systems for onshore systems shall be 50 Hz. For offshore systems the voltage of power system shall be based on engineering evaluation and decided by company engineer.

6.1.5.2 The factors affecting system voltage

At least the following points should be considered for voltage selection:

- 1) service voltage available from utility
- 2) load magnitude
- 3) distance the power is transmitted
- 4) rating of utilization device
- 5) result of load flow studies
- 6) safety
- 7) compatibility with existing installations

6.1.5.3 System voltage variation

An ideal electric power system is one which will supply constant frequency and voltage at rated nameplate value to every piece of apparatus in the system. In modern power system frequency is a minor problem but it is impractical to design a power system which will deliver absolutely constant rated nameplate voltage to every piece of apparatus. Since this cannot be attained what are the proper limits of voltage in an industrial plant?

This should be determined by the characteristics of the utilization apparatus.

The voltage at incoming terminal shall not deviate more than $\pm 5\%$ and the system frequency shall not deviate from the rated frequency more than $\pm 2\%$. the total harmonic distortion shall not be more than 8% and each harmonic distortion shall not be more than 5%.

6.1.5.3.1 Permissible voltage drop

Voltage drop in a distribution system is the difference at any instant between the voltages at the source and utilization end of a feeder branch circuit or transformer. Voltage spread is the difference between the maximum and minimum voltages existing in any one voltage class system under specified steady state condition. Voltage regulation is a measure of the change in voltage between no load and full load in terms of the full load voltage.

$$\text{Percent regulation} = \frac{(\text{no load voltage}) - (\text{full load voltage})}{\text{full load voltage}} \times 100$$

The electrical power system shall be so designed to limit voltage drop (base on nominal voltage) in the feeder cables to the following values:

- Feeders to area sub-station	1%
- Feeders from area sub-station	1%
- Motor branch circuit (at full load)	5%
- Power source to panel board	2%
- Lighting circuits from panel board to last lighting fixture	3%
- The maximum voltage drop in the motor feeder cable during motor starting	15%

Note:

The total voltage drop to the terminals of motors shall not exceed 15% of the nominal system voltage during the motor starting period under the worst conditions of the supply through the distribution network.

For medium and high voltage motors the cable voltage drop at motor full load shall not exceed 3.25%.

6.1.5.3.2 Improvement of voltage conditions

If voltage condition must be improved the following are suggested lines of consideration:

- Changing circuit constants
- Changing the transformer taps

6.1.5.4 Motor starting voltage drop

It is characteristic of most alternating-current motors that the starting current is much higher than their normal running current. Synchronous and squirrel-cage induction motors starting on full voltage may draw a current as high as seven or eight times their full load running current. This sudden increase in the current drawn from the power system may result in excessive drop in voltage unless it is considered in the design of the system. The motor starting KVA, imposed on the power-supply system and the available motor torque are greatly affected by the method of starting used.

Table 1 gives a comparison of motor starting common methods.

Table 2 shows general effect of voltage variations on induction motor characteristics.

TABLE 1 - COMPARISON OF MOTOR-STARTING METHODS*

Type of Starter (Settings given are the more common for each type)	Motor Terminal Voltage Line Voltage	Starting Torque Full-Voltage Starting Torque	Line Current Full-Voltage Starting Current
Full-voltage starter	1.0	1.0	1.0
Auto transformer			
80 percent tap	0.80	0.64	0.88
65 percent tap	0.65	0.42	0.46
50 percent tap	0.50	0.25	0.30
Resistor starter, single step (adjusted for motor voltage to be 80 percent of line voltage)	0.80	0.64	0.80
Reactor			
50 percent tap	0.50	0.25	0.50
45 percent tap	0.45	0.20	0.45
37.5 percent tap	0.375	0.14	0.375
Part-winding starter (low-speed motors only)			
75 percent winding	1.0	0.75	0.75
50 percent winding	1.0	0.50	0.50
Star delta starter	0.57	0.33	0.33

*** Notes:**

1) For a line voltage not equal to the motor rated voltage multiply all values in the first column by the ratio:

$$\left(\frac{\text{Actual voltage}}{\text{Motor rated voltage}} \right)$$

2) Multiply all values in the second column by the ratio:

$$\left(\frac{\text{Actual voltage}}{\text{Motor rated voltage}} \right)^2$$

3) And multiply all values in the last column by the ratio:

$$\left(\frac{\text{Actual voltage}}{\text{Motor rated voltage}} \right)$$

TABLE 2 - GENERAL EFFECT OF VOLTAGE VARIATIONS ON INDUCTION MOTOR CHARACTERISTICS

Characteristic	Voltage Variation		
	Function of Voltage	90 Percent Voltage	110 Percent Voltage
Starting and maximum running torque	(Voltage)	Decreases 19%	Increase 21%
Synchronous speed	Constant	No Change	No Change
Percent Slip	1/(Voltage)	Increase 20%	Decrease 17%
Full-Load Speed	(Synchronous Speed-Slip)	Decrease 1½	Increase 1%
<u>Efficiency</u>			
Full Load	---	Decrease 2%	Increase 1/2-1%
3/4 Load	---	Practically No Change	Practically No Change
1/2 Load	---	Increase 1-2%	Decrease 1-2%
<u>Power Factor</u>			
Full Load	---	Increase 1%	Decrease 3%
3/4 Load	---	Increase 2-3%	Decrease 4%
1/2 Load	---	Increase 4-5%	Increase 5-6%
Full-Load Current	---	Increase 11%	Decrease 7%
Starting Current	---	Decrease 10-12%	Increase 10-12%
Temperature Rise Full Load	---	Increase 6-7°C	Decrease 1-2°C
Maximum Overload Capacity	Voltage	Decrease 19%	Increase 21%
Magnetic Noise-No load in particular	(Voltage)	Decrease Slightly	Increase Slightly

*** Note:**

This data applies to motors above 25 horsepower (hp) .

6.1.6 power distribution systems

6.1.6.1 General

6.1.6.1.1 The distribution network shall be designed to carry continuously at least 120% of the 'After Diversity Maximum Demand' (ADMD) associated with peak design production at the maximum ambient conditions.

6.1.6.1.2 The selected distribution arrangement shall have a degree of reliability consistent with the type of load being supplied, and with the power supply design philosophy which provides for coincidental maintenance and unscheduled outage of the largest component of on site generating plant or unscheduled outage of the largest feeder component of the power supply equipment.

6.1.6.2 Radial systems

These systems distribute power radially from the power source to the load and shall be used in single, duplicate or triplicate arrangements.

6.1.6.3 Single radial

6.1.6.3.1 The single radial system provide power to non-essential electrical loads or loads where alternative sources of energy are available such as standby generating plant.

6.1.6.3.2 Each component of the single radial circuit shall be capable to supply 120% of the required electrical load. Transformers or other plant which includes forced cooling equipment shall not rely on the forced cooling arrangements to obtain the necessary rating.

6.1.6.4 Double radial

6.1.6.4.1 Critical and essential loads shall be supplied by two or more identically rated radial system.

6.1.6.4.2 In double radial systems, each circuit shall be capable of carrying 120% of the ADMD and all busbars shall include bus-section switchgear. They shall be arranged to ensure that unscheduled outage of any component of the circuit would not result in loss of power supply after the faulty equipment has been disconnected from the system, the only exception to this is the bus-section switch.

6.1.6.4.3 Double radially fed systems shall generally be operated in parallel with all bus-section switches closed. Also provision shall be considered for operation in "two out of three scheme" system.(non-parallel incomers)

6.1.6.4.4 Where switchgear fault levels are found to be above the values outlined in 6.1.8.3.2 attention shall be given to operating with bus-section breakers open as opposed to purchasing higher fault level switchgear. Where an open bus-section breaker philosophy is being given attention, the need to restore rapidly the supplies to drives shall determine whether automatic closure of bus section circuit breaker(s) is to be employed. Schemes with auto-reclosure are covered in 6.1.6.7.

6.1.6.5 Triple radial

6.1.6.5.1 Critical and essential loads may be alternatively supplied by triple identically rated radial systems. These systems are preferred to double radial systems wherever there is an overall total cost advantage.

6.1.6.5.2 Each circuit of triple fed radial systems shall be capable of providing 60% of the ADMD and all busbars shall be split into at least three sections with two bus-section switches. This will allow for the loss of any one of the three circuits, leaving the two healthy circuits still capable of providing 120% of the ADMD.

6.1.6.5.3 Triple radial systems shall be provided where the power flow is relatively large. They shall generally be operated with only two circuits in parallel to reduce switchgear fault levels. The incoming circuit breaker on the third identically rated feeder shall be left open and automatically closed in order to restore rapidly full supplies to the load. Triple radial system can also be operated with two non-parallel circuits closed and one open circuit for reserve.

Note:

For typical electrical distribution network see following typical single line diagrams 1,2 and 3.

6.1.6.6 Ring fed systems

6.1.6.6.1 Power may be distributed from a primary or central substation to number of subsidiary load centers by using two primary cable feeders connected in a ring emerging from the source busbar and controlled by circuit breakers.

6.1.6.6.2 Ring fed systems should normally duplicate only the primary cables to the load substation. They may however, duplicate the load substation transformers and the low voltage busbar by providing a low-voltage or secondary bus section breaker.

6.1.6.6.3 Ring fed systems may be operated with the ring closed or with it open at some point.

6.1.6.6.4 Where the ring feed is operated closed, intermediate primary circuit breakers, including unit feeder protection, shall be provided at all vital or essential load centers on the ring, thereby ensuring fault clearance of only the unhealthy section of the ring. The whole of the ring circuit shall

be fully rated to be capable of supplying 120% of the ADMD at all substations. Essential or critical loads may be supplied by ring systems if they are operated closed, their choice shall be based on the comparative reliability and cost as compared to the duplicate radial systems.

6.1.6.6.5 Ring fed systems which are operated open shall not include circuit breakers on the ring. Fault clearance shall be achieved at the source substation and in that event power will be lost to all loads fed between the source and the open point on the ring.

In order that a fully section of the primary ring may be disconnected and repaired without power loss during the whole of the repair period, the ring shall include isolating means at every load substation.

These ring dependent on availability, cost, and the need for rapid reconnection of load.

Open operated ring fed systems shall be permitted only to supply non-industrial system. Their choice shall be based on the comparative reliability and cost as compared with single radially fed systems with a non-automatic standby power supply back-up.

6.1.6.7 Automatic transfer schemes

6.1.6.7.1 Automatic transfer schemes shall be given attention where there is a need to obtain a reliability level consistent with two or more sources of supply. Their use shall be economically justified when compared against other ways of providing duplication of power sources, and shall be limited to installations where there is a need to reduce switchgear short circuit levels either for reasons of cost or non-availability. All schemes shall only include load transfers that never parallel the preferred and emergency sources. Load transfer schemes may use circuit breakers, or on-load transfer switches/contactors.

6.1.6.7.2 Load transfer schemes may be applied to either static loads or induction motor loads or combination of the two. They shall not be used where synchronous motor loads are supplied. The load transfer shall be arranged so that the residual voltage of induction motors has decayed to less than 25% of the rated source voltage before the transfer is initiated. The rate of residual voltage decay shall be calculated and the complete transfer scheme shall be subject to approval by the client.

6.1.6.7.3 Induction motors which are controlled by circuit breakers, or contactors of the DC controlled or AC controlled mechanically latched type shall include time delay under voltage relaying. This relaying shall be set to trip the controller in typically 2 seconds or more on voltage dips to below 85% of the rated voltage. Transfer schemes associated with switchgear supplying these types of induction motor controllers shall be designed either to be capable of reaccelerating the motors within if the transfer taken place within the motor under voltage tripping time, or time delaying the transfer to be in excess of the motor under voltage tripping time.

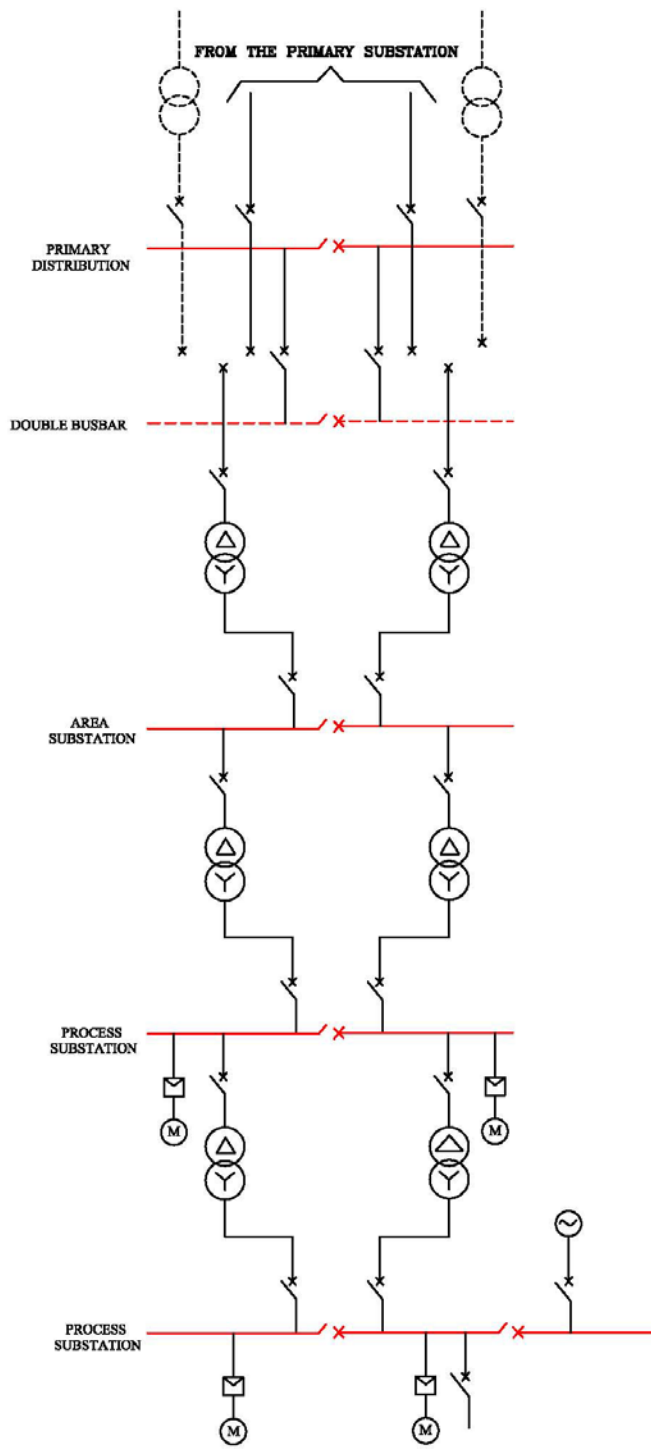
6.1.6.7.4 Motors which are controlled by unlatched AC, contactors will inherently disconnect from the supply on loss of voltage. Where it is required to restore power to these types of motor drives the auto-transfer schemes shall be supplemented by contactors control schemes which restart motors individually or in groups after a requisite time delay.

6.1.6.7.5 Load transfer schemes for the startup, run and loading of a standby generator on to a busbar normally fed from a preferred AC source shall be initiated by time delayed under voltage relaying set at 85% volts which shall trip the AC source and auto-start up the standby generator simultaneously. No transfer time delay is required in this case as standby generators take many seconds to be run up and loaded.

6.1.6.7.6 Power system re-acceleration and re-start studies to determine the most technically acceptable and cost effective solution shall be carried out for each load transfer scheme considered and all such studies and their conclusions shall be subject to approval by the client.

6.1.6.8 Manual transfer schemes

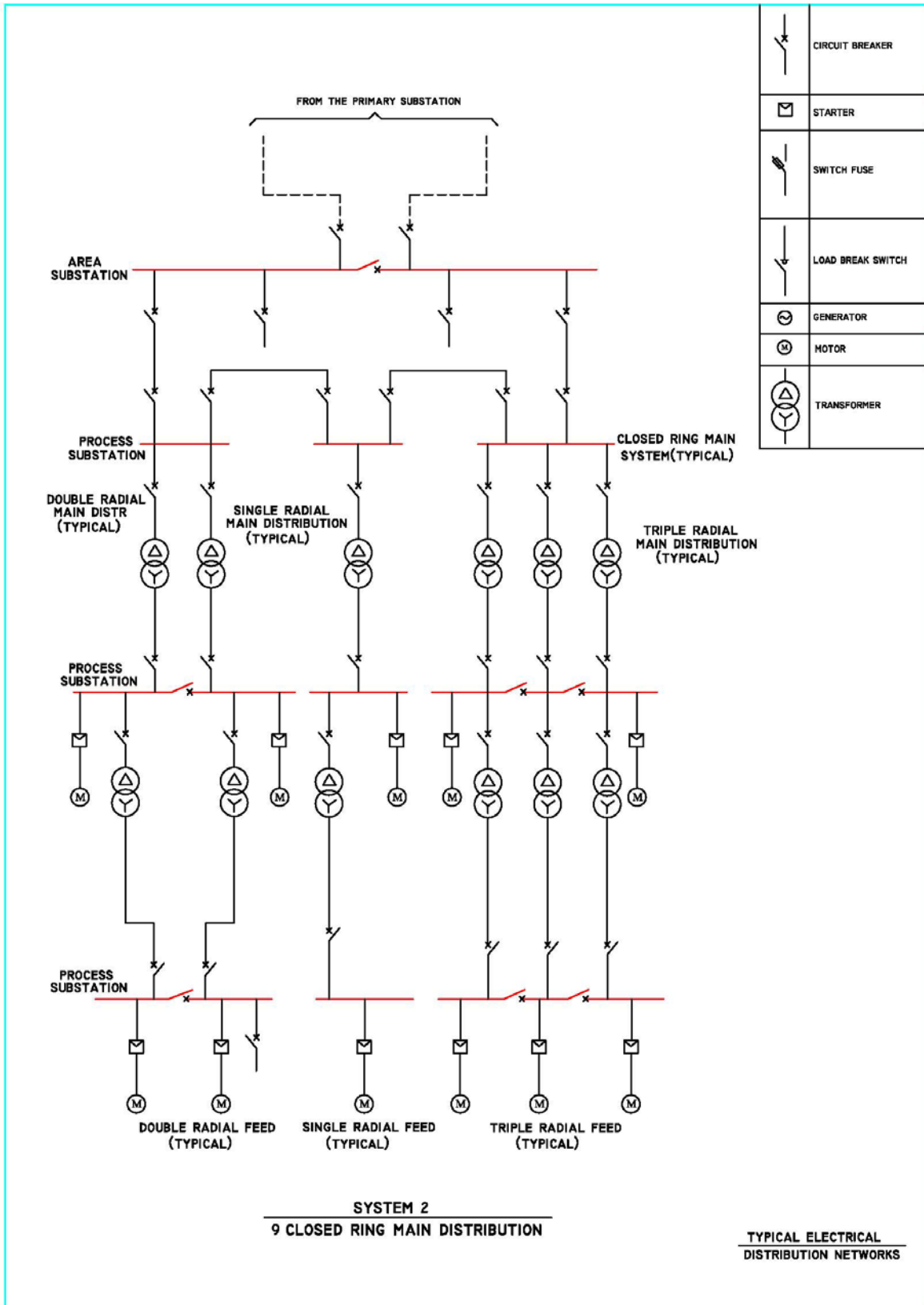
Interlock should be provided for 2 out of 3 systems, such that in every distribution only 2 breakers of 3 could be in close position.

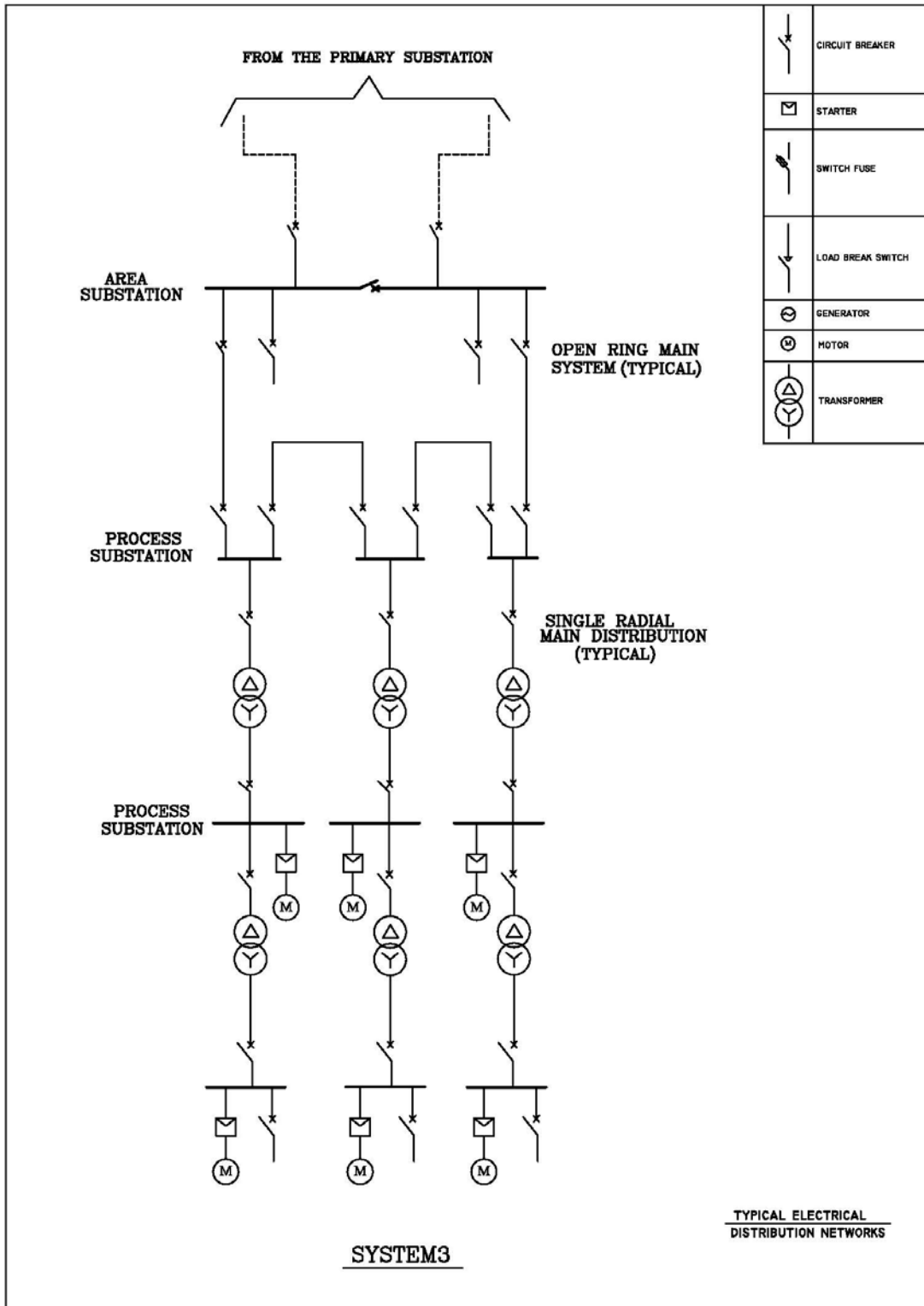


	CIRCUIT BREAKER
	STARTER
	SWITCH FUSE
	LOAD BREAK SWITCH
	GENERATOR
	MOTOR
	TRANSFORMER

SYSTEM 1
(DOUBLE RADIAL FEED DISTRIBUTION)

TYPICAL ELECTRICAL
DISTRIBUTION NETWORK





6.1.7 Power factor improving equipment

6.1.7.1 Power factor improving equipment shall be provided on all installation where energy is imported from a public utility which applies a tariff penalty associated with low power factor energy provision.

6.1.7.2 The equipment may be capacitors or synchronous motors depending on economics and suitability over the range of known operating condition.

6.1.7.3 Where the public utility system is normally in parallel with on site generation, the generating equipment shall be designed and operated to supply the load KVAR; this will avoid the need for power factor improving equipment to be installed for the normal parallel operating mode and will limit its provision to that required for standby (unparalleled operation alone).

6.1.7.4 The amount of power factor equipment provided shall be such as to avoid any possibility of paying power factor penalties under the worst conceivable plant operating condition.

6.1.7.5 Any power factor improving equipment provided either to reduce system losses (or to raise voltage levels alone) shall be subject to approval of client.

6.1.7.6 Where synchronous motors are supplied for power factor improvement, they shall include constant power factor control equipment.

Note:

In order to avoid risks of over voltages or high transient torques, induction motors shall not be switched as a unit with their power factor improving capacitors, unless the capacitive current is less than the no load magnetizing current of the associated induction motor.

6.1.7.7 Correction can be applied in the form of individual, group or central compensation to set the power factor at 0.95. A technical / economical study for the size and location of power factor correction equipment shall be performed.

6.1.8 Power system fault considerations

6.1.8.1 Fault calculations

6.1.8.1.1 The fault currents that flow as a result of short circuits shall be calculated at each system voltage for both three phase and phase to earth fault conditions. These calculated currents shall be used to select suitably rated switchgear and to allow the selection and setting of protective device to ensure that successful discriminatory fault clearance is achieved.

6.1.8.1.2 The voltage disturbance sustained during the faults and after fault clearance shall also be ascertained to ensure that transient disturbances do not result in loss of supplies due to low voltages or overstressing of plant insulation due to high voltages.

6.1.8.1.3 The calculation of fault currents shall include the fault current contribution from generators and from synchronous and induction motors. Both the AC symmetrical and DC component of fault currents shall be calculated at all system voltages. Public utility fault in feeds shall be obtained from the public utility concerned, and they shall exclude any decrement associated with fault duration, though maximum and minimum values consistent with annual load cycles shall be obtained.

6.1.8.1.4 Positive sequence impedances shall be used for calculating balanced three phase faults. Positive, negative and zero sequence impedances shall be used for calculating unbalanced faults.

6.1.8.1.5 Three phase balanced fault current calculations shall be carried out to obtain prospective circuit breaker ratings and shall include:

i) Asymmetric make capacity-expressed in peak amperes and calculated half a cycle after fault inception. Both AC and DC current decrements shall be included for the half cycle.

ii) Asymmetric break capability-expressed in rms amperes calculated at a time at which the breaker contacts are expected to part and allowing a maximum of 10 ms for instantaneous type protection operation. Both AC and DC decrements shall be included for the selected time.

iii) Symmetrical break capability-expressed in rms amperes calculated at a time as defined in item (ii) above. This assumes nil DC current component and shall allow for AC decrement for the selected time.

6.1.8.1.6 Earth fault currents may be assumed to be no greater than the maximum phase fault currents for solidly earthed systems. On systems where the earth fault currents are limited by neutral earthing equipment, the currents may be assumed to include no decrement and shall be considered constant whatever the level of bonding between the conductor and the faulted phase.

6.1.8.1.7 Both the AC and DC components of motor fault current contributions shall be calculated and included in calculation of prospective fault currents. At the instant of fault inspection the AC peak symmetrical component and the DC component shall be taken to be identical. Both values shall be taken as the peak direct-on-line starting current, this being dictated by the motor locked rotor reactance. Both these currents shall be taken to decay exponentially with time using AC and DC short circuit time constants respectively. The AC time constant shall be determined by using the ratio of the locked rotor reactance to the standstill rotor resistance. The DC time constant shall be determined by using the locked rotor reactance to the stator resistance ratio. In the case of faults not directly on the motor terminals, these time constants shall be modified to take account of external impedances to the point of fault.

6.1.8.1.8 The calculation of individual fault current contributions shall be carried out for individual motors of significant rating on the power system. Generally motors with ratings greater than 500 kw should be treated in this way.

6.1.8.2 Equipment fault current ratings

6.1.8.2.1 All switchgear and distribution equipment on the power system shall be capable of carrying the prospective symmetrical fault currents for specified short time duration of 1 or 3 seconds without deleterious effect. The choice between 1 and 3 second durations shall be dictated by availability, economics and fault current protection clearing times. Generally 3 second short time rating is preferred to avoid the necessity for rapid protection. The back-up fault current protection clearing times shall always be less than the equipment short time current rating.

6.1.8.2.2 The closure of switchgear on to a balanced or unbalanced fault shall not result in shock load damage to healthy parts of the system as a result of peak asymmetrical make currents following.

6.1.8.2.3 The selection of circuit breakers shall be dependent on the make and break duty which the breaker is required to cater for switching devices that may be closed on to fault shall have the necessary fault making capability.

6.1.8.2.4 Plant protected by fault current limiting HRC type fuses need not be designed to sustain the prospective shock or thermal loads obtained by calculating system fault currents.

6.1.8.3 Methods of limiting fault currents

6.1.8.3.1 The power distribution system shall be designed to provide the required security and quality of supply with prospective fault levels within the capability of commonly available switchgear acceptable maximum short circuit symmetrical breaking current for various system voltages unless otherwise specified or approved by company are as follows:

i) Power systems with a voltage in excess of 1000 V shall be so designed that the rms value of the AC components of the short-circuit breaking current of the circuit breakers is to IEC 60056 and or shall not exceed 25 KA.

ii) For power systems with a voltage less than 1000 volt, the rms value of the AC component of the short circuit breaking current of circuit breaker designed shall be IEC 60157 and shall not exceed 50 KA.

If the power system design indicates prospective short circuit requirements exceeding the maximum circuit breaker rating given above, the following alternatives should be considered:

- i) Increase the system reactance, provided this causes no other technical or commercial problem.
- ii) Change the operating mode by operating with certain breakers open and provide auto-transfer facilities to reinstate the supply security and quality levels.
- iii) Purchase switchgear and equipment to provide for the higher short circuit levels if these are available.
- iv) Provide fault current limiting devices other than fuses.
- v) Carry out any combination of the alternatives listed in items (i) to (iv) above.

6.1.8.3.2 To have an idea of the short time withstand current for switchgear the following are to be considered:

- a) All short circuit studies to be carried out in compliance with requirements of IEC standards.
- b) The minimum short time withstand current for busbars shall be according to figures given in Table 3.
- c) The minimum short time withstand current for low voltage busbars with explosion protection type Exd (EExd) shall be 15 KA.

TABLE 3

RATED VOLTAGE	WITHSTAND CURRENT
63-66 KV	20 KA (R.M.S.)
33 KV	25 KA (R.M.S.)
20 KV	25 KA (R.M.S.)
* 11 KV	25 KA (R.M.S.)
6 KV	25 KA (R.M.S.)
* 3.3 KV	25 KA (R.M.S.)
0.4 KV	50 KA (R.M.S.)

* Refer to: 6.1.5.1

6.1.8.4 Effects of faults on distribution systems

Bolted three phase faults on the system will depress the voltage at the point of fault and downstream of the fault to zero.

All locations between the sources of fault current and the fault will experience reduced voltages. This conditions will apply until the faulty section has been cleared at which stage voltages will be rapidly restored.

The following effects of three phase fault applications and clearances shall be investigated:

- i) Possible loss of synchronize between parallel running synchronous machines. This would only be likely for dissimilar machines or for identical machines connected to the fault which are not electrically symmetrical.
- ii) The possibility of motor contactors dropping out, and the consequential need to re-start the motors, either manually or automatically.
- iii) Possible extinction of certain discharge lamps and the time for re-ignition. The provision of emergency lighting systems avoids the need to study this.

- iv) Loss of electronic and control equipment supplies resulting in maloperation. The provision of DC or 'no break' supplies for vital loads avoids the need to study this.
- v) The extent of overvoltage on the system components resulting from fault clearance. This could cause unacceptable transient recovery voltages occurring for short periods which may have a destructive effect on electrical insulation.

6.1.9 System one line diagram

A one line diagram is one which indicates by means of single lines and simplified symbols the course and component devices or parts of an electric circuit or system of circuits.

In the preparation of preliminary plans for a system or specification it is not necessary to show all details in complete form on a one line diagram. Some of the more important items to be included are as follows:

- i) Voltage, phase and frequency.
- ii) The available fault level of system and (time).
- iii) The size, type and number of incoming and outgoing cables.
- iv) The ratings, impedances and connections of the transformers.
- v) The points at which power is metered (where applicable).
- vi) The amount and character of the load on all feeders.

The following items if given special attention during preparation ensure complete, accurate and clear diagrams.

- a) Keep the diagram simple
- b) Avoid duplication
- c) Use of standard symbols
- d) Show all known facts

By the following list before releasing a diagram the omission of some of the more important details can be avoided:

- Rating and protection of devices.
- Ratio of current and potential transformers.
- Connection of transformer winding.
- Circuit breaker rating.
- Switch and fuse rating.
- Function of relays.
- Rating of motors and transformers.
- Size and type of transformers.
- Size and type of cables.

A statement should accompany this information stating whether or not the neutral of any apparatus connected to the source is grounded. If grounded the statement should specify whether the ground is solid or through an impedances, if the latter, the value of the impedances should be given.

