MANUAL

ELECTRICAL ENGINEERING GUIDELINES

DEP 33.64.10.10-Gen.

December 1995
(DEP Circular 49/99 has been incorporated)

DESIGN AND ENGINEERING PRACTICE

PREFACE

DEP (Design and Engineering Practice) publications reflect the views, at the time of publication, of:

Shell International Oil Products B.V. (SIOP)
and
Shell International Exploration and Production B.V. (SIEP)
and
Shell International Chemicals B.V. (SIC)

The Hague, The Netherlands,

and other Service Companies.

They are based on the experience acquired during their involvement with the design, construction, operation and maintenance of processing units and facilities, and they are supplemented with the experience of Group Operating companies. 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 design and engineering practice applied by Group companies operating an oil refinery, gas handling installation, chemical plant, oil and gas production facility, or any other such facility, and thereby to achieve maximum technical and economic benefit from standardization.

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

When Contractors or Manufacturers/Suppliers use DEPs 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, the Principal will expect them to follow those design and engineering practices which will achieve the same level of integrity as reflected in the DEPs. If in doubt, the Contractor or Manufacturer/Supplier shall, without detracting from his own responsibility, consult the Principal or its technical advisor.

The right to use DEPs is granted by SIOP, SIEP or SIC, in most cases under Service Agreements primarily with companies of the Royal Dutch/Shell Group and other companies receiving technical advice and services from SIOP, SIEP or SIC. Consequently, three categories of users of DEPs can be distinguished:

1) Operating companies having a Service Agreement with SIOP, SIEP, SIC or other Service Company. The use of DEPs by these Operating companies is subject in all respects to the terms and conditions of the relevant Service Agreement.

2) Other parties who are authorized to use DEPs subject to appropriate contractual arrangements.

3) Contractors/subcontractors and Manufacturers/Suppliers under a contract with users referred to under 1) or 2) which requires that tenders for projects, materials supplied or - generally - work performed on behalf of the said users comply with the relevant standards.

All administrative queries should be directed to the DEP Administrator in SIOP.

NOTE: In addition to DEP publications there are Standard Specifications and Draft DEPs for Development (DDDs). DDDs generally introduce new procedures or techniques that will probably need updating as further experience develops during their use. The above requirements for distribution and use of DEPs are also applicable to Standard Specifications and DDDs. Standard Specifications and DDDs will gradually be replaced by DEPs.

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APPENDICES

1. INTRODUCTION

1.1 SCOPE

This DEP is a revision of that with the same title and number dated December 1992. It 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 SIOP and SIEP, the distribution of this DEP is confined to companies forming part of the Royal Dutch/Shell Group or managed by a Group company, and to Contractors nominated by them (i.e. the distribution code is "C" as defined in DEP 00.00.05.05-Gen.).

This DEP is intended for use in oil refineries, chemical plants, gas plants, supply/marketing facilities and production installations.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this DEP 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 with the object of obtaining agreement to follow this DEP as closely as possible.

1.3 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 (9).

2. DEFINITIONS

2.1 GENERAL DEFINITIONS

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

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

The **Principal** is the party which 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.

2.2 TECHNICAL BASIC DEFINITIONS

NOTE: The IEC code is stated, if 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 50

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 79-15.

Distribution of electricity, 601-01-10, IEC 50

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 50

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

Emergency Lighting

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

Escape Lighting

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

Essential service

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

Firm capacity

The installed capacity less the stand-by capacity.

Frequency deviation, 604-01-06, IEC 50

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

Generation of electricity, 601-01-06, IEC 50

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

Hazardous area, 426-03-01, IEC 50

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 50

The set of voltage levels in excess of low voltage.

Installed capacity

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

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 50

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

Nominal value, 151-04-01, IEC 50

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 50

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 nor 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 50

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 50

The transfer of electricity through a power transformer.

Transmission of electricity, 601-01-09, IEC 50

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 more than 0.5 ms.

Vital service

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

Voltage deviation, 604-01-17, IEC 50

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 50

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 50

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 50

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 50

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 50

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

Zone 21 (in the classification of hazardous dust areas), IEC 1241

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

NOTE: A dust layer may be present and should be taken into account.

Zone 22 (in the classification of hazardous dust areas), IEC 1241

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

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

2.3 INSTALLATION AND EQUIPMENT

Bus coupler circuit breaker, 605-02-40, IEC 50

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 50.

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

Controlgear, 441-11-03, IEC 50

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 50

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

Distribution substation/switchboard

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

Generating set, 602-02-01, IEC 50

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

Generator, 411-02-01, IEC 50

A machine which converts mechanical power into electrical power.

Intake substation/switchboard

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

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

Inverter

A converter for conversion from 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 50

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 50

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 50

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 50

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 (VSDS)

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

3. DESIGN AND ENGINEERING PRINCIPLES

3.1 STANDARDS, CODES AND REGULATIONS

This DEP 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 DEP.

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 DEP 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 DEP and/or MESC (Group Materials and Equipment Standards and Code) specifications, which in turn shall be considered as supplementary to IEC equipment standards.

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

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

In the event of contradiction between the requirements of this DEP and those of DEP specifications referenced in this DEP, 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.

3.2 OPERATIONAL SAFETY AND RELIABILITY

The design of the electrical installation shall be based on the provision of a safe and reliable supply of electricity at all times. Safe conditions shall be ensured under all operating conditions, including those associated with start-up and shutdown of plant and equipment, and throughout the intervening shutdown periods.

NOTE: Reference shall be made to Shell HSE Committee publication 'Recommendations for Electrical Safety'.

The design of electrical systems and equipment shall ensure that all operating and maintenance activities can be performed safely and conveniently and shall permit periods of continuous operation of at least 4 years. To 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 (4). The simultaneous failure of two pieces of equipment shall not be catered for.

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

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

Special attention shall be paid to provisional and temporary installations required for the erection of permanent installations to ensure compliance with basic rules for good working practice and safety and to cope with increased hazards which are present in temporary installations. The specific requirements associated with the design and installation of temporary facilities, as described in Appendix 5, shall be adhered to.

3.3 PROTECTION AGAINST EXPLOSION AND FIRE HAZARDS

3.3.1 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. For the installation of electrical equipment in hazardous areas, IEC 79-14 shall be complied with.

Electrical equipment should, as far as is reasonably practicable and economic, be located in the least hazardous area. Control rooms and switchhouses 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 79-14.

The construction of electrical equipment should comply with the requirements of the relevant parts of IEC 79 or CENELEC documents EN 50014 to 50020 inclusive, EN 50028 and EN 50039. Appendix 1 summarises the various types of protection of electrical equipment that are permissible in hazardous areas, and lists some national standards that are equivalent to the above-mentioned CENELEC standards, and as such are also acceptable. The specification or procurement of equipment complying with other standards, different from the above, requires specific approval from 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 equipment 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, all motors and inherently non-sparking equipment shall have type of protection 'n'. Inherently sparking equipment shall have type of protection 'd' or 'p', as stated for Zone 1. HV motors with type of protection 'n' shall not be installed in Zone 2 areas where:

  1) the motor voltage exceeds 11 kV,

  or 2) the motor drives a centrifugal/screw hydrocarbon gas compressor.
- For the purpose of commonality of spares and to cater for the possibility of re-classification of areas, consideration should be given to installing Zone 2 equipment in outdoor non-hazardous areas within process installations.

  NOTE: This applies specifically to motors, luminaires, RCUs and power and convenience outlets.
- Electrical equipment installed in indoor, non-hazardous areas within process areas shall be of a standard industrial type as specified in the relevant equipment DEPs.
  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 (7.1).
- 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.

3.3.2 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 1241.

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

For Zone 21, electrical equipment shall have dust-tight enclosures, i.e. IP6X.

For Zone 22, electrical equipment shall have dust-protected enclosures, i.e. IP5X minimum.

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

3.4 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.

3.5 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 DEP 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.

3.6 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.

4. ELECTRICAL SYSTEM DESIGN

4.1 GENERAL

The design of the electrical installation shall be based on the fundamental principles referred to in (3). 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 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 the production of a system design description, a key line diagram, basic layout drawings and functional/outline specifications.

The electrical system and associated controls shall be designed on the basis of forming 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 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 designing electrical power systems, 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.

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.

Power factor control and/or power transfer to alternative energy sources, mainly in connection with tariff characteristics of outside supplies, 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.

The scope of the system studies shall be defined by the Principal and agreed with the Contractor before their commencement. Where there is a public utility interconnection, the public utility's study requirements 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.

Reference shall be made to Appendix 10.

4.2 ELECTRICAL LOADS AND ELECTRICITY CONSUMPTION

4.2.1 Classification of loads

Electrical loads shall be classified as performing a service which is 'vital', 'essential', or 'non-essential', as defined in (2.2).

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

4.2.1.1 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 feedwater 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 on offshore platforms 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.

4.2.1.2 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 a view to maintenance requirements of the pumps,
- Power supply to process analysers by means of a duplicate supply system with changeover facility,
- Power supply to security lighting and plant area lighting.

4.2.1.3 Non-essential service

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

4.2.2 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 DEP 05.00.10.80-Gen. 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 (4.5).

Standard Form DEP 05.00.10.80-Gen. 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.

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 DEP 33.66.05.31-Gen.

4.3 SYSTEM VOLTAGES AND FREQUENCY

4.3.1 General

The system voltages shall be selected from IEC 38, 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 should be 400/230 V three phase and neutral. This voltage should also be considered for extensions to existing plants requiring new LV distribution systems.

NOTE: 400/230 V is the nominal value recommended in IEC 38 which also states:

"The nominal voltage of existing 220/380 V and 240/415 V systems shall evolve towards the recommended value of 230/400 V. The transition period should be as short as possible and should not exceed 20 years after the issue of this IEC publication (1983). During this period, as a first step, the electricity supply authorities of countries having 220/380 V systems should bring the voltage within the range 230/400 V +6%/-10% and those of countries having 240/415 V systems should bring the voltage within the range 230/400 V+10%/ -6%. At the end of this transition period the tolerance of 230/400 V ±10% should have been achieved; after this the reduction of this range will be considered."

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.

4.3.2 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 34-1.

All loads shall be balanced such that the negative phase sequence components of voltage and current at any point in the system shall not exceed the values quoted in IEC 34-1.

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.

4.3.3 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.

Harmonic voltage distortion at any point in the system should not exceed the values tabulated below:

Odd harmonics				Even Harmonics	
Order	**Relative Voltage**	**Order**	**Relative Voltage**	**Order**	**Relative Voltage**
3	5%	15	0.5%	2	2%
5	6%	17	2%	4	1%
7	5%	19	1.5%	6-24	0.5%
9	1.5%	21	0.5%		
11	3.5%	23	1.5%		
13	3%	25	1.5%		

Total Harmonic Distortion should be no more than 8%.

NOTES:

1. The values of maximum permissible harmonic distortion shown are taken from EN 50160 and 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 is consequently a matter to be ascertained for each project individually, depending on the relative magnitude of the above-mentioned parameters.
2. The above-mentioned 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.

4.4 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 such 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 or 30 minutes.

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.

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 HV electric motors (4.7.6). 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 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 (4.7.6).

4.5 SUPPLY CAPACITY

4.5.1 General

The firm capacity of the electrical points of supply (generation, and associated power plant switchgear, and/or grid intake transformers and switchgear) shall be capable of supplying continuously 125% of the peak load, assessed according to the applicable load data (4.2.2), without exceeding specified voltage limits (4.3.2), and equipment ratings.

NOTES:
1. The above-mentioned 25% spare capacity is a requirement to cater for the possibility of future debottlenecking and/or addition of units. Where future expansion plans are unlikely, or are specifically not to be catered for, the spare capacity at the finalisation of design may be reduced accordingly but shall never be less than 10%.
2. The applicable load data shall identify the future plant loads, if any, on which the assessment of firm capacity has been based.

