

PETRONAS TECHNICAL STANDARDS

DESIGN AND ENGINEERING PRACTICE

ELECTRICAL ENGINEERING GUIDELINES

PTS 33.64.10.10

OCTOBER 2010



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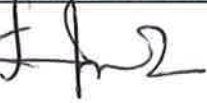
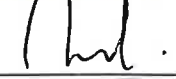
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This revision of PTS **33.64.10.10 – Electrical Engineering Guidelines (October 2010)** has been updated incorporating PETRONAS Lessons Learnt, Best Practice and new information issued by relevant industry code and standards.

The previous version of this PTS **33.64.10.10 Electrical Engineering Guidelines (February 2010)** shall be removed from PTS binder / e-repository and replaced by PTS **33.64.10.10 – Electrical Engineering Guidelines (October 2010)** herein onwards.

Document Approval

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PREFACE

PETRONAS Technical Standards (PTS) publications reflect the views, at the time of publication, of PETRONAS OPU/Divisions.

They are based on the experience acquired during the involvement with the design, construction, operation and maintenance of processing units and facilities. Where appropriate they are based on, or reference is made to, national and international standards and codes of practice.

The objective is to set the recommended standard for good technical practice to be applied by PETRONAS' OPU in oil and gas production facilities, refineries, gas processing plants, chemical plants, marketing facilities or any other such facility, and thereby to achieve maximum technical and economic benefit from standardisation.

The information set forth in these publications is provided to users for their consideration and decision to implement. This is of particular importance where PTS may not cover every requirement or diversity of condition at each locality. The system of PTS is expected to be sufficiently flexible to allow individual operating units to adapt the information set forth in PTS to their own environment and requirements.

When Contractors or Manufacturers/Suppliers use PTS they shall be solely responsible for the quality of work and the attainment of the required design and engineering standards. In particular, for those requirements not specifically covered, it is expected of them to follow those design and engineering practices which will achieve the same level of integrity as reflected in the PTS. If in doubt, the Contractor or Manufacturer/Supplier shall, without detracting from his own responsibility, consult the owner.

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1. INTRODUCTION

1.1 SCOPE

This PTS gives minimum technical requirements for the design, engineering and installation of electrical facilities, which comprise all fixed electrical installations for power and lighting up to and including main supply facilities for instrument and process control equipment and safeguarding systems, cathodic protection equipment, telecommunication equipment, fire-fighting and alarm equipment, etc.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by PETRONAS, the distribution of this PTS is confined to PETRONAS companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them.

This PTS is intended for use in oil refineries, chemical plants, gas plants, exploration and production facilities and supply/distribution facilities.

When PTSs are applied, a Management of Change (MOC) process should be implemented. This is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this PTS, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable with regard to the safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this PTS which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned, the objective being to obtain agreement to follow this PTS as closely as possible.

1.3 DEFINITIONS

1.3.1 The **Contractor** is the party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project, or operation or maintenance of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party that initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 TECHNICAL BASIC DEFINITIONS

NOTE: The IEC standard is stated where applicable.

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 recognised 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.

Conversion of electricity, 601-01-07, IEC 60050

The changing of the characteristics of the form and frequency of voltage and current by means of a converter.

Declaration of compliance

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

Distribution of electricity, 601-01-10, IEC 60050

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 utilisation of electricity.

Electrical power system, 601-01-01, IEC 60050

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

Electrical Network Monitoring and Control (ENMC)

A computerised system that is dedicated to monitoring and controlling defined aspects of an electrical network.

Electromagnetic Compatibility (EMC), 161-01-07, IEC 60050

The ability of a device, equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment.

Electrical Safety and Operability Review (ELSOR)

Qualitative assessment using systematic review of Electrical Safety & System Integrity Design and other applicable documents which will provides recommendations to reduce the risks to the installation as low as reasonably practicable (ALARP).

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, if it fails in operation or when called upon, will affect the continuity, quality or quantity of the product.

Firm capacity

The installed capacity less the stand-by capacity.

Frequency deviation, 604-01-06, IEC 60050

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

Generation of electricity, 601-01-06, IEC 60050

A process whereby electrical energy is obtained from some other form of energy.

Hazardous area, 426-03-01, IEC 60050

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.

NOTE: This applies equally to hazardous dust atmospheres.

High Voltage (HV), 601-01-27, IEC 60050

The set of voltage levels in excess of low voltage.

NOTE: Although not covered by an IEC definition, it has become industry practice to use the term Medium Voltage (MV) for voltages from 1 kV up to 52 kV.

Installed capacity

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

Instrumented Protective Function (IPF)

A function comprising the initiator function, logic solver function and final element function for the purpose of preventing or mitigating hazardous situations.
(Ref: PTS 32.80.10.12)

NOTE: Previously the term safeguarding was used.

Interruptible, maintained electricity 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 15 s.

Low Voltage (LV), 601-01-26, IEC 60050

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

Nominal value, 151-04-01, IEC 60050

A suitable approximate quantity value used to designate or identify a component, device or equipment.

Non-essential service

A service that is neither vital nor essential.

Non-hazardous area, 426-03-02, IEC 60050

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.

Non-toxic

A substance may be regarded as non-toxic if it causes no harm to the environment or to a person exposed to it or ingesting it, except only if exposed to it or ingesting it in an overwhelming dose or under unusual conditions.

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. Other systems (consumers) may also be connected to or near this point.

Rated value, 151-04-03, IEC 60050

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.

Transformation of electricity, 601-01-08, IEC 60050

The transfer of electricity through a power transformer.

Transmission of electricity, 601-01-09, IEC 60050

The transfer in bulk of electricity from generating stations to areas of consumption.

Uninterruptible, maintained electricity 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 longer than 0.5 ms.

Vital service

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

Voltage deviation, 604-01-17, IEC 60050

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, 604-01-25, IEC 60050

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, 604-03-14, IEC 60050

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

Zone 0 (in the classification of hazardous gas areas), 426-03-03, IEC 60050

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), 426-03-04, IEC 60050

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

Zone 2 (in the classification of hazardous gas areas), 426-03-05, IEC 60050

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 20 (in the classification of hazardous dust areas), IEC 61241

An area in which combustible dust, as a cloud, is present continuously or frequently, during normal operation, in sufficient quantity to be capable of producing an explosive concentration of combustible dust mixed with air, and/or where layers of dust of uncontrollable and excessive thickness can be formed.

Zone 21 (in the classification of hazardous dust areas), IEC 61241

Areas not classified as zone 20, in which a combustible dust cloud is likely to occur during normal operation, in sufficient quantities to be capable of producing an explosive concentration of combustible dust mixed with air.

Zone 22 (in the classification of hazardous dust areas), IEC 61241

Areas, not classified as Zone 21, in which combustible dust clouds may occur infrequently, and persist for only a short period, or in which accumulations or layers of combustible dust may be present under abnormal conditions and give rise to combustible 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 Zone 21.

1.3.3 INSTALLATION AND EQUIPMENT

Bus coupler circuit breaker, 605-02-40, IEC 60050

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), 605-02-41, IEC 60050.

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

Controlgear, 441-11-03, IEC 60050

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, 551-02-01, IEC 60050

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.

Distributed Control System (DCS)

A configurable microprocessor-based (process) control system.

Distribution substation/switchboard

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

Generating set, 602-02-01, IEC 60050

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

Generator, 411-02-01, IEC 60050

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.

Integrated Motor Control System (IMCS)

A system comprising control modules, central unit(s), a serial bus connecting the control modules to the central unit and a communication facility enabling connection of the central unit to a distributed control system (DCS) and/or a Supervisory Control and Data Acquisition System (SCADA).

Inverter

A converter for conversion from d.c. to a.c.

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), 602-01-01, IEC 60050

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, 421-01-01, IEC 60050

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 a.c. to d.c.

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), 605-01-01, IEC 60050

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, 441-11-02, IEC 60050

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.

Switchroom

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

Variable Speed Drive System (VSIDS)

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

1.4 CROSS-REFERENCES

Where cross-references are made, the number of the section or sub-section referred to is shown in brackets.

All publications and Standard Drawings referred to are listed in (8).

2. DESIGN AND ENGINEERING PRINCIPLES

2.1 STANDARDS, CODES AND REGULATIONS

This PTS is based on the publications of the International Electrotechnical Commission (IEC) and on the relevant documents issued by the European Committee for Electrotechnical Standardisation (CENELEC). Where relevant, the specific publications are referenced in this PTS.

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 PTS 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 PTS.

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. Equipment to be installed in the European Union Member States shall have the appropriate 'CE' marking.

In the event of contradiction between the requirements of PTS specifications and IEC, CENELEC or national standards, the former shall prevail, provided the statutory obligations in the country of installation are satisfied.

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

As far as is applicable, Standard Drawings in groups S 64, S 67, S 68 and S 69 shall be followed.

2.2 OPERATIONAL SAFETY AND RELIABILITY

Reference is made to PTS 60.2102 Recommendation for Electrical Safety, which specifies requirements and gives recommendations for the development of Electrical Safety Rules (ESRs).

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.

To ensure desirable condition is achieved, ELSOR (Electrical Safety and Operability Review) shall be conducted by ELSOR Team at the preliminary and detail design stages of new projects (green field) and existing plant (brown fields) projects. ELSOR assessment shall provide systematic review methodology to address any discrepancy and/or inadequacy with regard to design parameters, philosophy as well as installation, operation and maintenance of electrical-related systems and equipment.

Notwithstanding of the above, 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. For non-spared equipment in vital or essential duty, the period of continuous operation shall be determined by the major shutdown intervals of the associated plant, for which 6 years shall be assumed unless otherwise specified by the Principal. To fulfil 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., details of which are given in (3). 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.

Equipment that is known to be a source of electro-magnetic emission, e.g. Variable Speed Drive Systems, particularly larger units installed in modularised or containerised packages shall include external caution notices to warn heart pace-maker wearers of the risks of electro-magnetic sources. These caution notices shall be installed at the perimeter of the area that is considered dangerous for pace-maker wearers and also state the maximum approach distance to the particular installation.

NOTE: The actual acceptable approach distance shall be checked with the Manufacturer for each individual installation.

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. The specific requirements associated with the design and installation of temporary facilities, as described in (Appendix 13), shall be adhered to.

2.3 PROTECTION AGAINST EXPLOSION AND FIRE HAZARDS

2.3.1 Flammable gas/vapour hazards

To permit the proper selection of electrical apparatus for areas where flammable gas or vapour risks may arise, area classification drawing(s) shall be prepared based on the IP Model Code of Safe Practice Part 15, Area Classification Code for Petroleum Installations, as amended/supplemented by PTS 80.00.10.10. For the installation of electrical equipment in hazardous areas, IEC 60079-14 shall be complied with.