- e) Show future plans and extension where applicable.
- f) Include correct title data.

6.1.10 Device function numbers

While preparing single line diagrams, It is necessary to show the numbers indicating electrical instrument function.

The most common type of electrical/instrument function numbers which follow are extracted from:

IEEE Std. C 37.2 "Standard Electric Power System Device Function Numbers"

1	Master element
2	Time-Delay starting or closing relay
3	Checking or interlocking relay
4	Master contactor
5	Stopping device
6	Starting circuit breaker
7	Reserved for future application
8	Control power disconnecting device
9	Reversing device
10	Unit sequence switch
11	Multifunction device
12	Over speed device
13	Synchronous-Speed device
14	Under speed device
15	Speed or frequency matching device
16	Reserved for future application
17	Shunting or discharge switch
18	Accelerating or decelerating device
19	Starting-To-Running transition contactor
20	Electrically operated valve
21	Distance relay
22	Equalizer circuit breaker
23	Temperature control device
24	Volts per hertz relay
25	Synchronizing or synchronism check device
26	Apparatus thermal device
27	Under voltage relay
28	Flame detector
29	Isolating contactor
30	Annunciator relay
31	Separate excitation device
32	Directional power relay
33	Position switch
34	Master sequence device
35	Brush-Operating or slip-ring Short-Circuiting device
36	Polarity or polarizing voltage device
37	Undercurrent or under power relay
38	Bearing protective device
39	Mechanical condition monitor
40	Field relay
41	Field circuit breaker
42	Running circuit breaker
43	Manual transfer or selector device
44	Unit sequence starting relay
45	Atmospheric condition monitor
46	Reverse-Phase or phase-balance current Relay
47	Phase-Sequence or phase balance voltage Relay
48	Incomplete sequence relay
49	Machine or transformer thermal relay
50	Instantaneous over current or rate-of rise Relay

51	AC time over current relay
52	AC circuit breaker
53	Exciter or DC generator relay
54	Turning gear engaging device
55	Power factor relay
56	Field application relay
57	Short-Circuiting or grounding device
58	Rectification failure relay
59	Overvoltage relay
60	Voltage or current balance relay
61	Density switch or sensor
62	Time-Delay stopping or opening relay
63	Pressure switch
64	Ground detector relay
65	Governor
66	Notching or jogging device
67	AC directional over current relay
68	Blocking relay
69	Permissive control device
70	Rheostat
71	Level switch
72	DC circuit breaker
73	Load-Resistor contactor
74	Alarm relay
75	Position changing mechanism
76	DC over current relay
77	Telemetry device
78	Phase-Angle measuring or out-of-step Protective relay
79	AC reclosing relay
80	Flow switch
81	Frequency relay
82	DC reclosing relay
83	Automatic selective control or transfer Relay
84	Operating mechanism
85	Carrier or pilot-wire receiver relay
86	Lockout relay
87	Differential protective relay
88	Auxiliary motor or motor generator
89	Line switch (disconnecting switch)
90	Regulating device
91	Voltage directional relay
92	Voltage and power directional relay
93	Field-Changing contactor
94	Tripping or trip-free relay
95	Used only for specific application
96	Used only for specific application
97	Used only for specific application
98	Used only for specific application
99	Used only for specific application

6.1.11 Drawings and schedules

Unless specified otherwise, the consultant responsible for the system design shall provide the following:

- 1) Plant layout diagram
- 2) Hazardous area classification (where applicable)

- 3) General single line diagram
- 4) Single line diagram for each substation
- 5) Relaying and metering diagrams
- 6) Schematic and wiring diagram
- 7) Coordination diagrams
- 8) Substation layouts
- 9) Cable runs and schedules (type, size and length)
- 10) Lighting layout
- 11) Earthen layout
- 12) Load flow analysis
- 13) Short circuit studies
- 14) Stability studies
- 15) Load shedding system

6.1.12 Alarms, indication and communication system

6.1.12.1 Plant alarms

6.1.12.1.1 Each substation and each on-site generator shall be provided with an alarm annunciation system. This shall comprise an alarm panel which shall collect together all the alarm conditions associated with that particular substation or generator. A common alarm shall be derived from each substation or generator alarm panel for transmission to an emergency control center.

6.1.12.1.2 Each generator alarm panel shall have an alarm window associated with each separate alarm condition required.

6.1.12.1.3 A window shall be provided on the substation alarm panel for each switchboard circuit breaker way which has protective relaying.

Where battery chargers are provided for closing and tripping supplies a window shall be provided on the substation alarm panel for each battery charger.

6.1.12.1.4 Each alarm window of a substation alarm panel shall be operated by the combined alarm functions of the equipment the window is supposed to represent. For any circuit breaker each protective relay shall provide a contact into a common alarm circuit which shall operate the appropriate circuit breaker alarm window in the alarm panel. The alarms associated with a battery charger shall form a common alarm to operate the appropriate battery charger alarm window in the alarm panel.

6.1.12.2 Fire alarm

Fire alarm circuits should be installed in a manner that will guarantee the least interruption from faults and changes in buildings or plant operations. Lines should be arranged to provide easy means of testing and of isolating portions of the system, in case of fault or changes without interference with the balance of the system.

6.1.12.3 Indications

6.1.12.3.1 Local indication of status of circuit breakers on switchgear shall be as described on [IPS-M-EL-143\(2\)](#) and [IPS-M-EL-144\(2\)](#).

6.1.12.4 Plant communication system

Any plan for the protection of a plant must include an adequate and reliable system of communication, both within the plant and to the associated utilities and emergency services which may be called upon in case of need. This can be accomplished in several ways; a principal one is by a completely self-contained and self-maintained inter-plant system of telephones, alarms, etc., and may include modern radio equipment as well.

6.1.13 Safety and plant protection

6.1.13.1 Personnel safety

There are listed below items which shall be considered in order to provide safe working conditions for the personnel.

- 1) Interrupting devices shall be able to function safely and properly under the most severe duty to which they may be exposed.
- 2) Protection shall be provided against accidental contact with energized conductors by elevation, barriers, enclosures, and other similar equipment.
- 3) Disconnecting switches should not be operated while they are carrying currents, unless designed to do so. Suitable barriers shall be provided between phases to confine accidental arcs unless adequate space separation is provided.
- 4) In many instances interlocks between the disconnecting switch and the power circuit breaker are desirable, so that the breaker in series shall be opened first before the disconnects can be operated, thus preventing accidental opening of the disconnects under load.
- 5) Sufficient unobstructed room in any area containing electric apparatus shall be provided for the operator to perform all necessary operations safely.
- 6) A sufficient number of exits with panic hardware on all doors shall be provided from any room containing electric apparatus such as a substation, control room or motor so that escape from this area can be easily effected in the event of failure of apparatus in the room.
- 7) A protective tagging procedure shall be set up to give positive protection to men working on equipment. Such a procedure shall be coordinated with the local utility for the common equipment.
- 8) Industrial plant electric systems should generally be designed so that all necessary work on circuits and equipment can be accomplished with the particular circuits and equipment de-energized.
- 9) All circuits shall be marked in the switching station so as to be readily identified. Cables shall be identified with suitable tags at both ends and in all manholes for the protection of men working on them.
- 10) A fire crew shall be formed of local employees who are familiar with the equipment and the hazards involved. This group shall be trained in the proper procedures to follow in the event of fire in the electric apparatus, the proper use of the various types of extinguishers and methods of fire fighting.

For more details see IEEE Guide for Substation Fire Protection IEEE Std 979-1994.

6.1.13.2 Equipment safety

Electrical interlocks : Safety interlocks can be arranged for almost any machine and any operating condition.

"An interlock is a device actuated by the operation of some other device with which it is directly associated to govern succeeding operations of the same or allied devices."

Interlocks have three general functions:

- To assure personal safety
- To protect equipment
- And to coordinate complex operations
- Adequate machinery guarding is of course basic to any organized safety program.

Human habits and practices in the interest of safety are difficult to establish and maintain, however interlocking of equipment either by manufacturer or by the user removes hazards and is a critical part of safe design and installation. As a general rule the starting point in determining the need for interlocking is to consider the past accident history of injury or major material damage, the question of whether the use of an interlocking device to prevent the injury should be considered.

It should be remembered that interlocking devices and their application go beyond protecting the point of operation during the normal work process. They can be used to restrict, access areas through gate operated controls or through other device such as castle interlock.

Interlocks can initiate visual or audible warnings or stop an operation or malfunction. Key type interlocks are often employed for access and sequence control.

If a visual warning is desirable flashing red light may be considered. Immediately, there is the problem of "burned out" light and the system is not "fail safe". Two lights in parallel offer redundancy and are generally acceptable.

In a series of process operations interlocks can be provided which will afford the necessary safety for operator and equipment in the event of failure of sequence timers or controllers.

The design and application of interlocks usually affect a critical safety function. It follows that they must be extensively tested and proved be convenient to use, have fail safe provisions and if applicable have detailed procedures to verify proper function.

6.1.14 Hints on protection of property against fire

A potential fire or explosion hazard is inherent with the use of nearly all electric apparatus and proper arrangement and protection of the equipment at the start will minimize if not eliminate serious property damage or interruption to production when insulation failures or breakdown occur.

The fire and explosion hazard of oil-insulated and compound-filled equipment is one of the most common hazards to safeguard against. Fires or explosions in oil insulated transformers occur infrequently, but where they do the results may be disastrous depending upon the arrangement of the equipment and the safeguards provided. The old practice of locating oil-filled transformers in the same room with an important switchgear assembly or other valuable apparatus should be avoided because a fire in the transformer will usually involve the other equipment increasing the damage and prolonging the interruption to production.

The National Electrical Code clearly outlines the installation requirements for transformers of all types. Oil-insulated transformers installed indoors must be installed in a vault of fire resistant construction if the total capacity exceeds 75 KVA .

Where a vault is required, adequate ventilation and drainage facilities are necessary to prevent overheating of the transformer and to drain away, to a safe place, any oil that may be released or expelled.

The cost of a vault may be eliminated, and a saving in space effected, by substituting dry type transformers in place of the oil insulated type. Dry-type sealed-tank nitrogen-filled transformers are considered fire and explosion resistant and need no special safeguards from this standpoint.

Where oil-insulated transformers are installed outdoors they should be located at least 8 meters away from combustible buildings or structures. They should not be located under important bridges, conveyors, tanks or similar structures where heat from a fire in the transformer may cause collapse of or serious damage to the structure. Facilities such as crushed stone-filled basins or drained concrete basins should be provided under the transformers to drain away and oil that may be expelled from them in time of trouble. Where a fire in one outdoor oil-insulated transformer is likely to involve other transformers in the same bank, a non-combustible barrier or wall is sometimes provided between adjacent transformers to confine the fire to the unit in which it started.

Permanently piped fire extinguishing Co₂ systems shall also be installed over large oil-insulated transformers or other oil-insulated apparatus where the value or importance of the apparatus and nearby equipment justifies this expense. These systems may be arranged to discharge either manually or automatically. One system employs water spray nozzles connected to a reliable and strong water supply.

The grouping together of a number of valuable or important cables or wires in trenches, cable boxes, junction boxes and manholes should be avoided, particularly if they have combustible insulation. This applies to low, medium, and high-voltage installations, and lead sheathed cables as well. A failure in one cable or conductor can cause an arc that ignites the insulation on one cable and fire may destroy the entire group, or the arc can do extensive damage in the event of sustained arcing. Where it is necessary to group such cables together, they should be protected with a fireproof covering.

The control circuits in power houses and substations should be arranged so that they will not be exposed to damage by arcing or fire. When possible, these wires should have asbestos or similar fire-resistive coverings.

An adequate supply of fire extinguishers should be provided on the premises, particularly in the vicinity of large quantities of electric apparatus. Extinguishers suitable for use on live electric apparatus are the vaporizing liquid, carbon dioxide, and dry chemical types.

Where insulating oil or compound is present in large quantities in power houses, substations, and motor rooms where there are many large motors present.

Note:

For further information on fire protection see the following Standards:

[IPS-E-SF-260](#) Automatic detectors and fire alarm system

[IPS-G-SF-126](#) Hand and wheel type fire extinguishers

[IPS-E-SF-160](#) Co₂ gas fire extinguishing system

6.1.15 Special studies

6.1.15.1 Load flow analysis

The objective of load flow analysis is to check voltage profile and circuit loading conditions under steady state conditions. Systematic routine solution of load flow problems are outlined as follows:

- 1) Mesh current method and connection matrices.
- 2) Nodal voltage method and connection matrices.
- 3) Application of nodal voltage method to the solution of power system load flow problem.
- 4) Direct methods involving inversion of the nodal admittance matrix.
- 5) Modification of the inverse of the nodal admittance metric.
- 6) Iterative methods
- 7) Tearing

6.1.15.2 Short circuit studies

Refer to clause 12 under title power system fault consideration.

6.1.15.3 Stability study of system

A synchronous power system has steady state stability if after a small slow disturbance it can regain and maintain synchronous speed; a small slow disturbance is taken to mean normal load fluctuation, including the action of automatic voltage regulators and turbine governors. A power

system has transient stability if, after a large sudden disturbance it can regain and maintain synchronous speed: a large sudden disturbance is one caused by faults and switching. In order to develop the main principles simply it is assumed that the automatic voltage regulations and turbine governors are too slow to act during the period of the analysis. Dynamic stability refers to the case of transient stability where the regulations and governors are fast acting and are taken into account in the analysis.

The stability limit of the system is the maximum (Steady state) power which can be transformed through the system without loss of stability. The limits depend also on the magnitude, type and location of the disturbance. The stability factor is the ratio of the stability limit to the actual load-power transfer it can be shown that all the machines in a power exporting area can be reduced to an equivalent generator "G" and similarly that all the machines in a power importing area can be reduced to an equivalent synchronous motor 'M' the distribution or transmission system which connects these two areas is called interconnection (or tie line) the above two machine system can be reduced to one machine connected to an infinite busbar a constant voltage and constant frequency system.

Generally resistance will be neglected, relative to the inductive reactance of the system.

To analyze the transient and dynamic performance of power systems, after large load changes and fault disturbances. These should be used to check:

- a) The ability of the system to stay in synchronism.
- b) Induction motor stability after start.
- c) Re-acceleration and re-start schemes.
- d) The need and effectiveness of under frequency load shedding schemes.

They should also be used to consider the technical merit of:

- e) Auto changeover schemes.
- f) Parallel or open operation or radial feeders.
- g) Operation of fault limiting devices.
- h) Insertion of switched reactors or capacitors, etc.

6.2 Non-industrial electrical systems

6.2.1 General

This recommendation covers the basic requirements to be considered in design of electrical systems in non-industrial buildings that comprise all buildings outside the process area, e.g. workshops, warehouses, canteens, administration and residential buildings, fire stations, training centers, gatehouses, chemical stores, etc.

6.2.2 Planning guide for distribution design

The following procedure is given to guide the engineer in the design of an electric system for any non-industrial buildings.

6.2.2.1 Obtain a general layout and mark it with the major loads at various locations and determine the approximate total non-industrial buildings load in horsepower, kilowatts, and kilo volt-amperes.

Estimate the lighting, air-conditioning, and other loads from known data.

6.2.2.2 Determine the total connected load and calculate the maximum demand by using demand and diversity factors.

6.2.2.3 Investigate unusual loads, such as the starting of large motors, or welding machines, and operating conditions such as boiler auxiliary motors, loads that must be kept in operation under all conditions, and loads that have a special duty cycle.

6.2.2.4 Investigate the various types of distribution system and select the system or systems best suited to the requirements of the switchboard. Make a preliminary one line diagram of the power system.

6.2.2.5 If power is to be purchased from the utility, obtain such information concerning the supply system or systems as:

performance data, voltage available, voltage spread, type of systems available, method of system neutral grounding, and other data such as relaying, metering and the physical requirements of the equipment. The interrupting rating and momentary ratings of power circuit breakers should be obtained as well as the present and future short-circuit capabilities of the utility system at the point of service to the switchboard. Investigate the utility's power contract to determine if off-peak power at lower rates available, and any other requirements, such as power factor and demand clauses, that can influence power cost.

6.2.2.6 A cost analysis may be required of the different voltage levels and various arrangements of equipment to justify and properly determine the voltage and equipment selected. The study should be made on the basis of installed cost including all the components in that section of the system.

6.2.2.7 Check the calculations of short-circuit requirements to be sure that all breakers are of the correct rating. Review the selectivity of various protective devices to assure selectivity during load or fault disturbances.

6.2.2.8 Calculate the voltage spread and voltage drop at various critical points.

6.2.2.9 Determine the requirements of the various components of the electric distribution system with special attention given to special operating and equipment conditions.

6.2.2.10 Review all applicable national and local Codes for requirements and restrictions.

6.2.2.11 Check to see that the maximum safety features are incorporated in all parts of the system.

6.2.2.12 Write specification on the equipment and include a one-line diagram as a part of the specifications.

6.2.2.13 Obtain typical dimensions of equipment and make drawings of the entire system.

6.2.2.14 Determine if the existing equipment is adequate to meet additional load requirements. Check such ratings as voltage, interrupting capacity, and current-carrying capacity.

6.2.2.15 Determine the best method of connecting the new part of the power system with the existing system so as to have a minimum outage at minimum cost.

Naturally the above procedure will not automatically design the electric power system in itself; it must be used with good, sound, basic engineering judgement.

6.2.2.16 Estimate the future load, it is necessary to study building plans and area utilization plans of the relevant area.

6.2.2.17 A general layout of the buildings should be available before the engineer can begin his study. This layout usually gives the location and the size of the proposed building or buildings in the initial particular project. The extent of the available layout gives the engineer an idea of the possible expansion in the future, and must be considered by the engineer in planning the electric distribution system.

6.2.2.18 The voltage regulation of system shall not exceed $\pm 5\%$.

6.2.3 Selection of distribution voltage

In general the voltage levels of the low-voltage and medium-voltage systems are fixed for the utility supply authorities.

For the low-voltage system of the public supply, a uniform standard value of 230/400 Volt is recommended. Where a high proportion of load is in motors then in new installations 400 volt 3 phase is also employed.

The medium-voltage systems lying above the low-voltage systems must fulfill two main functions: It must be sufficiently powerful to transmit the high incoming power from the main substation (feeding

from the high-voltage systems) and its component parts on the other hand transmit energy economically to numerous main substations and consumer stations. The optimum values for high voltage systems are the voltage levels of 11 and 20 kV or 33 kV.

6.2.4 Power distribution systems

6.2.4.1 General

a) In locations where there is a significant rising demand for power the selection of voltage levels in the medium-voltage systems forms a particularly important part of the network planning. Frequently because of the hitherto development, numerous voltage steps are found and because of several transformation steps additional costs for investment and losses are incurred. It must, however, be checked whether these voltage levels are adequate in the future for increasing demand or whether a higher voltage system should be used. In this aspect it must be assessed whether an existing intermediate voltage can be omitted partially or even completely or should be revised.

b) The distribution network shall be designed to carry continuously at least 120% of the 'After Diversity Maximum Demand' (ADMD) associated with peak design production at the maximum ambient conditions.

c) The selected distribution arrangement shall have a degree of reliability consistent with the type of load being supplied, and with the power supply design philosophy which provides for coincidental maintenance and unscheduled outage of the largest component of on site generating plant or unscheduled outage of the largest feeder component of the power supply equipment.

6.2.4.2 Distribution arrangements

The distribution system shall be designed using one of the following arrangements:

6.2.4.2.1 Single radial

a) The single radial system provide power to non-essential electrical loads or loads where alternative sources of energy are available such as standby generating plant.

b) Each component of the single radial circuit shall be capable to supply 120% of the required electrical load. Transformers or other plant which includes forced cooling equipment shall not rely on the forced cooling arrangements to obtain the necessary rating.

6.2.4.2.2 Double radial

a) Critical and essential loads should be supplied by two or more identically rated radial system.

b) In double radial systems, each circuit shall be capable of carrying a 120% of the ADMD and all busbars shall include bus-section switchgear. They shall be arranged to ensure that unscheduled outage of any component of the circuit would not result in loss of power supply after the faulty equipment has been disconnected from the system; the only exception to this is the bus-section switch.

c) Double radially fed systems shall generally be operated in parallel with all bus-section switches closed.

d) Where switchgear fault levels are found to be above the values outlined in 6.1.8.3.2 attention shall be given to operating with bus-section breakers open as opposed to purchasing higher fault level switchgear. Where an open bus-section breaker philosophy is being given attention, the need to restore rapidly the supplies to drives shall determine whether automatic closure of bus section circuit breakers(s) is to be employed. Schemes with auto-reclosure are covered in 6.1.6.7.

6.2.4.2.3 Triple radial

- a) Critical and essential loads may be alternatively supplied by triple identically rated radial systems. These systems are preferred to double radial systems wherever there is an overall total cost advantage.
- b) Each circuit of triple fed radial systems shall be capable of providing 60% of the ADMD and all busbars shall be split into at least three sections with two bus-section switches. This will allow for the loss of any one of the three circuits, leaving the two healthy circuits still capable of providing 120% of the ADMD.
- c) Triple radial systems shall be provided where the power flow is relatively large. They shall generally be operated with only two circuits in parallel to reduce switchgear fault levels. The incoming circuit breaker on the third identically rated feeder shall be left open and automatically reclosed in order to restore rapidly full supplies to the load.

6.2.4.2.4 Ring fed systems

- a) Power may be distributed from a primary or central substation to number of subsidiary load centers by using two primary cable feeds connected in a ring emerging from the source busbar and controlled by circuit breakers.
- b) Ring fed systems should normally duplicate only the primary cables to the load substation. They may however, duplicate the load substation transformers and the low voltage busbar by providing a low-voltage or secondary bus section breaker.
- c) Ring fed systems may be operated with the ring closed or with it open at some point.
- d) Where the ring feed is operated closed, intermediate primary circuit breakers, including unit feeder protection, shall be provided at all vital or essential load centers on the ring, thereby ensuring fault clearance of only the unhealthy section of the ring. The whole of the ring circuit shall be fully rated to be capable of supplying 120% of the ADMD at all substations. Essential or critical loads may be supplied by ring systems if they are operated closed, their choice shall be based on the comparative reliability and cost as compared to the duplicate radial systems.
- e) Ring fed systems which are operated open shall not include circuit breakers on the ring. Fault clearance shall be achieved at the source substation and in that event power will be lost to all loads fed between the source and the open point on the ring.

In order that a fully section of the primary ring may be disconnected and repaired without power loss during the whole of the repair period, the ring shall include isolating means at every load substation. These ring dependent on availability, cost, and the need for rapid reconnection of load.

Open operated ring fed systems shall be permitted only to supply non-essential loads. Their choice shall be based on the comparative reliability and cost as compared with single radially fed systems with a non-automatic standby power supply back-up.

6.2.5 Power supply systems

6.2.5.1 General

For the estimation of loads for large building complexes the physical arrangement (vertical or horizontal) of the individual consumers and the distribution of load center within the building must be taken into consideration. Apart from consumer equipments spread across an area, e.g. light fittings and small appliances, mostly also concentrated loads (lifts, air conditioning equipment, or large kitchens) must be supplied.

6.2.5.2 Power requirement

To plan the incoming supply of the system under consideration from a higher level of voltage or from a power station requires knowledge of the total load to be expected. The time related differing

load peaks of individual system parts are taken into account when determining the power requirements. It is necessary to take care of Maximum Demand and Diversity.

6.2.5.3 Maximum demand

Maximum demand (often referred to as MD) is the largest current normally carried by circuits, switches and protective devices; it does not include the levels of current flowing under overload or short circuit conditions. Assessment of maximum demand is sometimes straightforward. For example, the maximum demand of a 220 V single-phase 8 kW shower heater can be calculated by dividing the power (8 kW) by the voltage (220 V) to give a current of 36.3 A. This calculation assumes a power factor of unity, which is a reasonable assumption for such a purely resistive load.

There are times, however, when assessment of maximum demand is less obvious. For example, if a ring circuit feeds fifteen 13 A sockets, the maximum demand clearly should not be $15 \times 13 = 195$ A, if only because the circuit protection will not be rated at more than 32 A. Some 13 A sockets may feed table lamps with 60 W lamps fitted, whilst others may feed 3 kW washing machines; others again may not be loaded at all. Guidance is given in Table 4.

Lighting circuits pose a special problem when determining MD. Each lamp-holder must be assumed to carry the current required by the connected load, subject to a minimum loading of 100 W per lamp holder (a demand of 0.45 A per lamp holder at 220 V). Discharge lamps are particularly difficult to assess, and current cannot be calculated simply by dividing lamp power by supply voltage. The reasons for this are:

- 1) control gear losses result in additional current,
- 2) the power factor is usually less than unity so current is greater,
- 3) chokes and other control gear usually distort the waveform of the current so that it contains harmonics which are additional to the fundamental supply current.

TABLE 4 - CURRENT DEMAND OF OUTLETS

Type of outlet	Assumed current demand
2 A socket outlet	At least 0.5A
Other socket outlets	Rated current
Lighting point	Connected load, with minimum of 100 W
Shaver outlet, bell transformer or any equipment of 5 W or less	May be neglected
Household cooker	10A + 30% of remainder + 5A for socket in cooker unit

Switches for circuits feeding discharge lamps shall be rated at twice the current they are required to carry, unless they have been specially constructed to withstand the severe arcing resulting from the switching of such inductive and capacitive loads.

When assessing maximum demand, account must be taken of the possible growth in demand during the life of the installation. Apart from indicating that maximum demand must be assessed, the Regulations themselves give little help. Suggestions for the assumed current demand of various types of outlet are shown in Table 4.

6.2.5.4 Diversity factor

A domestic ring circuit typically feeds a large number of 13 A sockets but is usually protected by a fuse or circuit breaker rated at 30 A or 32 A. This means that if sockets were feeding 13 A loads, more than two of them in use at the same time would overload the circuit and it would be disconnected by its protective device.

In practice, the chances of all domestic ring sockets feeding loads taking 13 A are small. Whilst there maybe a 3 kW washing machine in the kitchen, a 3 kW heater in the living room and another in the bedroom, the chance of all three being in use at the same time is remote. If they are all connected at the same time, this could be seen as a failure of the designer when assessing the

installation requirements; the installation should have two ring circuits to feed the parts of the house in question.

Most sockets, then, will feed smaller loads such as table lamps, vacuum cleaner, television or audio machines and so on. The chances of all the sockets being used simultaneously is remote in the extreme provided that the number of sockets (and ring circuits) installed is large enough. The condition that only a few sockets will be in use at the same time, and that the loads they feed will be small is called diversity.

By making allowance for reasonable diversity, the number of circuits and their rating can be reduced, with a consequent financial saving, but without reducing the effectiveness of the installation. However, if diversity is over-estimated, the normal current demands will exceed the ratings of the protective devices, which will disconnect the circuits - not a welcome prospect for the user of the installation! Overheating may also result from overloading which exceeds the rating of the protective device, but does not reach its operating current in a reasonably short time. The Regulations require that circuit design should prevent the occurrence of small overloads of long duration.

The sensible application of diversity to the design of an installation calls for experience and a detailed knowledge of the intended use of the installation. Future possible increase in load should also be taken into account. Diversity relies on a number of factors which can only be properly assessed in the light of detailed knowledge of the type of installation.

6.2.5.5 Applied diversity

Suggestions of values for the allowances for diversity are given in Table 5.

TABLE 5 - ALLOWANCE FOR DIVERSITY

Note the following abbreviations : X is the full load current of the largest appliance or circuit Y is the full load current of the second largest appliance or circuit Z is the full load current of the remaining appliances or circuits			
Type of final circuit	Type of premises		
	Households	Small shops, stores, offices	Hotels, guest houses
Lighting	66% total demand	90% total demand	75% total demand
* window-type cooler or air conditioner	100%	100%	100%
Heating and power	100% up to 10 A + 50% balance	100%X + 75%(Y+Z)	100%X + 80%Y + 60%Z
Cookers	10 A + 30% balance + 5 A for socket	100%X + 80%Y + 60%Z	100%X + 80%Y + 60%Z
Motors (but not lifts)		100%X + 80%Y + 60%Z	100%X + 50%(Y+Z)
Instantaneous water heaters	100%X + 100%Y + 25%Z	100%X + 100%Y + 25%Z	100%X + 100%Y + 25%Z
* Thermostatic water heaters	100%	100%	100%
Standard circuits	100%X + 40%(Y+Z)	100%X + 50%(Y+Z)	100%X + 50%(Y+Z)
Sockets and stationary equip.	100%X + 40%(Y+Z)	100%X + 75%(Y+Z)	100%X + 75%Y + 40%Z

*** Note: Depending on the ambient temperature the allowance for diversity can be considered by designer.**

6.2.6 Power supply in non- residential buildings

6.2.6.1 Supply and distribution considerations

In this section consideration is given to some of the special features and requirements of the installations in stores, office and leisure premises and other non domestic medium sized installations.

While single phase 25 A services are adequate for the smaller shop or office unit, premises with a prospective maximum demand in excess of about 5 kW will be provided with a three phase 230/400 volt supply.

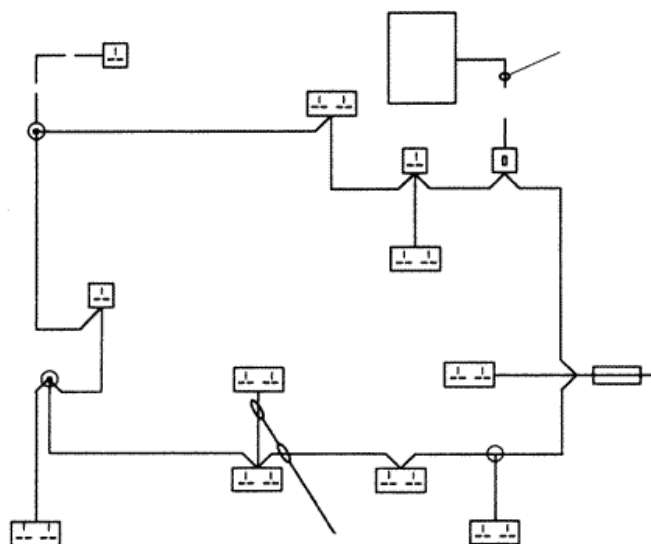
The service cable will be terminated in a cut-out located in agreement with the Electricity Authority where applicable. This should preferably be in a separate room away from stored materials, work areas etc., with adequate wall space for the meters, and the consumer's switchgear, together with access space for maintenance and alterations later. The switchboard will consist of a main fuse-switch or circuit breaker adequate in capacity for the installation, a busbar chamber and a number of circuit switch-fuses or circuit breakers which will in turn supply distribution. It is usually more economic to locate distribution boards as near as possible to the centers of the electrical load. Thus a building on three floors would have a distribution board on each floor fed by sub-main cables from the main switchboard.

Unless three-phase motors or other three-phase equipments are to be installed, the three phases of the supply should be segregated within the building. The lighting and all power circuits in any one area should be connected to the same phase so that the risk of 400 volt appearing between two adjacent outlets or pieces of equipment is minimized. Where, for good practical reasons, this separation cannot be achieved warning notices are required wherever two items of equipment connected to different phases are simultaneously accessible.

6.2.6.2 Circuits for power-using equipment

The growth in the use of telecommunications equipment, office machinery and data transmission equipment means that almost every desk and work station may need access to such facilities. The trend away from small offices towards large flexible open-plan areas which can be replanned to suit changing needs makes the provision of such facilities somewhat more difficult. However, the installation of a network of floor trunking which, if laid in a 2 meter matrix, provides the flexibility the user will require in the future without the risks which follow the use of long trailing flexes. Floor and skirting trunking systems are available with two or three compartments so that circuits supplying socket outlets, telephones and data processing equipment can be carried along the same route. A wide variety of floor trunking systems are available which are adjustable to match the finished floor level and carpet or other floor finishes can be applied to them to render them without being obstructed.

General purpose power circuits in commercial premises will usually be wired on the ring circuit principle, an adequate number of outlets within a 100 m² area being connected to a 32 A fuse or circuit breaker. However, this practice to connect sockets to a single ring should be exercised with care. The installation designer must be satisfied that the prospective demand on that circuit will not exceed the 32 A rating of the circuit protection.