The spare capacity at PLANT SUBSTATIONS shall be a minimum of 10% at start of the construction 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 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 shutdown 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.

4.5.2 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.

4.5.3 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 (e.g. of on-load tap-changers, circuit breakers, etc.), functional testing (e.g. of protective relays and trip circuits) and possible repair (e.g. cables and cable terminations) 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 (4.5.1).

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 of transformers feeding plant substations should be such that the rated current of their low voltage winding does not exceed 2000 A when feeding an HV switchboard, or 2500 A when feeding an LV switchboard. This results in the following preferred maximum transformer ratings:

- 20 MVA, if feeding a 6 kV or 6.6 kV switchboard,
- 10 MVA, if feeding a 3 kV or 3.3 kV switchboard,
- 1600 kVA, if feeding an LV switchboard.

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

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 such as to permit simultaneous maintenance of the feeder circuit.

4.5.4 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 on the basis of facilitating system extension and operating flexibility which would otherwise involve significant disruption of electricity supply or if facilitating a supply of differing priority/security from each busbar. An example of the latter would be where own generation and higher priority loads would be 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 case of grid supply interruptions.

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

HV and LV switchboards shall generally have a maximum of three sections and, consequently, a maximum of two bus section switches. LV switchboards with four sections in 'H' configuration are acceptable. 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: In the above context, 'normally open' and 'normally closed' refer to the bus section switch position when all the incoming switchboard circuits are available.

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 the selection of any main or stand-by consumers for operational use.

For recommended plant switchboard configurations, refer to Appendix 8.

Normally open bus section switches and/or interconnectors that may have to be operated simultaneously in the closed position shall be rated such 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.

4.5.5 Electric motors

Electric motors complying with DEP 33.66.05.31-Gen. 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 DEP 33.66.05.33-Gen.

4.6 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 the parallel operation of all supplies which can be operated in parallel, due regard being given to the distribution of short circuit current and to the limiting effect of system protective devices or control schemes, e.g. fuse links, Is-limiters, automatic supply changeover arrangements, etc.

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 interlocking 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 firm capacity of the supply is fully utilised,
- future planned increases in short circuit level due to the direct or indirect connection of machines, public utility supply or other sources of short circuit current.

For a new switchboard at intake, power plant or distribution substations, a margin of not less than +10% shall be allowed between the calculated fault level under the above-mentioned conditions and the specified short circuit rating of the equipment.

NOTE: The margin specified above is provided to allow for the tolerances permitted for machine characteristics and for increase in fault contributions arising from variations in system voltage.

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 when based on 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 shall be 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 particularly or economically realised without the use of such devices.

When determining equipment short circuit ratings, 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.

NOTE: Short circuit current contributions from asynchronous 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 56 and IEC 947-2. 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.

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

4.7 ELECTRICAL PROTECTION AND CONTROL

4.7.1 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 DEP 33.67.51.31-Gen. and DEP 33.67.01.31-Gen. for HV and LV switchgear respectively and with the relevant Standard Drawings in the S 67 series.

Notwithstanding these requirements, 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 (4.7.4) and (4.8).

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 (4.8). 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 to affect plant operations as little as practicable and economically justifiable after system or equipment failures, see (4.5.2) and Appendices 2 and 3.

The type and characteristics of protective relays 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 relays shall have IDMT characteristics of the standardised type A, type B or type C (standard inverse, very inverse or extremely inverse time respectively) in accordance with IEC 255-4.

Protective relay settings shall be based on a study of the fault conditions for which the protective system has been incorporated. Protective relay systems shall be selective and the settings shall be co-ordinated such 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 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 relay settings and co-ordinated relay and fuse characteristics, etc., plotted in graphical form.

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 relay settings.

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 loads may be accomplished.

The protection of the interconnections with the public utility shall be subject to the Principal's requirements and shall be co-ordinated and agreed with the public utility.

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.

4.7.2 Main generators

Depending on their duty, main generators shall, as a minimum, be equipped with the protection, control, alarm and metering equipment 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 (4.8.2).

Generator protection, control and monitoring equipment is normally designed and selected by the generating set supplier in accordance with the Principal's requirements. 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.

The trip signals from all protection relays shall trip the prime mover, the generator circuit breaker and 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.

Main generators shall be fitted with the following control equipment:

- 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 in the case of the automatic voltage control system failure. 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 maintain the generator power factor constant when operating in parallel with a public utility supply. This shall be automatically switched off when the generating set(s) is/are in island operation.

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.

Control shall be designed such 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.

Where it is intended that the power plant can be operated unmanned, or where it is desired to minimise operator intervention, the generators and their drivers can be operated under the control of a central load management control system. The need for, and the scope of, such a system shall be determined by the Principal. Alternatively, isochronous control of the largest generating set may be considered when operating an island mode.

Gas turbine and diesel engine driven generating sets shall be provided with automatic control schemes. This shall include the 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 independent of the rest of the power system.

Main generators shall be provided with the alarm equipment, indicating instruments and integrating meters stated in Appendix 6.

4.7.3 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.

Grid intake circuits shall be provided with the alarm equipment, indicating instruments and integrating meters stated in Appendix 6.

4.7.4 Switchgear

Unrestricted short circuit current and earth fault protective devices shall be applied at the supply end of the switchboard incoming circuit feeders (4.7.5, 4.7.8 and 4.7.9). 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 the case of transformer circuits, earth fault protection shall also be provided in the transformer secondary neutral-earth connection (4.7.5).

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 and shall be applicable 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 DEP 33.67.51.31-Gen.

4.7.5 Power transformers

Distribution transformers shall normally be connected Dyn.

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 which 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 relay which shall be energised by a CT placed in the neutral-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. The characteristic of this relay shall be extremely inverse for LV systems, or normal inverse or definite time for HV systems (4.7.1). The setting of the earth fault protection relay shall be the minimum practicable. In the case of an LV secondary winding, the setting shall correspond to a relay operating time of 1 s maximum for a relay operating current equal to 50% of the minimum prospective symmetrical 3-phase short circuit current.

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 DEP 33.65.40.31-Gen., and to Standard Drawings S 67.049 - S 67.052 inclusive. For alarm and instrumentation requirements, refer to Appendix 6.

4.7.6 Capacitors

HV capacitor banks shall comprise individually fused capacitor units. The fuses shall comply with IEC 549 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 by 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 x In, and must be able to withstand transient inrush currents up to 100 x In.

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

4.7.7 Electric motors

4.7.7.1 General

Motor starters shall comply with DEP 33.67.01.31-Gen. or DEP 33.67.51.31-Gen., as applicable.

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

NOTE: Fused contactors should not be applied on circuits exceeding 6.6 kV.

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 (4.8) and Appendix 9.

In cases where current operated overload relays 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 percent of the motor full load current in accordance with NFPA 20. Such motors shall be identified by the Principal.

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, as such, IMCS should 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 standard technical specification T-2.238.761.

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 "O" (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, in the case of use of an IMCS, via the central unit.

Motors which 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 relays protecting motors with type of protection 'e' in Zone 1 areas shall comply with EN 50019 and be provided with a certificate of conformity accordingly.

4.7.7.2 Variable speed drive systems (VSDS)

VSDS shall be equipped with the protection, control, alarm and metering equipment specified in DEP 33.66.05.33-Gen., in Standard Drawing S 67.057 and in Appendix 6 of this DEP.

4.7.7.3 Synchronous motors

Synchronous motors shall be equipped with the protection, control, alarm and metering equipment shown in Standard Drawing S 67.047 and stated in Appendix 6.

Synchronous motors shall be fitted with the following control equipment:

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

4.7.7.4 Asynchronous, cage induction motors

HV cage induction motors shall be equipped with the protection, control, alarm and instrumentation equipment specified in DEP 33.67.51.31-Gen. 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 the possibility of too frequent or consecutive starting exists (e.g. loading pumps), restrictive start relays shall be provided.

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 equipment specified in DEP 33.67.01.31-Gen. 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 have an annunciator panel with first failure alarm.

4.7.8 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 relays.

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 relay with the necessary time delay. The operating characteristic of the earth fault protection relay shall be co-ordinated with the upstream as well as the 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.

4.7.9 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 be subject to 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) at each end of the line. Earth wires may be omitted only after approval by the Principal. Lightning arresters shall be provided with counters.

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

4.7.10 UPS equipment

D.C. and a.c. UPS equipment shall be protected in accordance with DEP 33.65.50.31-Gen. and DEP 33.65.50.32-Gen. 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. MCCBs shall be used for feeders exceeding 400 A.

Sub-distribution circuits fed by d.c. or a.c. UPS systems shall be fuse protected.

4.7.11 Electric heaters

Control and protection of LV electric process heaters 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. Over-temperature protection shall be provided by at least two thermocouples located in the area of highest anticipated sheath temperature.

When static converters are required to control the heater output, they shall be equipped with the following as a minimum:

- incoming voltage monitoring,
- fuse protection for the semi-conductor devices,
- over-temperature in the converter panel.

4.7.12 Emergency generators

Control and protection of LV emergency generators shall be as shown in Standard Drawing S 67.070. Facilities shall be provided to enable full load tests of the generating set to be carried out during normal plant operation.

4.7.13 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 947-2, 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.

4.7.14 Other electrical equipment

Local isolating switches shall be provided for electric process heaters, motor operated valves (MOVs), trace heating systems, cathodic protection equipment, etc., and shall be located near to the equipment or on their pertaining 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.

4.7.15 Integrated control systems (ICS)

Central monitoring and control of the electrical supply and distribution system should be integrated with the plant process Distributed Control System (DCS). A dedicated ICS for the electrical power system should be considered where centralised metering and overall electrical system supervision is required.

In addition an ICS should provide additional features advantageous to plant operation and maintenance, e.g. alarm logging, fault recording, plant performance trends, self-diagnostic facilities, energy management and, if necessary, load shedding. The use of an ICS for remote control of switchgear should be subject to the Principal's approval.

Trip signals from the electrical protection shall be derived locally at the panel, and not form part of the external control system.

4.8 SYSTEM EARTHING

4.8.1 General

A.C. system neutrals shall normally be earthed as stated below. They shall not be designed for unearthed operation, except where forming an extension to an existing unearthed system.

The preferred system earthing arrangements are given in Appendix 9.

4.8.2 HV systems

HV electrical systems shall be earthed by means of dedicated earth electrodes connected to the plant main earth grid (6.5.1).

HV system neutrals shall be earthed at each source of supply (transformer, direct-connected generator) as shown in Appendix 9.

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). 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 it is found to be necessary to connect circuit breakers to an existing solidly earthed system, due consideration must be given to selection of C.T.s to prevent C.T. 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.

In situations 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, which ensures 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 the possibility exists for zero sequence harmonic currents (principally, the third harmonic) to 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 which exist 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.

DEP 33.65.11.31-Gen. quotes maximum acceptable harmonic voltages in the stator voltage waveform of synchronous generators.

In situations where generators of dissimilar ratings, characteristics or loadings are to be operated in parallel such 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 $3I_{co}$ 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.

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. It is advisable in this case to install a low value earthing resistor 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.

4.8.3 LV systems

LV electrical system neutrals at each source of supply shall be solidly earthed by means of dedicated earth electrodes which have a direct, low impedance connection to the plant main earth grid (6.5.1). The system of earthing shall be designated 'TN-S', in accordance with IEC 364-3.

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 (4.7) and the provision of earthing grid conductors (6.5). 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. (See Appendix 12).

4.8.4 UPS systems

A.C. UPS systems shall have their neutrals solidly earthed. This applies equally to single phase and three phase systems. The inverter (output) neutral shall be connected to the neutral of the bypass mains neutral, which is solidly earthed (4.8.3). If isolating transformer(s) are required in the UPS maintenance bypass supply, then the inverter neutral(s) and the transformer secondary neutral(s) shall be solidly earthed to the instrument 'clean earth' system (6.5.5). Reference shall be made to Standard Drawing S

67.006.