Electrical equipment shall, as far as is reasonably practicable and economic, be located in the least hazardous area. Control rooms and Substations should be situated in non-hazardous areas.

Where electrical equipment has to be installed in hazardous areas, equipment with a type of protection suitable for the relevant zones shall be selected and specified in accordance with IEC 60079-14.

The construction of electrical equipment should comply with the relevant parts of IEC 60079. Appendix 1 summarises the various types of protection of electrical equipment that are permissible in hazardous areas. The specification or procurement of equipment complying with other standards different from the above requires the specific approval of the Principal.

Although many types of protection are available, the following shall be used in the final selection:

- For Zone 1, LV motors and all inherently non-sparking equipment, e.g., junction boxes and luminaires, shall have type of protection 'e'. HV motors and all inherently sparking equipment, e.g., switchgear and controlgear, shall have type of protection 'd'. Where such type of protection is not available, e.g., large high speed HV motors, type of protection 'p' shall be used. HV motors with type of protection 'e' shall not be used.
- For Zone 2, motors and inherently non-sparking equipment shall have type of protection 'n', albeit equipment approved for Zone 1 is also acceptable. Inherently sparking equipment shall have type of protection 'd' or 'p', as stated for Zone 1.

HV motors with type of protection 'n' or 'e' shall not be installed in Zone 2 areas where:

- 1) the motor voltage exceeds 6.6 kV,

or 2) the motor drives a centrifugal/screw/reciprocating hydrocarbon gas compressor.

Notwithstanding the above, HV Ex'n' motor can still be considered, provided that mitigation measure is identified and implemented, risk assessment is conducted and remaining risk is acceptable. For example gas detection or purging system before start. It is mandatory to have separate lubrication system.

- Electrical equipment installed in indoor, non-hazardous areas within process areas shall be of a standard industrial type as specified in the relevant equipment PTSs. Small power and lighting equipment in such indoor areas shall be either of the industrial weatherproof type or of the domestic type depending on the function of the area (6.1).
- Equipment installed in non-hazardous areas outside process installations, e.g., offices, gatehouses, etc., shall be of a normal industrial/domestic type in accordance with national standards of the country of installation.

2.3.2 Flammable dust hazards

Area classification and the selection of apparatus for use in areas where there is a flammable dust hazard shall be in accordance with IEC 61241.

Hazardous dust areas are classified as either Zone 20, Zone 21 or Zone 22 according to the probability of the existence of a dust hazard.

The ingress protection as defined in IEC 60529 shall be:

- for Zone 20 and 21, electrical equipment shall have dust-tight enclosures, i.e., IP 6X;
- for Zone 22, electrical equipment shall have dust-protected enclosures, i.e., IP 5X minimum.

Electrical equipment should, as far as is reasonably practicable and economic, be located in the least hazardous area. Control rooms and Substations should be situated in non-hazardous areas.

2.4 STANDARDISATION OF EQUIPMENT AND MATERIALS

Equipment of similar nature and incorporating similar or identical components and of similar or identical construction should be of the same manufacture. This applies to HV and LV switchgear with the same rated voltage, to power and convenience outlets, and to luminaires.

Standardisation of materials and equipment shall be aimed for, as far as is compatible with rational design. Equipment, which will become obsolete in the near future shall not be installed.

2.5 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 PTS specifications, e.g., for generators, motors, VSDS, HV and 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.

2.6 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 9000 series.

3. ELECTRICAL SYSTEM DESIGN

3.1 GENERAL

The design of the electrical installation shall be based on the fundamental principles referred to in (2). It shall be commensurate with any specific design criteria, philosophy and/or objective that may be stated in the project definition phase, e.g., in the basis of design document and/or project specification, relating to a particular plant or facility. For instance, it may be defined by plant lifetime, skill of operating and maintenance personnel, operational flexibility, extension possibilities or noise limitations, etc.

The philosophies to be employed will depend on the size and complexity of the installation; those approved for a specific project shall be set down clearly during the project definition phase. Any fundamental deviation thereafter shall be subject to the Principal's approval.

The conceptual designs and philosophies relating to the electrical system shall be adequately illustrated by a system design description, a key line diagram, basic layout drawings and functional/outline specifications.

The electrical system and associated controls shall be designed so as to form an integral part of the process plant facilities, as far as is practicable. For example, on-site electricity generation by recovery of process heat energy and integration of the electrical system controls with process control systems shall be considered. Furthermore, due regard should be given to the selection and utilisation of efficient electrical equipment in order to reduce energy consumption. The use of high efficiency/power factor electric drives, the use of VSDs for speed, flow or power control, the selection of low loss transformers, etc. should be evaluated during the detail design and equipment procurement stages of a project.

When electrical power systems are designed, the following alternatives for the electricity supply shall be considered: own generation, public utility supply, or a combination of these within the limits and possibilities given by the Principal. The design and selection of power supply sources shall ensure a degree of availability commensurate with the service required. Reference is made to (Appendix 2) and to PTS 33.64.10.12.

Generating sets should normally be in an electrically centralised location and the distribution system arranged radially. Ring distribution systems shall be considered for residential/industrial facilities located at relatively large distances from the power source or from each other.

The requirement for islanding schemes shall be addressed. If an islanding scheme is adopted, the type of detection and timing shall be dependent on the specific characteristics of both the generating plant and the outside grid supply. Reference shall be made to (Appendix 3).

As part of the design, the requirement for an Electrical Network Monitoring and Control (ENMC) system shall be evaluated (3.7.15). Reference shall be made to manual PTS 33.64.10.11 and specification PTS 33.64.10.32.

Power factor control and/or power transfer to alternative energy sources, with account being taken of the tariffs charged for outside suppliers, shall also be considered.

A key line diagram of the electrical power system shall be prepared and kept up to date throughout the lifetime of the plant.

System studies and protection reports, etc., shall be provided in support of the design. Depending on the type, size and complexity of the installation, such studies may comprise the following:

- Loadflow studies;
- Fault level studies;
- Transient stability studies under three phase fault conditions;
- Dynamic performance studies under motor starting and/or loss of generation conditions;
- Protection grading studies, including relay setting schedules;

- Harmonic distortion studies;
- Motor restarting and re-acceleration;
- Vital Supply recovery following total power failure, including emergency diesel generator(s), UPS, instrumentation, DCS and IMCS.

The scope and timing of the system studies shall be defined by the Principal and agreed with the Contractor before their commencement.

The scope of the studies also depends on that stage of the project at which such studies are done. At the conceptual design stage, a limited study is often sufficient to define the overall feasibility of the design. During the detailed design, a more extensive study is generally done to further define electrical system requirements. When all actual equipment data is available, essential elements of the study should be repeated to provide an 'as installed footprint' of the electrical system.

Where there is a public utility interconnection, the study requirements pertaining to the public utility should be considered within the scope of these studies.

The key line diagram, system studies and protection reports shall be subject to approval by the Principal.

The Vital Supply Recovery Study shall document the principle of recovery from total power failure and shall identify vital drives and circuits that must be reinstated and the source of the reinstatement supply or command. Examples of reinstatement sources include:

- Emergency Diesel Generator systems;
- Process control (DCS), safeguarding (IPF), integrated motor control (IMCS);
- UPS, battery supplies;
- Manual operation.

Reference shall be made to (Appendices 5, 7 and 12).

3.2 ELECTRICAL LOADS AND ELECTRICITY CONSUMPTION

3.2.1 Classification of loads

Electrical loads shall be classified as performing a service, which is 'vital', 'essential', or 'non-essential', as defined in (1.3.2).

An electrical power system having a degree of reliability commensurate with the required service shall be provided.

3.2.1.1 Vital service

A vital service is, by definition, a safety matter. Complete duplication of the energy source, of the lines of supply and of the equipment is necessary.

- Examples
- Boiler feed water supply system by means of one electrically driven and one steam driven pump, or two electrically driven pumps supplied from independent sources;
 - Life support systems, e.g. electric motor driven fire pumps on offshore installations supplied from independent sources;
 - One or more uninterruptible power supply (UPS) units to provide electrical supply to systems, and process control systems;
 - Emergency lighting and escape lighting.

3.2.1.2 Essential service

An essential supply is, by definition, an economic matter. Therefore the economics of partial or complete duplication of the energy source, of the lines of supply or of the equipment, or the introduction of automatic restarting or changeover facilities etc., shall be evaluated in relation to the consequences of service interruptions.

- Examples: - Product transport by means of duplicated pump sets with account being taken of pump maintenance requirements;
- Power supply to process analysers by means of a duplicate supply system with changeover facility;
 - Power supply to security lighting and plant area lighting.

3.2.1.3 Non-essential service

Example - Power and lighting supplies to offices, warehouses, residential areas, etc.

3.2.2 Load assessment and electricity consumption

A schedule of the installed electrical loads, the maximum normal running plant load and the peak load, expressed in kilowatts and kilovars and based on the plant design capacity when operating under the site conditions specified, shall be prepared using Standard Form PTS 05.00.10.80. The latter shall be completed and updated regularly throughout the design stage of the project and shall form the basis for provision of the necessary electricity supply and distribution system capacity (3.5).

Standard Form PTS 05.00.10.80. gives formulae for determining the total electrical loads:

- Maximum normal running plant load = $x(\%)E + y(\%)F$
- Peak load = $x(\%)E + y(\%)F + z(\%)G$

where E = sum of all continuously operating loads

F = sum of all intermittent loads

G = sum of all stand-by loads

x, y and z are diversity factors

Values shall be determined by the Principal for the diversity factors appropriate to the type of plant. The values of the diversity factors x, y and z must take account of the individual drives or consumers which make up the continuous, intermittent and stand-by loads, respectively. For example, $y(\%)F$ cannot be less than the largest individual intermittent drive or consumer.

The various loads are classified as follows:

- E - "Continuous"; all loads that may continuously be required for normal operation, including lighting and workshops;
- F - "Intermittent"; the loads required for intermediate pumping, storage, loading, etc.;
- G - "Stand-by"; all loads required in emergencies only, such as fire-water pumps or those of normally not running electrically driven units in stand-by mode for normally running steam-driven ones, e.g., charge pumps, boiler feed pumps, etc.

NOTES: 1. Subject to the above considerations, the following default values could be used for initial load assessments, or if the diversity factors have not been finalised:

x = 100 % (by definition, at rated plant throughput all driven equipment should be operating at its duty point. However, some diversity may need to be applied to non-process loads, e.g., offices and workshop power and lighting (typically 90 %)).

y = 30 %.

z = 10 %.

2. A separate schedule shall be prepared for each switchboard, the total of all switchboard loads being summarised as required to arrive at the maximum normal running and peak loads for each substation and for the plant overall. Account should be taken of large intermittent or stand-by loads for these summations, as described above. All loads to be shed during an underfrequency condition shall be identified as such in the 'remark' column. All loads to be automatically restarted after a voltage dip shall be identified as such in the 'restarting' column.