RING CIRCUIT FEEDING SOCKET OUTLETS
Fig. 1

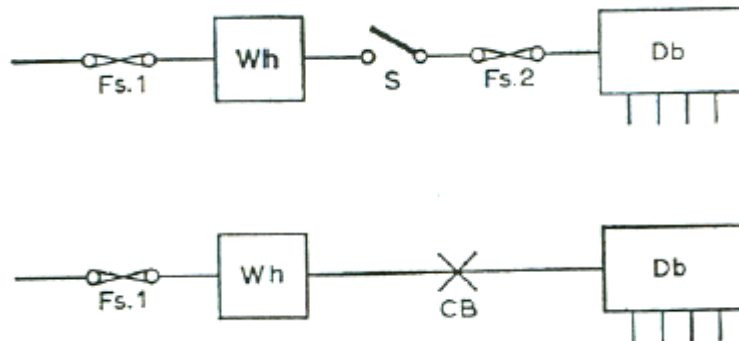
6.2.7 Power supply in residential buildings

6.2.7.1 General

The supply enters the buildings at the service entry point, and then passes through the house service cut-out which contains the main fuse and meter. In new properties these may be situated in special boxes on the exterior of the house, while in flats they may be communally sited for ease of reading by the Electricity Company staff. The distribution of electricity to all circuits in a house is controlled by a consumer's unit (Fig. 2), incorporating a main switch to isolate the supply. Each circuit inside the house is connected to its own terminal, with a fuse or preferably miniature circuit breaker matched in rating to the circuit it protects.

Consideration should be given at the earliest stage to the prospective short circuit current at the origin of the installation. This is, in practical terms, the current which would flow if a short circuit occurred in the consumer's main switch. The level and duration of this current is dependent upon the electricity network and fuse characteristics. The designer needs to satisfy himself that the main switch or consumer's unit proposes to use will withstand the worst short circuit condition that could be imposed upon it and must therefore relate the data provided by the power authority with the manufacturer's data.

In the event of a fault occurring in an installation, whether in an appliance or part of the wiring, it is essential that the faulty section be disconnected from the supply immediately, although the remainder of the system should remain in operation. This can be achieved by an adequate system of fuses or miniature circuit breakers, and by the provision of earthing.



TYPICAL ARRANGEMENTS FOR FEEDING FINAL CIRCUITS IN A NON-INDUSTRIAL BUILDING
Fig. 2

6.2.7.2 Circuits for domestic installations

In selecting consumer's unit the designer should consider:

- a) The adequacy of the main switch for the maximum demand of the installation.
- b) The number of circuits required to be connected to it and their respective loadings.
- c) The benefits of installation of miniature circuit breakers rather than fuses.
- d) The added safety provided by one or more residual current devices.
- e) The desirability of providing at least two spare way for future needs.

The designer shall decide on rating of main switches.

The decision regarding the number of circuits is to some extent subjective but the following represents a typical selection:

- a) Lighting circuit, ground floor.

b) Lighting circuit, first floor (although the total prospective load could be contained by 5 A circuit, the consequences of a circuit failure plunging the whole dwelling into darkness should persuade the designer to use two circuits).

***c)** Immersion heater(s)(which must be on separate circuits, not connected to a ring main).

d) Kitchen/laundry area socket outlets.

e) Socket outlets ground floor.

f) Socket outlets-first floor. (Where applicable)

***g)** Cooker circuit(s).

***Note: In rare cases.**

6.2.7.3 Domestic socket outlet circuits

A domestic ring circuit may serve adequate number of sockets within a floor area of 100 m². However consideration of the probable growth of electricity usage in future makes the use of two or three ring circuits i.e. ground floor, first floor and kitchen, highly desirable.

Table 6 gives the number of socket outlets recommended in the new houses, and the desirable minimum indicated by a reasonable consideration of the growth in ownership of appliances over the next few years.

TABLE 6 - RECOMMENDED MINIMUM PROVISION OF SOCKET OUTLETS IN DOMESTIC PREMISES

PART OF THE HOME	RECOMMENDED NUMBER OF SOCKETS
Kitchen	4 - 8
Dining room areas	2 - 4
Living rooms	5 - 8
Each bedroom	2 - 4
Hall	2 - 4
Storage or garage	1 - 2
Total for typical 3 bed house	16- 30

Not only must the number and distribution of socket outlets provide for the appliances the householder may own, it must also provide for the fact that the positioning of furniture and the utilization of appliances varies from family to family with time. Flexible cords between sockets and appliance must always be as short as possible and never longer than 1.5-2 meters, from which it follows that a dual socket should be available within 1.5 meters of every point in a room at which a future occupier may wish to utilize an appliance or portable luminaries.

It is not necessary for every socket outlet to be connected into a ring circuit.

Often it is not fully appreciated that an adequate number of socket outlets must be provided if an installation is to be safe under all conditions. Apart from the convenience of being able to use appliance in any required position, a reasonable number of socket outlets will eliminate lengths of trailing flex and other dangers.

The mounting height of the fittings above finished floor level shall be as follows:

- Socket outlet (general) 30 cm
- Socket outlet (in kitchen) 110 cm
- Light switch 110 cm
- Door bell push wall type 110 cm

6.2.7.4 Special precautions in bathrooms

Socket outlets are not permitted in bathrooms nor within 2.5 meters of a shower cubicle or bath in a bedroom. This is because the consequences of a shock when the person is wet, has bare feet or is in contact with earthed metal are far more likely to prove fatal than if the same shock were

sustained elsewhere. For the same reason, lamp holders within 2.5 meters of a bath must be shrouded or totally enclosed and no fixed wall switches or heaters may be installed within reach of a person using a bath or shower. Pull cord switches are permissible and are indeed the preferred way of meeting the switching requirements of a bathroom.

6.2.7.5 Sockets for outdoor installations

Weatherproof socket outlets according to demand shall be provided outdoor where deemed necessary.

6.2.8 Power supply for high rise buildings

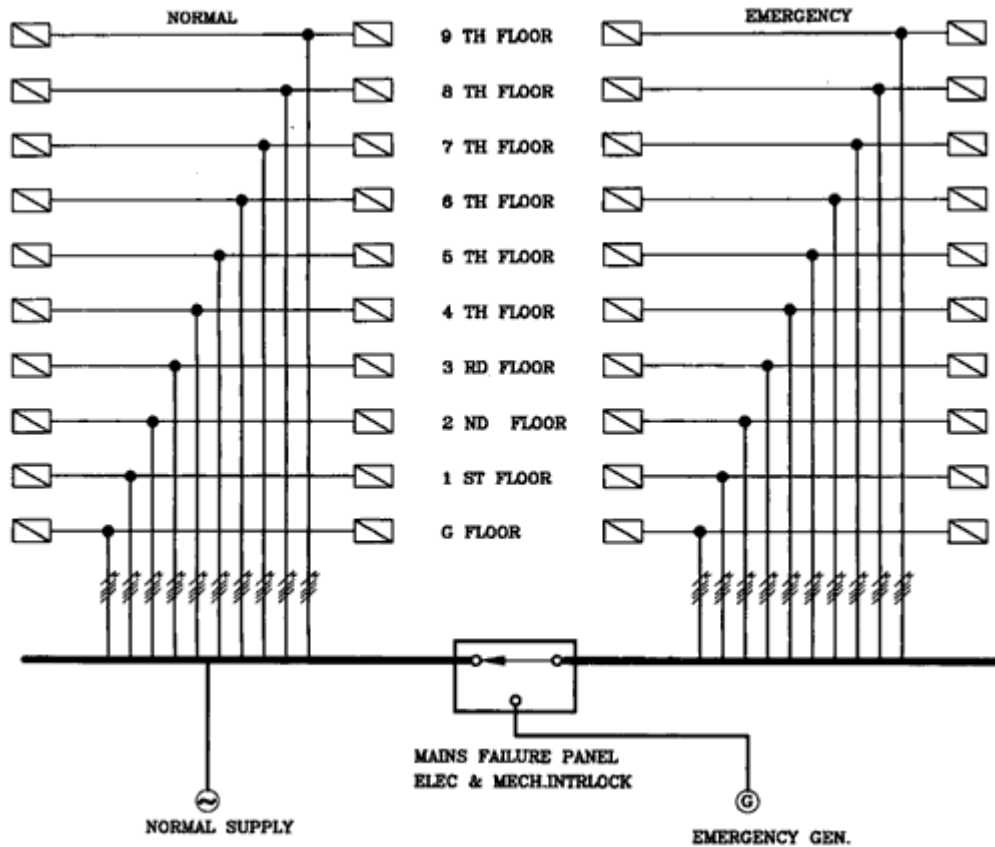
Power supply to different floors shall be via power cables. Alternatively bus trunking can be utilized upon approval.

If cables are used each floor shall be fed by one individual feeder.

Normal loads shall be supplied from normal supply bus and emergency load shall be supplied from emergency bus in normal conditions both buses are to be supplied from mains power supply. In case of mains power failure an emergency diesel generator shall be started via a suitable mains failure panel which opens the bus coupler and closes the emergency generator circuit breaker when frequency reaches 50 Hz. On resumption of normal supply, the generator circuit breaker shall open and busbar coupler closed through properly designed interlocks, after 3 minutes the diesel engine shall stop. See Fig.3.

When requirement dictates power feeder shall be provided for:

- 1) Central cooling machinery**
- 2) Ventilation**
- 3) Smoke stack, fire pumps**
- 4) Central power factor correction equipment**
- 5) Lift(s)**



TYPICAL ELECTRICAL SYSTEM IN HIGH RISE BUILDING
Fig. 3

6.2.9 Load increase in existing supply systems

In existing systems load increase can occur, e.g. due to extensions and modernization of dwellings or commercial premises.

The expected load is calculated using an annual rate of increase based on the present load and preceding development. Depending on the type of building development in the area of supply and the probable in filling of vacant spaces, growth rates of between 2 to 5 % per year can arise.

Furthermore, without a general load increase due to alterations or change of consumers, local deviations of the load must be expected requiring a suitable extension to the system.

6.2.10 Selection of equipment

The fundamental consideration in selecting equipment is to choose optimum equipment consistent with the requirements of the buildings. Frequently it costs no more in the long run to use the best equipment available as it pays dividends in service continuity and lower maintenance.

The following design notes shall be considered:

- a) Metal clad switchgears for medium voltage and low voltage main distribution boards.
- b) Metal enclosed for low voltage subsidiary distribution boards.
- c) Dry type transformers for substations in or attached to buildings.
- d) Factory assembled equipment for easier field installation and better coordination as far as possible.
- e) Copper conductor, armored cable for medium voltage and low voltage.

- f) Galvanized steel conduit and fittings for the electrical installation of buildings.
- g) i- Minimum cross section for ring circuit of socket is 2.5 mm²
 ii- Minimum cross section for lighting fixtures is 1.5 mm²
- h) The size of conduit should be designed such that at most %40 of the cross section is occupied.

6.3 Electrical Apparatus for Potentially Explosive Gas Atmospheres

For this section refer to latest revision of [IPS-E-EL-110](#).

7. DESIGN AND SELECTION REQUIREMENTS FOR EQUIPMENT

7.1 Electric Network Supply and Emergency Systems (Diesel Generator ...)

7.1.1 Scope

This standard covers the minimum requirements for design of industrial revolving field, cylindrical pole construction, self exciting, brushless self regulating L.V. and M.V. & 3 phase (4 wires in L.V.) 50HZ 4 pole 1500 R.P.M. at 0.8 lagging P.F. AC generator.

7.1.2 Design and construction of alternator

7.1.2.1 General

- 1) All machines shall be of continuous running duty S1 and continuous Max. rating in addition diesel driven units shall be capable of running at full. Load for one hour in every twelve hours.
- 2) The ingress degree of protection for rotating machines shall be IP54. The degree for all other electrical equipments shall be as followings:

Off shore	outdoor locations	IP55
On shore	outdoor locations	IP54
On/Off shore	Indoor locations	IP42

Between adjacent compartments in electrical apparatus IP40

- 3) Rotating machines which are to be located in a hazardous area shall be provided with and appropriate type of protection.
- 4) The generator and its auxiliaries shall comply with [IPS-M-EL-138](#) and part 7.1 of this standard and may be used for based load generation or standby duties based on technical/economical studies.
- 5) For generators above 1250 KVA, each generator set shall be provided with its own LV auxiliary switchboards for the supply and control of all its motor driven auxiliaries. This switchboard should be treated as an essential services switchboard.

7.1.2.2 Stator winding

- 1) Stator windings shall be fabricated from copper conductors.
- 2) The insulation class shall be F with design temperature rise limited to class B.

7.1.2.3 Rotor

- 1) The shaft shall be precisely machined from high quality steel and adequately hardened and shall carry the rotating field system , DC exciter rotor winding rotating three phases roll wave rectifier assembly and cooling fan.
- 2) The complete rotor assembly shall be securely braced and statically and dynamically balanced on completion. Balance weights shall be of non ductile material such as lead. And rotor design shall allow for balance weights attaching if necessary.
- 3) The direction of the air flow shall be such that the discharged air does not pass over the driver. The ventilation system shall include air intake filter.
- 4) The rotor shall include excitation system independent of external power supply.
- 5) Winding conductor of the rotor shall be copper with mica paper, glass cloth and epoxy resin insulations. Impregnation and curing shall be either by the resin method or vacuum. And shall be baked and treated to provide a hard setting , oil and moisture resistant anti-tracking finish suitable for a dusty saline and tropical environ meant.
- 6) The direction of rotation shall be clearly and permanently indicated by means of an arrow on the external surface of the frame at the N.D.E. painted or adhesive tape methods of indication are not acceptable.

7.1.2.4 Main terminals

- 1) Terminal box and cable terminations shall be suitable for operation at given faulty level.
- 2) Means shall be provided for electrically isolating individual windings from each other and from the main outgoing connections without involving motor dismantling of the machine or risking damage to the windings or connections.
- 3) Space shall be provided for the installation of current transformers.
- 4) Terminal box shall be of air insulated pattern in which the protection of passes conductors against electrical short circuit is done by adequately spaced bare conductors with appropriate insulated supports.
- 5) Terminal marking. Shall be U-V-W and provided in a clear and permanent manner.
- 6) Terminal arrangement shall have adequate space to accommodate easily the size and type of cable required.
- 7) Mechanical metallic glands shall be provided for the type and size of cable required.
- 8) The earthing terminal shall be external to the terminal box.
- 9) Heater and any other additional connections shall be clearly identified. Circuits shall be separated and terminals fully shrouded.

7.1.2.5 Exciter and automatic voltage regulator

- 1) The excitation system shall be of brushless type and power for field excitation shall be supplied from the shaft driven pilot exciter.
- 2) The system should be complete without needing external power supply, and power may be derived from generator terminals.
- 3) The excitation system shall be capable of providing at least 3 times the rated current under three phase terminal short circuit conditions for at least 10 seconds.
- 4) A timed current limiting circuit shall be provided if static thruster exciter is required to prevent sustained overload.
- 5) It is necessary to initially provide a high excitation current during fault conditions to supply additional reactive power demanded during fault condition and to maintain a synchronous torque at

low voltage levels rotor current limitation is necessary to prevent the undesirable disconnection of the generator due to overload of the rotorcraft current.

- 6) The A.V.R. shall be of solid state design and including protection against over voltage and be provided with means to adjust the set point of the main generator output voltage over a range of $\pm 10\%$ nominal voltage rating at full load.
- 7) The A.V.R shall have an adjustable reactive current droop characteristic and be suitable for reactive load sharing known as quadrature current compensation (Q.C.C.) providing the ability for generators in parallel to share reactive currents in equal of proportional amounts.
- 8) The A.V.R shall allow 100% voltage to be generated at 80% of speed under all conditions of operation.
- 9) Over fluxing control shall be provided, this shall not reduce excitation until frequency is less than 75% of rated frequency.
- 10) Max. excitation limitation and max. Volts/hertz facilities shall be included within the A.V.R. unit.
- 11) Temp. stability of the voltage regulation shall be better than 0.5% for temperature between max. and min. of ambient temperatures.
- 12) The A.V.R shall regulate the voltage within 2.5% of the set point between No-Load and full-load and for all speed droop variations. The regulation capability of the AC generation and A.V.R system under transient conditions shall be arranged such that following any transient disturbance, voltage shall be restored to 2.5% within 10 seconds, and voltage will be restored to 97% of nominal voltage within 1 second.

7.1.2.6 Built-in temperature detection

- 1) Stator winding shall include built-in thermal protection, two levels of detection, alarm and trip. The alarm and trip setting differential should be such that adequate time would be available for the plant operator to shed load in the event of slow overload. Trip setting, slow and rapid should be as high as practicable under all operating conditions.
- 2) A minimum of six resistances temperature detectors shall be provided and spaced equally around the circumference of the stator, and two for bearings.
- 3) All detector's leads shall be metric. Armored detectors shall be located between coil sides in the stator slots with their centers at the longitudinal midpoints of the stator.

7.1.2.7 Bearings and lubrication

- 1) For emergency generator applications self lubricated bearings are preferred. Hydrodynamic radial bearings shall be fitted to all machines of 1 moa rating and above with R.T.D. for 2 moa and above.
- 2) On both oil and grease lubricated bearings it shall be possible to re lubricate in safety without stopping the machine. Where oil lubricated bearings use level indicator or a non rest active oil flow indicator to each bearing shall be provided.
- 3) where hydrodynamic radial bearings are fitted they shall be provided with local dial type thermometers with detachable stainless steel thermo wells and accuracy within 1% range over scale to read oil bath or oil outlet temperatures.
- 4) Machines without thrust or location bearings shall be stated. As such in the initial proposal and on the manufacturer's drawing. The machine shall be coupled to the driver by limited end float coupling. The machine rating plate shall be marked ("limited end float" (L.E.F).
- 5) The correct running positions on the rotor shall be permanently marked together with the limits of permissible movement. It shall be possible to describe the rotor position at all times relative to the above marks.
- 6) All bearings shall be fully insulated from the machine carcass and/or bedplate to prevent a flow of shaft current unless type tests demonstrate that the shaft voltage measured at any load across the

ends of the shaft is less than 150mv-rms. The insulation method shall be permanent and non-deter 10 rating. This shall include any lube oil supply and drain connections to the bearing housing.

7) Machines shall be tested with their service bearings fitted. If transit bearings or other devices are employed for transport purposes, clear labels starting this shall be affixed to the machine.

8) Bearing housings shall have provision for mounting two shaft proximity type vibration probes at each radial bearing with the probes mounted 90 ± 10 circumferentially apart and shall be furnished with standard breather.

9) All bearings shall provide shaft access for vibration measurement through or adjacent to the bearings.

10) The critical speeds of the rotor shall not be within 20% of any speed in the operating range nor within 20% of two times operating speed range.

7.1.2.8 Machine cooling

1) Machine cooling shall be either by air or water. Air cooling is the preferred method. Whenever water cooling is utilized, A leak detection system shall be provided and measures taken to prevent damage to the machine in the event of a leak and shall include temperature detecting system with contacts for alarm annunciation.

2) Precautions shall be taken to ensure no corrosion occurs due to contact between dissimilar metals.

3) Water cooling system shall be included as part of the package. In water cooling, water supply shall not be derives from outside the package excepting the case of an off skid located radiator water coolers shall be side or bottom mounted. Top mounted water coolers are not acceptable.

4) Coolers shall be so designed that if one section is intended to be taken out of serve for cleaning the unit can carry at least two third of the rated load continuously without the permissible temperatures of the active parts of the machine being exceeded.

5) The following elements should be considered in water cooling:

- a) Cooling water supply pressure
- b) Cooling water supply pressure
- c) Test pressure , that should be twice the working pressure

6) Fans for generators cooling shall be brass, bronze or aluminum. Plastic or non metallic fans and housing are not acceptable. And shall be of non sparking material.

7.1.2.9 Earthing

1) The neutral point of the alternator in the connecting terminal box shall be grounded solidly or through resistor.

2) Generator frame and skid shall have grounding bolts to be grounded.

Connections to the bearing housings of generators having insulated bearing pedestals shall ensure that no connection, including that of the bearing sheath, provides a by pass around the insulation.

The generator shall be provided with at least two main earthing points to which 70mm^2 copper cable strip will be made. The location of the earth points shall be in an accessible place to enable external connections to be made and subsequently inspected or tested. Any equipment which is part of main generator skid shall be effectively bonded to the base frame. Any electrical equipment which will be separately mounted from the base frame shall have provided, means for earth bonding to the main frame.

Earth bonding by holding down bolts will be generally acceptable. However particular attention should be made to the arrangements for bonding that equipment which may rest on insulating anti-vibration mountings. For these applications a supplementary earth bond may be necessary, particularly if the item of equipment has an electrical supply.

7.1.2.10 Lifting points

- 1) All equipment shall be mounted on a single skid frame. The skid frame shall be provided with lifting lugs to enable the package to be moved by the use of an over head crane.
- 2) Lifting points shall be an integral part of the generator frame. Where this is not the case and the lifting is by the use of eye bolts, these shall be collar pattern.
- 3) All necessary spreader beams, slings, shackles and lifting gear shall be provided to enable the package to be hand kept at the jobsite and all necessary specular tools to enable maintenance to be carried out.
- 4) Facilities shall be provided for the application of jacking screws in all three planes, and their location marked on the machine general arrangement drawings.
- 5) Where it is intended to use spreader bars for lifting all or part of the machine or where other spicier handling precautions are necessary these requirements shall be identified on a suitable plate attached to the external surface of the machine.

7.1.2.11 Generator control panel

- 1) The package shall be provided with its own unit control equipment logic system and alarm annunciation necessary for the protection and operation of the compete set as an integral part of the package.
- 2) The control panel shall be installed in a front access cubicle. And shall have an Ip55 enclosure and be suitably protected against a saline atmosphere. It shall be made from 2.5mm steel sheet. The unit control panel shall be mounted either on or off the equipment skid. If the panel is mounted on the skid it shall be protected from vibration by means of suitable anti vibration mountings.
- 3) If the panel is mounted remotely from the skid all cables etc. Shall be routed to a junction box located on the skid and the panel shall have a matching junction box.
- 4) The control panel shall be protected by a canopy. The control panel doors shall be hinged and lockable. The enclosure shall be constructed and assembled so that it will have the strength and rigidity necessary to resist the abused to which it is likely to be subjected without total or partial collapse resulting in a risk of fire, electric shock or injury to persons due to reduction of spacing, loosening or displacement of parts or other serious defects.
- 5) The control panel shall typically include the following:
 - a) AC generator synchronizing and alarms.
 - b) AC generator voltage regulation.
 - c) AC generator protection.
 - d) Speed raise/Lower.
 - e) Voltage raise/Lower.
 - f) Emergency stop push button.
 - g) Normal start/Stop push buttons.
 - h) Trip/Close switch and position indicator for generator circuit breaker.
 - i) Local/Remote control selector.
 - j) Excitation manual/Off/automatic(are) selector.
 - k) Start selector manual/Auto-standby/Off.
 - l) Jacket water heater switch.

6) If manual synchronizing facilities are included in the scope then check synchronizing relays shall also be included in the scheme.

If automatic synchronizing facilities are included Then manual synchronizing backup together with check synchronizing relays shall also be provided.

7) The drivers of all machines shall be fitted with speed governing equipment.

Where the generator is to operate in isolation the governor shall provide isochronal control.

8) Where the generator is to operate in parallel with other generators then adjustable droop control shall be provided.

9) Facilities shall provide to repeat information's and alarms to a remote control room, each alarm signal shall be wired to output terminals in the unit control panel. A common remote alarm facility shall also be arranged.

10) The following are accessories which may be selected depending on rating, voltage and application of specific cases:

- a)** Power factor meter.
- b)** KVRH meter.
- c)** KWH meter.
- d)** Generator voltage.
- e)** Generator current.
- f)** Frequency meter
- g)** Hours run counter
- h)** Under/Over frequency protection.
- i)** Short circuit sustaining protection.
- j)** Ground fault protection.
- k)** Surge protection.
- l)** Differential protection.
- m)** Lightning arrested.
- n)** Synchronizing check recap.
- o)** KW Indicator.
- p)** Aver/Manual excitation null balance meter.
- q)** Running and incoming volt meters.
- r)** Running and incoming frequency meters.
- s)** Exciter field volt meter.
- t)** Exciter field ammeter.
- u)** Synchronizing lamps.
- v)** Alarm indications.
- w)** Synchrony scope

11) Electrical instruments shall be of the flush mounted, industrial grade, enclosed in dust and damp proof casing, non projecting dial with non-glare, non-reflecting windows.

12) All abnormal conditions which would ultimately lead to a shutdown shall have warning pre alarms where possible the interval between set points shall be sufficient for corrective action to be taken.

13) In the event of an equipment trip a "first out" facility shall be provided to identify the original fault.

14) Repeat volt free contacts shall be provided for remote indication of each alarm and shutdown condition wired to panel outgoing terminal.

15) Facilities shall be provided to permit remote acceptance of alarms.

16) For analogue additional remote signals 4-20mA transducers shall be used.

- 17) In the event of an automatic shutdown due to low engine lube oil pressure, over speed or high jacket water temperature attempts to restart shall be automatically inhibited until the trip has been locally reset.
- 18) All shutdowns except over speed, shall be via fuel cutoff, over speed shutdown shall be by both fuel shutdown and air intake close up.
- 19) The package control system shall be fitted with a local/Remote control switch and a manual/Auto standby/Off control switch, both switches shall be mounted on the control panel.
- 20) Local start and stop shall be by push buttons on the unit control panel, the local stop signals shall be operative in both the local and remote modes of control. Terminals shall be provided for multiple remote start and stop signals.
- 21) Facilities shall be provided for remote emergency shutdown of the set from the emergency shutdown system.
- 22) With the local/Remote switch in the "Remote" position, remote control shall only be effective with the remotely located mallow switch in the (Auto) position under these circumstances the remote control shall enable a manual over ride start is the auto-start has failed a manual stop shall also be provided at the remote control point. The auto start shall be initiated by a maintained close to start contact.
- 23) In the "manual" or "auto standby" modes the generator shall automatically run up to the selected speed upon start initiation.
- 24) As specific requirements facilities shall be provided for data logger and ground fault resistors.

7.1.2.12 Vibration

- 1) Bearing housings for hydro dynamic radial bearings shall have provision for the fitting of non-contacting dual proximity type vibration probes or accelerometers (rms velocity readings).
- 2) In a manner similar to temperature monitoring a complete package vibration monitoring system shall be required.
- 3) The vibration amplitude of machines fitted with non-contacting vibration monitoring equipment shall not exceed peak to peak level (unfiltered) of 63 micrometers including mechanical and electrical run out. Total run out shall not exceed 13 micro meters.
- 4) The vibration level for machines fitted with flexible rotors passing through the first critical speed shall be within the following limits:
 - a) Machines fitted with hydrodynamic bearing:
The peak to peak amplitude shall be less than 75% of the nominal bearing clear acne.
 - b) Machines fitted with rolling element bearings.

Less than three times the limits given below

The vibration limits for all machines not flitted with non contact vibration monitoring equipment shall meet the requirements of bus 1999 part149 as follows:

For a shaft height less than 400mm table1 quality R.

For a shaft height 400mm or greater table2 column 1.

7.1.2.13 Noise

- 1) The Max. noise level at 1m away from the machine shall not exceed 85 db(A) when operating as an alternator at rated voltage, rated speed at no load.
- 2) The noise emissions details of the machine shall be provided in octave bands. Also any narrow band noise details that are noticeable to the ear shall be provided together in octave band or in bands in which it occur.

3) Where the noise limiting requirements can not be met without the provision of noise reducing features the levels with and without these features shall be stated.

Details of any noise reduction features shall be provided.

7.1.2.14 Rating plate

1) A metallic corrosion resistant rating plate shall be fixed on the generator frame and shall give the following information's in English:

- a)** Manufacturer's name
- b)** Customer order No. and date
- c)** Type and frame size and serial No
- d)** Year of Manufacture
- e)** Rated output in KVA
- f)** Rated power factor
- g)** Rated voltage
- h)** Rated frequency
- i)** R.P.M. at rated output
- j)** Class of insulation
- k)** Rated current
- l)** Transient and sub transient reactance
- m)** Standards reference numbers and date
- n)** Phase rotation clockwise or counter clockwise.
- o)** Exciter voltage and current at rated output
- p)** Weight of rotor and stator in KG.

7.1.2.15 Enclosure

- 1)** The enclosure shall be designed as an integral part of the package.
- 2)** Outdoor installations would normally be expected to be supplied with an enclosure in order to be weather proof. Indoor locations may be specified without enclosures and may involve separate mounting of the cooler radiator, master fuel tank and exhaust system.
- 3)** For offshore installations the enclosure walls shall have a minimum fire rating of A60 and shall comply with local regulations.
- 4)** The enclosure shall be designed to allow adequate access for routine maintenance and operation and shall be equipped with as minimum lighting/ lighting points, over head lifting beams and drainage.

7.1.2.16 Ventilation

- 1)** Where diesel engine powered emergency generator package have an integral enclosure, a ventilation system shall be provided to maintain the temperature of the enclosure at an acceptable level during operation.
- 2)** The ventilation fan shall be driven off the engine either directly or by the use of hydraulic transmission, alternatively an electric motor drive may be used with power derived direct from the generator via a local starter.

3) Where union closed diesel engine powered emergency generators are installed in dedicated rooms any requirement for connections (e.g. power and control) to ventilation system will be specified.

7.1.2.17 Lighting and small power

- 1) Enclosures which personnel may enter for operation or On-line maintenance shall have emergency lighting.
- 2) The preferred type of luminary is fluorescent. The emergency luminaries shall be supplied either from a central battery system or the integral battery type shall be used.
- 3) At least two normal lighting circuits shall be installed and both circuits shall be utilized in all areas.

The design shall allow maintenance and modification of one circuit whilst the second circuit is in operation.

- 4) Small power outlets shall be provided and distribution within the package shall be by the vendor.
- 5) Electrical power for battery charger shall be derived from a single supply to the package.

7.1.3 Design and construction of diesel engine

7.1.3.1 Performance

- 1) The engine continuous net brake power, fuel consumption and lubricating oil consumption and overload power shall be declared under ISO conditions. It is to be recognized that the unit should be capable of the emergency duty as required at the site max. ambient conditions.
- 2) The engine's continuous net brake power at all operating conditions shall be sufficient to enable the generator to produce power as specified in the name plate rating.

7.1.3.2 Starting system

- 1) Each engine shall be provided with a starting system, the preferred system shall be electric, based on the use of batteries.
- 2) Often, emergency generators are auto started. Where the start system proves inadequate for the task, manual start would need to be undertaken.
- 3) Power for successive cranking cycles shall be provided by a battery unit having sufficient capacity, at the site extremes of temperature, to maintain the cranking speed recommended through a 192 seconds cycle (8 seconds cranking and 7 seconds rest in 12 consecutive cycles). Where auto started, the engine shall attempt 9 of the possible 12 starts and then show a fail alarm. The remaining 3 start attempts shall be individually initiated manually. Where the emergency generator is considered sufficiently critical, all 12 automatic start attempts may be specified for the primary starting.
- 4) All batteries shall be of the recombination cell type. Sealed lead – Acid battery type represents the usual recombination type of battery expected and nickel cadmium types would represent the highest reliability, performance and expected lifetime.
- 5) On offshore installations the starting battery shall be capable, of being isolated by a remotely controlled contactor contained within an axed enclosure. The contactor shall be used for isolation purposes only. Control of this contactor will be from the installation's fire and gas detection system.
- 6) It is expected that the battery system provided would be equipped with suitable electrical protection devices fuses or circuit breakers would be acceptable, and that the battery wiring would be sensibly arranged to eliminate the probability of short circuits.
- 7) An independent dedicated constant voltage type charger and charge control system shall be provided, each charger shall comply with the following:

- a) Have aerate of charge consistent with:
 - Recharging the respective battery in the minimum time.
 - Not causing damage to the battery
 - Not reducing battery design life
 - Restoring full charge to the battery within 24 hours following any stylize of discharge.
- b) The charger shall be marked with the ampere-hour rating of the largest capacity battery that it can recharge in compliance with (a) above.
- c) An ammeter with an accuracy of 5% of the normal charging rate shall be furnished to indicate the operation of the charger.
- d) Have an electrical supply which is independent of the terminal output of the emergency generator.

There should be adequate safety notices arranged on the emergency generator charger to show the system is live unless isolated elsewhere.

7.1.3.3 Cooling system

- 1) Either direct air cooling or water cooling of the engine is acceptable provided they are of the manufacturer's standard design.

Water cooling system shall be sized for the engine continuous net brake power at the max. Ambient and cooling water temperatures. The system also include capacity for cooling the air within the engine/generator enclosure or room and for cooling the engine exhaust, as an alternative separate system may be proposed for each duty.

- 2) Under some circumstances it may prove necessary for the exhaust of the engine to be cooled sufficiently to ensure that the temperature is below the ignition point of the hydrocarbon explosion hazard this may be achieved with the aid of a water bath around the exhaust manifold.

- 3) The radiator fan shall be driven from the engine either directly or electrically taking power direct from the generator but put terminals or by the use of hydraulic transmission.

It shall not be independently powered.

- 4) The engine shall be provided with thermostatically control jacket water heaters and is necessary a circulating pump, to ensure optimum engine starting temperature at the minimum specified ambient temperature.