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.

4.9 ELECTRICITY SUPPLY FOR VITAL SERVICES

4.9.1 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, as follows: (For typical electricity supply arrangements that fulfil the requirements of each of the following categories, refer Standard Drawing S 67.006.)

4.9.2 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 DEP 33.65.50.32-Gen. Parallel operation of duplicate a.c. UPS units is not preferred because of the risk of common mode failure.)

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 DEP 33.65.50.31-Gen.

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, itself, shall 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 seconds. (Refer 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.

4.9.3 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.

4.9.4 Battery autonomy times

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

For onshore installations:

- 1/2 hour for process plant shutdown
- 1 hour for utility plants
- 1 hour for emergency lighting
- 10 minutes for non-process computer installations
- 8 hours for fire fighting, fire alarm systems and telecommunication systems.

For offshore installations:

- 3 hours for fire and gas detection and alarm systems
- 30 minutes for emergency shutdown and depressurising systems
- 45 minutes for process monitoring and control systems
- 3 hours for public address, platform audible alarms and status lights
- 24 hours for SOLAS communications equipment
- 90 minutes for emergency and escape lighting
- 96 hours for navigational aid systems and helideck lighting

The above autonomy times should not be reduced, even if an emergency diesel generator is installed to provide back-up supplies to UPS units (4.9.5).

4.9.5 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 to 15 seconds.

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 of greater than one hour are a reasonably frequent expectation, 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 (4.9.4). 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 hours full load operation.

For offshore installations the start sequence of the emergency generator(s) shall be inhibited or the set(s) shut down in the event of gas detection 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.

5. DESIGN AND SELECTION REQUIREMENTS FOR EQUIPMENT AND CABLES

5.1 GENERATORS

5.1.1 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.

When 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, such 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.

5.1.2 Large synchronous generators (≥ 1250 kVA)

The generator and its auxiliaries shall comply with DEP 33.65.11.31-Gen., and will normally be used for base load generation services, rather than emergency or stand-by duties.

NOTE: DEP 33.65.11.31-Gen. refers to synchronous generators rated 1250 kVA and above, and so relates primarily to HV generators; however, it may be applied equally to LV generators of any rating which perform a base load duty.

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.

Main cable termination arrangements shall be in accordance with DEP 33.65.11.31-Gen. 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, (4.5.4) and (Appendix 8), 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.

For generator protection, control, instrumentation and alarm requirements, refer to (4.7.2) and (Appendix 6).

5.1.3 Small synchronous generators (< 1250 kVA) (Packaged Units)

The generator and its auxiliaries shall comply with DEP 33.65.11.32-Gen. 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 - 1000 kW, and supply an emergency LV switchboard. However, for power plant black-start duties, 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 (4.9.3).

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

5.2 SWITCHGEAR

5.2.1 General

Switchgear and controlgear shall be of the compartmentalised metalclad type and shall be designed to minimise any risk of developing a short circuit 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.

5.2.2 HV switchgear

HV switchgear and controlgear shall be of the withdrawable type in accordance with DEP 33.67.51.31-Gen. The selection of switching media for new installations shall be:

either - SF_6 (sulphur hexafluoride): its thermal and dielectric properties make it the best available arc-quenching and insulation medium, especially at higher voltage levels,

or - Vacuum: this can be generally applied up to a highest system voltage of 36 kV. This type is preferred for fused contactor feeders.

Other switching media, i.e. oil and air, shall only be considered for extensions to existing switchboards using those media, and their utilisation is subject to approval by the Principal.

Withdrawable units shall be designed such 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 36 kV.

Indoor gas insulated switchgear (GIS) shall only be considered for voltages exceeding 60 kV when available space is limited or when environmental conditions would result in unreliable operation of open terminal switchgear. Where GIS is installed measures shall be taken to prevent an uncontrolled release of SF_6 gas. See also (7.1.3.1).

NOTE: This does not preclude the use of pole-mounted isolators, fuses, etc. at voltages up to and including 36 kV in association with overhead distribution networks in field areas.

5.2.3 LV switchgear

LV switchgear and controlgear shall be in accordance with DEP 33.67.01.31-Gen.

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 355 A.

5.3 POWER TRANSFORMERS

5.3.1 General

Power and distribution transformers shall be in accordance with DEP 33.65.40.31-Gen.

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.

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 touching the encapsulation.

NOTE: In accordance with IEC 76, transformer kVA rating refers to rated (full load) current and rated (no load) voltage, not system voltage. The maximum load which 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 DEP 33.65.40.31-Gen.

The voltage ratio of generator transformers should be selected such 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.

Preference shall be given to transformer designs that have been short circuit tested, see IEC 76-5. For motor unit transformers, a motor starting test as described in DEP 33.66.05.31-Gen. or alternatively a short circuit test is a requirement.

5.3.2 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 ± 5%.

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

5.4 UPS EQUIPMENT

5.4.1 General

UPS equipment shall be selected based on 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 for 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.

5.4.2 A.C. UPS units

Two types of a.c. UPS units should be considered:

- static UPS units, which shall comply with DEP 33.65.50.32-Gen.,
- hybrid UPS units.

NOTE: Hybrid UPS units should be specified in accordance with manufacturers' standards.

Subject to satisfying the requirements of Standard Drawing S 67.006 with respect to UPS interconnections, the use of static UPS units up to 400 kVA unit rating is preferred on the grounds of:

- lower capital cost;
- smaller space and weight requirement;
- low maintenance requirement;
- adequate reliability.

For loads requiring UPS units of higher rating, consideration should be given either to sub-dividing the load into logically arranged groups, e.g. on a geographical and/or plant unit basis, or to using hybrid UPS units.

Hybrid (static/rotary) UPS units are preferred in situations requiring duplicate (redundant) UPS units to operate in parallel and provide a single a.c. source of power to an indivisible load, e.g. at computer centres.

When supplied from a static a.c. UPS system, either direct or through rectifiers, loads shall be arranged such that their circuit fuse ratings are sufficiently low to ensure the fuse exhibits cut-off in the event of a short circuit. To facilitate this, fuse ratings should not exceed 10% of the rated output current of each UPS unit. Load circuit fuse ratings exceeding 10% of the UPS rated current should only be permitted if the mains supply frequency is sufficiently stable to enable the UPS static bypass circuit to be relied on to operate the fuse in the event of a load circuit fault.

The required limits on the output conditions of voltage, phase symmetry, frequency and distortion are stated in DEP 33.65.50.32-Gen., and are equally applicable to hybrid UPS units.

5.4.3 D.C. UPS units

D.C. UPS units shall be in accordance with DEP 33.65.50.31-Gen.

Conventional thyristor controlled bridge rectifiers should be used in d.c. UPS units. However, the switched mode power supply (SMPS) type of d.c. UPS unit may be considered for applications where a physically small unit is necessary because of space limitations, or where the superior dynamic output response and lower ripple voltage are required by the load. The use of switched diodes or battery cell tap regulation as a means of controlling the output voltage of d.c. UPS units within the specified operating limits is not preferred. The correct selection of battery capacity and provision of redundancy in accordance with the preferred arrangement in Standard Drawing S 67.025 should obviate this need.

5.4.4 Batteries

DEP 33.65.50.32-Gen. specifies three alternative types of battery that are technically acceptable for UPS duty:

- vented lead-acid batteries (Planté type) complying with IEC 896-1,
- vented nickel-cadmium (Ni-Cd) batteries (pocket plate type) complying with IEC 623,
- valve-regulated gas recombination type lead-acid batteries complying with BS 6290 Part 4.

NOTE: IEC 896-2 for valve-regulated lead-acid batteries is currently under preparation.

The lower capital costs and lower maintenance requirements associated with valve-regulated batteries and the fact that no dedicated battery room is required normally provides an economic incentive to select this type of battery. Users should be aware, however, that this type of battery requires close control of its working temperature if the desired reliability and lifetime are to be achieved. A working temperature not exceeding 20 °C is preferable.

NOTES:
1. Valve-regulated lead-acid batteries require no special ventilation as the amount of gas normally produced can be safely dissipated in a naturally or mechanically ventilated room (i.e. not gas-tight), housing other equipment.
2. The life expectancy of a valve-regulated lead-acid battery is dependent on its working temperature. A "10 year battery" will only give this lifetime if operated at 20°C. Lifetime will halve for every 10°C rise in working temperature.

Vented lead-acid or Ni-Cd batteries should be used where:

- battery capacities in excess of 400 Ah are required, so as to avoid the need to connect batteries in parallel;
- where extreme temperature fluctuations are expected under normal operating conditions, e.g. outside the range of 10-30 °C.

For switchgear tripping and closing supplies, Ni-Cd batteries shall be used because of their greater dependability in terms of being able to provide the necessary tripping and closing power within the permitted voltage tolerances and throughout the temperature variations experienced in substations, during the (typically 20 year) life expectancy of the battery.

For installations such as power plants, or large substations where a number of switchgear assemblies are installed, consideration may be given to using duplicated common DC supply for control, signal and alarm functions. A lead acid battery of the Plante or valve regulated type may then be specified.

NOTE: Vented lead-acid and Ni-Cd batteries should not be used within the same plant for the same application.

5.5 CAPACITORS

Capacitors shall be of the low-loss, metal-enclosed, hermetically sealed type. LV capacitors should be of the self-healing type complying with IEC 831, and may be of either single phase or three phase unit construction. HV capacitors shall comply with IEC 871. All capacitor units should have individually fused elements; if this is not feasible for certain types of LV capacitor, internal overpressure disconnectors shall be provided. Internal fuses and internal overpressure disconnectors shall comply with IEC 593.

HV capacitor banks shall be installed outdoors.

Attention shall be paid to the capacitor inrush currents and in particular to the possibly very high inrush currents when being paralleled with already energised capacitors. Air cored reactors should be installed in HV capacitor banks to limit the inrush currents. See IEC 831 or IEC 871, as relevant.

Consideration shall be given to the relatively long discharge times (from the operating voltage down to 75 V) allowed in the relevant IEC standards, i.e. 3 minutes for LV capacitors and 10 minutes for HV capacitors. Shorter discharge times shall be specified where necessary to satisfy national or local requirements. In any event a clear warning notice shall be posted on any cubicle or compartment containing capacitors. An interlock system shall be provided for all automatically controlled capacitor banks to prevent re-energisation, when the residual voltage is above 10% Un.

5.6 ELECTRIC MOTORS

5.6.1 General

The minimum/maximum power ratings of electric motors in relation to system voltage are stated in DEP 33.66.05.31-Gen.

The selection of motor voltages and power ratings should conform to the following:

Switchboard nominal voltages	Maximum LV motor rating	Minimum HV motor rating
LV and 3.0/3.3 kV	110 kW	132 kW
LV and 6.0/6.6 kV	185 kW	200 kW

The installation of LV motors of higher rating than the above-mentioned maxima may be justifiable where, for example, the installation of an HV system would be avoided.

Any motor driven auxiliaries associated with the main motor or its driven equipment shall be fed from a nearby switchboard, which shall have a load classification (4.2.1) equal to or better than that of the main drive. The auxiliary drives shall be connected to a section of the switchboard which is fed from the same supply source and supply circuit as the main unit in order to obtain optimum availability of the total system.

Asynchronous cage induction motors are preferred on account of their simple robust construction and lower capital cost. Synchronous motors are more efficient than asynchronous motors (of equal rating), but they have a higher capital cost. The use of synchronous motors will normally be cost effective at ratings exceeding 10 MW, depending on speed, manufacturer, etc. For low speed applications and for installations in which power factor compensation is beneficial, synchronous motors of less than 10 MW may be economically justifiable. Synchronous motors should not be considered at ratings below 2 MW.

The generation of pulsating torques by a synchronous motor during run-up may need to be addressed by the driven equipment manufacturer.