3. The percentage of total intermittently operating load that contributes to the maximum normal running load will depend on plant operations.

4. Depending on steam/electricity supply availability, the use of non-electrical drivers for stand-by duties and the total number of units installed, only a small number of the largest electrical stand-by units may have to be considered when establishing the peak load.

5. Where a group of drives operate as a unit, it shall be considered as an individual consumer.

The power consumption of electric motors shall be based on motors rated in accordance with the requirements of PTS 33.66.05.31.

3.3 SYSTEM VOLTAGES AND FREQUENCY

3.3.1 General

The system voltages shall be selected from IEC 60038, subject to compatibility with any existing installation with which interconnection is intended. The selection of system voltages shall be determined by the Principal.

On 50 Hz systems the nominal LV power supply voltage for new plants shall be 400/230 V three phase and neutral as recommended in IEC 60038. This voltage shall also be considered for extensions to existing plants requiring new LV distribution systems.

The frequency for onshore installations shall be that used by the local public utility.

Nominal system voltage(s) and frequency and the positive phase sequence of three phase systems shall be indicated on the key line diagram. The phase sequences shall be specified in the order L1, L2, L3, each phase reaching its maximum in time sequence in that order.

3.3.2 Deviations in supply voltage and frequency

During normal system operation and under steady-state conditions, the voltage at generator and consumer terminals shall not deviate from the rated equipment voltage by more than 5 % and the system frequency shall not deviate from the rated frequency by more than 2 %. The combined voltage and frequency deviations shall lie within Zone A as described in IEC 60034-1.

All loads shall be balanced so that the negative phase sequence components of voltage and current at any point in the system shall not exceed the values quoted in IEC 60034-1.

During starting or reacceleration of direct on line motors, either singly or in a group, the voltage at the motor terminals shall not deviate by more than +10 % or -20 % from rated equipment voltage.

Transient voltage deviations occurring at switchgear busbars during motor or group motor starting/reacceleration shall be such as to maintain a minimum of 90 % voltage on switchgear busbars, and at least 80 %, but not more than 110 %, of rated equipment voltage on all other consumers.

Notwithstanding the above requirements, the limits set by the public utility regarding the maximum voltage deviations that a consumer is permitted to cause at the point of common coupling (PCC), e.g., due to the starting of electric motors, shall be adhered to.

Equipment having special requirements with respect to variations in voltage and/or waveform shall be provided with a power supply that is adequately stabilised and/or filtered.

NOTE: For certain installations, e.g. offshore, the Principal may advise conditions which differ from the above.

3.3.3 Deviations and variations in supply waveform

Electrical loads having non-linear characteristics such as to produce voltage and current waveform distortion of a magnitude detrimental to the lifetime or performance of system electrical equipment shall not be utilised unless appropriate measures are taken to render harmless the effects of such distortion, e.g., by filtering or phase displacement, etc.

Two levels of distortion are recognised:

- a) The distortion level for extensions to an existing electrical system:

The harmonic voltage distortions at any point of the system up to a voltage of 36 kV should not exceed the levels as defined in IEC 61000-3-6 table 1. The Total Harmonic Distortion (THD) shall not exceed 8 %

- b) The distortion level for new projects or developments

For new projects the planning levels are defined in IEC 61000-3-6 table 2. The Total Harmonic Distortion (THD) for system voltages up to 36 kV shall not exceed 6.5 %. Total Harmonic Distortion for system voltages higher than 36 kV shall be limited to 3 %

- NOTES:
1. The values of maximum permissible harmonic distortion as given in IEC 61000-3-6 are to be regarded as a guide to good practice aimed at minimising the risk of damage to or malfunction of system electrical equipment and at preventing system overvoltages and overcurrents due to resonant effects. However, the latter possibility is dependent on the system capacitance (including that employed for power factor correction), the source and load impedances and the harmonic current requirements of the non-linear load, etc. The necessity of protective measures shall consequently be ascertained for each project individually, depending on the relative magnitude of the above-mentioned parameters.
 2. The harmonic voltage distortion limits do not apply to the input terminals of individual items of harmonic generating equipment, e.g., converters, which are supplied via transformers or series reactors.

Equipment, which will produce a sustained d.c. component in the a.c. supply system shall not be utilised.

3.4 SYSTEM POWER FACTOR

The overall system power factor, inclusive of reactive power losses in transformers and other distribution system equipment, shall not be less than 0.8 lagging at rated design throughput of the plant. The power factor shall be determined at

- the terminals of the generator(s), when power is supplied from the Principal's own generation,
- the PCC, when power is supplied from a public utility. The plant power system shall be designed so that the power factor stated by the public utility is achieved with a design margin of at least 2 %.

NOTE: As measured, the power factor will be an average value determined over the metering integration period, typically 15 min or 30 min.

Any improvement of power factor beyond that necessary to achieve the foregoing aims shall be considered on an economic basis, e.g., reduction in distribution system equipment ratings, reduction in kVAr charges.

NOTE: Electricity supply authorities may dictate a minimum power factor allowed under the terms of the electricity supply contract.

The requirement for power factor correction shall be agreed with the Principal at an early stage of the design. Where necessary, power factor correction shall be effected by one or more of the following methods, which are stated in order of preference. The method selected depends on reliability and economic considerations.

- Variation of the excitation of synchronous generators.
- Variation of the excitation of synchronous motors.
- Static capacitors connected in parallel with, and switched in conjunction with, individual electric motors (3.7.6). The selection of motors for the application of power factor correction capacitors shall be subject to technical and economic considerations. In particular, capacitors shall not be connected in parallel with motors performing a vital or essential service, e.g., drives of instrument air compressors, fire water pumps, etc. Preference shall be given to the individual power factor correction of continuously operating motors.
- Permanently energised static capacitor banks connected to distribution switchboards or group motor control centres via suitably protected switching devices (3.7.6).

3.5 SUPPLY CAPACITY

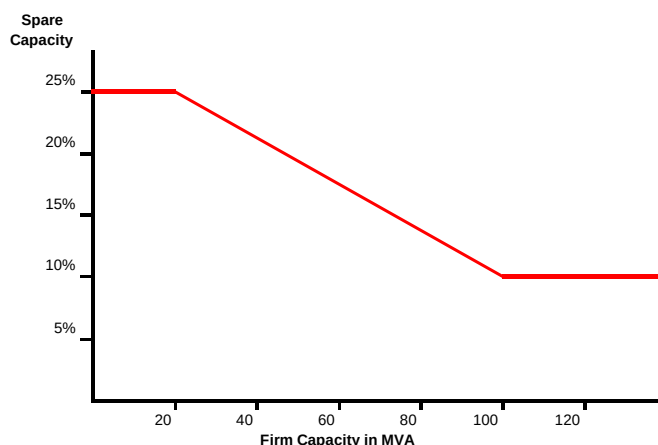
3.5.1 General

The design of new facilities shall ensure that the firm capacity of the main HV distribution system (power plant switchgear, and/or grid intake transformers, distribution switchgear

and interconnecting cabling) have sufficient spare capacity commensurate with the type and size of facilities it supplies.

By default the distribution system shall be capable of supplying continuously between 110 % and 125 % of the peak load, assessed according to the applicable load data (3.2.2), without exceeding specified voltage and frequency limits (3.3.2), and equipment ratings.

The graph below gives the spare capacity that shall be provided for facilities with firm capacities as indicated



However, for certain process facilities the spare capacity may be reduced, but a minimum of 10 % spare shall be maintained at end of the detailed design phase.

Where applicable, the Principal shall establish, during the conceptual design phase, a reduced spare capacity for the particular facilities for which:

- future expansion plans are unlikely,
- future expansion will be of large capacity, e.g. additional train(s) at an LNG plant,
- spare capacity of more than 10 % will not be specifically catered for.

The spare capacity at Plant Substations shall be a minimum of 10 % at the end of the detailed design phase, the 10 % spare capacity being retained for future plant debottlenecking and changes

The provision of stand-by capacity shall be considered in relation to safety, reliability and the requirements with respect to continuity of plant operations.

Moreover, the reliability of distribution systems shall be at least comparable to that of their supply systems, each incorporating sufficient stand-by capacity to enable maintenance work, tests and inspection checks to be carried out. Electrical system maintenance requirements shall be considered in relation to plant shutdowns for overhaul of process units.

General rules relating to the provision of necessary spare and stand-by capacity, and to the rating of supply and distribution equipment for each part of the electrical system, are given in subsequent sections.

3.5.2 Power generation

The number of generating sets to be installed and their individual ratings depend on many factors, e.g., maintenance requirements, economic size, future load development pattern, unit reliability, etc. Sufficient stand-by capacity shall be incorporated to fulfil the requirement of the peak load with the largest generating set out of service.

The availability of further stand-by supply capacity to cater for generating set failures during such maintenance/repair periods shall be provided where the aggregate maintenance/repair time warrants this.

For plants with own generation capable of operating in island mode, an automatic load shedding scheme shall be provided.

NOTE: If the data necessary to determine the extent of spare/stand-by capacity, as outlined above, are not available, the following guidelines can be used. For a plant with no public utility connection and where spinning reserve, i.e., running stand-by capacity is required under all normal power plant operating conditions because of the nature of the process, e.g., continuous process plants, $n+2$ generating sets shall be installed, where n is the number of main generating sets required to supply the peak load. Otherwise, $n+1$ generating sets may be installed, provided there is non-essential load at least equal to the rating of one generating set, which can be shed. Reference is made to (Appendix 3)

3.5.3 Transmission and distribution systems

The economic consequences of electricity supply interruptions to essential services generally justify the provision of stand-by feeder capacity to facilitate the isolation of individual circuits for the purpose of equipment maintenance (of on-load tap-changers, circuit breakers, etc.), functional testing (of protective relays and trip circuits, etc.) and possible repair (of cables and cable terminations, etc.) while maintaining electrical services operational. Therefore, the stand-by feeder capacity shall enable the largest supply circuit to be withdrawn from service while satisfying the peak load requirements with the margins specified in (3.5.1).

The provision of stand-by capacity to non-essential service loads shall also be subject to an evaluation of the load requirements in conjunction with the relevant factors that may affect circuit reliability and circuit availability for carrying out maintenance, testing and inspection.

The maximum rating for transformer feeding plant substations should be sized that the optimized number of cables run, number of transformer, space and depends on distribution configuration.

NOTE: In order to keep the level of the prospective short circuit within the range of commercially available switchgear, transformers with a higher impedance than specified in PTS 33.65.40.31 may be considered. Reference is also made to (3.6)

Single overhead line circuits are not acceptable as a means of supplying vital or essential consumers. Duplication of circuits to non-essential consumers may also be required to improve reliability and to permit regular maintenance.