- 5) Where a water circulating pump will be provided and independently powered from the utilities supplies to the emergency generator package, the voltage of the motor should be selected in accordance with the information regarding utilities.

- 6) If necessary , provision shall be made for the prevention of over heating of the coolant due to local high temperature after shutdown.

7.1.3.4 Fuel system

- 1) Each diesel engine shall have a dedicated fuel storage tank , it shall be sized to provide a net capacity of fuel in accordance with statutory regulations (e.g. for offshore use 24 hrs base down fuel consumption at engine continuous net rated power). It is to be recognized that emergency diesel generators would generally be expected to have a dedicated "Day Tank" and therefore any additional diesel storage and fuel forwarding system should incorporated the tank within the overall design.

- 2) Under no circumstances shall the tank be located above the hot exhaust ducting or the engine itself. Where the fuel tank cannot be accommodated as an integral part of the emergency generator skid, the location will be arranged according to the available space availability tanking into account other plant and services.

- 3) Where a gravity fed fuel systems are employed a locally operated manual valve shall be installed in the fuel line to the engine at the tank outlet. If the tank is located within the room / enclosure this valve shall also be operable from outside the room / enclosure.
- 4) The tank shall be provided with a man way opening , and connections for filling swan neck vent flow, return, drain, over flow and instrumentation e.g. level gauge and high/low level alarms.
- 5) A thermo – statically controlled tank heating system shall be provided if ambient conditions could result in the viscosity of the fuel.
- 6) The fuel suction filters shall be of the duplex type with replaceable elements and a changeover facility to permit removal and replacement of dither element without need for engine shutdown. Filter mesh size shall be specified.
- 7) Provision shall be made for priming and bleeding the fuel injection system.
- 8) For unmanned installations high pressure fuel lines between remote fuel pumps and injectors shall be double skinned, seamless tubing with fuel leak monitoring and alarm. On manned installations the fuel lines may be as above or heavy seamless tubing.
- 9) Flame resistant flexible hoses shall be provided within the fuel supply and return piping systems between the engine and off skid pipe work at the EDGE of the engine skid. There shall be no shut off valve in the return line to the tank.

7.1.3.5 Exhaust system

- 1) The exhaust system shall include silencers, bellows and spark arresters. If two or more generator packages are provided each engine shall have its own exhaust system.
- 2) The discharge location from the exhaust system will be specified. The extent of the vendor's supply will be identified.
- 3) Hot exhaust system piping within the confines of the package and constituting a danger to personnel shall be insulated or protected to limit surface temperature to 65⁰C.
- 4) Where exhaust systems can be exposed to hazardous area conditions, they shall be water cooled to limit surface temperature. The temperature and the length of the system requiring cooling will be specified.

7.1.3.6 Air intake system

- 1) Dry replaceable filters shall be provided for the combustion air intake. Filter condition gauges shall be provided. The location of the air intake should be arranged to be in a "SAFE" area with no possibility of hydrocarbon ingestion.
- 2) An automatic shut-off valve actuated by engine over speed shall be fitted in the air intake manifold. Operation of the valve shall be independent of external power sources and shall be capable of manual operation.

7.1.3.7 Lubrication system

- 1) Lube oil filters shall be of the replaceable element type, and shall be equipped with relief valves and , if no other label oil pressure indication is provided, a differential pressure gauge, filters shall be of duplex type with manual changeover facility.
- 2) Engines shall be suitable for starting under all conditions without the need for engine pre-lube.
- 3) Electric sump heaters, if provided, shall have a power density not exceeding 2.3 W/cm²

7.1.3.8 Couplings

- 1) It shall be possible to remove couplings without the need to move the engine or driven equipment.

- 2) All flexible couplings incorporating a spacer piece shall be of a design in which the spacer piece is positively constrained from flying out in the event of failure of the flexible elements.
- 3) The max. coupling torque shall be limited to a max. of 80% of the coupling rating.

7.1.3.9 Torsion vibration and critical speed

- 1) The engine shall be carried out a torsion vibration analysis for each complete equipment string and shall be submitted for review.
- 2) Each engine, coupling, driven unit system shall be so designed to ensure that the complete installation starts, operates and stops free from torsion vibration and oscillation, the first lateral and torsion critical speeds for the max. Operating speed no lateral or torsion critical speed shall lie within the operating speed range of the system.
- 3) Diesel engine rams velocity of vibration shall not exceed 11.2 mm/s at any operating condition.

7.1.3.10 Speed control

- 1) Under normal steady state operating conditions the governor shall maintain the frequency of the generators electrical output within 1% of the value identified for all loading conditions. A full load rejection shall be possible without causing an over speed trip.
- 2) Speed droop will be necessary whenever the emergency generator is required to operate in parallel with the power system (for testing and re-instatement purposes). Under these conditions the speed droop should be set at 4%.
- 3) A mechanically initiated over speed protection system is expected for engine protection.
Additionally an electronic over speed protection controller should be contemplated. The settings of the devices should be arranged with at least 5% speed between their in initiation.
- 4) When starting the largest size motor identified. The generators output frequency shall not dip by more than 5% this requirement shall be based upon the assumption that the motor shall be started with the generator fully loaded except for the motor under start.
- 5) A standard value of 10% speed variations for a step load of 100% would be common for naturally aspirated engines with the step load equating to this speed variation being a function of turbo charger performance for those engines provided with turbo chargers. An electrical motor direct on line start would present the engine with up to 25% of its rated demand at one point of its starting transient. The 5% speed variation is based on national electrical power system expectation and may be relaxed to 10% if electrical loads supplied by the particular emergency generator can accept such frequency deviations.

7.2 Switchgear, Controlgear and Substations

7.2.1 General

Low voltage switchgear and control gear constitute the link between on the one hand the means of generation (generators) transmission (cables) and, voltage transformation (transformers of electric power and on the other hand the consuming equipment such as motors, lighting, heating and air conditioning plant.)

The selection criteria grouped in five categories

7.2.1.1 Current

- Rated current of busbar
- Rated current of in feeds and bus section
- Rated current of outgoing feeders

- Short circuit withstand capability of busbars
- Short circuit breaking capacity of circuit breakers

7.2.1.2 Nature of protection and installation

- Degree of protection
- Method of installation (against a wall, or free standing)
- Number of operating faces
- Enclosure material
- Protective measure

7.2.1.3 Equipment mounting

- Fixed
- Withdraw able

7.2.1.4 Application

- Main switch board
- Industrial distribution board
- Non-industrial distribution board
- Motor control center
- Power factor correction equipment
- Control board

7.2.2 Recommendation for selection

7.2.2.1 The equipment shall be a factory built assembly (F.B.A) from manufacturer capable of providing an acceptable technical and commercial back- up service.

7.2.2.2 Selection of main power distribution board and M.C.C

The following parameters shall be considered for selection of switchgear:

- The highest current rating of the equipment up to 4000 amps.
- Sheet steel or alozinc as the enclosure material
- The maximum height shall be in accordance with [IPS-M-EL-143\(2\)](#)
- Short circuit withstand capability up to 50 kA rms
- Mounting method for equipment:
Withdraw able
- Enclosure protection IP42 (indoor)

7.2.2.3 Selection of non- industrial distribution board

The flowing shall be considered in selection of distribution boards:

- Rated current of up to 1250A.

- Sheet steel as the enclosure material.
- Maximum height of distribution board 220 cm.
- Equipment items mainly fixed.
- Short circuit capability up to 50KA
- Ingress protection IP42 for indoor and IP55 for under shelter installation.

7.2.2.4 Selection of industrial distribution board and M.C.C

- Rated current of up to 1250 A.
- Sheet steel as the enclosure material.
- Height of individual less than 170 cm
- Equipment items mainly withdrawable.
- Short circuit withstands capability based on area condition:
 - a) Up to 50KA for safe areas.(base on calculation)
 - b) Maximum 25ka for explosive hazardous areas.
- Ingress of protection IP42 for indoor and IP 55 for under shelter and IP 65 for on protected installation.

7.2.2.5 Current rating and short- circuit withstand capability

Circuit breakers in accordance with the data sheet shall have normal current rating selected from the following ratings:

630, 800, 1250, 1600, 2000, 2500 and 4000 amperes.

The above mentioned figures shall be derated for maximum summer temperature i.e.50 °c .Short circuit breaking and making rating current shall not be less than 50 KA and 150KA respectively for a fault capacity for 3 seconds unless otherwise Determined under different circumstances.

Where switchgear and controlgear assembly motor control centers are located in explosive hazardous areas they shall be explosion proof, and fault current shall not exceed 25 KA for 1 second.

7.2.2.6 Protective measures

All metal parts of switchgear assembly and distribution boards shall be provided with protective conductor (PE).

7.2.2.7 Selection of apparatus to zone of hazard

For selection of apparatus in hazardous area refer to [IPS-E-EL-110\(1\)](#).

7.2.3 Feature to Be Considered in Installation, Access and Controls circuit.

7.2.3.1 Type of installation

- On the floor against wall
- On the floor free standing in the room.
- Fixed to a wall or a recess for non-industrial board.

7.2.3.2 Nature of access.

- Front or rear access for cable connections and alteration.
- Top access for modification to or installation of busbar.

7.2.3.3 Special requirements

Possible special requirements such as for example explosion protection, against hostile Atmospheres and earthquake shall be considered in design stage.

7.2.3.4 Outgoing feeder circuit breaker rated up to 400 ampere can be molded case circuit breaker (mccb) type, when approved by company representative.

7.2.3.5 The voltage of the spring motor as well as the circuit breaker close and trip voltage shall be 110 volt dc supplied from the substation dc Power supply system.

230V.AC can be utilized for the spring charging motor if approved by company representative.

7.2.3.6 All remote controlled circuit breaker and contactors shall have the closing device local to the panel either omitted or made inoperable when the circuit breaker or contactor is in the normal operating position.

7.2.3.7 A motor starter shall normally be opened and closed from a control station adjacent to the motor.

7.2.3.8 Any emergency stop control for motor starters shall form part of the primary stop control circuit and the use of interposing circuit or relays shall be avoided.

7.2.3.9 For motor contactor units directly controlled via control circuits over 600 meter long the following alternatives shall be considered:

- i) The use of interposing relays.
- ii) 110V DC control.

7.2.3.10 The voltage drop for the control circuit supplied controlled shall not be exceed 5%

7.2.3.11 Adequate clearance shall be provided around the switchgear for maintenance, operation, access and anticipated extensions.

Note:

In absence of local regulation minimum clearance of 1.5 meter shall be considered in front of switchboards. When withdraw able equipment is fitted a minimum clearance of 1.5 meter shall be allowed when the equipment is fully withdrawn. a minimum clearance of 0.8meter shall be allowed at the rear of switchboards.

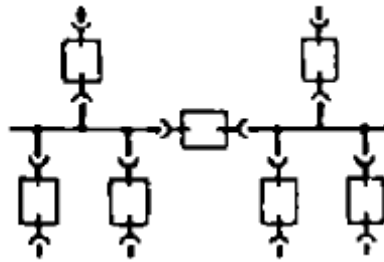
7.2.4 M.V. & H.V. switchgear

Selection Criteria For M.V. And H.V. Switchgear

7.2.4.1 Busbars

7.2.4.1.1 Switchgear Installations for normal service conditions should be preferably equipped with single busbar systems.

These are clean in their arrangement simple to operate, Require relatively little space and are low in initial cost and operating expenses see Fig. 4.



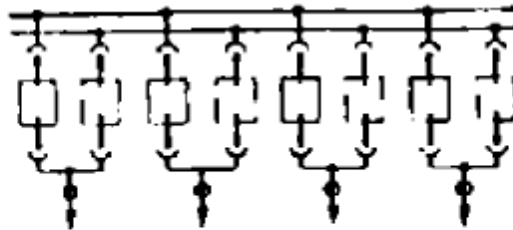
SINGLE-BUSBAR WITH BUS-TIE BREAKER

Fig. 4

7.2.4.1.2 Double busbar switchgear and controlgear (switchboard)

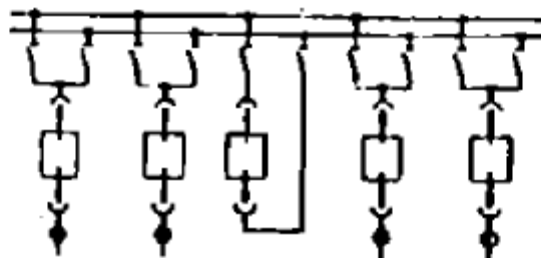
double busbar switchgear and controlgear can offer advantages in the following:

- Operation with asynchronous feeders.
- Feeders with different degrees of importance to maintain operation during emergency conditions.
- Isolation of consumers with shock loading from the normal network.
- Balancing of feeders on two systems during operation.
- Access to busbars required during operation see Figs. 5 and 6:



DOUBLE BUSBARS WITH DUAL FEEDER BREAKERS

Fig. 5



DOUBLE BUSBARS WITH SINGLE FEEDER BREAKERS

Fig. 6

7.2.4.2 For all of the above mentioned switchgear and controlgears the following rating terms may be used:

Rated Frequency

The standard values of the rated frequency for MV/HV pole switchgear and controlgear are 50 Hz.

Rated Normal Current

The rated normal current of a switching device is the rms value of the current which the switching device shall be able to carry continuously under specified condition of use and behavior. The values of rated normal current shall be selected from the R 10 series specified in IEC 60059.

The Rated Voltage

The rated voltage indicates the upper limit of the highest voltage of systems for which the switchgear and controlgear is intended. Standard values of rated voltages are given below:

3.6 kV. , 7.2 kV. , 12 kV. , 24 kV. , 36 kV. , 72 kV .

7.2.4.3 Choice of interrupters

Depending on the switching duty in individual switchboard and feeder basically the following types of primary interrupters are used in the switchgear cubicles. M.V. and H.V. switchgear for indoor installation shall comply with IPS-M-EL-144(2).

7.2.4.3.1 Vacuum circuit breakers

Vacuum circuit breakers shall be used for all general purpose applications for indoor HV. and M.V. switchgear.

7.2.4.3.2 SF 6 circuit breakers

SF 6 circuit breaker proposed as an alternative option in system voltage above 24 kV.

7.2.4.3.3 Vacuum contactors

Vacuum contactors are used for frequent switching operations in M.V. motors, transformers and capacitor bank feeders up to 1000kW/1000 KVA /1000 KVAR. These are reliable and compact device with maintenance free interrupters.

Since contactors cannot interrupt fault current they must always be used with current limiting fuses to protect the equipment connected.

Note 1:

Out door switchgear shall only be considered for voltage exceeding 36 KV.

Note 2:

For existing extension or where the incoming circuit is one feeder and one transformer, 33KV/20kV and 11 KV may be used as outdoor switchgear.

7.2.4.4 Control requirements

7.2.4.4.1 Circuit breakers shall be controlled from remote control panel in a separate room.

7.2.4.4.2 Control of a motor starter shall be from a control station adjacent to the motor or control panel in allocation remote from both the motor and starter equipment (ex. Control room)

7.2.4.4.3 stop control for motor starters located beside The shall form part of primary stop control circuit and the use of interposing relays shall be avoided, if an interposing relay is unavoidable then the circuits shall be fail safe.

7.2.4.4.4 For motor contactor unit directly controlled via control circuits over 600 meter long, the use of interposing relay and/or 110 v.DC control shall be considered.

7.2.4.5 Switchgear installation

7.2.4.5.1 Access

Adequate clearance shall be provided around the switchgear for maintenance, operation, access and anticipated extensions.

7.2.4.5.2 A minimum clearance of 2.5 meter in front and 1 meter in rear of switchboards shall be considered. the appropriate distance in both end of switchboards shall be considered for future extension. The minimum clearance for both ends shall be 2.5 meter to the wall. The equipment manufacturer shall always be consulted for recommended clearances.

7.2.5 Substations

7.2.5.1 General

Substations shall contain all the equipment required for the safe and secure distribution of electricity to a predetermined area, plant or region, such as H.V./M.V. and L.V. switchgear and control gear installations, transformers and the pertaining auxiliary facilities.

The substation shall be located in non-hazardous areas and preferably near the center of the load they are required to supply.

The location of the substations shall also be such that interference between H.V./M.V./L.V. cables, instrument cables and other services, e.g. pipelines is minimized.

In exceptional cases e.g. in view of restricted space on offshore platforms, electrical substations may be located in hazardous areas classified as zone 2, subject to approval by the principle. The following requirements shall apply:

The interior of the building shall be pressurized in accordance with IEC 60079-13;

An over pressure of at least 50Pa (0.5 bar) shall be maintained, using a duplicate fan system with a suitable dry element dust filtering system to ensure a supply of clean air, each fan being capable of supplying the required pressure;

The fan system shall be suitable for a Zone 1 area and shall be supplied from tow independent sources of electricity supply;

Both fans shall normally be in operation and shall have individual alarms to indicate failure in a manned control center;

7.2.5.2 Outdoor substations

H.V. outdoor open terminal switchgear installations should be designed to Internationally accepted standards, such as. BS 7354, and shall allow unrestricted walking access to the whole site.

Open terminal outdoor substations should be sited at least 100 m from process unit battery limits. If this separation is not feasible, switchgear shall be and installed in an indoor substation.

Note 1:

Outdoor switchgear shall be treated as sparking equipment, and the minimum distance from the process unit should be determined from the analysis of gas cloud behavior by the process engineering department.

The installation of all components shall be coordinated in accordance with IEC 60071.

The installation class and creepage distance of the isolators shall be selected in accordance with the expected pollution rate and the likelihood of reduced possibility of maintenance. If not further specified, a minimum creepage distance of 40 mm/KV shall be applied for insulators.

Note 2:

For further guidance refer to IEC 60815, and if necessary, consult with the local public utility.

Busbars and the connections to the equipments shall be made of copper aluminum tubes or aluminum conductors. Bi-metallic connectors shall be used at joints between dissimilar metals.

Equipment support structures and line portals shall be of hot-dip galvanized steel and shall have integral climbing facilities for repair and cleaning purposes.

A 2.4 m high, un climbable perimeter fence with (pad) lockable access gates shall be provided, but no internal fencing, e.g. around transformers, is required, provided the ground and safety the clearances stated in the above mentioned standards are satisfied.

Control and auxiliary cables shall be installed in hard covered, pre-cast concrete cable trenches the top of which shall be surrounding ground level. The trenches shall be well drained and not stand filled.

Note 3:

All supporting structures and equipments shall be earthed to the substation earthing system.

The perimeter fence shall be earthed at regular intervals (maximum 30 m) by means of earth electrodes directly connected to it.

Note 4:

The perimeter fence shall not be connected to the substation earth so as to avoid the danger of touch voltage.

protection against lightning strikes shall be provided by means of over head earth wires

The substation equipments shall be protected against lightning and switching over voltages by lightning arrestors.

Control, protection and auxiliary power supply equipments associated with outdoor switchgear shall be installed in a building which shall comply with the relevant requirements of (7.3). This substation building, if suitably sub-divided, could also accommodate other switchgear and controlgear at lower voltages.

7.2.5.3 Indoor substations

7.2.5.3.1 Switchrooms in indoor substations

Onshore, indoor substations shall be single story switchrooms with cable gallery unless otherwise specified by company representative.

“HV. / M.V.” and LV. switchgear shall be located in a separate room unless otherwise specified by company representative. Each switchroom shall have two door which shall lead directly to the outside from each switch room, and a personnel doors which may connect adjacent rooms.

If electrical equipment is installed on the roof of the substation e.g. air conditioning compressor/condensers, a cage ladder shall be provided from an entrance platform.

In the cable vault underneath the substation cable tray/racks shall be installed for all cables to the switchgear and for all interconnecting auxiliary cables between switchgears, panels, etc. For the power cables to the switchgear vertical cable supports shall be installed.

All cable entry holes in the substation floor or walls shall be suitably sealed. Where such cable entry holes are required to be gas tight and/or fire resistant, silicon foam or chemical compound with subliming heat resistant and fire retardant properties shall be used.

Substation lighting and small power installations shall comply with section 7.10

To provide the required environmental conditions, the electrical substations and switch houses shall be complete with heating, ventilation and/or air conditioning systems

When air conditioning is provided to cool and dry the substation air in relation to the outside air, provisions shall be made to avoid warm, humid outside air entering directly on to electrical equipment, causing condensation.

A smoke detection system comprising point detectors shall be installed in the substation. A common alarm shall be routed from each substation direct to the plant's central fire and gas alarm system i.e. independent of the substation alarm annunciator.

At least one hand held extinguisher shall be provided near each door.

Note:

The separate room shall be considered for MV. Capacitor bank.

7.2.5.3.2 Switchgear in plant rooms

In the context of this clause a plant room is a room in a building other than a substation, e.g. an administration building, workshop, etc. which contains service and equipment for that building, e.g. HVAC plant.

In general only L.V. switchboards and, where required, associated indoor transformers shall be installed in these rooms in accordance with (7.3.1),but subject to the following additional requirements.

The switchboard shall be installed back to the wall with 1m free space at rear and at least 2.5m free space in front for safe operational and maintenance access. 2m free space shall be considered in both sides for future extension.

Service lines, e.g. fuel, water and air lines shall not be routed over the switchgear, Fuel and water lines shall be positioned at least 2 m clear of it.

7.2.5.3.3 Battery installation and battery rooms

A separate battery room shall be provided in the substation and have an access door from outside the substation.

The battery room shall be designed to contain the battery bank only. The size of the room shall be adequate to allow access to at least three sides of each battery bank for maintenance purposes.

The doors shall be lockable and fitted with an internal panic bolt. The ceiling shall be flat. A water tap, eye wash basin, sink and drain shall be installed in the room.

All non current carrying metalwork in the room, e.g. cable tray, battery stands etc. shall be bonded to earth. All metalwork shall be protected against corrosion.

Heating, ventilation and/or air condition of battery rooms shall be included in the HVAC system of the building.

Exhaust fan motors shall have type of protection 'e' or 'd', gas group C, exhausting to the outside of the battery room.

The luminaries and convenience outlets shall be suitable for Zone 1, gas group C.

Flexible cables to the batteries may be installed provided they are the EPR or H07 RN-F type or equivalent.

Smoke and hydrogen detectors shall be considered for battery rooms with alarm indication in control room.

7.2.6 General design requirements for switchgear rooms

7.2.6.1 Switchgear room floor level shall be at least 1 meter above surrounding ground level.

7.2.6.2 Switchgear room floor shall be made from first-grade trazoatile.

7.2.6.3 The width of switchgear room trench shall be proportional to the depth of panels to make possible the entry of control cables from the front of panels and power cables from rear and bottom of the panels.

7.2.6.4 The following electrical signals shall be provided in plants control room:

- Main incoming status
- 24v & 110v dc battery chargers failures
- Generator status (off, running)
- 3.3kV & 11kV motor's running status

7.2.6.5 Emergency lighting , self-contained, with a back-up time of 4 hours , shall be provided in all switchgear rooms in sufficient numbers to provide at least 100 lumen/m² (lux).

7.2.6.6 Remote control panel (Rcp) shall also accommodate mimic diagrams on its front door.

7.2.6.7 The following accommodations shall be provided in switchgear room:

- Metal cabinets for storage of switchgear's documents, drawings, manuals, etc.
- Etal cabinet for storage of switchgear's accessories such as operating handles, control adaptors, tools , etc.
- Office desk and chairs :
 - 1 no office desk & 4 nos. chairs
- Telephone & wall clock

7.2.7 Package substations

Package substations may be used for temporary or permanent installations.

Temporary package substations should be used for temporary construction supplies and comprise LV distribution boards and, optionally, transformers and HV ring main switchgear.

Package substations shall be supplied as complete factory assembled and tested transportable units.

The HV switchgear, transformer and LV switchgear shall be located in separate compartments, each accessible from the outside by lockable doors. Sufficient space shall be available in the compartments to terminate cables and operate the switchgear safely. The switchgear compartments shall be at least protected to IP 55. The transformer compartment of oil filled transformer shall be equipped with a leak-proof oil contaminant area.

Note:

Dry type transformers may be mounted on site with the LV switchgear or in a separately fenced enclosure in the LV switchgear compartment.

Heating, ventilation and/or air-conditioning provisions shall be made in the substation as appropriate and as necessary to ensure that specified operating temperature limits of the installed equipment are not exceeded.

Each compartment shall be provided with luminaries and convenience outlets of the weatherproof industrial type.

7.3 Transformers

7.3.1 General

7.3.1.1 Scope

7.3.1.1.1 This part (transformers) of IPS-E-EL-100(1) specifies general requirements for engineering considerations, selection and sizing of power and distribution transformers, reactors and earthing transformers with highest voltage (U_m) up to and including 72 kV (acc. to IEC 60076-3). If there is no specific IPS standard for transformers with voltages above 72 kV, this part should be applied as minimum.

7.3.1.1.2 Types of transformers included are dry type & oil immersed (hermetically sealed and conservator type). Exclusions are:

- i) single phase transformers rated less than 1 KVA.
- ii) polyphase transformers rated less than 5 KVA.
- iii) voltage and current transformers.
- iv) transformers for static convertors.
- v) starting transformers.
- vi) testing, welding & traction transformers.

Note 1:

Dry type transformers shall comply with the requirements of [IPS-M-EL-151\(1\)](#).

Note 2:

Oil immersed transformers shall comply with the requirements of [IPS-M-EL-152\(1\)](#).

7.3.1.2 Electrical conditions

- i) The system supply voltage variation will be $\pm 10\%$ rated value.
- ii) The system frequency variation will be $\pm 5\%$ rated value.
- iii) System fault level at transformer primary terminal.

7.3.1.3 Method of cooling

7.3.1.3.1 Transformers are identified according to cooling method employed . Letter symbols used in conjunction with cooling are given in Table 7.

TABLE 7- LETTER SYMBOLS FOR COOLING

KIND OF COOLING MEDIUM	SYMBOL
Mineral oil or equivalent flammable synthetic insulating liquid	O
Non-flammable synthetic insulating liquid	L
Gas	G
Water	W
Air	A
KIND OF CIRCULATION	SYMBOL
Natural	N
Forced (oil not directed)	F
Forced (directed oil)	D

7.3.1.3.2 Transformers shall be identified by four symbols for each cooling method for which a rating is assigned by the manufacturer .

7.3.1.3.3 Dry-type transformers without protective enclosures are identified by two symbols only for the cooling medium that is in contact with the windings or the surface coating of windings with an overall coating (e.g. epoxy resin) .

7.3.1.3.4 The order in which the symbols are used shall be as given in Table 8. Oblique strokes shall be used to separate the group symbols for different cooling methods .

TABLE 8- ORDER OF SYMBOLS FOR COOLING SYSTEM

1 ST LETTER	2 ND LETTER	3 RD LETTER	4 TH LETTER
Indicating the cooling medium that is in contact with the windings		Indicating the cooling medium that is in contact with the external cooling system	
Kind of cooling medium	Kind of circulation	Kind of cooling medium	Kind of circulation

7.3.1.3.5 Examples:

AN: for dry type transformer without a protective enclosure or with a ventilated enclosure and with natural air cooling.

ANAN: for dry type transformer in a non-ventilated protective enclosure natural air cooling inside and outside the enclosure.

ONAN/ONAF, ONAN/OFAF: for oil immersed transformers in which the alternatives of natural or forced cooling with non-directed oil flow are possible .

ODAF: for an oil-immersed transformer with forced-directed oil circulation and forced air circulation.

7.3.1.4 Recommended values of ratings

7.3.1.4.1 Rated power: Transformers shall be continuously rated . The ratings shall be determined from the series given in table II of IEC60076-1 . Preferred values of rated power for three phase transformers are:

5 / 6.3 / 8 / 10 / 12.5 / 16 / 20 / 25 / 31.5 / 40 / 50 / 63 / 80 / 100 / 125 / 160 / 200 / 250 / 315 / 400 / 500 / 630 / 800 / 1000 KVA and etc .

7.3.1.4.2 Rated voltage: The rated voltages of transformer windings shall be selected from IEC 60038 . The followings are most commonly used voltages in oil industries:

230 v / 400 v / 3.3 kV / 6 or 6.6 kV / 10 or 11 kV / 20 kV / 33 kV / 63 or 66 kV .

7.3.1.4.3 Rated ratios : The rated ratio is defined as ratio of primary to secondary voltage at full load & 0.85 lagging power factor with principal tapping. the most common voltage ratios are in Table 9.

TABLE 9 - COMMON RATED RATIOS

PRIMARY VOLTAGE (KV)	SECONDARY VOLTAGE (KV)
3.3 / 6 or 6.6 / 10 or 11 / 20 / 33	0.4
10 or 11 / 20 / 33 / 63 or 66	3.3
10 or 11 / 20 / 33 / 63 or 66	6 or 6.6
20 / 33 / 63 or 66	10 or 11
33 / 63 or 66	20
63 or 66	33

7.3.1.4.4 Rated impedance voltage: Unless a specific transformer impedance voltage is required, the values shall be chosen from typical values given in Table I of IEC60076-5 (table 10). The impedance voltage shall be that applicable to principal tapping and rated current. Typical values of impedance voltage for transformers with two windings are as follows:

TABLE 10 - COMMON RATED IMPEDANCE VOLTAGES

RATED POWER (KVA)	IMPEDANCE VOLTAGE (%)
Up to 630	4.0
631 to 1250	5.0
1251 to 3150	6.25
3151 to 6300	7.15
6301 to 12500	8.35
12501 to 25000	10.0

7.3.1.4.5 Rated short circuit capacity: The short circuit withstands ability of transformers and reactors will be in accordance with IEC 60076-5. If the short circuit apparent power of the system is greater than those given in Table II of IEC 60076-5 (table 11), the manufacturer shall be informed. Short circuit apparent powers of the systems which may be used in absence of specification are as follows:

TABLE 11 - COMMON RATED SHORT CIRCUIT APPARENT POWER

HIGHEST SYSTEM VOLTAGE (KV)	SHORT CIRCUIT APPARENT POWER (MVA)
3.3	150
7.2 / 12 / 17.5 / 24	500
36	1500
52 / 72.5	2500

7.3.2 Transformer sizing

7.3.2.1 Power & distribution transformers

The rated power of a transformer is decided on the basis of the maximum active power demand determined in the course of project planning by applying the expected power factor.

Note:

A reserve of power for the expected yearly rate of increase of power (KVA) must be considered if required.

A schedule based on the plant design capacity of the installed electrical loads shall be prepared. In this electrical load list, loads are determined as continuous, intermittent and standby.

7.3.2.1.1 First step is to find peak load value in kW's & KVAR 's .

If :

A = Sum of all continuously operating loads.

B = Sum of all intermittent loads.

C = Sum of all standby loads.

Then :

Maximum normal running load = $X \times A + Y \times B$

Peak load = $X \times A + \text{Max} \{Y \times B, \text{largest intermittent load}\} + \text{Max} \{Z \times C, \text{largest standby load}\}$

X, Y, Z are diversity factors determined by principal.

The following default values for X, Y, Z could be used for initial load assessments or if diversity factors have not been finalized.

X = 100% , Y = 75% , Z = 10%

7.3.2.1.2 After calculating peak load value, maximum load KVA is determined by using total power factor (or using total KVAR value).

$$\text{Maximum load (KVA)} = \frac{\text{Peak load (kW)}}{\text{Total power factor}}$$

or

$$\text{Maximum load (KVA)} = \sqrt{\text{peak load (kw)}^2 + \text{peak load (KVAR)}^2}$$

7.3.2.1.3 The required KVA is determined by multiplying maximum load KVA by 120% for possibility of future expansion . Since the value of required KVA is not normally the same as a standard value , the transformer KVA will be the nearest standard transformer rating above the required KVA .

7.3.2.1.4 The required transformer KVA may be increased by load flow & motor starting studies due to voltage drop calculations .For the starting study , the greatest electric motor should be considered with other normal loads connected .

Note 1:

The percentage of total intermittent load that contribute to the normal running load will depend on plant operation .

Note 2:

The second term in peak load formula is the biggest value between $Y \times B$ and largest individual intermittent load.

Note 3:

The third term in peak load formula is the biggest value between $Z \times C$ and largest individual standby load.

Note 4:

Transformers shall be rated for maximum ambient temperature.

Note 5:

Maximum rating of transformers feeding plant substations should be such that the rated current of their secondary winding does not exceed 2000 A when feeding an MV switchboard, or 2500 A when feeding an LV switchboard . This results in the following maximum ratings:

1600 KVA if feeding LV switchboard.

10 MVA if feeding MV 3.3 KV switchboard.

20 MVA if feeding MV 6 or 6.6 KV switchboard.

40 MVA if feeding MV 10 or 11 KV switchboard.

Note 6:

Higher ratings should be considered only if a significant cost saving can be proven.