5.6.2 Synchronous motors

The synchronous motor and its related equipment shall comply with DEP 33.66.05.31-Gen., but shall as an overriding factor fulfil the requirements imposed upon it by the power system and its operational requirements, overload capabilities, load/speed/time responses, etc.

5.6.3 Asynchronous cage induction motors

The asynchronous motor and all its related electrical auxiliary equipment shall comply with DEP 33.66.05.31-Gen.

5.6.4 Special motors

Submerged motors driving sump pumps shall be fed by oil-resistant cables.

D.C. motors shall generally be specified by the relevant driven equipment supplier to fulfil the duty required at the minimum specified d.c. system voltage. D.C. motors shall comply with the relevant clauses of DEP 33.66.05.31-Gen., e.g. enclosure classification, bearing requirements, etc.

5.6.5 Variable speed drive systems (VSDSs)

The electric VSDS with all its related equipment shall comply with DEP 33.66.05.33-Gen.

The application of a VSDS shall be considered where it can be demonstrated that the VSDS will benefit the operation, maintenance and efficiency of the plant.

NOTE: These considerations shall be reviewed by an appropriate multi-disciplinary team.

Examples of the types of drives where a VSDS can be beneficial are:

- centrifugal pumps, including submersible pumps,
- recycle gas compressors and booster compressors,
- fin-fan coolers,
- extruders.

Some of the benefits that can accrue include:

- wide range of throughput at improved efficiency, resulting in energy savings in comparison with constant speed drive and throttling control,
- direct drive of driven equipment, i.e. dispensing with gearbox.

The factors stated in (5.6.1) relating to the selection of synchronous or asynchronous motors also apply to VSDS, subject to the following point.

For drive ratings exceeding 4 MW, synchronous motors are preferred on account of their proven technology.

5.7 METERING, PROTECTION, AND CONTROL EQUIPMENT

5.7.1 General

The selection of metering, protection, and control equipment shall be based on

- fulfilling the design and safety requirements stated in (4.7),
- satisfying the operational requirements of the plant,
- optimising capital and operating costs.

The majority of this equipment should be purchased with the associated main equipment, e.g. switchgear and generators, and shall comply with the requirements specified in the relevant DEPs and Standard Drawings. In certain cases the equipment may be specified separately if an overall protection, control or supervisory system, e.g. a load-shedding scheme, is required.

5.7.2 Meters, relays and instrumentation

The requirements for the above are stated in DEP 33.67.01.31-Gen., DEP 33.67.51.31-Gen., Standard Drawings S 67 and Appendix 6 of this DEP.

5.7.3 Protection relays

Both electromechanical and electronic relays are acceptable. Microprocessor based electronic relays using digital measuring techniques are preferred for new installations. Electronic relays shall be provided with electromechanical output elements to provide electrical isolation, and shall have disturbance immunity in accordance with IEC 255 and IEC 801.

5.7.4 Instrument transformers

Current transformers (CTs) and voltage transformers (VTs) shall be specified with characteristics, e.g. rated output and accuracy class, which are adequate for the associated protection, control and/or monitoring equipment. They shall comply with the requirements stated in DEP 33.67.51.31-Gen. or DEP 33.67.01.31-Gen.

The rated output of VTs shall, as a minimum, be equal to the connected burden of the protection, control and/or monitoring devices, including the lead burden, plus 25% spare, rounded up to the next standard rating.

5.7.5 Annunciator panels

Each substation with HV switchgear and/or any electricity generation capacity installed shall be provided with an annunciator panel centralising the individual alarm and trip functions of the substation equipment.

Electronic annunciators are preferred. The annunciator panel shall provide a voltage-free common alarm to a manned control room. In the 'fault acknowledged' state the common alarm shall have been cleared.

The annunciator panel shall monitor at least the alarms and/or trip functions stated in Appendix 6. The annunciator panel shall either be supplied from an uninterruptible, maintained electricity supply or have internal rechargeable batteries.

5.8 CABLES, WIRES AND ACCESSORIES

5.8.1 General

Wherever possible and consistent with the design of other plant facilities, underground cabling should be used because of the inherent protection against fire and mechanical damage. However, the application of above ground cabling is acceptable, subject to the Principal's approval, provided a definite cost advantage can be demonstrated, or where it is standard local practice.

Depending on the possibility of soil contamination or chemical attack, cables shall be provided with a lead sheath.

Unless the soil will definitely remain free from contamination, lead sheathed underground cable shall be used in oil and chemical plants. Non-lead-sheathed cables shall only be used in areas:

- where the probability of hydrocarbon or chemical contamination of the ground is very low, for example in gas plants (LNG/NGL);
- with predominantly above ground installations.

The use of multicore cables is preferred to single core cables. However, single core cables may be used for practical and/or economic reasons on short runs, e.g. generator and transformer secondary cables or in the case of high current ratings where two parallel multicore cables of the largest cross section permitted would not suffice.

Cables for protection, controls, indications and alarms for a particular item of plant or circuit (e.g. generator, motor, transformer, etc.) shall be dedicated to that item of plant or circuit.

NOTE: This requirement need not apply to 4-20 mA transducer signals.

Individual cables shall be used for each of the following:

- CT secondary circuits,
- VT secondary circuits,
- interlock/intertrip circuits,
- pilot wire differential circuits.

NOTE: The requirements of the preceding paragraph do not apply to motor control and ammeter circuits to an RCU, nor to combined power and control circuits to small LV motors in accordance with Standard Drawing S 67.004.

All power, lighting, control and earthing cables shall have copper conductors and shall be in accordance with MESC 68.

In specific cases, cables with aluminium conductors may be used for long distribution feeders, if economic and approved by the Principal. Care must be taken over the installation of bi-metallic terminations.

5.8.2 HV Cables

5.8.2.1 Three core cables

Three core HV cables shall normally be dry cured cross-linked polyethylene (XLPE) insulated, lead sheathed, single galvanised steel wire armoured and PVC oversheathed. If the location of the installation permits, the lead sheath can be omitted (5.8.1).

Paper insulated, mass impregnated non-draining, lead sheathed, single galvanised steel wire armoured and PVC oversheathed cable is also acceptable.

HV multicore cables shall have a minimum cross sectional area of 25 mm^2 and a maximum cross sectional area of 240 mm^2.

5.8.2.2 Single core cables

Single core HV cables shall either be XLPE insulated or ethylene propylene rubber (EPR) insulated, screened, unarmoured and PVC oversheathed.

Paper insulated, mass impregnated non-draining, lead sheathed and PVC oversheathed cable is also acceptable.

These cables shall be installed only above ground or in preformed trenches, where access is restricted.

Single core cables which are directly buried or installed outside the restricted access area shall have a lead sheath, or alternatively, if the soil condition does not necessitate the installation of a lead sheath, a copper earth-screen. The cables shall have a polyethylene outer sheath. No aluminium or copper armour is required since it does not provide much additional mechanical protection over and above that provided by the polyethylene outer sheathing.

5.8.3 LV cables

5.8.3.1 Twin and multicore cables

Twin and multicore power, lighting and control cables shall be cross-linked polyethylene (XLPE) insulated, galvanised steel wire armoured (or braided for sizes up to and including 10 mm^2) and PVC oversheathed. These cables shall be used for above ground and underground installations. Depending on soil contamination, a lead sheath may be required (5.8.1).

Maximum cross section shall be 185 mm^2 for motor cables and 240 mm^2 for distribution cables. For power, lighting and control cables the minimum cross section shall be 2.5 mm^2, except for signalling and indication purposes, where a minimum cross section of 1.5 mm^2 may be used.

Mineral-insulated metal-covered cables shall not be used, except with the specific approval of the Principal.

5.8.3.2 Single core cables

Single core cables for above ground connections between transformers and LV switchgear shall be XLPE or EPR insulated, PVC sheathed. For standardisation purposes, HV single core cables may be used for this application.

NOTE: It is accepted in this case that the LV cables will have an outer sheath colour-standardised for HV cables.

5.8.4 Earthing Cables

Earthing cables shall be PVC sheathed, coloured yellow/green, for both underground and above ground use. The PVC sheath is a protection against electrolytic corrosion.

5.8.5 Flexible cables

Flexible cables for voltages up to 450 V to earth shall be heavy duty neoprene rubber insulated, PVC sheathed.

5.8.6 Wires in conduit

Wiring shall be PVC insulated in accordance with IEC 227 and MESC 68.

Minimum cross section shall be 2.5 mm^2, except for the phase connection between a switch and a luminaire, where 1.5 mm^2 can be applied, but always taking into account the correct current rating and the maximum voltage drop. Wiring colours shall be:

blue - neutral

brown - phase

black - switched phase

green/yellow - earth.

Local rules requiring other colours shall prevail.

5.8.7 Cables with increased fire withstand capabilities

The following types of cables should be used in circumstances requiring an increased fire withstand capability depending upon the application:

- Reduced flame propagation: These cables do not propagate the fire and are self-extinguishing when the flame is removed. They will not remain in operation under fire conditions. They do emit hydrogen chloride and smoke. Reference should be made to MESC 68.46 series.

NOTES: 1. Cables with reduced flame propagation properties should be used in areas where, because of the method of cable installation, a local fire could rapidly propagate along the cable route causing a major disruption to the operation of the facilities.

2. An example of the above is main cable routes comprising overhead cable trunking between two process modules (onshore and offshore) with a large number of cables bunched together.

- Reduced flame propagation, zero halogen, low smoke: These cables are as stated above, but do not emit halogen (<0.5%) and the smoke emission is limited. Reference shall be made to MESC 68.48 series.

  NOTE: These cables shall be installed in normally manned areas where escape to an area with clean air is not possible, typically in accommodation areas on offshore platforms and in non-ventilated, indoor operational areas on offshore platforms.

- Fire resistant, zero halogen, low smoke: These cables will remain in operation for a specified time under fire conditions, but do not emit halogen and the smoke emission is limited. Reference shall be made to MESC 68.48 series.

NOTES: 1. These cables shall be installed in those facilities which are required to continue in operation during a fire, typically for fire fighting equipment.

2. The above is mainly applicable to LV cables. HV fire resistant cables are not yet commercially available.

3. As cables shall normally be installed as a single unjointed length, the type of cable selected from the above shall be that applicable to the most arduous conditions applicable along the cable route.

5.8.8 Cable accessories

Accessories for terminating and jointing of cables shall be selected from the range of MESC 68, as appropriate.

Cable glands shall be selected to suit the type of cable and termination box/enclosure, and shall be of the appropriate type of protection, e.g. Ex'd', Ex'e'. Effective earth continuity shall be ensured between the cable armour/braid and the gland plate or the internal earth terminal.

Non-metallic cable glands should be used with non-metallic termination boxes, and the following conductor shall be terminated at the internal earth terminal, as appropriate to the type of cable construction:

- the braided earth lead of the cable,
- the copper wires in the cable armour,
- the steel armour wires via a flexible lead.

Metallic cable glands should be used with metallic termination boxes. Depending on the type of cable, brass compression glands with an armour clamping feature may be used as an alternative to the method described above.

5.9 OVERHEAD LINES

5.9.1 General

Conductors, insulators, support and all related equipment shall be designed to provide adequate protection against the adverse effects of all prevailing site conditions, e.g. lightning, icing, polluting atmospheres, etc.

The design of overhead lines should take into account local utility practice in determining the type of construction and the selection of materials, if there is no previous experience in the locality.

5.9.2 Supports

The supports may either be wood poles, steel poles or lattice steel towers, as determined on an economic basis after satisfying the technical design parameters.

Wood poles shall comply with BS 1990. Steel poles and towers should comply with manufacturers' standards.

NOTE: Depending on the topography and soil conditions, pole supports (rather than steel towers) will generally be economic at all the voltages covered by these guidelines, except in the case of double circuit lines at 72 kV and above.