NOTE: Single circuit lines or ring distribution circuits should only be considered for supplies to individual plants or facilities that are periodically shut down for maintenance so as to permit simultaneous maintenance of the feeder circuit.

3.5.4 Switchgear

Currently available switchgear is considered to be sufficiently reliable to require no duplication in itself. Consequently, distribution and plant switchboards, including group motor control centres, shall have a single busbar system and a single switching device per circuit.

HV switchboards at intake substations and power plant substations incorporating double busbar systems may be selected as an alternative to the above arrangement, but only if justifiable in terms of facilitating system extension and operating flexibility (which would otherwise involve significant disruption of electricity supply) or of facilitating a supply of differing priority/security from each busbar. An example of the latter would be where own generation and higher priority loads are connected to one busbar and a public utility supply (of poorer reliability) together with lower priority loads to the other busbar. The bus coupler circuit breaker would be utilised to effect disconnection in the event of grid supply interruptions.

Switchboards with double busbar systems shall incorporate one circuit breaker per circuit.

HV switchboards shall generally have a maximum of three sections and, consequently, a maximum of two bus section switches. LV switchboards may have two, three or maximum four sections (in 'H' configuration). Where the LV load exceeds the capacity of a four-section switchboard, additional switchboard(s) shall be installed rather than having switchboards of more than four sections. Special arrangements, e.g., automatic changeover, may be required for switchboards supplying vital services, where an alternative supply is required.

In the absence of quantitative analysis of circuit reliability data relating to a specific design that would support an alternative operating mode, and unless specific system design requirements dictate otherwise, the normal operating position of switchboard bus section switches shall be as follows:

- For LV switchboards the bus section switches shall be operated normally open, except on switchboards at the source of supply, i.e., at LV generator switchboards.
- For HV switchboards the bus section switches shall be operated normally closed on switchboards at intake substations, power plant substations and distribution substations. Bus section switches shall be operated normally open on switchboards at plant substations.

NOTE: 1) In the above context, 'normally open' and 'normally closed' refer to the bussection switch position when all the incoming switchboard circuits are available.

2) Deviations from the above mode of operation may be required to satisfy criticality requirements

When a switchboard panel serves a stand-by function to one or more main consumers, it shall be connected to a different busbar section from that to which the main consumer or consumers are connected, provided that there is no possibility of a switchboard incoming circuit or busbar section becoming overloaded as a consequence of selecting any main or stand-by consumers for operational use.

For recommended plant switchboard configurations, refer to (Appendix 4).

Normally open bus section switches and/or interconnectors that may have to be operated simultaneously in the closed position shall be rated so as to permit the largest incoming circuit feeder to be withdrawn from service without the necessity to de-energise any switchboard busbar section or consumer circuit.

The configurations of intake, power plant and distribution switchboards shall permit one switchboard section to be taken out of service while still maintaining normal downstream plant operations.

3.5.5 Electric motors

Electric motors complying with PTS 33.66.05.31 are considered sufficiently reliable for single essential drives. For vital services, stand-by units shall be installed, and supplied from a separate source of supply.

Where a VSDS is used for a vital or an essential service, duplication of certain components of the system may be required to obtain an acceptable reliability level, as stated in PTS 33.66.05.33.

3.6 SHORT CIRCUIT RATINGS

All equipment shall be capable of withstanding the effects of short circuit currents and consequential voltages arising in the event of equipment or circuit faults.

NOTE: Damage occurring at the fault location is excluded from the above.

The short circuit ratings of equipment and cables, including the short circuit making and, where relevant, breaking capacity of circuit switching devices, shall be based on actual operational philosophy on site. For the circuit 2 identical transformers installed with ATS the short circuit rating should be based on one transformer in operation.

(Note: To consider future intend & condition for safeguarding for employing the above-to be proper written up)

NOTE: The short circuit current contributions from all supplies, which can be operated in parallel, shall include contributions via bus section switches or interconnectors, which are capable of being operated simultaneously in the closed position. This includes bus section switches or interconnectors, etc., which are intended for normally open operation and on which no (inter)locking has been provided to prevent simultaneous closure.

For new installations, including those forming part of plant extensions, the short circuit rating of the switchgear to be installed shall be based on the sum of the short circuit contributions from the following:

- the maximum short circuit level at the point of supply from which the new switchgear will be energised,
- an electrical loading of the new installation such that the nominal capacity of the switchboard is fully utilised,
- future planned increases in short circuit level due to the direct or indirect connection of machines or public utility supply.

NOTE: Generally the load of process facilities predominantly consists of induction motors. When no details are known at the time of order, 90 % of the nominal capacity of the switchboard should be taken as motor load.

At the time of order, an HV switchboard at intake, power plant or distribution substations shall have a margin of not less than +10 % between the calculated fault level under the above-mentioned conditions and the specified short circuit rating of the equipment.

NOTE: Short circuit calculations shall be based on nominal impedance values of the equipment. The margin specified above is provided to allow for the tolerances permitted for equipment characteristics.

Mechanical interlocking of switches shall be provided, where necessary, to ensure that equipment short circuit ratings are not exceeded, due regard being given to satisfying the above-mentioned operational requirements with respect to the provision of firm and stand-by capacity.

Automatic break-before-make changeover arrangements of supply capacity shall not be introduced with the specific aim of justifying the use of equipment having a lower short circuit rating than would otherwise be required for the parallel operation of all available supplies.

The use of current-limiting reactors, Is-limiters and similar devices intended specifically as a means of limiting the magnitude of short circuit currents is permissible only when they form part of extensions or interconnections with existing installations. The application of the above-mentioned current-limiting equipment shall be considered only as a means of achieving system extensions or interconnections, which could not otherwise be practicably or economically realised without the use of such devices or a new installation which could not otherwise be practicably or economically realized.

The installation of Is limiters or reactors shall be evaluated and documented during the conceptual design of the electrical distribution network.

When equipment short circuit ratings are determined, the effects of contributions from asynchronous and synchronous machines on the switching duties of switchgear and on the dynamic and thermal loading of the electrical installations in general shall be taken into account.

- NOTES:
- 1) Short circuit current contributions from cage induction machines need normally only be taken into account for determining the necessary dynamic withstand rating of equipment and the required making duty of circuit breakers tested in accordance with IEC 60056 and IEC 60947-2. However, where reliance is placed on circuit breakers having an enhanced making capacity, the effects of asynchronous machine contributions shall be taken into account in establishing the adequacy of the fault breaking duty of circuit breakers, taking into account the decay of the short circuit current contribution.
 - 2) A period of 100 ms after the fault shall be taken for establishing adequacy of the breaking capacity of circuit breakers.

Any restrictions imposed by the public utility with respect to short circuit current infeed to their supply network shall not be exceeded.

3.7 ELECTRICAL PROTECTION AND CONTROL

3.7.1 General

The electrical system shall be equipped with automatic protection, which shall provide safeguards in the event of electrical equipment failures or system maloperation.

The selection and specification of switching and protective devices, control circuits and associated auxiliary equipment shall be in accordance with PTS 33.67.51.31. and PTS 33.67.01.31., for HV and LV switchgear respectively, and with the relevant Standard Drawings in the S 67 series.

The application of microprocessor based numeric protection systems, in combination with electrical network control (ENMC), shall be considered; see (3.7.15).

NOTE: These systems generally incorporate the possibility to design blocking schemes, which in a number of cases could be applied instead of the traditional unit protection systems.

Automatic protective systems shall be designed to achieve selective isolation of faulted equipment with minimum delay. In any event this shall be within a time corresponding to the short circuit current withstand capability of equipment, system stability limits and the maximum fault clearance times specified in (3.7.4) and (3.8).

Adequate and selective phase short circuit and earth fault protection shall be provided, due regard being given to the magnitude of short circuit currents and method of system earthing (3.8). Limited duration overcurrents arising from single or group motor starting/reacceleration shall be permitted. Automatic control systems such as load transfer and motor restarting arrangements, and protective systems to initiate load shedding in the event of underfrequency conditions, shall be incorporated so that plant operations are affected to the minimum practicable and economically justifiable extent after system or equipment failures; see (3.5.2) and (Appendices 2 and 3).

The type and characteristics of protective devices shall be selected according to application and shall be compatible with those of any existing system with which interconnection is intended.

Unless otherwise specified by the Principal, unrestricted overcurrent protective devices shall have IDMT characteristics in accordance with IEC 60255.

Protection settings shall be based on a study of the fault conditions for which the protective system has been incorporated. Protection systems shall be selective and the settings shall be co-ordinated so that back-up protection is provided to initiate fault clearance in the event of protective system and/or switching device failure.

A protection diagram in the form of a single line diagram shall be prepared for the complete electrical power system to indicate the type and location of all protective devices and associated transformers to be provided. Based on this drawing, an electrical protection report shall be prepared which shall demonstrate the adequacy of all protective systems in fulfilling the above requirements. The protection report shall be a live document, which shall be maintained and kept updated over the lifetime of the installation. The protection report shall include at least a description of the system and of the system operating modes on which the settings have been based, together with relevant short circuit current calculations or computations for specified minimum and maximum generation or supply conditions, single line diagrams for each part of the system, tabulated settings of the individual devices and co-ordinated characteristics of the protection devices and fuses, etc., plotted in graphical form. Tabulated relay settings shall be provided for all electronic relay parameters irrespective of whether the individual functions are used or not.

The minimum generation and/or minimum supply capacity conditions shall be at least representative of those conditions, which can arise during normal operation of process units, production facilities and their utilities. The protection of distribution systems during more extreme conditions, such as those occurring at the time of starting up generating plant and utilities, may be catered for by appropriate adjustments of protection settings. This adjustment should, in particular where numeric protection devices are utilised, be realised via alternative setting groups. This may be achieved via the ENMC system or alternatively by switchgear position switches.

Where relevant, the dynamic performance of the system shall be analysed to verify the adequacy of the protection provided in ensuring successful system recovery to stable operation following the incidence of short circuits. In particular, systems incorporating own generation as a means of power supply shall be studied to establish the extent to which re-energisation of essential service load and other connected load may be accomplished.

The protection of the interconnections with the outside grid system shall satisfy the requirements of both the Principal and Public Supply Authority.

Fault criteria and system operating modes on which system studies are based shall be subject to agreement with the Principal.

The nomination of the party performing the relevant system studies and the type of power system analysis programs used shall be subject to the Principal's approval.

3.7.2 Main generators

Depending on their duty, main generators shall, as a minimum, be equipped with the protection, control, alarm and metering functions specified below. If a generator is connected to the system via a generator step-up transformer, this transformer shall be incorporated in the protection system of the generator. The neutral earthing of the generators shall be as stated in (3.8.2).