7.3.2.2 Motor unit transformers

Motor unit transformers with double wound, core- type, oil immersed, ONAN cooled, sealed, are used normally to avoid the installation of a switchboard with different voltage. For example when we have a 10 (or 11) kV switchboard and a single motor with voltage rating of 3.3 kV .

7.3.2.2.1 The unit transformer shall be specifically designed and used exclusively for supplying the 3.3 kV induction motor arranged for direct-on-line starting from the associated 10 (or 11) kV feeder circuit breaker.

Note:

Using of unit transformers shall be decided based on economical considerations.

7.3.2.2.2 Two main requirements for unit transformers are:

- i) The unit transformer shall be capable of withstanding full voltage motor starting current for 15 seconds unless otherwise specified.
- ii) The voltage drop at the motor terminals at startup shall not exceed 15%.

7.3.3 Transformer selection

7.3.3.1 Rated values

Rated values of transformers such as power, voltage, ratio, impedance voltage & short circuit capacity are selected from recommended values of ratings in section 7.3.1.

7.3.3.2 Type of transformers

7.3.3.2.1 Oil immersed transformers: oil immersed transformers or reactors shall either be of the sealed tank type or conservator type. The advantages of sealed tank design are their almost maintenance-free operation and with certain designs there is a space saving because of the absence of external pipe work.

Transformers for outdoor use and rated up to and including 2500 KVA shall be of the oil-filled hermetically sealed type. Transformers above 2500 KVA should be conservator type.

Note: Using of sealed type transformers above 2500 KVA shall be decided by company representative.

7.3.3.2.2 Dry-type transformers: In locations where fire risk must be minimized e.g. in public and residential buildings, on offshore platforms etc., dry-type transformer having cast resin encapsulated windings can be used. Cast resin encapsulated transformers are recognized as almost not-combustible, self-extinguishing and electrically unaffected by high humidity. They shall be used for ratings up to and including 1250 KVA with secondary voltage 400/230 v.

7.3.3.3 Vector group

Where there are no restriction due to parallel operation with other / existing transformers of different winding connection, step-down transformers shall be specified with Dyn5 or Dyn11 in accordance with IEC60076-4. Any other vector group should be subjected to agreement.

7.3.3.4 Voltage tapplings

Unless otherwise specified the higher voltage winding of all transformers should be provided with tapplings for constant KVA to compensate variations in the supply voltage.

7.3.3.4.1 Off-circuit tap changer: Unless otherwise specified all transformers should have an off-circuit tap changer with a principal and four additional tapplings. Tapping range shall be $\pm 5\%$ in four equal steps of 2.5% of the nominal primary voltage.

7.3.3.4.2 On-load tap changer: Main incoming supply transformers receiving power from public utility and rated 5 MVA and above with primary rated voltages equal or above 36 kV are usually fitted with on-load tap changers. There is no need for on-load tap changer if voltage variation range is less than $\pm 5\%$. Transformers at the end of long transmission lines (normally longer than 50 km) may need to have on-load tap changer. Maximum voltage variation at transformer location shall be calculated in project specification stage (engineering studies).

7.3.3.4.3 The use of on-load tap changers fitted to site distribution transformers shall be permitted only if it is anticipated that plant non-transient voltage variations of greater than $\pm 6\%$ could occur as a result of normal process operations and also that there would be process disruption if a transformer was switched out of circuit to alter the tapping out.

7.3.3.4.4 Tapping range and tap steps : On-load tap changers should have a minimum tapping range of $\pm 7.5\%$ in 13 taps with 12 tap steps of 1.25%, unless voltage variations dictate a wider range and more steps. Generally tapping range shall be at least 120% of anticipated/calculated voltage variation.

Note 1:

On-load tap changers shall be of automatic voltage control type. They shall also be manually operated either at the transformer or from a remote control location in substation or control room.

Note 2:

The high speed resistance type of on-load tap changer is preferred.

Note 3:

Where on-load tap changers are required , they shall comply with IEC60214 & IEC60542.

Note 4:

Tapping range and tap steps are normally determined by transformer manufacturer according to voltage variation, rated power and rated system voltage.

Note 5:

On-load tap changers are not normally required on generator step-up transformers.

Note 6:

Reactors shall not be fitted with on-load tap changer and earthing transformers shall not be fitted with any type of tap changer .

7.3.3.5 Type of transformer cooling

The type of cooling specified for transformers less than 15 MVA can be ONAN. This requires no particular maintenance and is not subjected to any exterior construction such as auxiliary power source, thermostat, relays, fans, pumps, etc.

7.3.3.5.1 If an economic case can be made for forced cooling or provision for forced cooling, the first level is ONAF and the second is OFAF. When a combination of cooling methods is specified (ONAN/ONAF or ONAN/OFAF) the transformer shall be capable of continuous operation with ONAN cooling at the specified output KVA rating.

7.3.3.5.2 Forced cooling or provision for forced cooling may be considered under the following circumstances:

- i)** It is anticipated that there could be a future plant load increase .
- ii)** Transformers for use on a triple radial system could under certain operating conditions experience higher than normal rated loads.

iii) A unit which usually runs as a base load has occasional periods of high load demand that would be outside the normal cyclic loading capabilities of the transformer or reactor.

Note 1:

Any requirement for forced cooling, and whether this is to be fitted at the time of initial purchase or to be added at a later date, shall be as specified in data sheet .

Note 2:

If provision for forced cooling is specified, the manufacturer shall allow for this in the transformer design.

7.3.4 More design and engineering considerations

7.3.4.1 Effect of altitude on transformers

7.3.4.1.1 Effect of altitude on transformer temperature rise: The effect of the decreased air density due to high altitude is to increase the temperature rise of transformers which are dependant upon air for dissipation of heat losses. For a naturally cooled transformer (. . AN), the limit of average winding temperature rise shall be reduced by 1°C for every interval of 400 m by which the installations altitude exceed 1000 m. For a forced cooled transformer (. . AF) , the reduction shall be 1°C for every 250 m .

7.3.4.1.2 Rated operation at high altitude: Transformers can be operated at rated KVA at altitudes greater than 1000 m without exceeding temperature limits provided the average temperature of cooling air does not exceed the value of Table 12 for the respective altitude .

Note:

It is recommended that the average temperature of cooling air be calculated by averaging 24 consecutive hourly readings . When the outdoor air is the cooling medium , the average of maximum and minimum daily temperatures may be used .

**TABLE 12 - MAXIMUM ALLOWABLE AVERAGE TEMPERATURE OF COOLING AIR (°C)
(According to IEC-60072-2)**

METHOD OF COOLING	1000 m	2000 m	3000 m	4000 m
Oil-immersed self-cooled	30	28	25	23
Oil-immersed forced-air-cooled	30	26	23	20
Dry-type self-cooled				
1) – 55 °C rise	30	27	24	21
2) – 80 °C rise	30	26	22	18
3) – 150 °C rise	30	22	15	7
Dry-type forced-air-cooled				
1) – 55 °C rise	30	24	19	14
2) – 80 °C rise	30	22	14	6
3) – 150 °C rise	30	15	0	-15

7.3.4.1.3 Operation at less than rated KVA at high altitude: Transformers can be operated at altitudes greater than 1000 m without exceeding temperature limits provided the load to be carried is reduced to below ratings by the percentages given in Table 13 for each 100 meters that the altitude is above 1000 m.

**TABLE 13 - KVA CORRECTION FACTOR FOR EACH 100 METERS
FOR ALTITUDES GREATER THAN 1000 METERS
(According to IEC-60072-2)**

TYPE OF COOLING	CORRECTION FACTOR (PERCENT)
Oil-immersed self-cooled	0.4
Oil-immersed forced-air-cooled	0.5
Dry-type self-cooled	0.3
Dry-type forced-air-cooled	0.5

7.3.4.2 Parallel operation of transformers

7.3.4.2.1 Parallel operation means direct terminal-to-terminal connection between transformers in the same installation . For successful parallel operation , the transformers require:

- i)** The same vector group .
- ii)** The same ratio with same tolerance and similar tapping range .
- iii)** Approximately the same impedance voltage (maximum permissible discrepancies ± 10%) .
- iv)** Approximately the same rated output KVA (not more than 1 : 2) .

Note:

Transformers built according to different design concepts are likely to present different impedance level and different variation trends across the tapping range.

7.3.4.2.2 Effect of unequal impedance voltages in parallel operation of transformers: When transformers with unequal impedance voltages are connected in parallel, the transformer with lower impedance voltage value will take up a higher percentage of its rated power. So that the absolute voltage drop will be the same for both transformers. This may cause marginally increased combined power loss for the transformation and may restrict the load ability of the installation.

In such a case to prevent the transformer with lower impedance voltage from overloading, the total power of installation should be calculated by equation as below:

$$S = S_{ra} + \frac{U_{ka}}{U_{kb}} \times S_{rb}$$

Where

S : Total power (KVA)

S_{ra} : Rated power of transformer with lower impedance voltage (U_{ka})

S_{rb} : Rated power of transformer with higher impedance voltage (U_{kb})

7.3.4.3 Earthing transformers

7.3.4.3.1 Earthing transformers are three phase transformers (or reactors) used to provide an artificial loading neutral for earthing of a system at a point where it is otherwise un-earthed. Connecting to earth can be done directly or through an earthing resistor.

Earthing transformers are usually connected either in zigzag or star/delta. A delta connected winding may be of the open type to adjust the zero-sequence impedance.

Note :

Earthing transformers may be specified with a low voltage winding having a continuous rated power for substation auxiliary supply.

Ratings :

7.3.4.3.2 Rated voltage of the main winding: Unless operating conditions justify the selection of a higher value, the rated voltage shall be equal to the line voltage of the associated system.

7.3.4.3.3 Rated neutral current: The rated neutral current shall be specified to be not less than the highest value of continuous current under service conditions, for example phase unbalance.

7.3.4.3.4 Rated zero-sequence impedance: The value of zero-sequence impedance may either be left open in the specification or be specified. (for example when the earthing transformer itself is used to limit the earth fault current)

Note:

Earthing transformers shall be designed to withstand without damage the thermal and dynamic effects of the rated current.

7.3.4.4 Reactors

According to IEC60289, there are approximately eight different types of reactors. The most important type that may be used in NIOC fields is as follows:

7.3.4.4.1 Current limiting reactors: The reactors intended for limiting the short-time current under system fault conditions or starting of AC motors. During normal operation a continuous current flows through the current limiting reactor.

Ratings:

7.3.4.4.2 Rated continuous current: Unless otherwise specified, the rated continuous current is a symmetrical three-phase current. Preferred values of the rated continuous current shall correspond to the series R10 in ISO standard 3.

7.3.4.4.3 Rated short-time current: The rated short-time current shall be specified to be not less than the highest value of current under recognized fault or starting conditions.

7.3.4.4.4 Rated short-time current duration: Unless otherwise specified, the rated short-time current duration shall be 2 seconds for current-limiting reactors.

7.3.4.4.5 Rated impedance: The value of rated impedance shall be specified together with the rated short-time current in accordance with the system parameters and the recognized case of system faults.

Note:

Current limiting reactors shall be designed to withstand the thermal and dynamic effects of the rated short-time current for its rated duration.

7.3.4.5 Neutral grounding resistor (NGR)

Power transformers with secondary voltage of 11 KV, 6 KV or 3 KV which supply electric motors, shall be equipped with suitable NGR's. The time rating of the NGR shall be 10 second. The current rating shall be calculated by designer.

7.4 Electrical motors**7.4.1 General**

Electrical motors are one of the most important components in oil, gas and petrochemical plants. The following general requirements shall be considered in design and selection of the rotating electric machines.

7.4.1.1 All the electrical motors shall be designed for the load characteristics and operational duty of the driven equipment.

7.4.1.2 All the electrical motors and their accessories shall comply with sound engineering practices to have an expected lifetime of minimum 20 years. (Excepting rolling element bearings).

7.4.1.3 Unless there is a clear technical/economic justification for preferring a synchronous motor over an induction motor, the squirrel cage induction motor generally would be recommended.

7.4.1.4 Synchronous motors generally should not be considered at ratings below 2 MW.

7.4.1.5 Synchronous motors shall be brush-less and the exciter shall consist of a brush-less three phase synchronous generator, rotating rectifier, a pilot exciter if applicable, field protection and shorting functions shall be accomplished by solid state control.

7.4.1.6 For synchronous motors, the excitation system shall be equipped with an automatic power factor controller to maintain the set power factor within a margin of $\pm 2.5\%$.

7.4.1.7 The DC motors could be used for special application such as fans, blenders, drilling mud pumps & seal or lube auxiliary pumps and etc.

7.4.1.8 The application of the VFD (variable frequency drive) systems shall be considered where it can be justified that the VFD system will benefit the operation, maintenance and efficiency of the plant. A technical/economical study regarding the above shall be performed and submitted to company engineer for approval.

7.4.2 Service condition

7.4.2.1 The motors will be generally installed outdoor in areas where the presence of flammable gas or vapor is foreseen. In case where the motor will be installed indoor, it will be indicated in data sheet.

7.4.2.2 The electrical motor shall meet the requirements of the classified areas as specified in this specification and indicated in data sheet.

7.4.3 Voltages and output ratings

7.4.3.1 The voltage levels adapted in the oil, gas and petrochemical industries of Iran are based on the IEC recommendation No 60038 and part 6.1.5.1 of this standard.

7.4.3.2 The low voltage system is generally 400/230 volt with solidly earthed neutral.

7.4.3.3 The voltage of the motors rated up to 0.4 kW can be selected as 230 volt single phase and neutral. If capacitor type single phase motor is used, the capacitor shall be metal clad with paper dielectric. Motors for critical services such as compressor auxiliaries, lube oil systems, special pumps, etc. shall be 400 volts, 3 phase.

7.4.3.4 The voltage of the motors 0.4 kW up to 150 kW shall be 400 volt three phase. The voltage of 150 kW motors can be selected as 400, 3300 or 6000 volt depending upon the availability of such voltage levels.

7.4.3.5 For special applications or existing facilities, other voltages may be specified. The nominal voltage of the motor will be indicated in data sheet.

7.4.3.6 The voltage of the motors rated 150 kW to 1000 kW shall be 3.3 KV or 6 kV.

7.4.3.7 The voltage of the motors above 1000 kW can be selected as 6 kV or 10 kV or 11 KV based on technical and economical considerations of the electrical power supply system, in particular the voltage drop during starting of the motor.

7.4.3.8 All rotating machines shall be capable of operating continuously at rated torque at any frequency between -2% and $+2\%$ of the nominal frequency together with a voltage variation of $\pm 5\%$. The nominal frequency is 50Hz.

7.4.3.9 The motors shall be capable of performing its primary functions at voltage variation of $\pm 10\%$ and frequency variation of $\pm 5\%$ according to IEC 60034-1. For generator and synchronous motor voltage variation shall be considered as $\pm 8\%$.

7.4.4 Motor sizing

7.4.4.1 Frame sizes and dimensions and the kW ratings of the motors shall be in accordance with IEC 60072-1.

7.4.4.2 Motors shall be sized, taking into consideration the appropriate multiplying factor/s related to each type and size of the driven equipment. The size of the motors versus the driven equipment shall be according to the recommendations of the driven equipment specifications.

7.4.5 Motor starting

7.4.5.1 Motors shall be suitable for Direct On Line Starting.

7.4.5.2 Upon the approval of company representative, star-delta or auto-transformer starting may be employed for 400 volt motors if required .

7.4.5.3 For motors rated up to 150 kW the maximum value of locked rotor apparent power shall comply with IEC 60034-12.

7.4.5.4 For motors rated above 150 kW , the starting current shall not exceed 6 times the rated current of the motor . A load flow study regarding starting of biggest electric motor shall be performed and any limitation in starting current of the motors shall be specified in relevant data sheets.

7.4.5.5 The motor design shall allow without injurious heating of insulated windings, at least three successive starts from cold against full load torque and two successive starts with the motor initially at full load operating temperature.

7.4.5.6 For high voltage motors individual dedicated unit transformer directly connected to the motor may be used, which shall be shown on single line diagram/s. The transformer shall withstand the thermal and dynamic stresses during repeated direct on line starting of the motors.

7.4.5.7 Motors rated 150 kW to 1000 kW shall be controlled by vacuum type contactors. Motors rated above 1000 kW shall be controlled by vacuum type circuit breakers. The motors shall be designed to withstand the switching surges of vacuum interrupters.

7.4.5.8 The starting performance and pull up torque of the motor shall be coordinated with the driven equipment supplier.

7.4.5.9 Motors shall be able to overcome starting load inertia as well as accelerating the load to rated speed, when the applied voltage is 80% of the nominal voltage.

7.4.5.10 In case of power interruption during operation, the motor may be reconnected to the supply voltage at any time. The residual voltage magnitude and phase angle shall not have any detrimental effect on the motor.

7.5 Electrical Protection, Metering & Control

7.5.1 General

7.5.1.1 This section specifies those items which apply generally to the selection and application of protective relays which are supplied to provide electrical power system protection for National

Iranian Oil Company installation. Importance, voltage level and cost are the considerations in selection of protection systems.

7.5.1.2 Protective relays requirements

i) All protective relays shall be microprocessor based. Single function relays (such as thermal overload, earth leakage relays for low voltage system) may be static or electromagnetic type by approval of company representative. Relays for incomers and bus couplers (HV., MV., and LV.) shall be flush mounted. All facilities such as softwares, links, ports and test sockets for communication, networking and configuration shall be considered for microprocessor relays. These relays shall have data and disturbance recording facilities.

ii) Unless otherwise specified by the principle the overcurrent and earth fault protective relays shall have Inverse Definite Minimum Time (I.D.M.T.) characteristics of the standard types A, B & C in accordance with I.E.C.60255-4.

7.5.1.3 Selectivity and co-ordination

i) The automatic protective systems shall be designed to achieve selective isolation of faulted equipments with minimum delay. In many events this shall be within a time corresponding to the short circuit current withstand capability of the equipment, system stability limits and the maximum fault clearance times.

ii) Adequate and selective phase short circuit and earth fault protection shall be provided based on the magnitude of short circuit currents and method of system earthing.

The short circuit currents calculation for this propose shall be based on IEC 60909-1, 60909-2, and 6090-3.

iii) Protective relay system shall be selective and the settings shall be coordinated such that back up protection is provided to initiate fault clearance in the event of protective system and/or switching device failure.

7.5.1.4 Additional requirements

i) Limited duration overcurrent arising from single or group motor starting/ reacceleration shall be permitted.

ii) Automatic control systems such as load transfer, motor restarting arrangements and protective system to initiate load shedding shall be incorporated to affect plant operations as little as practicable and economically justifiable after system or equipment failures.

iii) Protective relay settings shall be based on a study of fault conditions for which the protective system has been incorporated.

A protection and metering diagram in the form of single line diagram shall be prepared for the complete electrical system to indicate the type and location of all metering and protective devices and associated instrument transformers to be provided. In addition to this single line diagram a tabulated relay settings and coordinated relay and fuse characteristics etc. plotted in graphical form shall be included.

7.5.2 Main incomer and feeder protection

7.5.2.1 Main incomer

7.5.2.1.1 Single or more non parallel incomers supplied from public utility and no on-site generation

i) Phase fault overcurrent protection (50,51)

- ii) Earth fault overcurrent protection (50N,51N)
- iii) Under voltage and phase sequence voltage protection (27,47)
- iv) Breker failure protection (50BF)

Note:

For outdoor substation busbar protection is an option.

7.5.2.1.2 Parallel incomers supplied from public utility and no on-site generation the protection requirement shall be as described in 7.5.2.1.1 with the addition of directional overcurrent and directional earth fault protection for each incomer.

Note:

If unit feeder protection is considered ,directional protection relays may not be required.

7.5.2.1.3 Public utility supply in parallel with on-site generation

Where the on-site generation is normally or frequently parallel with public utility supply the protection requirements appropriate to 7.5.3. shall be supplemented by means for detecting and clearing external public utility faults to permit uninterrupted operation minimum down time of the site power system. The additional protection shall be as follows:

- i) Directional overcurrent and directional earth fault protection (67, 67N).
- ii) Sensitive reverse power protection (32).
- iii) Frequency relay with a time definite relay (81).

Definite time undervoltage relay (27).

Synchronizing check relay (25) - would be decided by company representative.

Items (ii),(iii) and (iv) shall be arrange such that during a reverse power(export) condition, tripping of main incomers does not occur unless there is a simultaneous under frequency (iii) or under voltage (iv) condition. The tripping times shall be determined from stability studies.

7.5.2.2 Feeder protection

7.5.2.2.1 Cables or very short over head lines(less than 5 K.m.) without load end switchgear

For the cables and overhead lines directly connected to plant such as transformers without switchgear at load end the following protections shall be considered:

- i) Phase fault overcurrent protection (50,51).
- ii) Earthfault protection (50N,51N).

The protection installed at source end shall be comprised both cables / overhead lines and also load end.

7.5.2.2.2 Cables or very short over head lines(less than 5 K.m.)with switchgear at both ends

In addition to the above protections, differential protection shall be provided on all 3.3,6,11,20,33,66 K.V. feeders where:

- i) Feeders can be operated in parallel.
- ii) Short circuit overcurrent and earth fault protection clearance time is required.

Inter tripping with remote end circuit breakers shall be provided on duplicate feeders.

7.5.3 generator protection

7.5.3.1. This subsection specifies the electrical protection requirements for generators. It does not cover mechanical protective requirements of prime mover/generators.

Note:

The method of connection of a generator to the electrical power system (direct or unit connection) dictates the type of neutral earthing and protective relaying requirements.

7.5.3.2 Low voltage generator from 100 KVA up to and include 500 KVA

- i) IDMT phase overcurrent protection (50,51)
- ii) Earth fault protection (50N,51N)
- iii) Undervoltage protection (27)
- iv) Over voltage protection (59)
- v) Frequency relay (81)
- vi) Overload protection (49)
- vii) Reverse power relay (32) for generators which may be operated in parallel to gether or with other power sources.

7.5.3.2.1 All above protections,exept over voltage protection, shall trip the generator breaker device.Over voltage protection shall also shut down the generator.

7.5.3.3 Low voltage generator above 500 KVA

The protection of this size of generatore shall be as described in 7.5.3.2 and additional protection shall be as follow :

- i) Restricted earth fault relay (64)
- ii) Winding temprature monitor protection (49T)
- iii) Reverse power relay (32) for generators which may be operated in parallel with other power sources.

Note:

The current transformers for short circuit protection purpose(phase and earth) should be placed on neutral point terminal box.

7.5.3.4 Medium voltage generators up to 2 MVA

- i) Phase overcurrent protection (50,51)
- ii) Earth fault protection (50N,51N)
- iii) Differential protection (87G)
- iv) Under and over voltage protection (27,59)
- v) Frequency protection (81)
- vi) Reverse power protection (32)

- vii) Overload protection (49)
- viii) Winding temperature monitor relay (49T)
- ix) Loss of excitation protection (40)

The current transformers for short circuit protection purpose(phase and earth) shall be placed on neutral point terminal box.

7.5.3.5 Medium voltage generators include and above 2 MVA

The protection of this size of generators shall be as described in 7.5.3.4 and additional protections shall be as follows:

- i) Voltage control overcurrent protection (50V,51V)
- ii) Rotor earth fault relay (64R)
- iii) Negative phase sequence relay (46)
- iv) Field diode failure (above 15 MVA only)
- v) Over excitation relay (24)
- vi) Voltage Balance (60)

7.5.3.5.2. Where two or more generators required operate in parallel mode ;synchroscope shall be used.

7.5.3.6 Trip and alarm orders and facilities

The operation of all protective relay shall trip the C.B. except following alarms:

- Stator winding temperature(first stage)
- Rotor earth fault (first stage)
- Overload relay (first stage)
- Over Voltage

The following trip commands shall shut down the primmover and trip the C.B.:

- Rotor earth fault (second stage)
- Stator winding temperature (second stage)
- Emergency stop- manual
- Generator differential (87G)
- Short circuit (51)
- Earth fault (50GN)

Any primmover shut down shall trip the circuit breaker.

7.5.4 Power transformer protection

7.5.4.1. This subsection specifies industrial power transformer protection scheme

7.5.4.2. Transformers up to and include 250 KVA

- i) Fuse

7.5.4.2.1 The fuse shall not be ruptured under magnetizing inrush condition.

Note:

Fuse is the minimum protection requirement for both primary and secondary sides.

7.5.4.3 Transformers above 250 KVA rating up to and including 2500 KVA (sealed type)**a) Primary side**

- i) Phase fault overcurrent protection (50,51)
- ii) Earth fault protection (50N,51N)
- iii) Breker failure protection (50BF)

b) Secondary side

- i) Phase fault overcurrent protection (50,51)
- ii) Earth fault protection (50N,51N)
- iii) Standby earth fault relay (51G) for transformers rating of 500 KVA and above. This relay shall be of I.D.M.T. type.
- iv) Overload relay (49).
- v) Oil temperature device with alarm and trip contacts for transformers rating of 500KVA and above (26).
- vi) Resetting sudden pressure, spring loaded, relief device with operating Contacts (63P).
- vii) Pressure/vacuum gauge incorporating alarm contacts ().
- vii) Oil level indicator with operating contacts (71).
- viii) Breaker failure protection (50BF)

7.5.4.3.1 Restricted earth fault protection (64) shall be considered for all M.V/M.V, H.V/M.V transformers.

7.5.4.3.2 The C.T.s for restricted earth fault protection shall be of class X. The high impedance scheme employing stabilizing resistor and a voltage operated relay is preferred.

7.5.4.3.3 If transformers of 250 KVA up to 2500 KVA rating are conservator type they shall incorporate Buchholz relay completed with alarm and trip contacts.

7.5.4.3.4 The Inverse Definite Minimum Time (I.D.M.T.) overcurrent and earth fault relay's characteristics shall be of inverse, very inverse ,extremely inverse and definite time to match to old system protection.

7.5.4.3.5 Either earth fault element of a conventional 3 pole phase and earth relay (2 phase and 1 earth fault) or one single pole earth fault relay supplied by a core balance C.T. can be used as earth fault protection of transformer primary side (i.e. delta winding).

7.5.4.3.6 In the secondary side, where the transformer neutral point earthed solidly or via resistor the following shall be considered:

- i) Where the transformer is solidly earthed, the primary current ratio of current transformer shall be of power transformer approximate nominal current.
- ii) If the transformer is earthed through an impedance, the primary current rating of current transformer for stand by earth fault protection shall be of earthing resistor current let through.

7.5.4.4 Transformers above 2500 KVA up to 5000 KVA

All protection schemes used for transformers of 250KVA up to 2500 KVA (item 7.5.4.3 except vii) shall be used for the above transformer category. in addition the following shall be added:

- i) Restricted earth fault protection shall be used for all transformers (64).
- ii) Buchholtz relay with alarm and trip contacts (63).
- iii) Overload protection (49).
- iv) Winding temperature device with alarm and trip settings and appropriate Contacts (49T).

7.5.4.5 Transformers of 5000 KVA rating up to 10000 KVA**a) Primary side**

- i) Phase fault overcurrent protection (50,51).
- ii) Earth fault protection (50N) and (50G).
- iii) Breker failure protection (50BF)

b) Secondary side

- i) Phase fault overcurrent protection (50,51).
- ii) Earth fault protection (50N,51N).
- iii) Stand by earth fault relay (51G).
- v) Restricted earth fault relay (64).
- vi) Breker failure protection (50BF)

c) Overall transformer protection

- i) Differential protection (87).
- ii) Buchholtz relay completed with alarm and trip contacts (63).
- iii) Oil temperature relay with alarm and trip contacts (26).
- iv) Resetting sudden pressure, spring loaded ,relief device with operating contacts (63P).
- v) Oil level indicator with operating contacts (71).
- vi) Winding temperature device with alarm and trip settings and appropriate contacts (49T).

7.5.4.5.1 The transformer primary and secondary cables shall be included within the protection of differential protection scheme.

7.5.4.5.2 Differential protection relay shall be of the biased type to cater the maximum transformer ratio and shall include an harmonic resistant feature to avoid maloperation due to avoid magnetizing inrush current.

7.5.4.5.3 C.T.s for differential and restricted protection shall be class X.

7.5.4.5.4 Transformers which their primary and/or secondary sides are connected to overhead lines shall be equipped with lightning arresters.

7.5.4.6 Transformers of 10000 KVA rating and above

All protection schemes used for transformers of 5000KVA up to 10000 KVA (item 7.5.4.5) shall be applied to the above transformer rating . in addition, the following shall be added:

- i) Winding temperature device with alarm and trip settings and appropriate contacts (49T).

The microprocessor based temperature monitor conjunction with RTDs placed in each winding may be used.

ii) Over fluxing protection where supply frequency assumed to be varied in large scale(for example transformers supplied via a local generator) (24).

7.5.4.7 On load tap changer transformers

If transformers are equipped with on load tap changers the following protection shall be added:

- i) Buchholtz protection completed with alarm and trip contacts for tap changer or assembly (63).
- ii) Automatic voltage regulator relay for changing the transformer tap ().

7.5.4.8 Parallel transformers

Where two transformers normally operated in parallel condition, each feeder shall be supplied by directional overcurrent and earth fault relays (67) and (67N).The directional protection (67) and (67N) do not apply for case where the transformers are equipped with transformer differential protection.

7.5.4.9 Auxiliary relays for transformer mechanical protection

a) The transformer mechanical protection such as Buchholtz, oil temperature, etc. shall have their own dedicated hand reset flag alarm and tripping relay located on the respective transformer switchgear.

Where necessary the alarm signals would normally be routed to alarm annunciator within the substation.

7.5.4.10 Tripping requirements

7.5.4.10.1 Transformer protection trip shall be via dedicated hand reset lock out relays.

7.5.4.10.2 The following trips shall be generally operates the relevant lock out relay.

a) Primary lock out relay:

- i) Earth fault relay (50N, 51N)
- ii) Instantaneous phase overcurrent relay (50)
- iii) Differential protection (87, 87N)
- iv) Sudden pressure relief vent device (63P)
- v) Breker failure protection (50BF)

b) Secondary lock out relay:

- i) Restricted earth fault relay (64)
- ii) Non-unit earth fault relay (50N, 51N,50G)
- iii) Liquid surges (i.e. Buchholtz trip "63", pressure relief)
- iv) Winding temperature trip (49T)
- v) Directional overcurrent and earth fault trip (67, 67N)
- vi) Stand by earth fault relay (51G)

vii) Breker failure protection (50BF)

7.5.4.10.3. The intertrip send and receive relay shall be located respectively on secondary and primary switchgears. All protective relays which tripped secondary lock out relay shall energize send relay and consequently this relay shall send a signal to energize receive relay on primary switch-gear and the latest shall trip the circuit breakers.

7.5.5 Motor protection

7.5.5.1 This subsection specifies induction and synchronous motor protection requirements. The protection of special motors is not covered.

7.5.5.2 Low voltage motors

Single phase motors up to 400 watts rating shall be provided with:

- i) built-in or external thermal over load relay (49).
- ii) fuse or MCB.

7.5.5.2.1 Three phase motors between 0.4 KW up to 18.5 KW

- i) Fuse or MCCB (will be decided by company representative)
- ii) Over load relay (49)

7.5.5.2.2 Motors between 18.5 KW up to 150 KW

- i) Fuse
- ii) Over load relay (49)
- iii) Earth leakage relay (50G)
- iv) Time delay under voltage phase sequence relay -27,47- (will be decided by company representative)

7.5.5.2.2.1 Bimetal over load relay shall be three pole, ambient compensated, incorporating single phase protection.

7.5.5.2.2.2 The fuse shall be high rupturing type and shall have characteristic class of aM (According to IEC-60269).

7.5.5.2.2.3 The earth leakage relay shall be supplied by a corbalance current transformer and the minimum setting of relay shall be started from at least 10% of motor full load current.

7.5.5.2.2.4 Over load relay rating above 72 ampere shall be C.T. operated.

7.5.5.2.2.5 Where using solid state over load relays, these relays shall have facilities to test all characteristics curves.

7.5.5.3 Medium voltage motors

7.5.5.3.1 motors above 150 KW and up to 1000KW

- i) Thermal over load protection (49)
- ii) Fuse

- iii) Sensetive earth fault protection (50G)
- iv) Negative phase sequence protection (46)
- v) Under voltage protection (27)
- vi) Incomplete sequence protection (48)
- vii) Anti restart protection (66)
- viii) Locked rotor protection (51L)
- ix) Winding temperatour protection (49T)
- x) Breaker failure protection (50BF)

7.5.5.3.1.1 Main fuses shall be used only in motor starters. this fuses shall be striker pin type and shall have facilities to trip starter and have their own indications when operated.