Supports shall be designed for the following conditions, taking into account the specified factors of safety (7.3.4):

- intermediate straight line supports (including small deviations up to approximately 10° maximum),
- deviations greater than 10° and up to and including 30°, which can also be used for straight line section supports,
- deviations greater than 30° and up to and including 60°,
- deviations greater than 60° and up to and including 90°,
- line terminals at any approach angle,
- special conditions, e.g. abnormally long spans or supports including switches, fuses, cable terminations, tees, etc.

NOTE: The split between supports for different deviations may be optimised to suit the deviations actually required for an individual line route.

Pole supports for sections and deviations will require to be stayed. For non-conducting supports the staywire shall be fitted with a long staywire insulator.

The design of tower supports should be proof tested, i.e. at a tower testing station.

5.9.3 Conductors

Phase and earth conductors should be aluminium alloy, although ACSR (aluminium conductor steel reinforced) may be considered for reasons of standardisation with existing lines. Galvanised steel may also be considered for the earth conductors. Conductors shall comply with IEC 1089. Conductors shall be identified by code name, e.g. 'Elm', in accordance with the relevant national standard, e.g. BS 3242.

NOTE: ACSR conductors should not be used in coastal or corrosive environments.

5.9.4 Insulators

Post insulators and pin insulators shall be glazed porcelain, complying with IEC 383. They should be used as intermediate support insulators at voltages up to and including 36 kV.

NOTE: Semi-conducting glazes should not be used.

Cap and pin insulator discs shall be toughened glass, complying with IEC 383 and IEC 120. They should be used in suspension insulator strings on intermediate supports at higher voltages, and in tension insulator strings at all voltages.

NOTE: Insulators of different strengths will normally be required for different duties.

The insulator profile shall be selected to suit the site conditions, e.g. aerofoil profile in a desert environment or anti-fog profile in Northern European conditions.

The insulator creepage length shall also be selected to suit the site conditions, typically 35 mm/kV in a desert environment. In the absence of any site specific information, refer to IEC 815 for guidance.

NOTE: The specific creepage length is the ratio of the leakage distance measured between phase and earth over the r.m.s. phase to phase value of the highest system voltage for the equipment.

Consideration may also be given to the use of polymeric long rod insulators, complying with IEC 433.

5.9.5 Steel components

All steel components, including fasteners, shall comply with a relevant international or national standard and shall be hot-dip galvanised after fabrication in accordance with a recognised national standard, e.g. BS 729.

5.9.6 Lightning arresters

Lightning arresters complying with IEC 99-1 shall be installed at every cable termination and at every equipment connection point, e.g. transformer tee-off.

The current rating of the lightning arresters shall be selected to suit the system short circuit rating, and the voltage rating shall be determined as part of the insulation co-ordination, in accordance with IEC 71.

5.10 LIGHTING AND SMALL POWER EQUIPMENT

5.10.1 General lighting requirements

Industrial fluorescent lighting in 'white' colour shall in general be used for illumination. Where special requirements regarding colour distinction exist, these shall be met.

Long life lamps in combination with electronic ballasts shall be used in new installations, and for upgrading old installations, so as to take advantage of their increased lumen efficiency and economic life.

NOTE: Luminaires with 'TLD' bi-pin lamps are available with Ex's' certification; however, they are not yet accepted by all national authorities. Luminaires with 'TLX' single pin lamps are available with Ex'e' certification, and so should be used where the 'TLD' bi-pin lamps are not acceptable.

Incandescent lighting shall be applied only for decorative lighting.

High pressure discharge lamps should be used in the case of lighting in high buildings or large areas. In view of the restarting time of this type of lighting after a voltage dip, sufficient fluorescent luminaires shall be installed for basic lighting requirements of the area, equivalent to emergency lighting requirements (6.4.2).

Consideration shall be given to the use of floodlighting, especially around the perimeter of process and production plants. Care must be exercised to ensure that this does not result in shadows, especially at operating locations.

Low pressure sodium discharge lamps shall not be used, as they constitute a fire hazard in the event of breakage.

5.10.2 Plant lighting

In Zone 1 and 2 hazardous areas, fluorescent luminaires with type of protection Ex'e' shall be used in accordance with MESC 69.57. Luminaires for level gauge lighting shall be of the fluorescent type, bracket-mounted, in accordance with MESC 69. High pressure discharge luminaires in hazardous areas shall have type of protection Ex'd'. An isolating switch shall be included within the fitting to prevent the luminaire from being energised when it is not fully assembled.

For standardisation reasons the same type of Ex'd' or Ex'e' luminaires should be used in all plant areas, whether classified Zone 1, Zone 2 or non-hazardous.

5.10.3 Building lighting

Luminaires in closed buildings which are classified non-hazardous areas, e.g. control rooms and substations, shall be fluorescent bi-pin, switch-start, industrial pattern. Non-industrial luminaires may be used in control rooms, offices, etc.

5.10.4 Special lighting

Special lighting such as navigation aids, obstruction warning lights and aircraft warning lights shall comply with the applicable national and/or international rules and standards.

5.10.5 Portable lamps and tools

Hand-held lamps shall be rated for maximum 50 V a.c. supply.

The types of portable equipment to be used in both industrial and non-industrial areas (except in restrictive conductive locations as referred to below) shall be one or more of the following:

- double or reinforced insulation equipment, Class 2 of IEC 536, connected to the mains via a 30 mA RCCB, protecting both the supply cord and the equipment.
- 42 V equipment, Class 3 of IEC 536, connected to a safety extra-low-voltage circuit by using double-wound safety isolating transformers, complying with IEC 742 (SELV system);

In restrictive conductive locations which can be defined as locations where it is likely that a person could be in contact with conductive parts at two or more points simultaneously, no electrical hand-held equipment connected to an external supply shall be used. Instead, air-driven equipment or equipment with built-in batteries or air-driven generator shall be applied.

For the supply to portable hand lamps and safety tools an adequate number of suitably rated single phase double-wound portable safety isolating transformers, having a secondary no-load voltage of not more than 50 V, fully insulated from earth, shall be provided. Standard ratings for these transformers are 250, 630 and 1600 VA. For their specification, reference is made to MESC 65. The primary side of these transformers shall be provided with a suitable length of flexible cable and a plug for connection to a convenience outlet.

Hand torches shall be provided for all locations where operating personnel may be present at all times, e.g. control rooms, fire station, watchman's offices, etc. The equipment shall consist of fixed charging units with sockets and plug-in hand torches suitable for Zone 1 use, and be provided with rechargeable batteries in accordance with MESC 69. The number of hand torches per location shall not be less than the number of personnel present per shift.

Battery powered hand lamps shall be installed inside substations and switchhouses near all entrances. For plant substations they shall be suitable for Zone 1 use and provided with wall-mounted bracket-type battery charger and undervoltage relay for emergency lighting duty. Reference is made to equipment specified under MESC 69.

5.10.6 Power and convenience outlets

5.10.6.1 General

For maintenance purposes an adequate number of three phase and neutral power outlets for movable equipment, and single phase and neutral convenience outlets for the supply of portable tools and hand lamps shall be provided at suitable locations. Moreover, convenience outlets for portable igniting equipment of boilers and furnaces shall be provided in the vicinity of the burners.

The outlets shall be standardised for each rating and type throughout the complex and shall have an earth connection incorporated. The outlets shall comply with IEC 309 or local standard. The use of local standard material, however, requires Principal's approval.

Plugs shall not be interchangeable with sockets of a different voltage or current rating, nor shall it be possible to insert an industrial type of plug into a Zone 1 classified outlet.

5.10.6.2 Power and welding outlets

Power outlets shall have a standard supply voltage equal to the LV motor supply voltage selected for the complex. These outlets shall be rated for at least 100 A and be suitable for outdoor installation. They shall be located in a safe area along the battery limits, spaced in such a way that, with the aid of extension cables feeding movable secondary supply boards, all points can be served conveniently. The power outlets shall be connected so as to have the same phase rotation, ensuring that correct rotation of movable equipment is obtained from all outlets. Reference is made to MESC 67.

5.10.6.3 Convenience outlets

Convenience outlets shall have a standard supply voltage equal to the voltage selected for normal lighting.

For industrial areas the outlets shall be rated for at least 10 A and be suitable for outdoor installation in Zone 1 areas.

5.11 ELECTRIC HEATING EQUIPMENT

5.11.1 Process heaters

Process heaters with or without thyristor control shall be in accordance with specification T-1.706.053.

5.11.2 Heaters for frost heave prevention

Heaters for frost heave prevention of LNG/LPG tank bases and walls shall be in accordance with DEP 33.68.30.31-Gen.

5.11.3 Electrical trace heating

Electrical trace heating systems shall comply with DEP 33.68.30.32-Gen.

The following types of trace heating shall be used in order of preference:

- self-regulating heaters,
- constant wattage parallel heaters,
- mineral insulated heaters (M.I. cable).

In the case of all-welded pipelines without flanges, the system of skin electric current tracing (S.E.C.T.) heaters shall be considered.

6. ENGINEERING AND INSTALLATION REQUIREMENTS

6.1 GENERAL

The electrical installation shall conform to good working practice of high quality and safety. For commissioning of electrical equipment, reference is also made to DEP 63.10.08.11-Gen.

Where necessary, the Principal or the Contractor shall submit manufacturers' test reports, equipment certificates and site reports, etc., for approval by local authorities.

6.2 MAIN EQUIPMENT

6.2.1 General

Main equipment in electrical installations shall include HV switchgear, LV main switchboards and motor control centres, transformers, main generators and motors, including VSDS. In general the main equipment shall be installed in accordance with the installation instructions and supporting drawings provided by the manufacturer.

Foundation drawings, together with weights and loading data, shall be provided for all electrical equipment, to permit correct civil design of the relevant buildings and foundations. In the case of switchboards comprising switchgear and/or controlgear from more than one manufacturer, one composite foundation drawing shall be supplied for the complete switchboard.

Equipment arrangement and layout drawings shall also be obtained from the manufacturer or supplier, so that they can be incorporated into overall plant arrangement drawings, cabling design, etc.

The environmental requirements for indoor mounted equipment, e.g. heating and/or air conditioning, including any heat dissipated by the equipment itself under full load conditions, shall be checked.

Any main equipment modifications required during installation shall be approved by the Principal prior to implementation. All modifications shall be recorded and the information incorporated in the 'as-built' drawings (8.1).

As far as practicable, electrical equipment shall be located so as to minimise the risk of damage due to vibration. If such locations cannot be avoided, the use of anti-vibration mountings shall be considered.

Electrical equipment shall be so selected and located or protected that it is unaffected by sea-air, water, steam, oil or oil fumes, etc., to which it is likely to be exposed. If pipes must be run adjacent to electrical equipment there should be no joints in the immediate vicinity of the equipment.

Electrical equipment shall be so installed that it is bounded by sufficient space to facilitate maintenance requirements.

6.2.2 Generators

Generators shall be installed in a non-hazardous area.

Generators should be located close to their associated step-up transformers, if any, so as to minimise the length of heavy current connections. The generator, and its step-up transformer, if any, should also be located near the relevant substation.

The generator cooling system shall be independent of the accoustic enclosure ventilation systems.

A fire and gas protection system, comprising detection, alarm and fire fighting facilities, shall be provided inside a gas turbine driven generator enclosure.

6.2.3 Transformers

Oil-filled power transformers shall be installed outdoors in a fenced-in area of the substation. The fences shall have at least two lockable gates.

Each transformer shall have a minimum of 1 m clear space all round. Fire or blast walls are not required. Reference shall be made to Standard Drawing S 68.040.

For intake substations with large transformers, of 100 MVA and above, a blast wall between the transformer bays shall be provided.

Transformers shall be mounted on a flat concrete base, those of the non-sealed type shall be surrounded by a gravel-filled or gravel-covered oil catchment pit, which is sized to contain the total oil content of the transformer. The catchment pit should be:

- connected to the oily water drains system in a wet climate,
- arranged for pumping out by a suction tanker in a dry climate,
- connected to the storm water drains system through an oil/water separator, as determined by the Principal.