Generator protection, control and monitoring equipment is normally designed and selected by the manufacturer/supplier of the generating unit in accordance with the Principal's requirements. Where relevant these shall be incorporated in the ENMC system. For typical single line and protection diagrams, refer to Standard Drawings S 67.055 and S 67.056 for direct-connected and transformer-connected generators respectively.

Standard Drawings S 67.055 and S 67.056 include a table indicating which protection relays shall trip the prime mover, the generator circuit breaker and/or the excitation system.

The protection requirements shown on drawing S 67.056 apply to main generators for connection to HV switchgear up to 36 kV. Above this voltage additional requirements may apply, as determined by the Principal.

Generators running in parallel with the grid (3.7.3) shall comply with the relevant grid codes.

Main generators shall be fitted with the following control equipment:

Reference is also made to (Appendix 2)

- Manual and automatic synchronising with a check synchronising relay and a dead-bar override;
- Voltage control equipment consisting of automatic voltage control with a manual control stand-by system. Manual control system shall follow the setpoint of the automatic control system to allow for automatic changeover from the automatic to the manual control system without significant voltage transients if the automatic voltage control system fails. The voltage control system shall be suitable for island and parallel operation. Reactive-Power sharing among sets shall be provided for the voltage control system. Cross current compensation between generators employing Astatic Loop Circulating Current should only be considered for extensions to an existing power station where this feature is already provided;
- Power factor or reactive power control equipment arranged to adjust the AVR setpoint, so as to keep the generator power factor constant when operating in parallel with a public utility supply. This shall be

Generating sets operating in parallel with the grid may be controlled as follows:

- (a) speed control with a droop characteristic;
- (b) MW control where control of grid import/export is required;
- (c) back pressure control of steam turbines supplying process steam. automatically switched off when the generating set(s) is/are in island operation.

Control shall be designed so that on loss of grid connection, governor control will automatically revert to speed control.

For island operation the sets may be controlled as follows:

- (a) speed control;
- (b) isochronous control of one generator, the remainder by a combination of speed and (if applicable) back pressure control;
- (c) isochronous control of all sets with load sharing, if all machines are identical.

The Principal shall define the applicable modes of control. In cases where an ENMC system will be installed, reference shall be made to (3.7.15).

Gas turbine and diesel engine driven generating sets shall be provided with automatic control schemes. This shall include facilities for auto-starting, automatic synchronising and automatic loading.

Local control of generating sets shall include all the components necessary for commissioning, maintenance of and trouble-shooting the generating sets independently of the rest of the power system.

Main generators shall be provided with the alarm equipment, indicating instruments and integrating meters stated in (Appendix 8).

3.7.3 Grid intake systems

Grid intake circuits shall be controlled by circuit breakers, fitted with the protection, control, alarms, instruments and meters specified below. The overall design of these circuits shall be carried out in close liaison with the public utility, so that both parties' requirements are satisfied.

For typical single line and protection diagrams, refer to Standard Drawing S 67.060.

Where the grid intake circuits comprise transformer feeders and the transformers are fitted with on-load tap changers, automatic voltage control equipment shall be provided to control the intake substation switchboard voltage.

Grid intake circuits, which are required to operate in parallel with own generation, shall be provided with manual synchronising facilities, a check synchronising relay and a dead-bar override. These synchronising controls should be located where control of the frequency and voltage of the generators can be exercised.

Where applicable, the requirements for an islanding system shall be incorporated in the design. Reference is made to (Appendix 3)

Grid intake circuits shall be provided with the alarm equipment, indicating instruments and integrating meters stated in (Appendix 8).

3.7.4 Switchgear

Unrestricted short circuit current and earth fault protective devices shall be applied at the supply end of the switchboard incoming circuit feeders (3.7.5, 3.7.8 and 3.7.9). These protective devices shall serve as feeder protection, as protection of switchboard busbars in the event of busbar faults, and as back-up to switchboard outgoing circuit protection. In transformer circuits, earth fault protection shall also be provided in the transformer secondary neutral-earth connection (3.7.5).

The operating time of the above-mentioned circuit protection in the event of a busbar fault shall be as short as is reasonably practicable. It shall in any event not exceed the 'through fault' withstand duration of the switchboard corresponding to the switchboard rated short circuit withstand current, regardless of variations in the magnitude of busbar short circuit current.

For HV and LV switchboards, the rated short circuit withstand duration corresponding to the rated withstand current shall normally be 1 s. The maximum permissible operating time of circuit protection for a switchboard busbar fault shall therefore not exceed 1 s, irrespective of variations in the magnitude of prospective short circuit currents that may arise during normal operating conditions.

Additionally, for LV switchboards, the effect of fault arc resistance in limiting the magnitude of busbar short circuit or earth fault currents shall further be taken into account by ensuring that the above requirements are fulfilled for all short circuit currents equal to or greater than 50 % of the minimum prospective value.

The above requirements do not preclude the necessity of incoming circuit protective devices to initiate clearance of short circuit currents of lower magnitude, as may occur in switchboard busbars or on other parts of the system for which the protection has been provided.

Bus zone protection shall not be provided on LV switchgear. In principle, bus zone protection shall also not be provided on HV switchgear. In special circumstances, e.g., if the above mentioned 1 s busbar fault clearance time cannot otherwise be achieved, a limited bus zone protection scheme may be applied.

Manual initiation of the operation of HV distribution circuit breakers should normally be accomplished locally, either on the circuit breaker or an adjoining control panel. Automatic, remote trip functions are required within certain protection schemes, e.g., intertripping/load shedding. Remote operation of HV distribution circuit breakers is not recommended unless there are overriding reasons that could warrant it, e.g., large distances from manned control rooms. The necessary safeguarding features shall be provided to prevent unsafe switching operations, e.g., interlocks with earthing switches, etc. Selection of the necessary hardware components is given in PTS 33.67.51.31.

3.7.5 Power transformers

Distribution transformers shall normally be connected Dyn with clock numbers as advised by Principal.

Distribution transformers shall be controlled and protected on the primary side by either of the following:

- Circuit breakers in conjunction with phase short circuit and earth fault protective relays. Phase short circuit protection shall be by means of two-stage overcurrent relays. Stage 1 shall be IDMT and set to detect secondary side faults. Stage 2 shall be instantaneous in operation and set to detect primary side faults only. Primary side earth fault protection shall be by a residual current relay, set to achieve minimum fault clearance time;
- Fused contactors (incorporating a latched mechanism) in conjunction with overcurrent and earth fault protective relays. Phase short circuit protection shall be by IDMT overcurrent relay set to detect secondary side faults and by means of the main fuses for primary side faults. Primary side earth fault protection shall be by a relay connected to a core balance CT. The earth fault relay may require a short time delay to permit proper co-ordination between the fuses and the contactor.

For primary voltages up to and including 6.6 kV, fused contactors are preferred.

Additionally, transformers that supply an HV system shall be provided with biased differential protection and restricted earth fault protection. The transformer primary and secondary cables shall be included within the protected zone.

Unrestricted earth fault protection shall be provided on the (earthed) star connected windings of distribution transformers and generator step-up transformers. This shall be achieved by means of a device which shall be energised by a CT placed in the neutral to earth connection of the power transformer secondary winding. The primary current rating of the CT supplying this relay shall correspond to the nominal current of the transformer secondary or to the current as limited by resistance earthing. For LV systems, the characteristic of this device shall be extremely inverse and the setting shall correspond to an operating time of 1 s maximum for a device operating current equal to 50 % of the minimum prospective symmetrical 3-phase short circuit current. For HV systems (3.7.1), the characteristic of this device shall be normal inverse or definite time and the setting shall be the minimum practicable.

NOTE: Where more than one transformer is connected to an LV switchboard or a stand-by LV supply is provided, this form of protection requires all incoming and bus switches to be 4-pole to switch phase and neutral conductors.

For the specification of transformers and further protective measures, refer to PTS 33.65.40.31., and to Standard Drawings S 67.049 - S 67.052 inclusive. For alarm and instrumentation requirements, refer to (Appendix 8).

3.7.6 Capacitors

HV capacitor banks shall comprise individually fused capacitor units. The fuses shall comply with IEC 60549 and should be easily accessible for inspection and replacement. For large capacitor banks exceeding 1000 kVAr, the capacitors shall be connected in

double star with unbalance protection monitoring the star point voltages, or with differential current protection across the two halves of the capacitor bank. Capacitor failure shall trip the bank and provide an alarm indication. If recommended by the Manufacturer, overpressure switches should be fitted to HV capacitor units and connected to trip the capacitor bank.

Individual capacitors shall be controlled by contactors, circuit breakers or, for LV applications, fused switch units. The switching devices shall be approved for this duty by the switchgear Manufacturer. They shall be rated for at least $1.5 \times I_n$, and must be able to withstand transient inrush currents up to $100 \times I_n$.

Contactor or switch controlled capacitor banks shall be protected by means of fuses. In the case of circuit breaker control, phase fault and earth fault protection relays shall be provided.

In those cases where a capacitor is connected in parallel with an electric motor, a single switching device and associated relays and/or fuses that control and protect both the motor and the capacitor shall be provided.

3.7.7 Electric motors

3.7.7.1 General

Motor starters shall comply with PTS 33.67.01.31. or PTS 33.67.51.31., as applicable.

Electric drives shall be controlled by fused contactors or MCCB contactors, except where the rated voltage and power of the machine exceeds that of the available controlgear.

When an electric motor is fed via a unit transformer, it shall be protected as shown in Standard Drawing S 67.048. The secondary of the transformer shall be earthed in accordance with (3.8) and (Appendix 6).

Where current operated overload devices cannot be regarded as providing adequate protection, e.g., where cooling may be adversely affected by dust or speed variations, embedded temperature detectors shall also be provided. These shall be either positive temperature coefficient thermistors or Pt-100 RTDs.

Overload protection of electric motors that are required to remain operational in the event of fire shall be set at a minimum of 300 % of the motor full load current in accordance with NFPA 20. The Principal shall identify such motors.

The protection of motors in vital service, e.g. driving fire pumps on offshore facilities, shall be monitored and an alarm raised if the motor is not ready to start.

Large HV motors controlled by circuit breakers that could be tripped by an IPF (safeguarding) system may, in extreme cases, have breaker fail back-up protection that trips the upstream distribution circuit breaker(s) in the event that the motor circuit breaker fails to trip; this shall only be used as a last resort. At the conceptual design stage other solutions (e.g. via process control) shall be considered. The details of the back-up system shall be subject to the approval of the Principal, taking into account the negative aspects resulting from de-energising a large part of the electrical system. The IPF trip circuit shall be designed 'fail safe' with as few interposing relays as possible; the circuit breaker itself, however, shall not be regarded as a fail safe device.