7.5.5.3.1.2 Eearth fault or earth leakage protection shall be supplied by a corebalance current transformers and the minimum setting of relay shall be started at least 10% of motor full load current.

7.5.5.3.2 Motors rating 1000 KW and above

Protection of these size of motors shall be as described in 7.5.5.3.1. (except fuse) and other protection shall be added as follows:

- i) Differential protection (87)
- ii) Winding temperature monitor relay (49T)
- iii) Bearing over temperature
- iv) Phase fault over current protection (50,51)

7.5.5.3.2.1 Winding temperature relay shall have 6 channels to accept ,measures and monitoring 6 RTD's separately.

7.5.5.3.3 Synchronous motors

The protection of this type of motors (2000KW and above) shall be as described in 7.5.5.3.2. and other protection shall be added as follows:

- i) Under excitation protection (40)
- ii) Rotor earth fault relay (64R)
- iii) Out of step protection (55)

7.5.6 Differential busbar protection

7.5.6.1 Differential busbar protection should be considered for voltage level of 33 and 63/66 K.V. outdoor primary substations where the integrity of power supplies and plant operation would be seriously impaired by loss of a busbar or section of baranch.

7.5.6.2 For metal clad indoor switchgear with busbar insulation as specified in "IPS-M-EL-144 (2)" the differential busbar protection is not needed.

7.5.6.3.2 Differential busbar protection schemes shall employ high impedance type voltage operated relays with stabilizing resistors.

7.5.6.3.3 High impedance differential schemes shall have dedicated matched C.T.s of the same ratio in all incoming and outgoing circuits on the protected busbar or section. Therefore where busbars are sectionalized by breakers each section shall have its own differential scheme with C.T.s arranged to over lap at sectionalizing breakers. Class "X" C.T.s shall be used.

7.5.6.4.1 Test links shall be provided on all C.T.s circuits to facilitate busbar differential scheme testing.

7.5.6.4.2 busbar protection trips shall be via a single dedicated specific hand reset lock out relay which shall be arranged to trip the appropriate busbar breakers.

7.5.7 Capacitor protection

7.5.7.1 All capacitor units shall have individually internal fuse elements (according to IEC-60593). If this is not feasible for certain types of L.V. capacitors, internal over pressure disconnections shall be provided.

7.5.7.2 All capacitors shall have direct connected means of discharge. L.V. capacitors must discharge to a residual voltage <75 volts within 3minutes. A maximum discharge time of 10 minutes is allowed for M.V. capacitors.

7.5.7.3 External H.R.C. fuses are used only for short circuit protection of both M.V. and L.V. capacitors and do not provide adequate protection against overcurrent.operation of each fuse of each bank shall disconnect dedicated contactor by means of striker pin or over voltage relay which is paralleled to that fuse . For M.V. capacitors the minimum accepted rating of fuse is 1.35 times the rated capacitor current.(acc. to IEC- 60871-3).

7.5.7.4 In case where the capacitor is controlled by circuit breaker, phase and earth fault protection relays shall be provided.

7.5.7.5 For capacitor banks above 300 KVAR which controlled by contactor, C.T. operated over load relays should be used. The tripping current of these relays should be set to 1.43 times the rated current of the capacitor bank.

7.5.7.6 for large capacitor banks exceeding 1000 KVAR the capacitors shall be connected in double star with unbalance protection monitoring the star point voltage, or with unbalance current protection between neutrals (according to IEC-60871-3).

7.5.7.7 Air cored reactors shall be installed with M.V. capacitor banks to limit the inrush currents.

7.5.7.8 An interlock system shall be provided for all automatically controlled M.V. capacitor banks to prevent re-energizing when the residual voltage is above 10% of rated voltage.

7.5.7.9 In those cases where a capacitor is connected in parallel with an electric motor a single switch gear device and associated relays and/or fuses that control and protect both the motor and the capacitor shall be provided.

7.5.8 Over head line protection

7.5.8.1 The lines used in company fields are basically distribution lines and voltage levels are used up to and include 66 KV. Because of many considerations it is not possible to establish firm rules for line protection. However, the system design engineer should consider that the operation of protection on the system will be fully discriminative.

7.5.8.2 Radial lines/feeders

Radial feeders can be protected by non-directional overcurrent and earth fault relay.

- i) Phase fault overcurrent protection (50, 51).
- ii) Earth fault protection (50N,51N).

- iii) Lightning arrester for local and remote end.
- iv) Breker failure protection (50BF).

7.5.8.3 Parallel lines incoming feeders

- i) Phase fault overcurrent protection (50, 51).
- ii) Earth fault protection (50N,51N).
- iii) Directional overcurrent protection (67).
- iv) Directional earth fault protection (67N).
- v) Lightning arrester for local and remote end.
- vi) Breker failure protection (50BF).

7.5.8.4 Tee off protection

Tee off lines are normally used to supply the low power installations.(up to 1000 KVA). These lines are protected by fuses and lightening arrasters.The fuses are placed on both ends; Tee off end and incoming to the consumer. The selected fuses shall be fully discriminative with the upstream protective devices.The fuses shall be Cut out type.

7.5.8.5 Auto reclosing system

All over head lines which supplies main substations of oil and gas installations shall be completed by multi shoot auto reclosing system. This system is initiated by 50 or 50N protection contacts. This system shall be equipped by a selector switch to give two options for operation:

Auto reclosing in service/ Auto reclosing out of service

7.5.9 L.V. feeder protection

7.5.9.1 Mains and emergency incoming feeders

As described in subsection 7.5.2.1 and 7.5.3

7.5.9.2. Outgoing feeders to:

i) Motors

As described in subsection 7.5.5

ii) Capacitors

As described in subsection 7.5.7

iii) Cables

a) Cables with breaker or isolator at both ends:

For circuits up to 100 A fuse or MCCB and for circuits more than 100 A fuse- contactor or MCCB together with earth leakage function (decided by company representative if required) and circuit breaker shall be associated with 50'51'50N'51N protection

b) Cables without load end breaker or isolator:

Protection of such cables that connected to equipment such as transformers or motors shall be achieved by the protection of primary equipment installed at source end.

iv) Electric heaters for process

Protection of electric process heaters shall be by means of fuse or MCCB.

For fuse rating or MCCB trip settings exceeding 100A, earth fault protection shall be provided. Over temperature protection shall be provided by at least two thermocouples located in the area of the highest anticipated sheath temperature. When static converters are required to control the heater output, they shall be equipped with the following as the minimum:

- a) Incoming voltage monitoring
- b) Fuse protection for the semiconductor devices
- c) Over temperature in the converter panel

v) Socket outlets

Outlet circuit shall be protected by phase short circuit protection device and by current operated earth leakage protective devices, which are according with IEC 60947-2. i.e. residual current circuit breaker (RCCB). The RCCB operating current shall be 30 mA.

vi) Anti condensation heaters

The heaters shall be protected by a miniature circuit breaker and an earth leakage protection device at 30 mA. sensitivity (earth leakage will be decided by company representative).

7.5.9.3. Equipments such as battery charger, UPS, cathodic protection system, M.O.V. etc. which have their own protection, shall be protected by fuse or MCCB incorporating short circuit protection.

7.5.9.4 Lighting

All lighting circuits shall be protected by suitable fuse or MCB.

7.5.10 Instruments, Meters and Instrument transformers

7.5.10.1 Metering and instrumentation are essential to satisfactory plant operation. the amount depending upon the size and complexity of the plant, as well as economic factors. instruments and meters are need to monitor plant operating conditions as well as for power billing purposes and for determination of production costs.

7.5.10.2 Instrument transformers

- i) Current transformers shall be in accordance to IEC-60044-1.
- ii) The rated secondary current of current transformers should be preferably 5 amperes for switchgear mounted protective relays and instruments, and 1 amperes for remote mounted protective relays and instruments.
- iii) Current transformers shall have appropriate VA and saturation factor. The saturation factors shall not be less than 5 for measurement C.T.'s.
- iv) C.T.'s with separate secondary shall be used for protection and measurement duties.
- v) Current transformers for high impedance differential and / or restricted earth fault protection shall be exclusively used for that purpose (class X).

- vi) Voltage transformers shall be to IEC-60186
- vii) Voltage transformers shall have appropriate VA and shall not be less than 50 VA.
- viii) VT's with separate secondary shall be used for protective and measurement duties.
- ix) Voltage transformers for measurement purposes shall be of accuracy class 1 and for protection purposes shall be class 3P. V.T.'s for use with generator AVR/s shall be of accuracy class 0.5.

7.5.10.3 Main M.V. incoming supply

- i) Class 1.5 ammeter (with phase selector switch)
- ii) Analogue type class 1.5 voltmeter with selector switch on incoming side of circuit breaker.
- iii) Multifunction microprocessor based power measurement meter class 1 (KW, KVAR, KWH, max. demand, KVARH and so on). Relevant software and hardware for communication purpose and configuration shall be considered.

7.5.10.4 M.V. out going feeders

- i) class 1.5 ammeter (with phase selector switch).

7.5.10.5 M.V. motor starter

- i) Ammeter, local / remote refer to 7.5.10.8. below
- ii) Power factor meter for synchronous motor
- iii) KW meter for synchronous motor
- iv) Field current ammeter for synchronous motors.

7.5.10.6 L.V. main incomers

- i) Analog voltmeter class 1.5 (with selector switch)
- ii) Analog ammeter class 1.5 (with selector switch)
- iii) Multifunction microprocessor based power measurement meter class 1 (KW, KVAR, KWH, max. demand, KVARH and so on) - will be decided by company representative.

7.5.10.7 L.V. motor starter

- i) Ammeter, local/ remote refer to 7.5.10.8. below.

7.5.10.8 Ammeter for motors

Unless specified other wise, the provision of ammeter shall complied with the following:

a) Process area

- i) Ammeters shall be provided for motors above 4 KW except for those driving motorized valve, cranes and winches , furnace fan without vane control and general ancillary equipment such as drinking water coolers, etc..
- ii) Ammeter shall be located adjacent to or be incorporated in the associated push button station. Current transformer and ammeter for this purposes preferably of accuracy class 3.

b) Other than process area

- i) Ammeter shall be provided for motors of above 4 KW as stated under (i) above.
- ii) Ammeter shall be located on the motor starter panel in associated sub-station or sub-distribution board.

c) Special cases

In certain cases where supervisory control is exercised from a central control position, it may be necessary to have a meter located at the central control position, typical cases are those of remotely control crude oil forwarding pumps and /or other process pump derives. when such arrangements are required they will be specified in view of distances. where indicated in the single line diagram/and or data sheet, 4-20 MA out put transducer/s complying with IEC 60688 shall be provided for selected analogue signals to be transmitted to a remote supervisory system such as distributed control system (DCS). All MV motor starter shall have transducers and for LV motor starters decided by company representative.

d) General

- i) All remote ammeters shall be operated from a current transformer mounted in the motor starter panel.
- ii) Scales shall be selected so that full load current appears between 50% and 70% of full angular deflection. full load motor current (design value) shall be indicated by a red line on the scale.
- iii) Ammeters for motors shall be capable of repeatedly withstanding the appropriate motor starting current without accuracy being impaired. the ammeter scal shall be shown 6 times motor reted current.

7.5.10.9 Generators**7.5.10.9.1 M.V. generators**

The following instruments and meters shall be provided at the relevant control locations for M.V. generators:

- i) KW meter
- ii) Power factor meter
- iii) KVAR meter
- iv) Analog voltmeter (with phase selector switch)
- v) Ammeter (with phase selector switch)
- vi) Frequency meter
- vii) KWH meter
- viii) Elapsed time meter
- ix) Dc field current ammeter

Where remote monitoring of generator's output is required, such as in main control room, suitable transducers shall be provided at the generator switchgear to facilitate this.

7.5.10.9.2 L.V. generators up to and include 500 KVA

- i) Analog voltmeter (with phase selector switch)
- ii) Analog frequency meter

- iii) Ammeter (with phase selector switch)
- iv) Power factor meter
- v) KW / KVAR meter
- vi) Elapsed time meter

7.5.10.9.3 L.V. generators above 500 KVA

As described in 7.5.10.9.1

In case of paralleling of two sources of supply or generator synchronizing system is required.

7.5.10.9.4 Special C.T. and V.T. requirement for generators

- i) The primary rating of line C.T.s should be approximated 150% full load current of the generator. Neutral connection C.T.s shall have a primary rating at least equal to resistance rating. for generators earthed via a power transformer the neutral connected C.T. shall be a 1:1 ratio.
- ii) VT's for the AVR shall be exclusively used. The same policy shall be adopted for VT's for synchronizing. these VT's shall not be single phase.

7.5.11 Control, tripping and alarm

7.5.11.1 H.V., M.V., L.V. control and automation

7.5.11.1.1 Switchgear on M.V. and H.V. system shall not be controlled directly from the front of the circuit breaker panel. The operation of switchgear shall be from a separate control panel within the substation or from a completely separate room. The closing of switchgear shall be provided in front of switchgear panel only for test position.

7.5.11.1.2 Local tripping facilities shall be provided even when remote control is applied.

7.5.11.1.3 Automatic transfer system shall be applied to LV, MV and HV incomers. This system initiates closing order to bus section C.B. when one of the incomers loses their supply.

7.5.11.1.4 Manual transfer system shall be applied to LV, MV and HV motor control center. This achieved by means of synchro check relay and relevant selector switches. By this system it shall be possible to change each incomer by bus section C.B. and vice versa without any interruption of supply. Use of PLC devices with suitable ladder diagram (algorithm) is acceptable.

7.5.11.1.5 Automatic transfer shall be applied to L.V. emergency generator and main supply. This is achieved by own generator solid state control system. Adequate interlocks shall be considered to prevent closing of main circuit breaker and generator circuit breaker simultaneously.

7.5.11.1.6 When the main supply restored, transfer from generator to mains shall be achieved by a pushbutton installed in generator control panel.

7.5.11.2 Tripping and alarm

7.5.11.2.1 Tripping of all circuit breakers shall be initiated by separate tripping relay (86). The relay operating coil shall be energized by protective schemes. The relay shall be heavy duty and hand reset type with clear reset indication.

7.5.11.2.2 The tripping and closing circuit, alarm circuit, microprocessor based meters and relays auxiliary supply and C.B. motor charging supply circuit shall be supplied by four distinct fuses with appropriate sizes.

7.5.11.2.3. Each feeder at least shall have four indication lamps on panel:

- i) Red lamp for close position
- ii) Green lamp for open position
- iii) Yellow or orange lamp for tripping or fault purpose
- iv) Red lamp for earth switch close position
- v) The trip circuit supervision system (T.C.S.) shall be achieved by use of digital input of microprocessor base relay with associated LED, or with separate T.C.S relay.

7.5.12 Power management system

7.5.12.1 General

A Suitable Power management system shall be provided to facilitate management of the whole electrical Power generation and distribution system within utility plants. The power management system shall be designed in such away to allow:

- i) Synchronizing of generators, if any
- ii) Automatic load sharing between running generators
- iii) Automatic load shedding/restoration
- iv) Loop reconfiguration
- v) Main distribution system (HV/MV AND main LV switchgears) operation and reconnection
- vi) Graphic representation of substation single line diagram
- vii) Continuous monitoring of main and emergency generators
- viii) Continuous monitoring of HV/MV and main LV switchgears
- ix) Management of emergency diesel generator
- x) Alarm annunciation of main and emergency generators
- xi) Alarm annunciation of power distribution i.e. switchgear, charger
- xii) Import/Export MW, MVAR, MWH and MVARH From/to the network shall be recorded in power management system
- xiii) Time-dependent programming and tariff management
- xiv) Fault recording

7.5.12.2 Mode of operation

Operator shall be able to select the manual control mode or automatic control mode from PMS work station.

7.5.12.2.1 Manual control

In this mode of operation, operator shall be able to close and open all incomings and bus couplings in HV/MV and main LV switch boards plus MV outgoing Feeders (Except Motors Starters) From PMS work station.

In addition, in this mode of operation, operator shall be able to remotely start, stop or parallel main generators and stop, starts emergency diesel generator and also close/trip associated circuit breakers.

7.5.12.2.2 All safety means shall be considered such away to ensure operations described in 2.1 will be safe and according to inter locking system of system philosophy.

7.5.12.2.3 Automatic control

Automatic control mode consists of some automatic sequence that shall be programmed in to PMS. These sequence shall control all incoming and coupling in HV/MV and main LV switchgear and also emergency diesel generator. Some features areas below:

- i) Automatically close bus coupler in loss of 1 incoming voltage.
- ii) Automatically Running diesel generator in total network loss.

7.5.12.2.4 Manual transfer

Due to a maintenance schedule or any reason, in manual transfer mode operator shall be able to change one incoming by coupling (and vice versa) without any interruption in supply of whole HV/MV or main LV bus bars.

7.5.12.3 System architecture

In order to run an electrical network and its associated Automatic system, a control and monitoring system uses computer hardware in combination with a set of software applications all of which communication over a network.

So that the PMS shall be consist of:

- i) Main rack cabinet with internal marshaling board
- ii) Main sever computer as MMI, consist of one printer, one 19" LCD display, keyboard and mouse mounted on suitable work desk
- iii) Required software
- iv) Communication network and interconnections
- v) Gate way to other computer system
- vi) Synchronization of various pieces of equipment
- vii) Electrical power supply shall be 110 OR 230 V AC 50 HZ single phase from UPS

7.6 Batteries, Chargers and UPS

7.6.1 General

This section defines general requirements for electrical power switchgear substation supplies and distribution for control systems. Such control systems may include instrumentation, data collection, fire and gas detection systems, telecommunication equipment, computers and associated equipment and may be onshore or offshore, within established infrastructures or in remote locations.

7.6.1.1 Control systems and their power supplies

Control systems and their power supplies shall be selected as Class A or Class B to reflect the following factors as stated in [IPS-E-IN-180](#) (1):

- i) The required availability of each part of the overall system.

The importance of the connected load in terms of overall plant operation.

- ii) The control system loads shall be tabulated and their classification defined. The definition of the classes is given in 7.6.1.2 to 7.6.1.4.

7.6.1.2 Class a systems

Class A systems are defined as those which by malfunction or failure can cause any of the following:

- a) A shutdown of the whole or major part of a plant or process
- b) A failure to shut down, under emergency conditions, the whole or major part of a plant or process.
- c) A loss of monitoring facilities on any equipment which may itself cause a shutdown of the whole or major part of a plant or process.
- d) A loss of alarm annunciation for fire and gas detection

Note 1:

Emergency and shutdown systems such as ESD and F&G shall be classified class A.

Note 2:

Some equipment requires a single power source and then sub-divides this for multiple purposes. Where any of these purposes are classified as Class A, then the entire system shall be classified as Class A.

Note 3:

Flame failure devices or monitoring equipment on certain items of machinery which are critical to the whole or major part of a plant shall be considered as Class A systems.

7.6.1.3 Class B systems

Class B systems are defined as those which their malfunction or failure can cause any of the following:

A degradation of normal control or monitoring of the plant or process where alternative methods of control, such as local plant control panels, hand wheels etc are available.

A loss of alarm annunciation facilities not Covered by 7.6.1.2.

7.6.1.4 Class C systems

Apparatus is that by their malfunction or failure cannot directly prevent the operation of the plant. This class comprises of indicators, integrators, recorders and most analyzers.

7.6.2 Basic design requirements

7.6.2.1 Design of DC power supplies shall comply with [IPS-M-EL-174\(2\)](#) and AC power supplies shall comply with [IPS-M-EL-176\(2\)](#).

7.6.2.2 Voltage levels of supplies to all equipment shall be selected according to a sensible evaluation of systems which may be already existed on a plant. Supplies to control systems should not exceed nominal voltages of 120V r.m.s AC or 120V Dc (nominal 24V DC. for control instruments supply and 110 volts DC is used for switchgear supply shall be considered as default).

7.6.2.3 Wherever possible, power supply equipment shall be located in a non hazardous area.

7.6.3 Particular requirements: class a power supplies

7.6.3.1 Class A power supplies shall automatically maintain a continuously uninterrupted electricity supply within required control system tolerances upon failure or deterioration of the primary source, or any other item of the power conversion equipment.

7.6.3.2 Duplicate fully rated rectifier-battery systems shall be used. The AC supplies to the rectifiers shall be supplied from different switchboards or different busbars of the same switchboard. Where standby or emergency generation is available, at least one of the AC supplies to the rectifiers shall be supplied from the generator busbar.

7.6.3.3 Class A power systems shall be designed such that upon the occurrence of a fault in any one incoming power circuit, the faulty circuit shall be isolated without supply disruption and the alternative supply shall then maintain the load within the defined tolerance.

7.6.3.4 Autonomy time for, class A, dc loads shall be as indicated in [IPS-E-IN-180](#).

7.6.3.5 Autonomy time for F& G systems shall be as indicated in [IPS-E-SF-260](#).

7.6.3.6 Autonomy time for switchgear control system in attendant plants shall be as indicated in [IPS-M-EL-174\(2\)](#).

7.6.3.7 Autonomy time for switchgear control system in non attendant plants shall be 8 hours.

7.6.3.8 Each charger shall be sized to supply total load plus $0.2C_5$ of total battery capacity required.

7.6.4 Particular requirements: class b power supplies

7.6.4.1 Class B power supplies may be DC or AC and, after primary supply loss, shall automatically maintain continuity of electricity supply within the specified control system tolerances for a period of 60 min, or as otherwise specified. Normal and standby circuits shall be provided. The changeover on failure of the normal circuit shall not affect process operations.

For those systems requiring DC power, the normal circuit shall be via a rectifier-battery system and the standby circuit via battery.

For those systems requiring AC power, the normal circuit shall be via rectifier-battery-inverters. The standby circuit which will feed the load, through static switch during inverter failure shall be connected to the primary AC source. The AC supplies to the normal and standby circuits shall be supplied from different switchboards or different busbars of the same switchboard. Where emergency generation is available, one of the circuits shall be supplied from the generator busbar.

"Class B" AC power supplies should not produce any transients due to changeover which could cause mal-operation of the connected equipment.

7.6.5 Particular requirements: class c power supplies

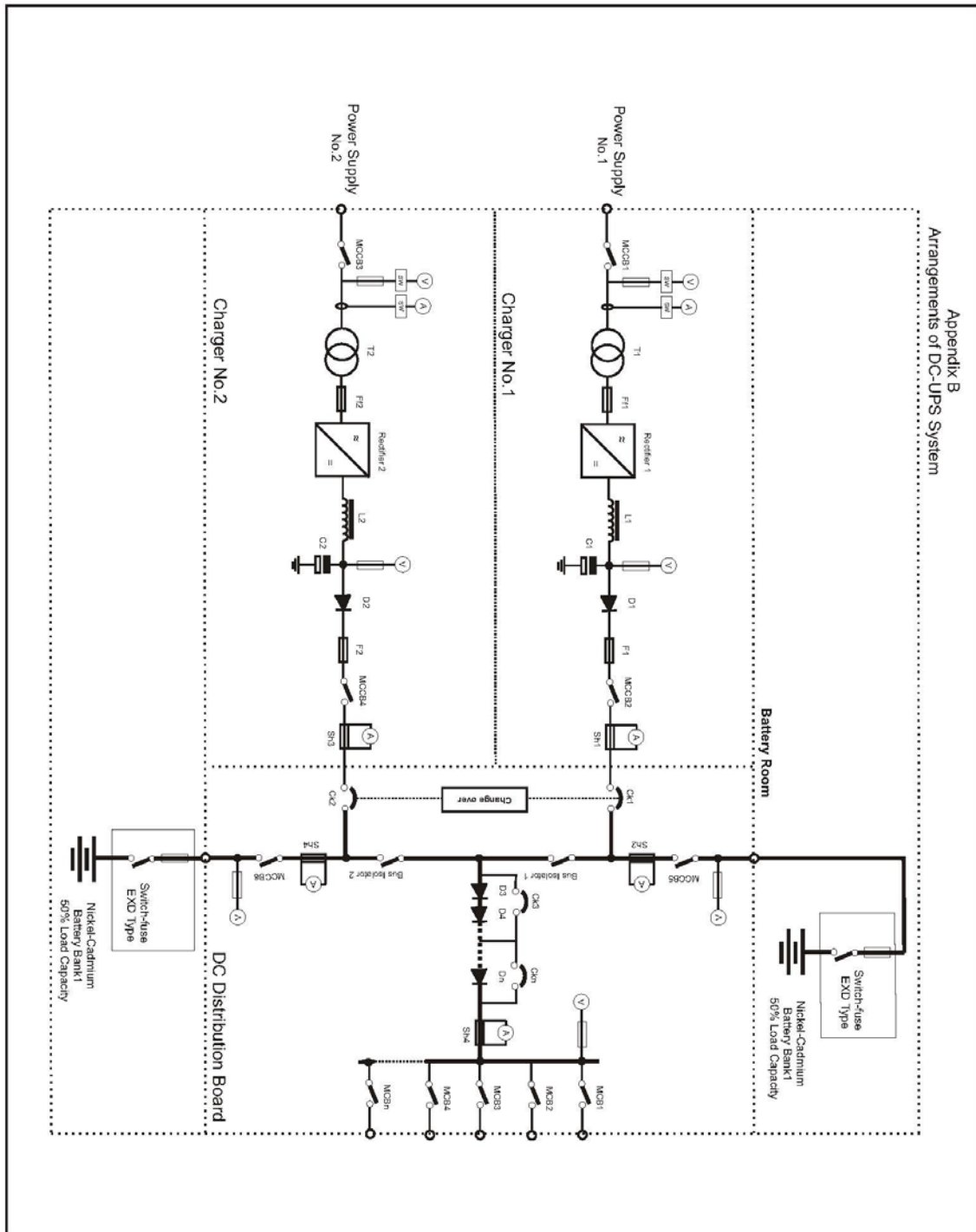
"Class C" power supplies should normally be AC and fed from a primary source without standby.

7.6.6 Power supply configurations for different classes

7.6.6.1 "Class A"

"Class A" power supply shall consist of two similar static battery chargers each rated 100% and two battery bank each rated for 50% of required capacity and one distribution panel. Technical requirement for design, manufacturer, quality control and testing of battery chargers, batteries and DC distribution panel shall comply with [IPS-M-EL-174\(2\)](#). single line diagram of proposed system is shown in Fig. 7

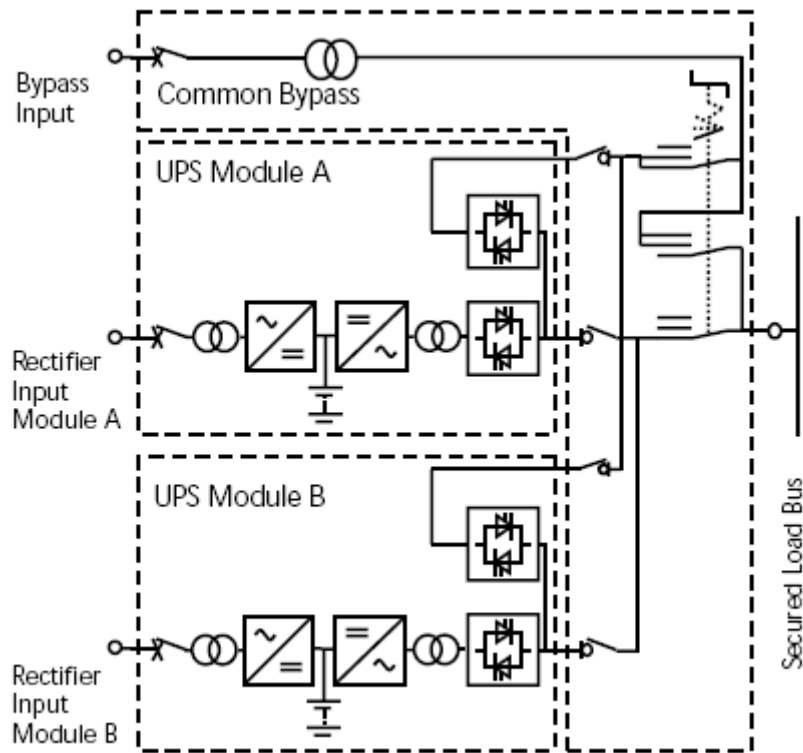
Power supplies are shown in following Fig. 7 shall be provided from main and emergency busbars.



SINGLE LINE DIAGRAM OF PROPOSED SYSTEM (HOT DUTY STANDBY TOPOLOGY)

Fig. 7

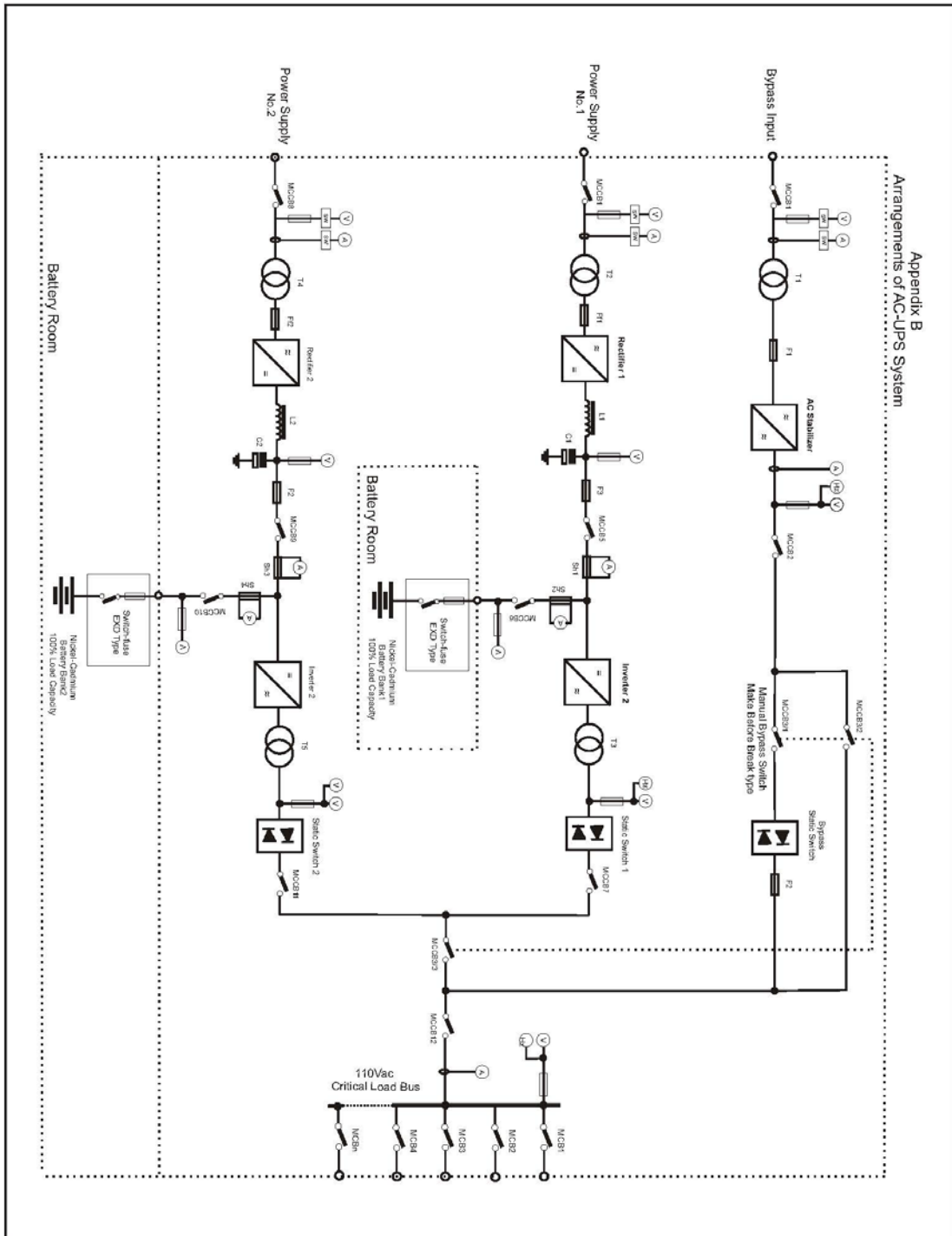
Where DC is not technically acceptable to the manufacturer of the control equipment, AC power supply is acceptable. In such case dual redundant ups shall be used. Dual parallel redundant ups are indicated in Fig. 8.



PARALLEL REDUNDANT CONFIGURATION

Fig. 8

In case where DCS with dual redundant controls is used two identical single battery charger or two identical single ups as indicated in Fig. 9 can be used.