Holding down and/or grouting of transformers is not required.

Transformers shall be positioned and oriented in such a way as to minimise cable crossings, especially when multiple single core cables are required.

The dielectric strength of the oil shall be tested before it is used to fill or top up the transformer. For the filling of the transformer an oil filter/heater pump unit shall be used. The transformer shall be filled from the bottom drain valve and air released at the top. The oil shall be circulated/filtered for at least 48 h, after which the oil shall be tested. If the test result is unsatisfactory, the oil shall be circulated/filtered until a satisfactory test result is obtained.

If a dry-type transformer does not have an integral metal enclosure, it shall be installed within an earthed, demountable metal barrier or fence of at least 1 m high on all sides. The fence shall have a lockable personnel access gate, which shall provide at least 1 m clearance from the extremities of the transformer and its cable terminations to allow safe access for visual inspection of the live transformer.

Due account shall be taken of the magnetic field surrounding the transformer, when positioning any sensitive electronic equipment, and when designing any adjacent metallic building structures. If necessary, a magnetic flux plot shall be obtained from the Manufacturer.

6.2.4 Switchgear

Switchgear should only be installed when the switchroom civil and building works are complete, so as to minimise the ingress of dust and dirt during or after erection.

Switchgear foundations, including any inserts to be cast in, shall be in accordance with Manufacturer's drawings and shall be level to within the Manufacturer's specified tolerances.

Substation floors shall be smooth and level to permit the handling of equipment on rollers, regardless of whether cranage is provided.

After assembly and alignment, switchgear busbar joints shall be tightened to the manufacturer's recommended torque settings. Special attention shall be paid to busbar adaptors between two types of switchgear. After correct installation, busbar joints shall be insulated in accordance with the Manufacturer's instructions.

All withdrawable switching devices shall be checked for free movement and correct alignment.

6.2.5 Electric motors

Whilst in outdoor storage and depending on the period of storage before commissioning, motors shall be provided with initial and thereafter periodic preservation procedures in accordance with the manufacturer's instructions. As a minimum these shall include proper sealing of the motor shaft and cable entries and, for HV motors, the energisation of the anti-condensation heaters.

The location of the RCU and/or safety switch should be on the opposite side of the motor to the main terminal box.

Noise hoods shall in no way obstruct the free flow of cooling air to the motor or the motor heat exchanger.

Where required, shim plates shall be of non-magnetic material. Dowel pins may be installed to facilitate reinstallation after maintenance or repair.

6.3 CABLING AND WIRING

6.3.1 General

Cables and accessories shall be selected for the applicable voltage rating taking into account the earthing method of the system (5.8).

At an early stage of the area plot plan development, reservation of appropriate routings and adequate space for underground and/or above ground cable installations shall be made in cooperation with the other engineering disciplines concerned. A dimensional cable routing plan shall be made (8.4.2.6).

When requisitions for cables and wires are prepared, the total measured length required in accordance with the layouts and drawings, for each type and size, shall be increased by 5% of the total for each type and size, to allow for slack, jointing and termination.

For new plant construction, joints in cabling shall only be permitted where the route length exceeds commercially available cable drum lengths. Teed cable joints shall not be used. Cable joints shall be recorded and their locations marked accurately on the 'as-built' drawings.

It shall be ensured that during transport, storage, and installation, cable ends of all types of cable are suitably sealed to avoid ingress of water.

Changes of direction in cable trenches and on racks or trays shall cater for the following minimum cable bending radii, where D is the overall diameter of the cable:

Lead-sheathed cables ≤ 12 kV	Single core	15D
	Multicore	12D
Lead-sheathed cables > 12 kV	Single core	21D
	Multicore	18D
Non-lead-sheathed cables LV	All	8D
Non-lead-sheathed cables HV	Single core	20D
	Multicore	12D

For special types of cable construction and for cables rated at voltages above 36 kV, refer to the manufacturer for minimum installation bending radii.

At the end of hard-floored cable trenches, short ducts or pipes shall slope down into the surrounding soil, to avoid cable damage on the edges owing to settling of the soil.

Single core cables pertaining to one three phase circuit shall be laid together and separated from multicore cables. They shall be laid in trefoil formation, rather than laid flat (6.3.3.1), except in the case of short cable runs, e.g. transformer secondary cables within substations. Reference shall be made to Standard Drawing S 68.021.

Cables should enter buildings above ground level, but where they have to enter below ground level, a watertight seal shall be provided, e.g. multi-cable transit blocks.

Amended per Circular 49/99

Instrument, telecommunication and computer/data cables shall be laid in trenches or on trays separated from those used for HV and or LV cables. For further instructions, refer to DEP 32.37.20.10-Gen.

Open pipe trenches shall be crossed by means of bridges over the pipe trench. Cable bridges shall be fabricated from adequately supported cable ladders, manufactured from the appropriate material and installed in accordance with (6.3.4) or shall be constructed from reinforced concrete and backfilled with a 20:1 sand/cement mix.

Where cable trenches cross roads, an additional number of pipes (ducts), e.g. 3 to 5 at normal cable laying depth, shall be provided to accommodate future cables.

NOTE: In the case of load-carrying cables the assigned current ratings shall be governed by rating factors based on the less favourable heat dissipation properties of such pipes.

Detailed cross-sectional drawings shall be prepared (8.4.2.6).

The armouring, and lead sheath, if any, of multicore cables shall be solidly bonded at both ends.

The lead sheath or the copper earth screen of single core cables shall normally be solidly bonded at both ends.

NOTE: In solidly bonded single core cables, the current flowing in the sheath and/or screen causes additional heating, which results in a derating of the cable in comparison with single point bonded or cross-bonded installations. (This is normally taken into account in the rating factors given by the cable manufacturer).

For single point bonded installations, the bond shall be at the field end of the circuit, i.e. the generator, motor or transformer terminations. Insulated cable glands shall be provided at the switchboard termination. The standing voltages on the armouring at the insulated glands shall not exceed:

- 60 V under conditions of rated full load current, nor
- 430 V under conditions of maximum short circuit current.

In cases where these standing voltage limits would be exceeded, the sheath or screen shall be cross-bonded. This alternative should only be considered for circuit lengths exceeding approximately 500 m.

6.3.2 Sizing of cables

6.3.2.1 General considerations

For the sizing of cables the following aspects shall be taken into consideration:

- thermal short circuit capacity,
- voltage drop,
- current rating,
- maximum cable loop impedance for earth faults in accordance with (4.8.3).

6.3.2.2 Short circuit current rating

The short circuit rating of cables shall be determined in accordance with:

- the rated short circuit breaking current of the source switchboard;
- the fault clearance time associated with the operation of the primary (i.e. not back-up) protection.

6.3.2.3 Voltage drop

The voltage drop in a.c. cables shall not be more than 5% based on continuous maximum current loading and rated voltage. Moreover, during starting or re-acceleration the voltage dip at the terminals of any motor shall not be more than 20% of the rated equipment voltage.

NOTE: The voltage drops stated above relate to the total voltage drop up to the terminals of the end user equipment, and assume that the associated main switchboard from which that equipment is controlled will normally be operated at a voltage of not less than 100% nominal (4.3.2).

The voltage drop in d.c. cables shall be consistent with the minimum system voltage at the distribution board and the minimum equipment operating voltage, but should not exceed 5% in any case.

6.3.2.4 Current rating

Current ratings and rating factors for cables shall be calculated in accordance with the cable manufacturer's declared current ratings, and rating factors derived from the laying pattern, and local environmental conditions. For cables manufactured to British Standards, use can also be made of ERA report 69-30 to establish current ratings and rating factors for the types of cable given in the report.

NOTE: Rating factors are given in ERA report 69-30 for:

- depth of laying,
- ground/ambient temperature,
- soil thermal resistivity,
- grouping of cables.

For sizing of plant cables the maximum sustained nameplate rating of the equipment shall be used. For distribution cables current loadings in accordance with (4.5) shall be applied.

A positive tolerance of 5-10% can be allowed on the overall rating factor because:

- cable sizes are selected on the next larger standard size,
- not all motors are fully loaded at the same time,
- spare units are installed.

Taking the factors stated above into account for plant cabling laid in accordance with the preferred methods in (6.3.3.2) or (6.3.4.2) as relevant, the overall rating factors should not be lower than:

	Direct buried	In air
Tropical climate	0.40	0.60
Temperate climate	0.60	0.80

NOTE: Where different overall rating factors apply to different parts of a route, the lowest factor shall be applied.

6.3.3 Underground cabling

6.3.3.1 General

All cables shall follow a direct and logical route without infringing on the battery limits of unrelated plants and facilities. General distribution cables shall run alongside the roads, and not through plant areas. Through cables which are not related to a particular plant or tank farm shall be routed around such installations.

Plant cables shall run in either of the two directions formed by the main axes of the plant, avoiding as much as possible crossings with instrument cable trenches and pipelines, and preferably away from heavy-load-bearing restricted areas, e.g. transformer bays.

Furthermore, underground cable routes shall be designed to avoid close pipe crossings and adjacent runs with underground pipelines, i.e. a clear distance of at least 300 mm between cable and pipe (including insulation) shall be maintained. Cables should cross underneath buried pipelines except where the depth measured at the top of the pipeline is more than 1 metre.

If close crossings with underground pipelines carrying hot liquids or gases, or which are regularly steam-cleaned, cannot be avoided, the pipeline shall be insulated in order to limit its outside temperature to a maximum of 60 °C, and the clear distance increased to 600 mm. In these cases cables may need to be run above pipelines using a sand-filled concrete bridge (6.3.1).

Cable crossings shall be made either in the cable area directly under the corresponding switchgear panel or at the branching-off point of the particular cable from the main trench.

Single core cables, when laid in trefoil formation, shall be braced by preformed non-magnetic clamps or ties. Such formations shall be laid in their own individual trench with a minimum separation of 600 mm from other cables.

6.3.3.2 Laying pattern

As a standard, load-carrying cables shall be laid in a single layer formation, and shall only be laid in a double layer with the Principal's approval. Non-load-carrying cables shall be installed either as an additional layer on top of the load-carrying cables or as a block adjacent to the load-carrying cables.

NOTE: Load-carrying cables are those cables which may be expected to carry a continuous load during operation. Cables to spare drives shall also be regarded as load-carrying. Non-load-carrying cables are for instance lighting cables, MOV power supply cables, welding switchgear feeder cables and combined motor power/control cables of 2.5 mm^2.

HV cables may be laid in the same trench with LV cables. HV distribution cables shall be separated from LV cabling, e.g. by means of a continuous row of cable tiles placed vertically between the two cable types, by any other suitable barrier or by a clear space of at least 600 mm.

In plant areas the associated control cable may be installed in the space between the power cables.

Typical arrangements for a number of formations are shown in Standard Drawing S 68.009.

Specific attention shall be given to ensure adequate separation of cables in the vicinity of substations and at other areas of congestion. The 70 mm spacing stated in Standard Drawing S 68.009 shall be maintained wherever possible or the overall rating factors in (6.3.2.4) shall be reduced accordingly. Alternatively all cabling approaching and underneath substations should be installed on above ground ladders or racking.

6.3.3.3 Cable trenches

Cables shall be buried directly in the ground, whenever possible, i.e. not in preformed trenches or pipes.

Cable trenches in unpaved, brick-paved or tiled areas and crossing roads shall be in accordance with Standard Drawing S 19.002.

The cables shall be laid on and covered by a clean sandfill, duly compacted and protected by protection tiles. The top finish over the protection tiles may be in accordance with the surrounding area.

Cable trenches in concrete paved areas shall be in accordance with Standard Drawing S 19.001. Cable trenches wider than 1 m shall be permanently covered by heavy-duty or light-duty paving compatible with the surrounding pavement, but coloured red.