Integrated Motor Control Systems (IMCS), which are microprocessor controlled motor starters as opposed to the conventional types, provide additional drive monitoring and protection features and self-diagnostic and communication facilities. Such features could be specifically useful in a DCS controlled plant, and IMCS shall therefore be considered for new installations, provided it can be demonstrated that they are cost effective in comparison with conventional motor starters. The IMCS shall comply with Appendix 1 of PTS 33.67.01.31.

Electric drives shall be provided with an RCU mounted local to the motor. By means of this RCU, motors can be started/stopped and, in the "0" (neutral) position, automatically controlled. Relevant control circuits are shown in Standard Drawings S 67.004, S 67.028 and S 67.071.

If automatic control is necessary, then the auto on/off control signals shall be given via separate interposing relays or, if an IMCS is used, via the central unit.

Motors that are mounted above grade, e.g., fin-fan cooler motors, and controlled from grade level for operational convenience, shall have safety switches located near the motors.

Where motors are fitted with anti-condensation heaters, a heater safety switch shall be installed adjacent to the motor's RCU.

Thermal overload devices protecting motors with type of protection Ex'e' in Zone 1 areas shall comply with IEC 60079-7 and be provided with a certificate of conformity accordingly.

3.7.7.2 Variable speed drive systems (VSDS)

VSDS shall be equipped with the protection, control, alarm and metering equipment functions in PTS 33.66.05.33., in Standard Drawing S 67.057 and in (Appendix 8) of this PTS.

3.7.7.3 Synchronous motors

Synchronous motors shall be equipped with the protection, control, alarm and metering functions shown in Standard Drawing S 67.047 and stated in (Appendix 8).

Synchronous motors shall be fitted with the following control equipment:

- voltage control/excitation control equipment;
- equipment for controlled start-up, e.g., via start switch;
- equipment for controlled shutdown, e.g., via normal stop switch;
- equipment for crash shutdown, e.g., via emergency stop switch.

3.7.7.4 Cage induction motors

HV cage induction motors shall be equipped with the protection, control, alarm and instrumentation functions specified in PTS 33.67.51.31. and shown in Standard Drawing S 67.028, S 67.045, S 67.046, S 67.048, S 67.058 or S 67.071, as appropriate.

For the protection of submerged motors, or where excessively frequent or consecutive starting is possible, e.g., load pumps, restrictive start relays shall be provided. In addition to this, submerged pumps shall have underload protection installed.

All HV motors shall be provided with protection to safeguard against stall conditions that can arise during starting and normal running.

LV cage induction motors shall be equipped with the protection, control, alarm and instrumentation functions specified in PTS 33.67.01.31. and as shown in Standard Drawings S 67.004 and S 67.019.

Cage induction motors shall be switched direct on line. If this is impractical or uneconomic, current restricting start-up equipment shall be used.

Motors with auxiliary equipment, water cooling or special detection facilities, e.g., cooling air/water temperature detectors, water leakage detectors, etc., shall be connected to an alarm annunciation system with first failure alarm.

3.7.8 Plain cable feeders

Plain cable feeders for HV sub-distribution shall be controlled and protected by circuit breakers in conjunction with phase short circuit and earth fault protective devices.

Differential protection shall be provided on all HV feeders, which can be operated in parallel, or where instantaneous fault clearance time is required. Reference shall be made to Standard Drawings S 67.053 and S 67.054.

Plain cable feeders for LV sub-distribution shall be controlled and protected by fuse-switch combinations or by moulded case circuit breakers (MCCB) incorporating short circuit and earth fault protective devices. The MCCB shall co-ordinate with outgoing circuit protective devices on the receiving end sub-distribution switchboard.

The rating of any fuse protected LV circuit, which derives a supply from a distribution switchboard, should not exceed 25 % of the rating of a supply transformer, which energises the switchboard. Where the rating of the fuse protected LV circuit exceeds the above-mentioned value, and in order to ensure proper co-ordination with the earth fault protection in the transformer secondary neutral-earth connection, one of the following devices may have to be fitted in addition to fuses:

- a latched contactor with a d.c. trip coil, operated by a core balance earth fault protection device with the necessary time delay. The operating characteristic of the earth fault protection device shall be co-ordinated with the upstream and downstream protection characteristics;
- a contactor with d.c. hold-in coil and the above protection;
- an air circuit breaker, also with the above protection.

NOTE: The above devices will normally be required for plain cable feeders with ratings exceeding 400 A.

Similarly, the rating of any fuse protected LV circuit, which derives a supply from a distribution switchboard, should not exceed 50 % of the rating of a fuse protected LV circuit, which energises the switchboard. This is to ensure that the circuit protective devices can be fast operating and selective in isolating short circuits.

3.7.9 Overhead line circuits

Overhead lines of primary distribution feeders shall be controlled and protected by circuit breakers in conjunction with phase short circuit and earth fault protective relays. Where distance protection is employed, it shall be provided in conjunction with overcurrent and earth fault protection, the latter serving as back-up protection. The selection of protection shall depend on the circuit interconnections, method of system earthing, and general service conditions. Reference shall be made to Standard Drawing S 67.059.

Connected equipment shall be protected against the effects of lightning by means of earth wires, and lightning arresters (surge diverters) with counters at each end of the line. At road crossings Where overhead lines cross roads via underground cables, each side of the overhead line at the road crossing shall be provided with lightning arrestors. Earth wires may be omitted only after approval by the Principal.

Three or single phase auto-reclosure schemes shall be considered in relation to the general service conditions.

3.7.10 UPS equipment

D.C. and a.c. UPS equipment shall be protected in accordance with PTS 33.65.50.31. and PTS 33.65.50.32. respectively.

Feeders to rectifiers and UPS equipment shall be controlled and protected by a fuse-switch or an MCCB incorporating short circuit and earth fault protection. For feeders exceeding 400 A, MCCBs shall be installed.

Sub-distribution circuits fed by d.c. or a.c. UPS systems shall be adequately protected against short circuits with account being taken of the limited short circuit current available from UPS systems.

3.7.11 Electric heaters

Protection and control of electric process heaters shall be as specified in PTS 33.68.30.33.

Feeders to the power and control assemblies of the heaters directly connected to the LV system shall be by means of a fused switch or an MCCB supplemented with a contactor if required. For fuse ratings or MCCB trip settings exceeding 100 A, earth fault protection shall also be provided.

Feeders to electrical process heaters connected via a unit transformer shall be as specified in PTS 33.68.30.33. and (3.7.5).

3.7.12 Emergency generators

Control and protection of LV emergency generators shall be as shown in Standard Drawing S 67.070.

Control and protection of HV emergency generators shall be as shown in Standard Drawing S 67.055.

Facilities shall be provided to enable full load tests of the generating set to be carried out during normal plant operation.

3.7.13 Power and convenience outlets

Each LV power and convenience outlet circuit shall be protected by phase short circuit protective devices and by current-operated earth leakage protective devices, which are in accordance with IEC 60947-2, i.e., residual current circuit breakers (RCCB). The RCCB operating current shall be 30 mA for circuits of less than 125 A and 300 mA for circuits equal to or greater than 125 A.

3.7.14 Other electrical equipment

Local isolating switches shall be provided for, motor operated valves (MOVs), trace heating systems, cathodic protection equipment, etc., and shall be located near to the equipment or on the appertaining control panels. Where automatic control is required for such equipment and its controlgear is located in the substation, then this shall be accomplished with an RCU similar to those used for motor control.

3.7.15 Electrical Network Monitoring and Control (ENMC)

Reference shall be made to PTS 33.64.10.11 and PTS 33.64.10.32.

The overall monitoring and control philosophy of the electrical supply and distribution system shall be established and documented in an early stage of the project and is subject to specific approval by Principal.

A dedicated ENMC for the electrical supply and distribution system shall be considered where centralised metering and overall electrical system supervisory control and data acquisition is required to ensure safe and stable operation of this power system.

Some examples of where the installation of an ENMC system can be greatly beneficial are:

- Control of generators in large systems in which generator units are connected to different busbars / substations, and systems which cover a wide geographical area.
- To aid recovery after electrical disturbances in systems which might become separated from the grid or split internally.

The main purpose of an ENMC system is:

- a) Control of set points and modes of operation for generator units and transformers with automatic voltage regulation. Some examples of this are:
 - control of MW and MVA_r import/export
 - change mode of operation of generator units after island initiation
 - control of load flows and voltage in the network
- b) Safeguarding to maintain the safety and stability of the overall power system. Some examples:
 - load shedding in island situations
 - alarming when operating outside design envelop
 - restart and reacceleration
- c) Supervisory control of major elements of the power system under normal and emergency operation conditions
- d) Monitoring and data logging

In the process/utility plant Distributed Control System (DCS) a limited number of screens can be created to monitor the main electrical supply and distribution system. A limited number of control functions could also be realised via the DCS, e.g. remote operation (open/close) of circuit breakers, initiating automatic synchronising of generators.

NOTE: Item 'b' above requires a very fast response, which cannot be realised with currently available DCS systems

3.8 SYSTEM EARTHING

3.8.1 General

The neutral of a.c. systems shall normally be earthed as stated below. These shall not be designed for unearthed operation, unless they form an extension to an existing unearthed system.

The preferred system earthing arrangements are given in (Appendix 6).

3.8.2 HV systems

HV electrical systems shall be earthed by means of dedicated earth electrodes connected to the plant main earth grid (5.5.1).

HV system neutrals shall be earthed at each source of supply (transformer, direct-connected generator) as shown in (Appendix 6).

For grid infeed system voltages above 36 kV, the neutral point of transformers should be solidly earthed, unless otherwise required by the public utility.

NOTE: Grid infeeds with solidly earthed neutral points can result in high earth fault currents flowing in the general mass of earth in the vicinity of the substation. They must be designed such that these currents do not result in dangerous step and touch potentials. Detailed guidance is given in IEEE Standard 80 (IEEE Guide for Safety in AC Substation Grounding) and further reference is made to IEC 60479-1. A system employing earth rods alone is unlikely to be adequate, and a buried grid will be required. Within typical refinery networks, however, where the distribution network is predominantly cable, most of any potential earth fault current will flow in cable sheaths/armouring and the plant cable earth grid rather than the general mass of earth, and the substation earthing arrangements as detailed in Standard drawing S 68.030 will be adequate. Electricity Association document S.34 provides further guidance on current distribution.

Transformer feeders to HV switchboards with a system voltage not exceeding 36 kV shall be resistance earthed. The rating of each resistor shall be such as to limit the earth fault current supplied by the equipment to which the resistor is connected, to a magnitude approximately equal to the rated full load current of the supply equipment (generator or transformer). Where circuit breakers have to be connected to an existing solidly earthed system, suitable CTs shall be selected so as to prevent CT saturation under earth fault conditions.