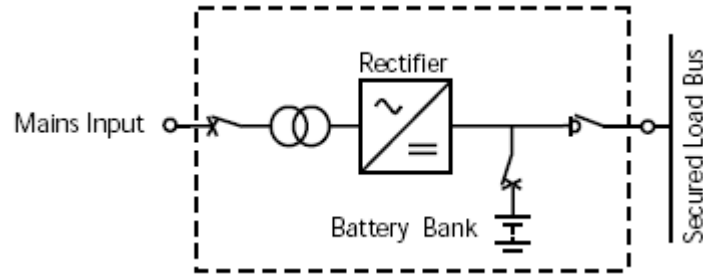


SINGLE LINE DIAGRAM OF DUAL PARALLEL LOAD SHARING UPS CONFIGURATION
Fig. 9

7.6.6.2 Class B

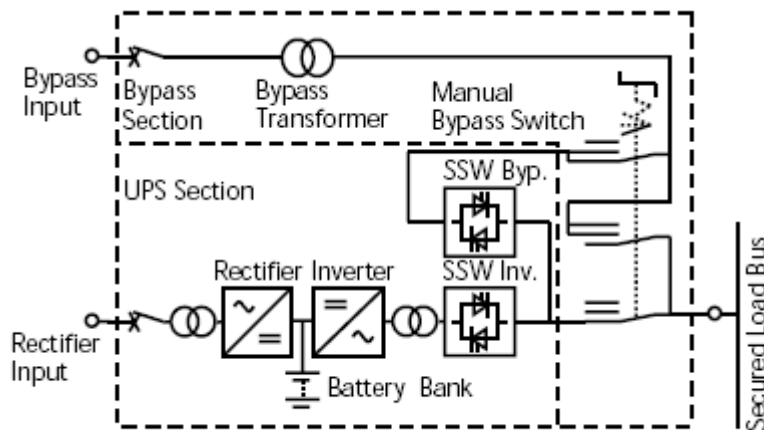
7.6.6.2.1 Class B power supply may be DC or AC and after primary power supply loss shall automatically maintain continuity of supply.

7.6.6.2.2 In case of DC power supply, a single battery charger with one bank of battery as indicated in Fig. 10 can be used.



A SINGLE BATTERY CHARGER WITH ONE BANK OF BATTERY
Fig. 10

7.6.6.2.3 For ac power supply single UPS as indicated in Fig. 11 can be used. For material standard refer to be made to [IPS-M-EL-176\(1\)](#) single unit.



AC POWER SUPPLY SINGLE UPS
Fig. 11

7.6.7 Battery rooms

7.6.7.1 Introduction

Since Hydrogen gas is normally evolved during charging phase of battery operation, some requirements regarding battery room construction shall be considered.

7.6.7.2 Design aspects recommended considerations

7.6.7.2.1 All electrical equipments installed inside of battery room shall be explosion proof type.

7.6.7.2.2 A Hydrogen in air mixture of 4% or greater substantially increases the risk of an explosion. The concentration of Hydrogen shall be kept below 1 % to provide a safety factor. For volume of Hydrogen release and ventilation refer to battery manufacturer recommendations.

7.6.7.2.3 Smoke detectors and Hydrogen detectors shall be installed in battery rooms.

7.6.7.2.4 The room ceiling shall be flat to ensure that pockets of trapped Hydrogen gas do not occur. False ceiling shall not be used for battery rooms.

7.6.7.2.5 Carbon Dioxide portable fire extinguisher shall be installed in battery rooms.

7.6.7.2.6 Batteries installed outside battery rooms, e.g. in service plant, shall be installed in non metallic cabinets. These cabinets shall be naturally ventilated and either house the battery alone or the battery in combination with the associated battery charger.

7.6.7.2.7 In battery rooms, eyewash fountain and flow water drain shall be provided.

7.6.7.2.8 The floor and walls of battery rooms shall be covered by ceramic tiles.

7.6.7.2.9 No trench shall be constructed in battery rooms.

7.6.7.2.10 The door of battery rooms shall be opened toward outside.

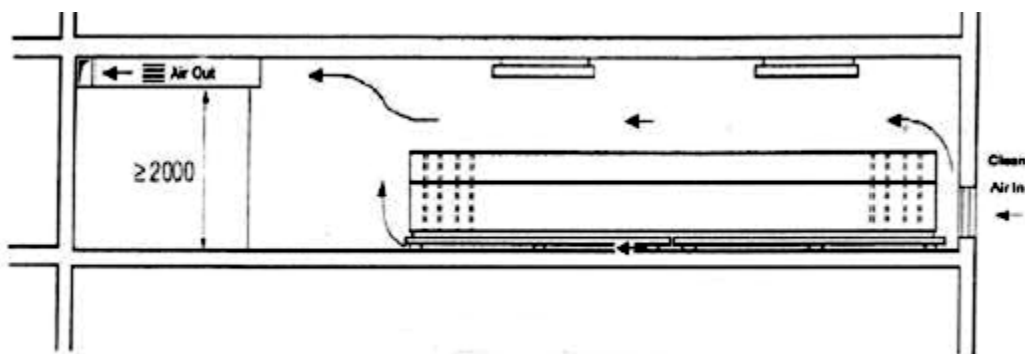
7.6.7.2.11 The size of a room shall be adequate to allow access to at least three sides of each battery bank for maintenance purposes.

7.6.7.3 Applicable standard battery room ventilation requirements

To achieve clause 7.6.7.2.2 the following methods are recommended:

- 12 air changes per hour for battery room
- Forced air supply & positive exhaust system
- Air inlets to be located near the floor & outlet openings at the high point in the room,

See Fig. 12:



AIR CIRCULATION IN BATTERY ROOMS

Fig. 12

7.7 Power Cables

7.7.1 Scope

This standard specifies the requirements for the design, selection, application and installation of multicore and single core cables which are required to have copper conductors for use on systems up to and including 33 kV for the purpose of power, control, indication and protection.

7.7.2 Cable system design

7.7.2.1 Voltage rating

7.7.2.1.1 The voltage designation or rating, U_0/U , should be selected from the standard ratings given in the relevant cable standard, e.g. 600/1000V, 3600/6000V, etc., and shall be appropriate to the type of system and the earthing arrangements. U_0 is the voltage between phase conductors and earth and U is the voltage between phase conductors.

7.7.2.1.2 The voltage levels adopted in the oil, gas and petrochemical industries of Iran are based on the IEC 60038.

7.7.2.1.3 The cables designated up to and including 0.6/1 kV rms are called low voltage (LV) cables, the cables designated above 0.6/1 kV rms and up to and including 3.6/6 kV rms are called medium voltage (MV) cables, and the cables designated 6/10 kV, 12/20 kV and 18/30 kV are called high voltage (HV) cables.

7.7.2.2 Current carrying capacity

7.7.2.2.1 Cables shall be sized to operate within their current carrying capacity as determined by the maximum continuous temperature of the insulation, see Table 14.

Note:

Several factors are involved in the sizing of conductors and whilst continuous current capacity is paramount, others such as voltage drop and ability to carry short circuit currents must not be neglected.

7.7.2.2.2 In assessing the size of conductor required for a given design current the following factors shall be taken into account:

- Ambient temperature
- Grouping and proximity to other loaded cables
- Method of installation
- Thermal conductivity of the medium in which the cable is installed.
- Thermal conductivity of the cable constituents.

7.7.2.2.3 The design current, I_d , shall be determined as follows:

Circuits supplying single fixed loads

I_d = rated current of the load.

Note:

Circuits supplying two or more final subcircuits should be rated in accordance with the total connected load but may, where justified, be subjected to application of diversity factor.

Radial circuits supplying socket outlets

I_d = rated current of the socket outlet

Incoming feeders to switchboards and sub-distribution panels.

I_d = maximum current associated with peak design production with an additional 10% contingency.

Note:

The maximum current should account for appropriate application of diversity factors. Such allowances require the judgement of a qualified electrical engineer with knowledge of the operational requirements of the plant.

Typically, where switchboards are fed by transformers, the incoming cables are sized to the rating of the transformer. Where there are no infeed transformers to the switchboard or sub-distribution panel, then the infeed cables are sized to the rating of the incoming switch or busbar whichever is the smaller.

7.7.2.2.4 Where cables are laid in mixed groups of different types, sizes and loading, the group rating factor of each cable should be calculated or assessed for each cable, taking into consideration the thermal effect of all the other cables of the group. IEC 60287 provides the mathematical basis for determining individual cables ratings when installed in mixed groups.

7.7.2.2.5 For 3 phase, 4 wire circuits, multicore cables the neutral conductor shall be no smaller than 50% of the size of the phase conductors. Reduced sizing of neutral conductors should not be applied where there is likely to be serious load imbalance, significant harmonic distortion in normal service or in any circuit where the load is predominately discharge lighting.

7.7.2.3 Short-circuit rating

7.7.2.3.1 The short time maximum current carrying capacity of the cable should be considered with regards the current/time characteristics of the circuit protection device to ensure that cables do not suffer damage due to overheating under maximum through fault conditions. In some cases, particularly where cables are protected by non-current limiting circuit breakers, the cable size is determined by the magnitude and duration of the maximum through fault current, rather than by the continuous current capacity or voltage drop constraints.

7.7.2.3.2 The minimum cross-sectional area should be assessed from the following formula:

$$A = \frac{I\sqrt{t}}{K} \quad (mm^2)$$

where:

A = Cross sectional area of the conductor (mm^2)

I = Short circuit current (amps)

t = Total fault clearance time (seconds)

K = Constant dependent on the type of conductor, the insulations, the initial and final temperatures.

Values of K for various types of insulation in contact with copper conductors are given in Table 14.

TABLE 14 - MAXIMUM PERMITTED CONDUCTOR TEMPERATURES AND VALUES OF K FOR VARIOUS INSULANTS (COPPER CONDUCTORS)

Insulation	Cable types	Maximum working temp T ₁ °C	Final temp at end of short circuit T ₂ °C	Value of K for temps T ₁ , T ₂
PVC	Up to 185 mm ²	70	150	109
PVC	240 mm ² and above	70	130	95
EPR	All types	85	220	134
XLPE	All types	90	250	143

The values of K given in Table 14 assume that the cable is operating at its maximum current carrying capacity. If this is not the case, true value may be determined from the formula:

$$K = 225.7 \times \sqrt{Ln \frac{234.5 + T_2}{234.5 + T_1}}$$

Where: T_1 = initial temperature of conductor ($^{\circ}C$)
 T_2 = final temperature of conductor ($^{\circ}C$)

Note:

For medium voltage power cables controlled by circuit breaker, the minimum fault clearance time shall be considered 0.3 seconds.

7.7.2.4 Voltage Drop

7.7.2.4.1 Cables shall be sized so that the maximum voltage drop between the supply source and the load when carrying the design current does not exceed that which will ensure safe and efficient operation of the associated apparatus, or 5% of nominal voltage, whichever is lower.

The supply source will be the switchboard or MCC upstream of the load, at which the voltage can be adjusted. This adjustment can be made either by changing taps on the incoming transformers or through AVRs of directly connected generators. In the majority of cases the load will be connected directly to the supply source through a single cable. However there will be cases where the load is fed from a sub-circuit and in such cases there may be two interposing cables between the load and the supply source. In such cases the permissible voltage drop of 5% needs to be accounted for from the supply source through the two series connected cables to the load terminals.

The maximum cable length for a low-voltage motor of given rating may be calculated from the following formulas:

$$L_s = \frac{V_s \times 1000}{\sqrt{3} I_s (R \cos \phi_s + X \sin \phi_s)}$$

$$L_r = \frac{V_r \times 1000}{\sqrt{3} I_r (R \cos \phi_r + X \sin \phi_r)}$$

The maximum route length is the lesser of these two lengths.

R = Cable resistance ohms/kM

X = Cable reactance ohms/kM

L = Maximum cable length (m)

V = Maximum cable volt drop (V)

I = Motor current (A)

ϕ = Motor power factor

Subscripts r and s refer to running and starting values of the above parameters respectively.

7.7.2.4.2 Cables shall be sized so that during motor starting, voltages throughout the network shall not fall by more than 15% of nominal values.

7.7.2.4.3 For medium and high-voltage motors, the voltage drop along the cable to the motor due to the load current shall not exceed 3.25% of nominal voltage during normal running at full load.

7.7.2.5 Computer-aided design of cable systems

Computer-aided design methods may be used to solve problems of cable sizing, route allocation and traywork design, provided that accepted criteria are used consistent with this document and that the resulting design is both technically adequate and economical.

7.7.2.6 Documentation

The documentation requirements for the cable system design shall be agreed with the company representative. The following is a guide of typical requirements:

7.7.2.6.1 Design dossier including basis of cable sizing together with specimen calculations. This dossier should normally form part of the permanent records of the site.

7.7.2.6.2 Cable routing diagrams.

7.7.2.6.3 Constructional details of cable traywork and cable tray support systems.

7.7.2.6.4 Cross sections of cable routes showing the actual arrangement of cables, and separation distances.

7.7.2.6.5 Interconnection diagrams showing the cable numbers, the core identification numbers and equipment terminal numbers.

7.7.2.6.6 Cable schedules.

7.7.2.6.7 Cable gland schedule.

7.7.3 Selection of cables

7.7.3.1 General

7.7.3.1.1 For onshore installation, the conductors shall be circular plain annealed stranded copper in accordance with IEC 60228.

7.7.3.1.2 No PVC cable should be installed at temperatures lower than 0 degC unless special low temperature grade PVC has been specified, in which case installation at ambient temperatures down to -10 degC may be possible.

7.7.3.1.3 Depending on the possibility of soil contamination or chemical attack, specially in process areas, cables shall be provided with a lead sheath.

7.7.3.1.4 Unless the soil will definitely remain free from contamination, lead sheathed underground cable shall be used in oil and chemical plants.

7.7.3.1.5 The use of multicore cables is preferred to single core cables. However, single core cables may be used for practical and/or economic reasons on short runs, e.g. generator and transformer secondary cables or in the case of high current ratings where two parallel multicore cables of the largest cross section permitted would not suffice.

7.7.3.1.6 Cables for protection, controls, indications and alarms for a particular item of plant or circuit (e.g. generator, motor, transformer, etc.) shall be dedicated to that item of plant or circuit.

7.7.3.1.7 Individual cables shall be used for each of the following:

- CT secondary
- VT secondary
- Interlock / intertrip circuits
- Pilot wire differential circuits

Note:

The requirements of the preceding paragraph do not apply to motor control and ammeter circuits to a Remote Control unit (RCU), nor to combined power and control circuits to small LV motors.

7.7.3.1.8 The armouring of single core power cables shall be made of non magnetic materials.

7.7.3.1.9 All power, lighting, control and earthing cables shall be in accordance with the latest version of [IPS-M-EL-271](#), [272](#) and [273](#).

7.7.3.2 Medium and high voltage power cables

Medium and high voltage cables shall be copper conductor with Cross Linked Polyethylene (XLPE) insulation, lead sheathed, single wire armoured and PVC overall jacket.

MV and HV multicore and single core cables shall have a minimum cross sectional area of 50 mm².

MV and HV multicore cables shall have a maximum cross sectional area of 240 mm².

MV and HV single core cables shall have a maximum cross sectional area of 400 mm², Unless otherwise approved by the company representative.

Selection of single or multicore cables shall be approved by the company representative.

7.7.3.3 Low voltage cables

7.7.3.3.1 Power cables

Low voltage power cables shall be copper conductor with XLPE or PVC insulation 600/1000 V grade, lead sheathed, single wire armoured, with PVC overall jacket. These cables shall be used for above ground and underground installations.

For low voltage single core power cable, conductor sizes up to and including 10 mm² can be solid copper.

Unless otherwise approved by the company representative, the maximum conductor cross section shall be limited to 240 mm² for low voltage 3 and 4 core power cables and 400 mm² for low voltage single core power cables.

7.7.3.3.2 Control cables

Twin and multicore lighting and control cables shall be copper conductor with PVC insulation 600/1000 V grade, lead sheathed, single wire armoured, with PVC overall jacket. These cables shall be used for above ground and underground installations. Unless otherwise approved by the company representative, the minimum cross section for lighting and control cables shall be 2.5 mm² except for signaling and indication purposes, where a minimum cross section of 1.5 mm² may be used.

7.7.3.3.3 Mineral insulated copper sheathed cables

- a) In areas where high temperature is expected, mineral insulated or heat resistant copper-sheathed cables (MICC) shall be used for small power and control.
- b) Where mineral insulated cables are specified, the cables shall be copper conductor, copper sheathed with PVC outer covering. The mineral insulated cables shall be manufactured according to IEC 60702-1.
- c) Mineral insulated copper-sheathed cable (MICC) should in general be restricted to domestic, commercial and light industrial applications such as in offices, accommodation modules, substations, control rooms and workshops. Its inherent, but limited, fire resistant properties can make MICC suitable for essential circuits such as fire alarms, although it may also be used more generally for power, lighting, heating and air conditioning plant.

- d) MICC shall not be used in situations where the equipment to which it is connected is subject to vibration or where the cable may need to be disconnected regularly for maintenance. A loop of cable shall be formed just before the gland where MICC is connected to a motor.
- e) Where MICC is to be used in a highly inductive circuit, precautions may need to be taken to protect against breakdown due to the high transient voltage which occurs on switching the current off. In such cases, cables shall be protected by suitable surge suppressers across the supply terminals.
- f) MICC used indoors in dry locations may be bare copper sheathed. However, where such cables are used outdoors or where appearance is to be a consideration, they shall have an over sheath of PVC.

7.7.3.3.4 Earthing cables

Earthing cables and wires shall be single core with plain stranded or solid copper conductor, PVC sheathed rated voltage of 600 V, coloured green - yellow for both underground and above ground use. The PVC sheath is a protection against electrolytic corrosion.

7.7.3.3.5 Wires

Low voltage wires shall be stranded or solid copper conductor, PVC insulated, rated voltage 600 volt according to IEC 60227. Wires shall be suitable for installation in rigid steel galvanized conduits or trunking. Minimum cross section shall be 2.5 mm². Wires in conduit systems shall be applied only for lighting, communication and convenience outlets in closed buildings in non-hazardous areas. The insulation color of low voltage wires shall be according to [IPS-M-EL-271](#).

7.7.3.3.6 Flexible cables

Flexible cables for voltages up to 450V to neutral shall be heavy duty neoprene rubber insulated, PVC sheathed. For applications where the equipment connected to the power or control cable is subject to vibration, flexible cables or wires shall be used. Flexible cables and wires shall be capable of withstanding bending and other mechanical stresses occurring in normal use and shall comply with the requirements of IEC 60227-2.

7.7.3.4 Cables for use offshore

7.7.3.4.1 Conductors shall be longitudinally water sealed stranded copper wires, conforming to class 2 of IEC 60228.

7.7.3.4.2 The insulation shall be extruded Cross Linked Polyethylene (XLPE). Ethylene-Propylene Rubber (EPR) insulation may be quoted as an option.

7.7.3.4.3 Cables used offshore for any application other than one calling for a fire resistant cable, should normally be Flame retardant. For small projects requiring limited quantities, cables by EPR insulated, galvanised steel or copper alloy braid armour, accordance to IEC 60092-3 shall be used where economical or expedient.

7.7.3.4.4 Where an armour is required for single core cables it shall consist of a phosphor bronze wire braid complying with IEC 60092-3.

Note:

Submarine cables selection shall be accordance with the IPS-M-EL-273(1).

7.7.3.5 Cables for special fire risk areas

7.7.3.5.1 When cable routes are being planned, special fire risk areas shall be avoided as far as possible. Fire risk diagram(s) indicating areas of fire risk and the sources of fire hazard shall be produced.

7.7.3.5.2 Within a special fire risk area, the following types of circuit shall be fire resistant, i.e. able to continue operating in the presence of a fire of specified temperature and duration.

- Circuits necessary to provide a safe and orderly shutdown of the plant, including essential instrumentation and monitoring circuits.

- Emergency or 'escape' lighting.

- Cables essential for the operation of life saving equipment, e.g. fire alarms, evacuation alarms, gas detection, etc.

7.7.3.5.3 Depending on the application and the fire withstand requirements, cables shall be Fire resistant cable. Alternatively, MICC may be used, subject to the restrictions of section 7.7.3.3.

7.7.3.5.4 Cables in special fire risk areas which do not fall into any of the categories of 7.7.3.5.2 shall have flame retardant properties in accordance with IEC 60332-3.

7.7.3.5.5 For most installations, except as required in 4.5.2, fire resistant cables should not be specified solely to attempt to keep a plant operating in the event of a fire. In the case of the emergency lighting, a combination of floodlighting and selfmaintained luminaries should be used to reduce the amount of cable exposed to fire risk.

7.7.3.6 Environmental considerations

Cables shall be constructed with suitable sheathing materials which will withstand exposure to the environment in which they are installed. Wherever possible, however, measures shall be taken to avoid prolonged exposure to conditions which could in the long term produce degradation of the cable.

Specific attention shall be given to the following environmental factors:

7.7.3.6.1 Exposure to seawater or salt spray.

7.7.3.6.2 Exposure to intense heat radiation from the sun or from a flare.

7.7.3.6.3 Excessively high or low ambient temperatures.

7.7.4 Cable installation methods and materials

Refer to [IPS-C-EL-115\(1\)](#).

7.8 Static power factor correction equipment

7.8.1 General requirements

1) In electrical circuits, industrial capacitors or synchronous motors are used in order to decrease reactive power and power factor correction.

2) Absolute reactive power of capacitor is calculated as follow:

$$Q_C = V_{\text{eff}} \times I_{\text{eff}} \times \sin \phi ; I_{\text{eff}} = V_{\text{eff}} / |Z_C| = V_{\text{eff}} \times 2 \pi F \times C ; \phi = \pi / 2$$

Then : $Q_C = 2 \pi F \times C \times V_{\text{eff}}^2$

In which :

- Q_c : Absolute reactive power of capacitor
- V_{eff} : RMS voltage of capacitor
- I_{eff} : RMS current of capacitor
- F : Frequency
- C : capacitance

- 3) Distortions and harmonics which are due to non linear loads result in decreasing power factor and this can not be corrected by capacitors however it needs filters.
- 4) Where the calculated system power factor at full load is less than 85% lagging, capacitor bank/s shall be installed. The capacitor bank/s shall be sized to improve the system power factor to 95% lagging at system full load.
- 5) In case where the calculated system power factor at full load is more than 85% but less than 90% lagging, power factor correction capacitor/s will be required when power is received from outside source/s. In such case the capacitor bank/s shall be sized to improve the system power factor to 95% lagging at system full load.
- 6) Capacitor banks can be installed in the main power plant or individual substations.
- 7) Capacitor banks shall be permanently energized. Installation of capacitors parallel to individual motors which is switched on and off together with the motor is not desirable.
- 8) Low voltage capacitors shall be of the self-healing type and shall comply with the requirements of IEC 60831 and may be of either three phase or single phase construction.
- 9) For further information refer to latest version of IPS-M-EL-181.

7.8.2 Capacitor sizing method

The Capacitance calculation of capacitor units and a method for this calculation is as below:

$$\text{a) } P = \sqrt{3} \times V_{L-L} \times I_L \times \cos \phi_1 \quad ; \quad Q_1 = P \times \tan \phi_1$$

In which :

- $\cos \phi_1$: Primary power factor
- P : Total active power
- Q_1 : Primary reactive power

$$\text{b) } Q_2 = P \times \tan \phi_2$$

In which:

- $\cos \phi_2$: Power factor after correction
- Q_2 : Reactive power after correction

$$\text{c) } Q_c = Q_1 - Q_2$$

In which:

- Q_c : Produced reactive power of capacitor

$$\text{d) } Q_c = P \times [\tan \phi_1 - \tan \phi_2]$$

Example: For power factor correction from 0.6 to 0.96 in the unit with RMS load of 300 KVA we will have this according to above :

$$\begin{aligned}\cos \phi_1 &= 0.6 \quad \cos \phi_2 = 0.96 \\ P &= 300 \times 0.6 = 180 \text{ Kw} , \tan \phi_1 = 1.33 , \tan \phi_2 = 0.29 \\ \text{So: } Q_c &= 180 \times (1.33 - 0.29) = 187 \text{ KVAR}\end{aligned}$$

7.8.3 Service condition

Refer to latest revision of [IPS-M-EL-181](#).

7.8.4 Synchronous motors

Wherever synchronous motors are supplied for power factor correction they shall include constant power factor control equipment.

7.9 Overhead Lines

Refer to latest revision of [IPS-E-EL-160](#).

7.10 Lighting

Scope :The purpose of this section is the provision of lighting fitting, illumination, emergency, security lighting and special lighting for the industrial and non industrial plant areas.

7.10.1 General lighting requirements

7.10.1.1 The lighting in the process plants shall be fluorescent type in white color as far as practical, flood lights with mercury vapor lamps can be used where applicable.

7.10.1.2 Long life lamps in combination with electronic ballasts shall be used in new installations, and for upgrading old installations, so as to take advantage of their increased lumen efficiency and economic life.

7.10.1.3 The lighting fixtures for street lighting and high industrial buildings such as generator buildings, compressor buildings, workshops and similar, shall be with mercury vapor lamps. In view of the restarting time of this type of lighting after a voltage dip, sufficient fluorescent luminaires shall be installed for basic lighting requirements of the area, equivalent to emergency lighting requirements.

7.10.1.4 Consideration shall be given to the use of floodlighting, especially around the perimeter of process and production plants. Care must be exercised to ensure that this does not result in shadows, especially at operating locations.

7.10.1.5 Low pressure sodium discharge lamps shall not be used in process area, as they constitute a fire hazard in the event of breakage.

For selection of lighting equipment refer to [IPS-M-EL-161\(1\)](#).

7.10.2 Plant lighting

7.10.2.1 Plant lighting circuits shall be fed from dedicated lighting distribution boards installed in the plant substations.

7.10.2.2 Plant lighting circuits shall be single phase and neutral or three phases and neutral. Plant lighting distribution boards shall include 20% spare outgoing circuits.

7.10.2.3 Adjacent luminaries shall not be supplied from the same circuit, or in case of three phase circuits, from the same phase.

7.10.2.4 As far as practical fluorescent lighting shall be used throughout the plant installations. The lighting system shall be designed to give illumination levels as shown in Table 15.

Lighting installations shall be designed to obviate stroboscopic effects.

7.10.2.5 Luminaries on structures shall be so located that maintenance and lamp changing can be effected without the use of ladders or scaffolding. In cases where luminaries mounted from an elevated walkway or platform does not overhang it, the lamp post shall be arranged to swivel for maintenance purposes. In high buildings, such as compressor and turbo generator houses, maintenance and lamp-changing shall be possible by using the overhead crane.

7.10.2.6 Where no structure is available to support luminaries, fixed lighting poles of adequate length with high pressure discharge floodlighting shall be used to supplement the fluorescent luminaries. Lighting poles shall be in accordance with [IPS-M-EL-161\(1\)](#).

7.10.2.7 For fixed floodlighting columns lamp changing will be carried out using a mobile platform, e.g. vehicle mounted. Alternatively, hinged lighting columns may be used, if space is available for the columns to be lowered.

7.10.2.8 Plant lighting circuits shall be designed for automatic switching via photo-electric relays.

7.10.2.9 Control circuits for photo-electric relays shall be 'fail-safe', i.e. to switch the lights on if a fault occurs in the photo-electric relay. The plant lighting shall be designed in such a way that in daytime the lighting of furnaces, boilers and the ground level plant can be switched on by means of a switch overriding the appropriate photo-electric relay contact. The remaining photo-electric relay-operated plant lighting shall have the facility to be switched off at night-time. These override switches shall be located either outside the plant substation or in the control room, as required by plant operations. Moreover, the lighting distribution board shall be provided with an override switch for maintenance purposes.

7.10.2.10 Level gauge lights shall not be switched by the above-mentioned photo-electric relays and shall have no maintenance override switches. Level gauge lights should normally be on.

7.10.2.11 Internal lighting of non-process buildings and substations shall be switched inside the building.

7.10.2.12 Lighting near navigational waters, e.g. jetties and loading platforms, shall not hinder navigation in any way.

7.10.2.13 The lighting installation in the control rooms shall be designed for switching off, independently, ceiling lighting groups to suit operators' need. The luminaries shall be situated in such a way that reflection on Video Display Units (VDUs), instrument windows and displays is avoided.

7.10.2.14 In Zone 1 and 2 hazardous areas, fluorescent luminaries with type of protection Ex'e' shall be used. Luminaries for level gauge lighting shall be of the fluorescent type, bracket-mounted.

7.10.2.15 High pressure discharge luminaries in hazardous areas shall have type of protection Ex'd'. An isolating switch shall be included within the fitting to prevent the luminary from being energized when it is not fully assembled.

7.10.2.16 For standardization reasons the same type of Ex'd' or Ex'e' luminaries should be used in all plant areas, whether classified Zone 1, Zone 2 or non-hazardous.

7.10.2.17 In hazardous areas classified as zone 0 according to article 4 of standard [IPS-M-EL-161\(1\)](#), no lighting fixtures shall be installed.

7.10.2.19 In hazardous areas classified as zone 1, the lighting fixtures shall be flameproof Exd type with a degree of protection IP65. The gas group classification of Exd fixtures shall be at least group IIB. Where hydrogen or acetylene is present, the gas group classification shall be group IIC. The maximum surface temperature of Exd fixtures shall be suitable for the appropriate gas in the subject area and shall in no case be more than 200°C which corresponds to T3 according to IEC 60079-0 (Exd IIBT3 or Exd IICT3).

7.10.2.20 In hazardous areas classified as zone 2 the lighting fixtures shall be increased safety Exe according to IEC 60079-7. Lighting fixtures suitable for zone 1 as specified in 5.3.11 can also be used in zone 2 areas. The lighting fixtures with explosion protection of ExnA or ExnC in accordance with IEC 60079-15 can be used in zone 2 areas with prior approval of the Engineer. The maximum surface temperature of Exe and Exn fixtures shall be suitable for the appropriate gas in the subject area and shall in no case be more than 200°C which corresponds to T3 according to IEC 60079 .

7.10.2.21 For standardization purpose, the same type of lighting fixtures selected for zone 2 areas shall be used in safe areas of industrial plants.

7.10.3 Emergency and escape lighting

7.10.3.1 Fixed emergency lighting shall be installed at strategic points in the installations, including control rooms, substations, fire stations, first-aid rooms, watchmen’s offices, the main entrances, and in all other buildings and areas where required for safety reasons. Location and electrical arrangement shall be such that danger to personnel in the case of a power failure is prevented, and escape routes are lit.

7.10.3.2 The emergency lighting system shall consist of a number of standard luminaries of the normal lighting installation, which shall be fed via circuits having a stand-by supply from an emergency generator or from a battery with an autonomy time of at least 2 Hr. In remote areas, where only a few fittings are required, self power emergency may be used.

7.10.3.3 In the case of an emergency generator supply, a number of luminaries in the control room and the basement of the control room, as well as field auxiliary rooms, shall have a standby supply from an independent source with battery back-up to avoid complete darkness during start-up time of the diesel.

7.10.3.4 The number of emergency luminaries as part of the total number of fittings shall be determined as follows:

- Utility Area	20%
- Process Area	10%
- Administrative Area	5%
- Control Room and Auxiliary Rooms (Including 10% Connected To DC System)	50%
- Substations, Field Auxiliary Rooms, Compressor and Generator Buildings	30%

7.10.3.5 The escape luminaries shall generally be part of the emergency luminary’s installation, but the luminaries shall have integral batteries rated to maintain the lighting for at least 30 minutes. Escape luminaries shall be provided in all buildings so as to lead personnel out of the building along defined escape routes to defined muster points, which shall also be illuminated.

7.10.4 Street and fence lighting

7.10.4.1 Street and fence lighting shall be fed from lighting distribution boards installed in a conveniently located plant substation. These lighting distribution boards may either be dedicated to street and fence lighting, or be one or more sub-sections of a plant lighting distribution board. This lighting shall also be photo-electric relay controlled and provided with a maintenance override switch, as for ground level plant lighting.

7.10.4.2 Generally, for street/fence lighting three phase and neutral LV supply shall be used. Each lighting pole shall include a fuse box as well as a four pole terminating box for looping the feeder cable. Tee cable joints are not allowed. Adjacent luminaries shall not be supplied from the same fuse. Fence lighting shall be placed in such a way that the fence as well as the area outside the fence will be illuminated. Normally fence lighting intensity shall be equivalent to the street lighting intensity stated in Table 15.

7.10.4.3 For fence lighting, the fixtures with high pressure mercury vapor lamps or high pressure sodium vapor lamps can be used, as selected by the Engineer. Sodium vapor lamps shall not be used in areas where fire hazard is envisaged.

7.10.4.4 If special security fence lighting is required, unless otherwise specified, a floodlight installation shall be designed, based on HP discharge lighting with a minimum illumination of 10 lux (for CCTV Monitors) at any point in the area between the fence and 5 m outside the fence.

7.10.5 Special lighting

7.10.5.1 General

7.10.5.1 Special lighting, e.g. navigation aids, obstruction warning lights and aircraft navigation lights, shall be installed in accordance with international and/or national standards. Long-life lamps or normal lamps at reduced voltage shall be used.