When permanently covered cable trenches are used, sandfilled dummy trenches normally 600 mm, but maximum 1 m, wide shall be provided for future cabling. These shall be covered with a red-coloured concrete top.

All cable trenches covered by concrete shall be completely filled with clean sand and compacted. No protection tiles need be installed. Trenches with solid concrete floors shall not be used except when unavoidable, e.g. cable bridges, etc.

Except for short lengths near the termination points of the cables in the plant area, underground cable pipes (ducts) shall be avoided, since relatively long pipes and ducts will affect the cable current rating unfavourably.

NOTE: For cables rated for direct burial, no further derating will be necessary for part installation in pipes (e.g. at road crossings), provided the pipe length does not exceed 7 m. If longer runs are necessary, then the cable shall be rated for installation in pipes.

In order to facilitate cable laying before finishing the concrete paving, the expansion seams in concrete floors should be located on each side of the cable trenches. The location of sleeves at termination points of cables shall be indicated on the civil drawings.

HV cables shall be terminated directly in the equipment terminal box. Cable through-joints shall only be permitted as stated in (6.3.1).

LV and auxiliary cables shall also be terminated as stated in the previous paragraph except in the following circumstances, when Ex'e' junction boxes may be installed between the underground and above ground cables:

- to provide a smooth construction interface, i.e. avoiding long coiled ends of underground cabling awaiting above ground installation;
- to reduce the cross-sectional area of that part of the cable route installed above ground, when the underground cable is significantly derated, i.e. more severely derated than the

overall rating factors given as a guidance in (6.3.2.4);

- to facilitate the replacement of the final cable connection to the equipment terminal box, if frequent disconnection is required or expected;
- to provide for expected settlement of the ground.

NOTE: If the underground cable is lead-sheathed, the above ground cable may be non-lead-sheathed.

6.3.4 Above ground cabling

6.3.4.1 General

Above ground cables shall be supported by cable racks, trays or cable ladders all the way up to their terminations. Individual cables may be fixed directly to the main structures, walls, ceilings or columns by means of proper fixing and supporting materials. However, no more than two cables shall be so installed along a common route.

6.3.4.2 Laying pattern

Multicore cables on racks or trays may be bunched in a maximum of two layers.

HV and LV single core cables shall be laid in trefoil groups with 150 mm clear spacing between trefoils.

On trays or racks HV cables shall be segregated from the LV cables.

Individual cables emerging from floors or soil shall be protected against mechanical damage by means of galvanised steel pipes or rigid PVC pipes. Single core cables emerging from floors or soil shall be protected by rigid PVC pipes. These pipes shall extend at least 100 mm above ground or floor level.

Grouped cables emerging from floors or soil shall be protected collectively by a properly designed metal shield or duct in such a way that heat dissipation of the sustained load-carrying cables is not hampered. The propagation of fire from one space to the other shall be prevented by proper sealing of openings around cables.

To avoid oil or chemicals leaking into the cable trench, the above-mentioned cable protection shall be sealed at the top around the cable(s) with a suitable sealing compound.

Cables or cable supports shall not be fixed directly or indirectly to plant, equipment or process piping which may require removal or replacement.

Cables shall be laid on racks or trays strictly in accordance with the laying patterns stated on the layout drawings. Metal parts of the cable racks and trays shall be bonded and connected to the common earthing grid.

6.3.4.3 Support structures

All cabling support materials, i.e. ladders, trays and relevant fixing materials, used throughout the plant shall be hot-dip galvanised unless the environment is considered to be particularly saliferous or sulphurous, such as to justify the use of materials offering a higher degree of corrosion resistance. In the latter case specific plants or areas shall utilise stainless steel (grade 304). Stainless steel (grade 316) shall be used offshore.

Bends and corners in the cable racks, trays or ladders shall take account of the minimum cable bending radii (6.3.1). Cable racks and trays shall be closed by removable top covers, allowing adequate ventilation, in situations where:

- mechanical damage of the cables is likely to occur during plant maintenance activities,
- oil or chemical spillages on the trays can be expected,
- sun shielding is required against direct solar radiation.

Vertical cable rack risers shall not be installed in front of, or over, pipe risers.

6.3.5 Flexible cabling

The application of flexible cables in industrial plants and installations shall be limited to:

- welding cables;
- trailing cables, e.g. for movable equipment, hand tools, hand lamps;
- winches, hoists, soot blowers, and electric motors, if connected by means of a nearby intermediate junction box.

An earth continuity conductor, equal in cross-sectional area to the largest phase conductor, shall be provided. This requirement applies even when the cable is armoured.

6.3.6 Wires in conduit

Wires in conduit systems shall be applied only for lighting, communication and convenience outlets in closed buildings in non-hazardous areas.

Conduit installations shall be made using rigid PVC conduit and non-metallic conduit boxes. Conduit box covers shall remain accessible. Materials for conduit installations are specified in MESC 68 and 70.

Where local regulations permit, unarmoured round installation cable can be used in cable ducts. Tee or straight-through joints shall be made in connection boxes.

6.3.7 Cable marking/numbering

Cable numbers shall be marked on the cables along their routes and at both termination points. For underground cabling, the spacing between cable numbers along the route should not exceed 5 m, and for above ground cabling, 25 m. Cables shall also be numbered where they branch off from a main route.

For underground cable marking purposes non-corroding strips shall be used, each having ample length to be wrapped twice around the cable and in which the cable number has been imprinted by means of letter/cipher punches.

For above ground cabling, plastic markers resistant to the site conditions shall be strapped round the cables.

Cable numbering shall be in accordance with (8.5) and Appendix 11.

For underground cabling, above ground route markers shall also be provided at every change of direction in the routing and at both sides of road or pipeline crossings, except when cable routing is already indicated by coloured concrete pavement.

6.4 LIGHTING AND SMALL POWER INSTALLATIONS

6.4.1 Plant lighting

Plant lighting circuits shall be fed from dedicated lighting distribution boards installed in the plant substations.

Plant lighting circuits shall be single phase and neutral or three phase and neutral, protected with maximum 16 A fuses or MCBs, but not be loaded higher than 12 A. Plant lighting distribution boards shall include 10% spare outgoing circuits. The lighting distribution board and its control circuits shall be arranged as shown in Standard Drawing S 67.022.

Adjacent luminaires shall not be supplied from the same circuit, or in case of three phase circuits, from the same phase.

As far as practical fluorescent lighting shall be used throughout the plant installations. The lighting system shall be designed to give illumination levels as shown in Appendix 4.

Lighting installations shall be designed to obviate stroboscopic effects.

Luminaires on structures shall be so located that maintenance and lamp changing can be effected without the use of ladders or scaffolding. In cases where a luminaire mounted from an elevated walkway or platform does not overhang it, the lamp post shall be arranged to swivel for maintenance purposes. In high buildings, such as compressor and turbo-generator houses, maintenance and lamp-changing shall be possible by using the overhead crane.

Where no structure is available to support luminaires, fixed lighting poles of adequate length with high pressure discharge floodlighting shall be used to supplement the fluorescent luminaires. Lighting poles shall be hot-dip galvanised.

Luminaires shall generally be mounted as shown in Standard Drawing S 69.001, S 69.002 or S 69.003, as appropriate.

NOTE: For fixed floodlighting columns lamp changing will be carried out using a mobile platform, e.g. vehicle mounted. Alternatively, hinged lighting columns may be used, if space is available for the columns to be lowered.

Plant lighting circuits shall be designed for automatic switching via photo-electric relays. Control circuits for photo-electric relays shall be 'fail-safe', i.e. to switch the lights on if a fault occurs in the photo-electric relay. The plant lighting shall be designed in such a way that in daytime the lighting of furnaces, boilers and the ground level plant can be switched on by means of a switch overriding the appropriate photo-electric relay contact. The remaining photo-electric relay-operated plant lighting shall have the facility to be switched off at night-time. These override switches shall be located either outside the plant substation or in the control room, as required by plant operations. Moreover, the lighting distribution board shall be provided with an override switch for maintenance purposes.

Level gauge lights shall not be switched by the above-mentioned photo-electric relays and shall have no maintenance override switches. Level gauge lights shall normally be on.

Internal lighting of non-process buildings and substations shall be switched inside the building.

Lighting near navigational waters, e.g. jetties and loading platforms, shall not hinder navigation in any way.

The lighting installation in the control rooms shall be designed for switching off, independently, ceiling lighting groups to suit operators' need. Electronic dimmer control shall be provided to adjust the illumination level smoothly down to 20% of the specified illumination. The luminaires shall be situated in such a way that reflection on VDUs, instrument windows and displays is avoided.

6.4.2 Emergency and escape lighting

Fixed emergency lighting shall be installed at strategic points in the installations, including control rooms, switchrooms, fire stations, first-aid rooms, watchmen's offices, the main entrances, and in all other buildings and areas where required for safety reasons. Location and electrical arrangement shall be such that danger to personnel in the case of a power failure is prevented, and escape routes are lit.

The emergency lighting system shall consist of a number of standard luminaires of the normal lighting installation, which shall be fed via circuits having a stand-by supply from an emergency generator or from an inverter having a battery with an autonomy time of at least 1 h. In remote areas, where only a few fittings are required, self-powered emergency luminaires in accordance with MESC 69 may be used, subject to economic considerations.

In the case of an emergency generator supply, a number of luminaires in the control room and the basement of the control room, as well as field auxiliary rooms, shall have a stand-by supply from an independent source with battery back-up to avoid complete darkness during start-up time of the diesel.

The number of emergency luminaires as part of the total number of fittings shall be determined as follows:

- utility area	20%
- process area	10%
- administrative area	5%
- control room and auxiliary rooms (including 10% connected to inverter system)	50%
- substations, field auxiliary rooms, compressor and generator buildings	30%

The escape luminaires shall generally be part of the emergency luminaire installation, but the luminaires shall have integral batteries rated to maintain the lighting for at least 30 minutes.

Escape luminaires shall be provided in all buildings so as to lead personnel out of the building along defined escape routes to defined muster points, which shall also be illuminated.

6.4.3 Street and fence lighting

Street and fence lighting shall be fed from lighting distribution boards installed in a conveniently located plant substation. These lighting distribution boards may either be dedicated to street and fence lighting, or be one or more sub-sections of a plant lighting distribution board. This lighting shall also be photo-electric relay controlled and provided with a maintenance override switch, as for ground level plant lighting, in accordance with Standard Drawing S 67.022.

Generally, for street/fence lighting three phase and neutral LV supply shall be used. Each lighting pole shall include a fuse box as well as a four pole terminating box for looping the feeder cable. Teed cable joints are not allowed. Adjacent luminaires shall not be supplied from the same phase.

Fence lighting shall be placed in such a way that the fence as well as the area outside the fence will be illuminated, leaving the patrol road in comparative darkness.

Normally fence lighting intensity shall be equivalent to the street lighting intensity stated in Appendix 4.

If special security fence lighting is required, unless otherwise specified, a floodlight installation shall be designed, based on HP discharge lighting with a minimum illumination of 5 lux at any point in the area between the fence and 5 m outside the fence.

6.4.4 Special lighting

6.4.4.1 General

Special lighting, e.g. navigation aids, obstruction warning lights and aircraft navigation lights, shall be installed in accordance with international and/or national standards. Long-life lamps or normal lamps at reduced voltage shall be used.

The installation shall be supplied from an interruptible, maintained source.

Navigational aids for offshore structures shall be in accordance with DEP 33.80.00.30-Gen.

6.4.4.2 Aviation warning lighting

Aviation warning lights shall be installed in accordance with Volume 1 Chapter 6 of Annex 14 to the Convention on International Civil Aviation. The luminaires shall consist of a double lamp unit with automatic changeover to the stand-by lamp upon failure of the operating lamp.

6.4.4.3 Illumination of areas to be observed by means of CCTV monitors

The lighting installation for areas that require observation by closed circuit television monitors shall be designed in particular with regard to uniformity of the level of illumination as well as to the location of the individual luminaires. Direct visibility of light-emitting bodies and/or reflections from covers of the luminaires shall be checked before commissioning of the plant.