NOTE: The above applies equally to the earthing of the neutral point of the HV winding of generator step-up transformers.

Where generators are to be directly connected to the main HV switchboard, i.e., not via generator transformers, each generator should be earthed via its own earthing resistor. This, however, is subject to verification that the zero sequence, triplen harmonic currents (3rd, 9th, 15th etc.) that could circulate through the resistors under various loading conditions of the generators would not be damaging to the resistors. The rating of each resistor should be such as to limit the magnitude of earth fault current to the rated full load current of the generator to which it is connected. A resistor of higher ohmic value than the aforementioned may be considered if such a resistor would limit the magnitude of circulating harmonic current to a harmless value, provided that with such a resistor, sufficient current would flow under each fault condition, to ensure positive operation of earth fault protection on all circuits. If the latter is not possible for any reason, other measures shall be adopted to limit such circulating currents, e.g., single point earthing at one of the supply sources or provision of controls to ensure that identical generators, each separately earthed, remain equally loaded and excited during normal operation.

NOTE: If multiple generators are directly connected to a switchboard and each is earthed via its own dedicated resistor, then zero sequence harmonic currents (principally, the third harmonic) may possibly circulate through the neutral-earth connections of the parallel operating machines. The magnitude of this circulating current will depend on:

- the difference in magnitude and phase of the triplen harmonic voltages in the stator voltage waveform of the respective generators operating in parallel (if the waveforms are not perfectly sinusoidal);
- the magnitude of neutral-earth resistances and of stator reactances (at the relevant harmonic frequency) of the respective generators.

Consequently, harmonic current can circulate in the neutral resistors of dissimilar machines operating in parallel, and also between identical machines operating in parallel if the harmonic voltage is sufficiently large and/or the electrical loading of the identical generators is sufficiently different.

If the sustained circulating current is such as to exceed the thermal rating of the resistor, then the current may be reduced by increasing the ohmic value of the resistor. This may be done provided the resultant earth fault current is at least 5 times the setting current of any earth fault relay on the relevant HV system.

PTS 33.65.11.31. quotes maximum acceptable harmonic voltages in the stator voltage waveform of synchronous generators.

Where generators of dissimilar ratings, characteristics or loadings are to be operated in parallel so as to give rise to circulating currents in the above-mentioned earthing resistors that would exceed the thermal rating of the resistors, then the HV system shall be earthed via one earthing resistor only. Each generator shall then be provided with a suitable switching device, i.e., remotely operated circuit breaker or latched contactor) to facilitate connection of any machine to the single earthing resistor. During normal operation, only one generator shall be connected to the resistor. If the generator so connected is tripped for any reason, an alarm is required to prompt manual intervention to close the neutral-earth switching device of one of the other operating generators to facilitate earthing of the system.

Where generators are connected to the main switchboard via individual generator step-up transformers, each generator neutral point shall be individually earthed through a single phase distribution transformer with a secondary resistor. The resistor shall be rated to limit the generator earth fault current to 10 A, or to $3 \times I_{co}$ where I_{co} is the per-phase capacitive charging current, whichever is the greater.

NOTE: The per-phase capacitive current is that due to the generator stator windings, generator transformer LV winding, and generator main cable/connections.

Each earthing transformer and resistor shall be rated to withstand the respective earth fault currents for a duration of not less than 10 s. Longer withstand times may be required, depending on the earthfault protection system applied.

Resonant impedance earthing, e.g., Peterson coil, may be considered for systems mainly comprising overhead lines, and thus subject to transient faults, e.g., lightning. In such cases, a low value earthing resistor should be installed in parallel with the normal high impedance device so that, if a fault on an outgoing circuit is not cleared within the allowed time, the resistor can be switched in to provide a higher fault current to allow clearance by back-up protection.

3.8.3 LV systems

The neutral of LV electrical systems shall be solidly earthed at each source of supply by means of dedicated earth electrodes that have a direct, low impedance connection to the plant main earth grid (5.5.1). The system of earthing shall be designated 'TN-S', in accordance with IEC 60364-3.

For fixed LV equipment, earth loop impedances shall be such as to effect circuit disconnection in a time not exceeding 1 s under solid (negligible impedance) earth fault conditions, and taking into account the Manufacturer's nominal time/current characteristic of the protective device.

NOTE: In compliance with the above requirements, recognition shall be given to the method of circuit protection (3.7) and the provision of earthing grid conductors (5.5). With respect to the latter, the earth loop impedance shall be assessed on the basis of an earth return circuit comprising the main earth grid conductors (main earth ring and branch conductors) in parallel with the protective conductor formed by the metallic sheath and/or armour of the supply cable (or, if relevant, the separate earth core within the supply cable) extending only to the equipment being protected. For offshore earthing, refer to item 6.2.

3.8.4 UPS systems

A.C. UPS systems shall have their neutrals solidly earthed. This applies equally to single phase and three phase systems. In order to provide galvanic separation, double-wound isolating transformers shall be installed at the UPS input as well as at the bypass. The inverter (output) neutral shall be connected to the neutral at the secondary side of the

bypass isolating transformer, and connected to the earthing grid as specified in (5.5.5). Reference shall be made to Standard Drawing S 67.006. It shall be ensured that there is no possibility of uncontrolled circulating neutral earth currents in the bypass/inverter output circuit.

D.C. systems supplying instrumentation loads and switchgear control and protection loads shall be earthed through a high resistance earth fault monitoring unit with a sensitivity of 5 mA, as shown in Standard Drawing S 67.025.

D.C. supplies for telephone systems shall be solidly earthed at the positive pole in line with normal telecommunication practice. D.C. supplies for special applications may be earthed as required by the equipment Manufacturer.

3.9 ELECTRICITY SUPPLY FOR VITAL SERVICES

3.9.1 General

Electricity supplies of enhanced reliability and having duplicate energy sources shall be provided to energise loads forming part of vital services. Such supplies shall, if required by the load, be uninterrupted on failure of one energy source. Loads which can tolerate an interruption in the power supply but which require restoration of the supply within a relatively short period of time shall be energised from an interruptible, maintained power source.

To meet the above requirements, the electrical power requirements for loads forming part of vital services are specified in three categories, (3.9.2), (3.9.3), and (3.9.5).

NOTE: For typical electricity supply arrangements that fulfil the requirements of each of the following categories, refer Standard Drawing S 67.006.

3.9.2 A.C. uninterruptible, maintained electricity supply

This is a power supply derived from one or more a.c. UPS units, each of which incorporates a battery to provide power in the event of failure of the mains electricity supply. The power supply is uninterrupted in the event of mains supply failure and is maintained throughout the battery discharge period.

An a.c. uninterruptible, maintained supply derived from a single a.c. UPS unit may be considered for batch process plants where the normal plant power supply is considered reliable. For a.c. UPS arrangements incorporating single or parallel UPS units, refer to PTS 33.65.50.32.

Parallel static units can be used to provide a single source of uninterruptible power with high levels of reliability and availability normally required for large indivisible loads; however load sharing controls shall not be subject to common mode failure problems.

For continuous process or production facilities, a.c. uninterruptible, maintained supplies shall be derived from two independent UPS units, each with its own battery, static changeover switch and maintenance bypass switch, as shown in Standard Drawing S 67.006.

Guidance on the rating and performance requirements of static a.c. UPS units is given in PTS 33.65.50.32.

The equipment fed from an a.c. uninterruptible, maintained power supply may be suitable for receiving a single or a duplicate supply. The following are recommended arrangements for energising equipment of each type:

Equipment suitable for receiving duplicate electricity supplies:

Systems or equipment requiring a duplicate a.c electricity supply shall derive one supply from each UPS distribution board.

NOTE: In order to preserve the high integrity of the redundant supplies shown on Standard Drawing S 67.006, the UPS distribution boards shall not be operated in parallel. Moreover, the a.c. supplies derived from the two UPS distribution boards shall also not be operated in parallel since each uninterruptible supply may be of marginally different frequency under certain operating conditions.

Equipment requiring duplicate power supplies that are required to operate in parallel shall derive each supply via rectifiers or switch mode power supply (SMPS) units; for example DCS systems. The rectifier or SMPS units should preferably be an integral part of the equipment or system being energised.

Equipment suitable for receiving a single electricity supply:

Equipment requiring a single a.c. electricity supply shall derive that supply from a distribution board which shall itself be energised from one UPS distribution board, but have an automatic, break-before-make changeover switch to derive a supply from the second UPS distribution board in the event of failure of the first supply. The operation of the changeover switch shall create an interruption in supply voltage to the load of not greater than 0.25 s, refer to Standard Drawing S 67.006.

To cater for the possible, but unlikely, failure of the output of one UPS unit, loads which have a single a.c. supply and which have a trip function on loss of the supply voltage are required to incorporate a time delay that will prevent tripping during operation of the above mentioned changeover switch.

3.9.3 D.C. uninterruptible, maintained electricity supply

This is a power supply that is derived from battery-rectifier units (d.c. UPS units) or from rectifier units energised from one or more a.c. uninterruptible, maintained supply sources (a.c. UPS units). The number of d.c. UPS units to be installed should be $n + 1$, where n is the number of units required to supply the load.

Such supplies should be considered for applications where the load is relatively small and closely concentrated, or to supplement a.c. UPS systems, e.g., for fire alarm or communications systems. Due consideration shall be given to the allowable voltage drop at the consumer terminals.

Where an a.c. uninterruptible, maintained electricity supply is available and the d.c. load does not exceed 15 % of the a.c. supply capacity, the d.c. uninterruptible, maintained electricity supply may be derived via duplicate rectifier units fed from the a.c. UPS distribution switchboards, as shown on Standard Drawing S 67.006.

3.9.4 Battery autonomy times

The batteries of UPS units shall be rated to energise the relevant loads for not less than:

For onshore installations:

- 30 min for process plant shutdown;
- 1 h for utility plants;
- 1 h for emergency lighting;
- 10 min for non-process computer installations;
- 8 h for fire-fighting and fire alarm systems;
- 8 h for telecommunication and radio systems.

Requirement for batteries in tripping (and closing) service of HV switchgear are specified in PTS 33.67.51.31.

If 100 % redundant emergency generators are supplying the duplicate UPS systems, the following changes to the battery autonomy time can be made, subject to approval by the Principal:

- All vital services, with the exception of telecommunication and radio systems, may be supplied via 100 % rated duplicate UPS systems with a battery autonomy time of 30 min;
- Telecommunication systems and radio equipment shall be supplied by a dedicated parallel or duplicate UPS system.