7.10.5.2 The installation shall be supplied from an uninterruptible, maintained source.

Navigational aids for offshore structures shall be in accordance with DEP 33.80.00.30-Gen.

7.10.5.2 Aviation warning lighting

7.10.5.2.1 Aviation warning lights shall consist of a double lamp unit with automatic changeover to the stand-by lamp upon failure of the operating lamp.

7.10.5.3 Illumination of areas to be observed by means of CCTV (Closed Circuit Television) monitors

7.10.5.3.1 The lighting installation for areas that require observation by closed circuit television monitors shall be designed in particular with regard to uniformity of the level of illumination as well as to the location of the individual luminaries. Direct visibility of light-emitting bodies and/or reflections from covers of the luminaries shall be checked before commissioning of the plant.

7.10.6 Building lighting

Luminaries in closed buildings which are classified non-hazardous areas, e.g. control rooms and substations, shall be fluorescent bi-pin, with electronic starter, and industrial pattern. Non-industrial luminaries may be used in control rooms, offices, etc.

7.10.7 Portable lamps

Portable lamps shall be suitable for 24 or 50 volts AC and shall be fed through double wound transformers fully isolated from earth. The voltage of portable lamps shall be selected by the Engineer.

7.10.8 Level of illumination

- 1) Illumination should generally conform to the requirements of Illumination Engineering Society (IES). Illumination levels in publications of Illumination Engineering Society for the petroleum, chemical and petrochemical plants are given in Table 15, according to table 4 of API-540.
- 2) Illumination from the emergency lighting system should be designed to permit safety of movement for personnel particularly from elevated platforms etc., in addition to that required at control positions.

7.10.9 Types of lamps and fittings

- 1) The use of fluorescent types of lighting is preferred, supplemented if necessary in local areas by compact fluorescent types or Quartz Halogen where there is a space limitation. Sodium type lamps are not normally permitted due to fire risk, and their use must be avoided. High pressure mercury vapor lamps shall be used for external lighting, street lighting, flood lighting and interior lighting industrial especially high bay workshops.
- 2) If lamps that are adversely affected by transient voltage disturbances are used in working areas, they must be adequately interspersed with lamps that are not so affected.
- 3) In the selection of types of lamps consideration should be given to the likelihood of producing undesirable color distortion.
- 4) Type of lamps and fittings should be a minimum.
- 5) In the selection of lamps and fittings consideration should be given to ensuring maximum lamp life and the minimum likelihood of internal moisture accumulation (i.e., effects of vibration, operating temperature and breathing).
- 6) All exposed lighting fittings should be of weatherproof construction.
- 7) For characteristics and application of various light sources see Table 16.

7.10.9 Arrangement and accessibility for light sources

7.10.9.1 Control rooms

Lighting should be provided at the front and rear of all control panels and the arrangement should preclude the likelihood of inconvenience due to failure of a single sub-circuit or phase. Schemes for front of panel and control desk illumination should be agreed.

7.10.9.2 Plants and General Areas

- i) The arrangement of lighting fittings on final sub-circuits should avoid a complete area of darkness should any one sub-circuit be isolated.
- ii) Fittings should, wherever possible, be mounted from structural steelwork installed for other purposes, except when this may adversely affect the lighting fitting due, for example, to vibration. Individual poles, etc., provided for the purpose of mounting, fittings must be of adequate strength to permit access for maintenance as detailed under (iii) below.
- iii) Fittings should be located as far as possible to permit safe access from portable ladders.
- iv) Floodlights should be mounted when necessary on metal or concrete masts equipped with permanent access ladders and a platform.

TABLE 15 - ILLUMINANCES LEVELS

AREA OR ACTIVITY	MINIMUM ILLUMINANCE LUX	ELEVATION MILLIMETER
I PROCESS AREAS		
A) General process units		
Pump rows, valves, manifolds		Ground
Heat exchangers	50	Ground
Maintenance platforms	30	Floor
Operating platforms	10	Floor
Cooling towers (equipment areas)	50	Floor
Furnaces	50	Ground
Ladders and stairs (inactive)	30	Ground
Ladders and stairs (active)	30	Floor
Gage glasses	50	Floor
Instruments (on process units)	50	Eye level
Compressor houses	50	Eye level
Separators	200	Floor
General area	50	Top of bay
	10	Ground
B) Control rooms and houses		
Ordinary control house		
Instrument panel	300	Floor
Console	300	1700
Back of panel	300	760
Central control house	100	760
Instrument	500	Floor
Back of pane	500	1700
	100	900
C) Specialty process units		
Conveyors		
Conveyor transfer points	20	Surface
	50	Surface
II NONPROCESS AREA		
A) Loading, unloading, and cooling water pump houses, Pump area		
General control area	50	Ground
Control panel	150	Floor
	200	1100
B) Boiler and air compressor plants		
Indoor		
Outdoor equipment 50	200	Floor
	50	Ground
C) Tank fields (where lighting is required)		
Ladders and stairs		
Gating area	5	Floor
Manifold area	10	Ground
	5	Floor
D) Loading racks		
General area		
Tank car	50	Floor
Tank trucks, loading point	100	Point
	100	Point
E) Tanker dock facilities		
F) Electrical substations and switch yards		
Outdoor switch yards		
General substation (outdoor)	20	Ground
Substation operating aisles	20	Ground
General substation (indoor)	150	Floor
Switch racks	50	Floor
	50	1200
G) Plant road lighting (where lighting is required)		
Frequent use (trucking)		
Infrequent use	4	Ground
	2	Ground
H) Plant parking lots		
	1	Ground
I) Aircraft obstruction lighting		

III Buildings		
A) Offices	500	
B) Laboratories		
Qualitative, quantitative and physical test		900
Research, experimental	500	900
Pilot plant, process and specialty	500	900
Glassware, washrooms	300	Floor
Fume hoods	300	900
Stock rooms	300	900
	150	Floor
C) Warehouses and stock rooms		
Indoor bulk storage		Floor
Outdoor bulk storage	50	Floor
Large bin storage	5	Ground
Small bin storage	50	760
Small parts storage	100	760
Counter tops	200	760
	300	1200
D) Repair shop		
Large fabrication		Floor
Bench and machine work	200	Floor
Crane way, aisles	500	760
Small machine	150	Floor
Sheet metal	300	760
Electrical	200	760
Instrument	200	760
	300	760
E) Change housed		
Locker room, shower		Floor
Lavatory	100	Floor
	100	Floor
F) Clock house and entrance gatehouse		
Card rack and clock area		Floor
Entrance gate, inspection	100	Floor
General	150	Floor
	50	Floor
G) Cafeteria		
Eating	300	760
Serving area	300	900
Food preparation	300	900
General, halls, etc.	100	Floor
H) Garage and firehouse		
Storage and minor repairs	100	Floor
I) First aid roomed	700	760

Notes:

a) These illumination values are recommended practice to be considered in the design of new facilities.

b) Indicates vertical illumination.

c) Refer to port authority for required navigational lights.

d) Luminance may be different from those recommended for other industries because of the nature of area.

e) Refer to local aviation authority for requirements of obstruction lighting and marking.

TABLE 16 - THE PRINCIPAL LIGHT SOURCES FOR GENERAL LIGHTING PURPOSES AND THEIR CHARACTERISTICS

Types	Compact Fluorescent (CFLs)	Metal Halide	High Pressure Sodium(HPS)	LEDs (Light-Emitting Diodes)
Characteristics				
Working Principle	These lamps is an electric discharge device with utilizes a low pressure a mercury vapor arc to generate ultra-violet energy. The ultra-violet energy is obsorbed a phosphor coat on the inside of the glass tube and converted by the phosphor to visible wavelenghts, the wavelenghts of light generated are determined by the composition of the phosphor.	A metal-halide lamp is a mercury vapor with other compounds (known as halides) added to the arc tube to improve both color and luminous efficacy.	Light is produced in a high-pressure sodium (HPS) lamp by an electric discharge through combined vapors mercury and sodium radiation dominating the spectral emission.	LEDs are solid-state semiconductor devices that convert electrical energy directly into light
Luminous Efficiency	20-55 lm/W	45-100 lm/W	45-110 lm/W	45-80 lm/W
Useful life	8000 to 12000 h	8000 to 12000 h	16000 to 20000 h	50000h
Color rendering	Warm White to Cool White 2700K-4000K	Warm White to White 3000K-4200K	Warm yellow 2000K	White to daylight 3500K-6000K
Application area	These bulbs are the ideal for your small lighting fixtures and suitable for all areas of application. especially where continous economical lighting is needed.	commercial office space, manufacturing plants, warehouses, sports lighting, and roadways.	Provides general illumination for outdoor use in residential and light commercial applications. Ideal for walkways, large yards, parking lots, barns and play areas creating an inviting exterior space as well as providing safety and security.	Street lighting, outdoor area lighting, households, accent lighting, retrofit lamp architectural lighting.

Note:

1 Lux ≡ 1 candela/m²

1 Candela ≡ one lumen. per steroidal

7.11 Earthing, Bonding and Lightning Protection

7.11.1 General

Proper earthing is essential to safe and satisfactory performance of a power system and an industrial plant. There are four requirements for such earthing:

- 1)** Providing a low impedance path for return of fault currents, so that an over current protection device can act quickly to clear the fault.
- 2)** Maintaining a low potential difference between exposed metal parts to avoid personnel hazards during normal and fault condition.
- 3)** Protect properties in the event of static charges and transient phenomena (lightning, switching operation) which may caused fire and explosion.

4) Over voltage control

The objects can be achieved by two kinds of earthing arrangements known as system earthing and equipment earthing. The former is essential to the security of electrical system and the latter is done to ensure the safety of human life and equipments.

7.11.2 System earthing

7.11.2.1 General

The regulation that one point of every system shall be earthed is designed primarily to preserve the security of the system by ensuring that potential on each conductor is restricted to such a value as is consistent with the level of insulation applied. From the point of view of safety, it is equally important that earthing should ensure efficient and fast operation of protective gear in the case of earth faults. The system earth – resistance must be such that when any fault occurs against which earthing is designed to give protection; the protective gear will operate to make the faulty feeder or equipment harmless. In most cases such operation involves isolation of the faulty feeder or equipment by circuit breakers or fuses. The common classifications of earthing in this standard are as follows:

- a) Solidly earthed
- b) Resistance earthed

7.11.2.2 M.V and H.V system earthing

7.11.2.2.1 M.V and H.V system neutrals shall be earthed TNS at each source of supply.

7.11.2.2.2 M.V and H.V Transformer neutral with secondary voltage less than 36kV shall be resistance earthed. The rating of each resistor shall be such that to limit the earth fault current approximately equal to the rated full load current of the transformer secondary.

7.11.2.2.3 In situation where generators are to be directly connected to the main H.V switchboard, each generator should be earthed via its own earthing resistor. This however, is subject to verification that the zero sequence, triple harmonic current (3rd, 9th, 15th, etc.) that could circulate through the resistors under various loading conditions of the generators would not be damaging to the resistors.

7.11.2.2.4 The rating of each resistor should be such as to limit the magnitude of earth fault current to the rated full load current or manufacturer recommended value of the generator to which is connected . These resistors should be solid type and shall be rated to withstand the respective E/F current for duration of not less than 10 seconds.

Note:

In any case the earthing current shall not exceed 630 A.

7.11.2.2.5 In situations where generators of dissimilar rating characteristics or, Loadings are to be operated in parallel such as to give rise to circulating currents resulting from triple harmonics then the system shall be earthed via one earthing resistor only. Each generator shall then be provided with a suitable switching device to facilitate connection of any machine to the single earthing resistor.

7.11.2.2.6 For grid in feed system voltages above 36 kV, the neutral point of transformers should be solidly earthed. In these situations high earth fault current flows in the general mass of earth in the vicinity of the substation so earthing arrangement must be designed such that these currents do not results dangerous step and touch potential. Detailed guidance is given in IEEE standard 80.

7.11.2.3 L.V system

7.11.2.3.1 L.V electrical system neutral at each source of supply shall be solidly earthed by means of dedicated earth electrodes which have a direct, low impedance connection to the plant main earth grid.

The system of earthing shall be designated "TN-S" in accordance with IEC 60364-3. For the other systems of earthing (such as "TN-C", "TN-C-S" & "TT") , refer to IEC 60364-3.

7.11.2.3.2 For fixed L.V equipment, each loop impedances shall be such as to effect circuit disconnection in a time not exceeding 1 s under solid (negligible impedance) earth fault condition.

7.11.2.3.3 The impedance between the earth electrode or earthing terminal and any point on the earth – continuity conductor should not exceed 1 ohm at frequency of the supply.

7.11.3 Earthing grid

7.11.3.1 For the earthing of electrical system, equipment and structures, each installation shall have one common earth grid connected to at least two groups of earth electrodes. The resistance of this grid to general mass of earth shall no be less than the value specified by this standard when one group of electrodes is disconnected for the purpose of measuring or inspection. The earth grid shall extend throughout the plant in form of a plant ring with branch interconnections to the equipment and structures to be earthed and shall from part of a single earth grid for whole site.

Note:

Instrument earthing such as intrinsically safe, non-intrinsically shall be considered and installed as stated in proper instrument IPS.

7.11.4 Equipment earthing

All electrical and non electrical equipment and parts of them which are liable to contact with live conductor or accumulate dangerous level of static charges shall be in effective contact with earth.

7.11.4.1 Electrical equipments earthing

7.11.4.1.1 A bar of high conductivity hard drawn copper shall be fixed inside the trench or cable gallery of the substation to which the earth bars of all switchboards and the metallic enclosures of all low voltage ancillary equipment shall be connected.

7.11.4.1.2 All main switchboards shall be connected to substation earthing system at two separate points. The tank of each main transformer shall be connected directly to the plant main earth grid.

7.11.4.1.3 The armouring and metallic sheath (if provided) of all multi core cables shall be bonded to the switchboard earth bar via termination or the gland. Where single core cables are used they shall be bonded to earth at one end only. The earthed end should be at hazardous end (if any).

7.11.4.1.4 The enclosures of all high and medium voltage motors shall be connected directly to the plant main earth grid or to local earth electrodes. A common earth electrode may be used for several motors in the same area.

7.11.4.1.5 The enclosure of low voltage equipments shall be bonded to the plant main earth grid.

7.11.4.2 Non electrical equipments earthing

7.11.4.2.1 Vessels

Two earthing connections shall be taken from the vessel to main plant earthing grid. This is not necessary done for the vessel which is mounted directly on the steelwork with well conducting to the earth. Where the vessel is too remote from the plant as to make connection to the main earthing system impractical, two connections shall be taken from the vessel to separate earth electrodes.

7.11.4.2.2 Storage tanks

Tanks up to 30 m diameter shall be provided with two, and tanks over 30 m diameter shall be provided with three equally spaced earthing bosses. For group of tanks earth electrodes common to the group may be installed provided that each tank has, as minimum two paths to earth. This ensures that during testing of one electrode the tank will remain earthed by system with an earth resistance less than 10 Ohms.

On floating roof tanks, multiple shunt connections shall be provided between the floating roof and the tubing shoe at adequate intervals around the roof periphery.

7.11.5 Lightning protection earthing

7.11.5.1 Lightning protection system if required shall be designed and installed in accordance with IEC 61024 or BS 6651.

7.11.5.2 In order to protect against a direct lightning stroke as a minimum the tallest structure on the plant shall be directly earthed as close to the base as possible with a minimum of two electrodes (less than 5 Ohm) and interconnected with main plant earthing grid.

7.11.5.3 Metal structures, e.g. vessels, etc., do not require additional protection beyond the earthing requirements specified in the equipment earthing.

7.11.5.4 The connection to earth should be as short and straight as possible.

7.11.5.5 Where the plant is located in proximity to the process area substation the lightning earthing system shall be connected to the power earthing system at two points.

7.11.5.6 In all areas classified as hazardous, steelwork such as stairways, cable racks, handrails, etc., which is mounted on or attached to non-metallic structures shall be bonded to the general earthing system either directly or via other earthed metal at intervals not exceeding 30 m.

7.11.5.7 Non-metallic structure less than 9 m in height do not generally require lightning protection. If greater than 18 m in height, they shall be provided with lightning protection.

7.11.5.8 The need for lightning protection on non-metallic structures between 9 m and 18 m in height shall be determined taking into account the heights of other adjacent structures, the nearness of flammables materials, consequences of damage, etc.

7.11.5.9 Metallic guy ropes used for supporting metallic or non-metallic stacks or other structure shall be bonded at their upper ends to the stack or structure if metallic, or to the lightning protective system in the case of non-metallic stacks or structures. The lower end of each guy rope shall be directly earthed.

7.11.5.10 For offshore installations, all plant which is not in metallic contact with earthed structural steelwork shall be connected to the platform steelwork and no separate lightning earthing system is required.

7.11.6 Earthing of offshore installation

7.11.6.1 The steel deck and structure of an offshore installation is an inherently very low impedance structure capable of conducting earth fault currents without giving rise to sparks or dangerous potential differences. Good electrical continuity is achieved by intimate metal to metal contact through equipment fixing bolt, clamping, riveting or by welding, such that bonding cables need not be used between pieces of non-electrical equipment and between equipment earth and the steel deck.

7.11.6.2 Earthing conductors are required to bond the main components of the generation and distribution system (namely M.V and L.V generators, transformers, reactors, switchboards, motors and UPS units) to the platform steelwork. They shall be individually identified, and record on drawings. The metallic sheath and armour of a submarine cable shall be solidly bonded to the platform steelwork at both ends of the cable.

7.11.7 Electronic and instrumentation earthing

7.11.7.1 Special attention shall be paid to electronic and instrumentation system earthing, if required for computer and control system. These equipments shall be separately earthed from the electrical earth system. This separate earth system called "clean earth" or "instrument earth" or "computer earth" (less than 1 Ohm) as relevant, can be one or a number of separate and independent earth system depending on manufacturers requirement.

7.11.7.2 The clean earth electrode(s) shall be located outside of resistance zone of power earthing electrode(s) (radius of this zone is generally 15 – 20 m).

7.11.7.3 The earth conductor between instrument clean earth bar in the auxiliary room and the clamp type earth bar in the instrument clean earth pit shall be braided or armoured. This braiding or armoring shall be bonded to the electrical earthing system to shield this earth conductor from surface stray earth currents which may cause unwanted interference.

7.11.7.4 The instrument clean earth and electrical earthing system shall be inter connected by a single 70 mm² earth wire in each field auxiliary room or control room.

7.11.7.5 Where interconnection between instrument clean earth and electrical earthing system may be subjected the effect of electrical storms, or high voltage induced, the interconnecting lines or cables shall be equipped with suitable surge diverters to prevent damage to instrument equipment.

7.11.8 Earthing where cathodic protection is applied

7.11.8.1 Bonding between cathodically protected equipments and any earthing system can reduce the efficiency of an impressed current cathodic protection system by diverting the flow of impressed current.

7.11.8.2 The cathodically protected sections of pipeline shall be isolated from unprotected sections and from any earthing system.

7.11.8.3 Where plant is cathodically protected, either by sacrificial anodes or by an impressed current system, the design of earthing system shall be agreed with the suppliers and designers of the cathodic protection system.

7.11.9 Earthing and protective conductor

7.11.9.1 Protective conductor shall be suitably protected against mechanical damage, chemical or electrochemical deterioration, electrodynamic forces and thermodynamic forces.

7.11.9.2 Buried earthing and protective conductors should normally be bare copper cable or tapes. However, if there is a likelihood of corrosion PVC sheathed, colored yellow / green type shall be used.

7.11.9.3 Joints in protective conductors should be avoided.

7.11.9.4 The following metal parts are not permitted for use as protective conductor or as protective bonding conductors:

- Metallic water pipes
- Pipes containing flammable gases or liquids
- Constructional parts subjected to mechanical stress in normal service
- Flexible metal parts
- Support wires

7.11.9.5 Protective conductors may consist of one or more of following:

- a) a conductor in multicore cables
- b) insulated or bare conductor in a common enclosure with live conductors
- c) fixed installed bare or insulated conductor
- d) metallic cable sheath, cable screen, cable armor, wire braid concentric conductor, metallic conduit subject to the conditions stated in 7.11.9.5 "a" and "b".

7.11.9.6 Where the installation contains equipment having metal enclosures such a low voltage switchgear and controlgear assemblies or busbar trunking system, the metal enclosures or frames may be used as protective conductors if they simultaneously satisfy the following three requirements:

- a) Their electrical continuity shall be assured by construction or by suitable connection so as to ensure protection against mechanical, chemical or electrochemical deterioration.
- b) They comply with the requirement of protective conductor sizing and jointing.
- c) They shall permit the connection of other protective conductors at every predetermined tap off point.

7.11.9.7 Earthing / protective conductor sizing

7.11.9.7.1 The cross-sectional areas of protective/earthing conductors shall not be less than the value determined as below:

- 1) By the following formula applicable only for disconnection times not exceeding 5 seconds

$$S = \frac{\sqrt{I^2 t}}{K}$$

Where:

- S: is the cross – sectional area, in mm²
- I: is the value (r.m.s) in ampere of prospective fault current
- t: is the operating time of the back – up protection device
- K: is the factor dependent on the material of the protective conductor, the insulation and other parts and the initial and the final temperatures. (For calculation of K, see IEC 60364-5-54 annex A)

- 2) Specified sizes in tables 17 and 18.

TABLE 17 - CONDUCTOR SIZE FOR BRANCH EARTH CONDUCTORS, CONNECTED TO INDIVIDUAL SWITCHGEAR AND CONTROL GEAR ASSEMBLIES, MOUNTED IN SUBSTATIONS, SWITCH ROOMS AND CONTROL ROOMS

Rated short current and duration	Conductor size in mm ²
20 KA / 1 s	2x70
25 KA / 1 s	2x70
31.5 KA / 1 s	2x70
40 KA / 1 s	2x70
50 KA / 1 s	2x120
63 KA / 1 s	2x120
80 KA / 1 s	2x150

Note:

2x70 means, 70mm² cable connected to two side switchgear and controlgear.

TABLE 18 - MINIMUM EARTHING / PROTECTIVE CONDUCTOR SIZE FOR VARIOUS APPLICATIONS

APPLICATION	SIZE / mm ²
Plant earth main ring	70
Branch to metallic enclosures of H.V & M.V electrical equipment	70
Branch to metallic enclosures of H.V & M.V electrical equipment , having a supply cable cross-sectional area 35 mm ²	35
Branch to metallic enclosures of H.V & M.V electrical equipment , having a supply cable cross-sectional area < 35 mm ²	25
Branch to control panels, etc.	25
Branch to non-electrical equipment exposed to lightning , e.g. tanks, columns and tall structures	70
To other non-electrical equipments	25
Interconnection cable between clean earth and electrical earthing system	70
Interconnection cable between lightning earth electrode and structure to be protected	70
Main earth wire for temporary electrical installations	70
Branch earth wire for temporary electrical installations	25

7.11.10 Earth electrodes

7.11.10.1 Effect of shape on electrode resistance with all electrodes the greater part of the fall in potential occurs in the soil within a meter of the electrode surface, since it is here that the current density is highest. To obtain a low overall resistance the current density should be as low as possible in the medium adjacent to the electrode which should be so designed as to cause the density to decrease rapidly with distance from the electrode this requirement is met by making the dimensions in one direction large compared with those in the other two thus a pipe, rod or strip has a lower resistance than a plate of equal surface area.

7.11.10.2 There is different types of earth electrode may be considered, such as:

- Rod
- Plate
- Strip or conductor electrode
- Structural steelwork (for offshore)

7.11.10.3 Material and dimensions of the earth electrodes shall be selected to withstand corrosion and to have adequate mechanical strength.

7.11.10.4 Earth rods are generally used and available in standard length of at least 1.2 m and can be extended in length by suitable coupling.

7.11.10.5 In soils of uniform resistivity, it is more economical to install a number of rods connected in parallel from a single deeply driven rod. In such cases each rod shall be situated outside the resistance zone of any other. In practice the separation shall not be less than electrode length.

7.11.10.6 Earth strip or conductor electrodes should be used where high resistivity soil underlies shallow surface layers of low resistivity. They are frequently in form of untinned strip not less than 25 mm by 1.5 mm in section, but may be of bare copper conductor with cross section area not less 70 mm². In this case the company engineer approval is needed.

7.11.10.7 If several strip electrodes are required for connection in parallel in order to reduce the resistance the separation should be made by 2 meters.

7.11.10.8 The depth of strip embedding from the ground surface shall not be less than 50 cm.

7.11.10.9 Employing of structural steelwork as an earth electrode shall be limited in offshore installations.

7.11.10.10 Plates are not generally recommended because of used in small numbers, they least reliable type of made electrode. However may be suited in very rocky or coralloid land in which an earth well may be required.

7.11.10.11 Where the resistance of a single plate is higher than the required value, two or more plates may be used in parallel, provided that each plate is installed outside the resistance area of any other. This separation shall not be less than 2m.

7.11.10.12 Where each plates are used either copper type or cost iron type the thickness, shall not be less than 3mm and 12mm receptivity and the size employed shall not be greater than 1.2m by 1.2m.

7.11.10.13 The depth at which plates are set shall be such as to ensure that the surrounding soil is always damp.

7.11.10.14 each earth electrode shall be terminated in a suitable pit for inspection and measuring purposes.

7.11.10.15 where a group of electrodes are used at least one more than the required minimum number of electrodes shall be installed. By this means, each electrode can be disconnected one at the time for testing without affecting the integrity of the power earthing system.

7.11.11 Soil resistivity

7.11.11.1 The resistance to earth of an electrode of given dimensions is dependent on the electrical resistivity of the soil in which it is installed. Soil resistivity is varied according to the type of soil, moisture content, degree of compaction, chemical composition and soil temperature. The latest factor is only important near and below freezing point. The type of soil largely determines its resistivity. Typical values of soil resistivities are given in table 19 for preliminarily.

7.11.11.2 Soil resistivity measurements shall be made at the proposed electrode locations. These measurements and earthing system design should be carried out at an early stage of the project so that the electrode locations are compatible with plot –plant.

7.11.11.3 Where there is any option, a site should be chosen for the electrodes which are not naturally well drained. Locations where the ground is kept moist by water flowing over it shall be avoided. Wherever possible, dry sandy or rocky ground should also be avoided.

7.11.11.4 The effect of possible seasonal increases in electrode resistance due to drying out or freezing of ground shall be taken into account. Wherever possible, the each electrode should be installed deep enough to reach the water table or permanent moisture level, deeper than frost is likely to penetrate and to reach stable ground conditions. For more information refer to IEEE 80 and ISIRI 4123.

7.11.11.5 Soil resistivity may be reduce 15-90% by chemical treatment, depending upon the kind and texture of the soil. There are several chemicals suitable for this purpose, including sodium carbonate, magnesium and copper sulfate, calcium chloride and common salt (addition of less than one part by weight of salt to 200 of soil moisture has been found to reduce the resistivity by 80 percent).

7.11.11.6 Before chemical treatment is applied to soil, it should be verified that no deleterious effect on the electrode material will result.

TABLE 19 – GENERAL DATA ON EARTH RESISTIVITY

Type of soil	Climatic condition					
	A Normal and high rainfall (e.g. greater than 500 mm a year)		B Low rainfall and desert conditions (e.g. less than 250 mm a year)		C Under-ground waters (saline)	
	Probable value	Range of Values encountered	Range of Values encountered	Range of Values encountered	Range of Values encountered	
	Ohm cm	Ohm cm	Ohm cm	Ohm cm		
Alluvium and lighter clays	500	*	*	100 to 500		
Clays (excluding alluvium)	1 000	500 to 2000	1 000 to 10 000	300 to 1 000		
	2 000	1 000 to 3 000	5 000 to 30 000			
Marls (e.g. Keuper marl)	5 000	3 000 to 10 000	100 000 upwards	1 000 to 3 000		
		3 000 to 10 000				
Porous limestone (e.g. chalk)	10 000	3 000 to 30 000	100 000 upwards	10 000		
	30 000	10 000 to 100 000				
Porous sandstone (e.g. Keuper)	100 000	30 000 to 300 000	100 000 upwards	3 000 to 10 000		
Sandstone and clay shales)	100 000	100 000 up wards				
Quartzite, compact and crystalline limestone (e.g. carboniferous, marble, etc.)	200 000					
Clay slates and slaty shales						
Granite						
Fissile slates, Schists Gneiss and Igneous rocks						

* Depends on water level in locality

7.11.11.7 Earthing system resistance value, the resistance required varies inversely with fault current to earth. A suitably low resistance is necessary under all climatic conditions, depending on the system voltage and fault current level. The resistance and hence possible rise in potential between the main earth system and general mass of earth should be as low as can economically be contrived. However the resistance value for different earth system is specified in table 20 and shall be considered.

TABLE 20 – EARTH RESISTANCE VALUE FOR DIFFERENT EARTHING SYSTEM APPLICATION

EARTHING SYSTEM	RESISTANCE VALUE In Ω
M.V & H.V Substation	<1
M.V Power generation	<1
L.V Distribution system	<2
Plant Main earth grid	<4
Main earth grid	<1
Domestic *	<5
Lightning protection system	<5
Clean earth for instrumentation , control computer , and communication system	<1

* On condition that suitable earthing protective devices RCPD (Residual Current Protection Device) / RCD (Residual Current Device) have been used.

APPENDICES

**APPENDIX A
DOCUMENT LIST**

1.	Generation and Distribution System Studies	<i>Basic Design</i>	<i>Detail Design</i>
	1	criteria and Philosophies	
	2	Load Schedules	
	3	Load Flow Study	
	4	Short Circuit Study	
	5	Motor Starting Study	
	6	Harmonic Analysis	
	7	System Stability Load Shedding	
	8	VSDS Economic	
	9	Power Factor Correction	
	10	Cable Sizing Calculations	
	11	Lighting System Calculation	
	12	Earthing & Lightning Calculation	
	13	Cathodic Protection Calculation	
	14	UPS sizing	
	15	Batteries and charger sizing	
	16	Heat tracing calculation	
	17	Protective Relaying Setting & Graph	
2.	Diagrams		
	1	Single Line Diagrams	
	2	Control System Block Diagrams (Logic Diagrams)	
	3	Schematic Diagrams	
	4	Protection & Metering Diagram	
	5	Connection Diagrams	
	6	Cable Trench Details	
	7	Construction And Installation Details	
	8	MV , LV Switchgear Single Line Diagrams	
	9	Typical installation diagram	
	10	Lighting and socket outlet diagram	
3.	Layouts		
	1	Cable Racking /Trench Layouts	✓ 1
	2	Earthing Lighting Layouts	✓
	3	Lighting & Small Power Layouts	
	4	Substation Layouts	
	5	Hazardous Area Classification Layout	
	6	Heat Tracing Layout	
	7	Cathodic Protection Layout	

1: Main cable routing layout

4.	Schedules	<i>Basic Design</i>	<i>Detail Design</i>
1	HV Switchgear Schedules		
2	LV and MCC Switchgear Schedules		
3	Cable Schedules		
4	Electrical Equipment schedules		
6	Cable Drums Schedules		
5.	Equipment		
1	Generator	SP & DS	SP & DS
2	Transformer	SP & DS	SP & DS
3	Switchgear	SP & DS	SP & DS
4	Emergency Diesel Generator	SP & DS	SP & DS
5	Motor	SP & DS	SP & DS
6	Capacitor Bank	SP	---
7	Cable & Wire	SP	SP
8	Earthing & Lightning	SP	SP
9	Neutral Grounding Resistor	SP	SP
10	UPS	SP & DS	SP & DS
11	Battery & Battery Charger	SP & DS	SP & DS
12	Lighting System	SP	SP
13	Heat Tracing System	SP	SP
14	Cathodic Protection	SP & DS	SP & DS
15	Motor Driver	SP & DS	SP & DS
16	Navigational aids system	SP	SP
17	Bulk Material	SP	SP
18	CCTV System	SP	SP & DS
19	Air Craft Warning	SP	SP

SP: Specification

Ds: Data Sheet

6.	Miscellaneous	<i>Basic Design</i>	<i>Detail Design</i>
	1 M.T.O	✓	✓
	2 Installation Specification		✓
	3 Cable Procurement		✓
	4 Bulk Procurement		✓
	5 Equipment Bid Evaluation (Report)	✓	
	6 Equipment Bid Tabulation (Report)		✓
	7 Operating Manuals		✓
	8 Temporary Installation Specification		✓
	9 Inspection Test Plan		✓
	10 Testing Procedures (Site)		✓
	11 Test Record Forms (Site)		✓
	12 Spare Part List		✓

- For Feasibility studies refer to the scope of services which has been prepared by "Management and Planning Organization".