For offshore installations:

- 30 min for emergency shutdown and depressurising systems;
- 45 min for process monitoring and control systems;
- 3 h for public address, platform audible alarms and status lights;
- 3 h for fire and gas detection and alarm systems;
- 3 h for emergency and escape lighting (the latter with 1 h internal battery back up);
- 24 h for SOLAS (Safety of Life at Sea) communications equipment;
- 96 h for navigational aid systems and obstruction lights.
- 24 h for helideck lighting as per PTS 20.087

The above autonomy times for offshore installations may be reduced if two 100 % redundant emergency generators are installed that feed the duplicate UPS systems, but this is subject to specific approval by the Principal.

NOTE: Specific offshore country-specific requirements may apply.

3.9.5 A.C. interruptible, maintained electricity supply

This is a power supply which is derived from the main distribution system but which has back-up power supply, typically from an automatically started, emergency diesel generator. The interruption in voltage on mains supply failure is normally 10 s to 15 s. For typical emergency generator system supply configurations reference is made to (Appendix 5)

This category of supply is used typically for energising electric motors associated with cooling systems of enclosures housing process control and instrument systems, analysers, emergency lighting, etc.

Standard drawing S 67.006 shows a typical arrangement of an a.c. interruptible, maintained electricity supply.

If mains electricity failures lasting longer than 1 h are expected to be fairly frequent, then consideration should be given to using the emergency generator to energise the a.c. UPS units, thereby extending the duration of the relevant supplies beyond the UPS battery autonomy times mentioned in (3.9.4). Standard drawing S 67.006 shows this alternative arrangement.

If the emergency generator is to be used to energise UPS units, then due consideration shall be given to the magnitude of the harmonic currents required by the rectifier of each UPS unit to be energised, and to the consequent voltage distortion created. To take into account the effects of such non-linear loads, it is recommended that the rating of the emergency generator be not less than twice the rated output of the UPS unit.

Emergency generators shall be arranged to start automatically on detection of mains power failure and to take over the supply of power on closing of the generator circuit breaker. Facilities should be provided to permit periodic on-load testing of emergency generators by enabling the generator to be synchronised with the mains supply. Each generating set shall have sufficient fuel storage capacity for at least 8 h full load operation. Increased fuel storage capacity may be specified for offshore and remote land installations.

For offshore installations, the start sequence of the emergency generator(s) shall be inhibited or the set(s) shut down if gas is detected in the generator room or in the combustion air intake. For onshore installations, it should normally be possible to locate the emergency generator in a safe area and no gas detection will be required.

4. DESIGN AND SELECTION REQUIREMENTS FOR EQUIPMENT AND CABLES

4.1 GENERATORS

4.1.1 General

The rating, type and characteristics of the generating set shall fulfil the requirements imposed upon it by the electrical power system requirements, whether operating in island mode, in parallel with other generating sets, in parallel with a public utility or any combination of these.

The above requirements shall take account of factors such as overload capabilities, load throw-on/throw-off capabilities, real and reactive power sharing, maximum speed deviations, maximum response times, reactances, inertias, etc.

If the rated speed of the prime mover is less than or equal to 3000 or 3600 r/min, as appropriate, no gearbox shall be installed.

The kVA rating of the generator should be selected by the prime mover Manufacturer, in line with the specified requirements, so that the generator does not limit the output of the prime mover over the specified operating temperature range.

The generator rated power factor shall be 0.8 lagging, unless otherwise specified.

4.1.2 Synchronous generators $\geq$ 1250 kVA

The generator and its auxiliaries shall comply with PTS 33.65.11.31., and will normally be used for base load generation services, however, it may also be installed in (centralised) emergency or stand-by systems of large process facilities.

Main cable termination arrangements shall be in accordance with PTS 33.65.11.31. However:

- for generator ratings requiring more than three cables per phase, consideration should be given to the use of phase segregated busbar connections between the generator and its transformer or switchgear;
- for transformer-connected generators, phase segregation should be maintained for all the cabling and for busbars connected to the generator, so as to minimise the possibility of multi-phase short circuits.

Each generating set should be provided with its own LV auxiliary switchboard for the supply and control of all its motor driven auxiliaries. This switchboard shall be treated as an essential services switchboard, (3.5.4) and (Appendix 4), and be provided with a normal and a stand-by incomer. The normal supply should be taken from a utilities switchboard in the power plant. The stand-by supply shall be taken from an interruptible, maintained electricity supply (emergency) switchboard. The stand-by supply should be rated equal to the normal supply.

NOTE: For a plant equipped with own generation only, consideration should be given to installing at least 50 % of the main generating sets with a black-start capability, subject to a minimum of two sets.

In power systems with extensive distribution systems at voltages above 60 kV, light load conditions may give rise to leading power factor operation. In such cases the leading power factor capability of the generator shall also be specified.

For generator protection, control, instrumentation and alarm requirements, refer to (3.7.2) and (Appendix 8).

4.1.3 Synchronous generators < 1250 kVA (Packaged Units)

The generator and its auxiliaries shall comply with PTS 33.65.11.32. It will normally be used for interruptible, maintained electrical supplies, possibly together with black-starting duties, rather than for base load generation services.

The rating of these generating sets will normally be within the range of 50 kW to 1000 kW, and supply an emergency LV switchboard. However, for power plant black-start duties and emergency or stand-by systems of large process facilities, sets with a larger rating may be

required, possibly supplying an HV system. In sizing the generating set, account shall be taken of the related motor starting requirements and UPS loads (3.9).

The generating sets shall be suitable for unattended operation and for automatic black-starting on detection of failure of the mains supply.

4.1.4 Cage induction generators

The generator shall comply with PTS 33.66.05.31. This type of generator will generally require a Static Frequency Converter (SFC) to facilitate the connection to the electrical system at its fixed frequency and voltage. The basic design of the SFC shall comply with the relevant parts of PTS 33.66.05.33.

4.2 SWITCHGEAR

4.2.1 General

Switchgear and controlgear shall be of the compartmentalised metalclad type and shall be designed to minimise any risk of developing or propagating a short circuit. The design shall also be such as to ensure personnel and operational safety during all operating conditions, inspections, maintenance, during the connection of main, control and auxiliary cables and during the equipping and commissioning of spare panels while the switchgear is live and in operation.

NOTE: The design of the switchgear shall provide such level of safety that operators do not need additional Personal Protective Equipment (PPE) under all normal operational circumstances.

4.2.2 HV switchgear

HV switchgear and controlgear shall be in accordance with PTS 33.67.51.31. The selection of switching media for new installations shall be:

- Vacuum : Preferred type of switching medium for system voltages up to 36 kV.
- SF₆ : For system voltages above 36 kV, the thermal and dielectric properties of SF₆ make it the best available arc-quenching and insulation medium.

Withdrawable units shall be designed so that back-feed via the voltage/control circuit transformer is not possible when the unit is in the withdrawn/test position.

Outdoor switchgear should only be considered for voltages exceeding 52 kV.

NOTE: This does not preclude the use of pole-mounted isolators, fuses, etc., at voltages up to and including 52 kV in association with overhead distribution networks in field areas.

Where Gas Insulated Switchgear (GIS) is installed, measures shall be taken to prevent an uncontrolled release of SF₆ gas. See also (6.1.3.1).

4.2.3 LV switchgear

LV switchgear and controlgear shall be in accordance with PTS 33.67.01.31.

Attention shall be paid to the short-circuit strength of the switchgear and all its components and the relationship between peak and rms values of the short circuit currents that may occur, particularly when the switchboard is directly connected to generators.

For single line diagrams of switchboard panels, panel identification, etc., see Standard Drawing group S 67.

Fuse protection is preferred to moulded case circuit breakers with built-in protection.

Non-metallic enclosed switchgear and controlgear is acceptable for LV sub-distribution boards, providing they are protected by short circuit current limiting devices having a maximum nominal current of 400 A.

4.3 POWER TRANSFORMERS

4.3.1 General

Power and distribution transformers shall be in accordance with PTS 33.65.40.31.

Transformers for outdoor use and rated:

- up to and including 1600 kVA shall be of the oil filled hermetically sealed type;
- above 1600 kVA and up to and including 3150 kVA should preferably be of the oil filled hermetically sealed type, but may be of the oil filled conservator type, if so determined by the Principal;
- above 3150 kVA shall be of the oil filled conservator type.

NOTE: The type of enclosure is only dependent on the kVA rating and not on the transformer voltages. Reference is also made to (3.5.3)

For use in high-humidity tropical areas, a conservator that prevents contact between the oil in the transformer tank and the ambient air should be used. This may be either the membrane type or multi-compartment type of split conservator.

In locations where fire risk must be minimised, e.g., in buildings, on offshore platforms, etc., the dielectric/cooling liquid of transformers shall be synthetic with reduced ignitability and flame-retardant characteristics, e.g., silicone fluid. In the above locations, dry-type transformers having cast resin encapsulated windings may also be used. Attention shall be paid to the shielding of live parts and possible capacitive currents when the encapsulation is touched.

NOTE: In accordance with IEC 60076, transformer kVA rating refers to rated (full load) current and rated (no load) voltage, not system voltage. The maximum load that can be delivered continuously by the transformer is therefore approximately 95 % of its rating.

Depending on the expected use, transformers should be selected according to their annual operating cost versus capital investment. Loss capitalisation should be applied as stated in PTS 33.65.40.31.

The voltage ratio of generator transformers should be selected so as to obviate the need for an on-load tap changer, e.g., 34.5/11 kV for connection of an 11 kV generator to a 33 kV system.

For motor unit transformers the need for a tap changer shall be evaluated, and where possible deleted from the design. If adjustment of the voltage is required a tap changer with bolted connections should be installed, rather than one with a switching mechanism

Preference shall be given to transformer designs that have been short circuit tested, see IEC 60076-5. For motor unit transformers, a motor starting test as described in PTS 33.66.05.31. or alternatively a short circuit test is a requirement.

4.3.2 On-load tap changers

On-load tap changers should normally be specified for grid intake transformers, unless the public utility can guarantee a voltage variation range of less than $\pm 5\%$.

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

4.4 UPS EQUIPMENT

4.4.1 General

UPS equipment shall be selected according to the preferred arrangements for a.c. and d.c. uninterruptible, maintained electricity supplies for process control and safeguarding systems, as shown in Standard Drawings S 67.006, S 67.024, S 67.025 and S 67.080. The same arrangements shall, in general, also be applied in power plants and utilities systems.

Uninterruptible, maintained electricity supply distribution boards and the associated UPS units should be located as close as possible to the loads supplied.

4.4.2 A.C. UPS units

Static UPS units, which shall comply with PTS 33.65.50.32, shall be capable of fulfilling all the vital power requirements.

Parallel static UPS units can be used to provide a single a.c. source of power to an indivisible load, e.g., at computer centres.