6.4.5 Power and convenience outlet

Power and convenience outlets shall be supplied from the lighting distribution board in the plant substation. The circuits shall be manually controlled, as shown in Standard Drawing S 67.022. Sufficient outlets shall be installed to enable maintenance to be carried out throughout the installation.

Power and convenience outlets shall be mounted approximately 1 m above grade level, either on a free-standing support, on structural steelwork or on a building wall.

6.5 EARTHING AND BONDING

6.5.1 General

For the earthing of electrical systems, equipment and structures, each installation shall have one common earth grid connected to at least two groups of earth electrodes. The earth grid shall comprise stranded copper earthing cables with green/yellow PVC sheathing (5.8.4).

The earth grid shall extend throughout the plant in the form of a plant earth ring with branch interconnections to the equipment and structures to be earthed, and shall form part of a single earth grid for the whole site.

The earth resistance of each electrode shall be as low as is practicable, but shall in any event be such that the electrical resistance between the earth grid and the general mass of earth ensures the operation of all electrical protective devices. It shall not exceed 4 Ω when any one group of electrodes is disconnected.

Earth electrodes shall be made of galvanised steel, copper or stainless steel, the selection depending on the soil corrosivity to ensure adequate life. In areas where impressed current cathodic protection is used, only galvanised steel shall be used.

The connections between electrode heads and conductors shall be so executed that easy inspection and testing of the earth resistance of individual electrodes is possible without disconnecting the earthing conductors from one another, as shown in Standard Drawing S 68.030.

All bare parts of underground earthing conductors shall be suitably protected against direct contact with the soil so as to prevent electrolytic corrosion of plant equipment. All earthing terminations shall be made with compression cable lugs. Interconnections shall be directly made using thermoweld or compression branch connectors.

Pipelines shall not be used for earthing purposes. For further requirements with respect to earthing and bonding, reference is made to IEC 79-14, the contents of which shall be complied with. For typical design details of earthing systems, refer to Standard Drawing group S 68.

6.5.2 Earthing requirements for substations, switchrooms and control rooms

The earthing facilities to be provided in substations and switchrooms are detailed in drawing S 68.030.

Branch earth conductors connected to individual switchgear and controlgear assemblies shall be sized as follows:

Rated short circuit current and duration	Conductor size - mm^2
20 kA/1s	2×70
25 kA/1s	2×70
31.5 kA/1s	2×70
40 kA/1s	2×70
50 kA/1s	2×120
63 kA/1s	2×120
80 kA/1s	2×150

Sub-distribution boards shall be connected to the earth bar by two earthing conductors, and electrical auxiliary panels by a single earthing conductor. These earthing conductor sizes shall be as stated in (6.5.3).

The requirements of this sub-clause apply equally to equipment in control rooms and associated auxiliary rooms.

6.5.3 Earthing of plant equipment and structures

The metallic enclosures of electrical equipment shall be bonded to the plant earth ring. The metallic enclosures of non-electrical equipment, e.g. vessels, shall also be bonded to the plant earth ring or be provided with their own duplicate earth electrodes; in the latter case, the combined resistance to the general mass of earth shall not exceed 10 Ω.

Plant earthing ring conductors shall have a cross-sectional area of 70 mm^2.

The cross-sectional area of branch conductors connecting equipment and structures to the plant earth ring shall be as follows:

to metallic enclosures of HV electrical equipment	70 mm^2
to metallic enclosures of LV electrical equipment, having a supply cable cross-sectional area ≥ 35 mm^2	70 mm^2
to metallic enclosures of LV electrical equipment, having a supply cable cross-sectional area < 35 mm^2	25 mm^2
to control panels, etc.	25 mm^2
to non-electrical equipment exposed to lightning, e.g. tanks, columns and tall structures	70 mm^2
to other non-electrical equipment	25 mm^2

NOTE: The earthing grid conductors, comprising the plant earthing ring conductors and the branch conductors, shall be considered as supplementary to the protective earth conductor or the metallic sheath and/or armouring of the electrical equipment supply cable(s). The armouring of the cable shall not be used as the sole means of providing earth continuity.

6.5.4 Lightning and static electricity

Lightning protection systems shall be installed if required in accordance with local regulations. In the absence of such regulations, the need for lightning protection shall be determined, and the system, where required, shall be designed and installed in accordance with BS 6651, as supplemented by Appendix 7 of this DEP.

For the purpose of facilitating a low impedance lightning discharge path to earth, earth electrodes shall be located near the base of elevated structures requiring lightning protection. The electrode(s) shall be connected to the structure to be protected and interconnected with the plant earth ring by 70 mm^2 earth cables.

The combined resistance to the general mass of earth of the electrodes provided for lightning protection shall not exceed 10 Ω when isolated from the plant earth ring.

Metal structures, e.g. tanks, vessels, etc., do not require additional protection beyond the earthing requirements specified above.

6.5.5 Electronic equipment

Special attention shall be paid to the electronic system earthing, if required for computers and control systems.

Computer systems and instrumentation DCS equipment should be earthed separately from the electrical earth system. The metallic housing of such electronic equipment shall be connected to the main earth.

NOTE: The earthing of power electronic equipment, e.g. VSDSs, should take account of the Manufacturer's requirements.

This separate earth system, called the 'clean earth', 'instrument earth' or 'computer earth', as relevant, can be one or a number of separate and independent earth systems depending on Manufacturers' requirements. For instrumentation DCS equipment the clean earth system is designated as the instrument earth and is intended for the earthing of the instrument power supply isolating transformers, signal cable screens, etc. Reference shall be made to DEP 32.37.20.10-Gen.

The instrument clean earth system typically consists of screened copper earth conductors connecting the DCS equipment and/or isolating transformer neutral, possibly via earth test/grouping busbars, to dedicated earth electrodes which shall have a resistance to the general mass of earth not exceeding 4 Ω. The clean earth electrode(s) shall be of the same type as those used on the electrical earthing system but the earth conductor between the instrument clean earth bar in the auxiliary room and the clamp type earth bar in the instrument clean earth pit shall be braided or armoured. This braiding or armouring shall be bonded to the electrical earthing system to shield this earth conductor from surface stray earth currents which may cause unwanted interference. For typical arrangement see Standard Drawing S 68.030.

The instrument clean earth and the electrical earthing systems shall be interconnected by a single 70 mm^2 earthwire in each field auxiliary room or control room.

6.5.6 Electromagnetic compatibility (EMC)

Measures to achieve EMC should be chosen in accordance with IEC 1000-5-2 and BS 6651.

Cables which carry small power signals through electromagnetically polluted areas will require special consideration during the design phase of a project.

Lightning shall be included as a possible disturbance source. The maximum value of peak lightning current shall be assumed to be 200 kA. The maximum value of the rate of rise of lightning current shall be assumed to be 200 kA/µs.

7. DESIGN AND ENGINEERING REQUIREMENTS FOR PARTICULAR INSTALLATIONS

7.1 SUBSTATIONS

7.1.1 General

Substations shall contain all the equipment required for the safe and secure distribution of electricity to a predetermined area, plant or region, such as HV and LV switchgear and controlgear installations, transformers and the pertaining auxiliary facilities.

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

The location of these substations shall also be such that interference between HV/LV cables, instrument cables and other services, e.g. pipelines, is minimised.

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

- the interior of the building shall be pressurised in accordance with IEC 79-13;
- an overpressure of at least 50 Pa (0.5 mbar) shall be maintained, using a duplicate fan system with a suitable dry element dust filtering system to ensure a supply of clean air, each fan system being capable of supplying the required pressure;
- the fan systems shall be suitable for a Zone 1 area and shall be supplied from two independent sources of electricity supply;
- both fans shall normally be in operation and shall have individual alarms to indicate failure in a manned control centre.

If substations form part of an overhead line distribution system, and depending on the location of the substation, the available space and the pollution rate in the area, outdoor switchgear installations may be considered. Due attention shall be paid to the most demanding environmental and climatic conditions for that area when specifying the equipment.

In all other cases, for reasons of reliability and serviceability the electrical switchgear installations shall be located indoors in allocated, and if need be, heated and/or air-conditioned, buildings.

The locks used on access gates or doors of substations shall be of a special series, different from locks used for non-electrical buildings, premises or yards.

Each substation, and each building (or part of a building) in which electrical equipment is installed, shall be numbered in accordance with (8.5) and Appendix 11.

7.1.2 Outdoor substations

HV outdoor open terminal switchgear installations should be designed to internationally accepted standards, e.g. BS 7354 or DIN-VDE 0101, and shall allow unrestricted walking access to the whole site.

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

NOTE: Outdoor switchgear shall be treated as sparking equipment, and the minimum distance from the process unit battery limits should be determined from the analysis of gas cloud behaviour by the process engineering department. Reference shall be made to the Shell HSE committee publication 'Static electricity, technical and safety aspects'.

The insulation of all components shall be fully co-ordinated in accordance with IEC 71.

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

NOTE: For further guidance, refer to IEC 815 and, if necessary, consult with the local public utility.

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

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

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

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

NOTE: Where required, pneumatic control lines should be installed in the control cable trenches.

The substation neutral system earth(s) and all metal supporting structures and equipment shall be earthed to the substation earthing system.

The perimeter fence shall be earthed at regular intervals (maximum 50 m) by means of earth electrodes directly connected to it.

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

If the need for lightning protection is determined in accordance with (6.5.4), protection against direct lightning strikes shall be provided by means of overhead earth wires and/or lightning rods attached to substation structures.

The substation equipment shall be protected against lightning and switching overvoltages by lightning arresters.

Control, protection and auxiliary power supply equipment associated with outdoor switchgear shall be installed in a building which shall comply with the relevant requirements of (7.1.3). This substation building, if suitably sub-divided, could also accommodate other switchgear and controlgear at lower voltages.

7.1.3 Indoor substations, switchrooms and battery rooms

7.1.3.1 Switchrooms in indoor substations

Onshore, indoor substations shall be single storey buildings with a general layout and construction in accordance with Standard Drawing S 68.040 and DEP 34.17.00.32-Gen.

HV switchgear at voltages above 20 kV should be located in a separate room. An equipment access door should lead directly to the outside from each switchroom, and internal personnel doors may connect adjacent rooms. All access doors shall be fitted with internal panic bolts for emergency exit.

There shall be at least space for two additional panels for future extension at each end of each switchboard.

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

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

All cable entry holes in the substation floor or walls shall be suitably sealed. Where such cable entry holes are required to be gas tight and/or fire resistant, multi-cable transits blocks shall be installed, or silicone foam, weak-mix concrete (in floors only) or a chemical compound with subliming heat resistant and fire retardant properties may be used.

Instrumentation and control system interface panels should be located in the same switchroom as the associated switchboard.

Substation lighting and small power installations shall comply with (5.10) and (6.5).

To provide the required environmental conditions in which electrical equipment is to operate in accordance with the DEP requirements and the IEC recommendations, the electrical substations and switchhouses shall be complete with heating, ventilation and/or air-conditioning installations in accordance with DEP 31.76.10.10-Gen.

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

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

One hand-held extinguisher shall be provided near each door. No fixed or automatic firefighting facilities shall be provided.

SF_6 Gas Insulated Switchgear (GIS) shall be installed in a separate room. This room shall have a gas detection and alarm system which shall provide for an alarm display at the outside near the entrance doors, and a remote alarm in a manned control room. An exhaust system shall be installed which shall automatically be switched on in the event of a gas release. The exhaust shall be at floor level, and shall be directed to the outside of the building at a location where quick dilution with air will take place.

Warning plates shall be provided at the outside of the building, instructing people not to enter without personal protection when the alarm display is on.

All auxiliary equipment related to the GIS, e.g. protection and control systems, shall be installed in a separate room.

7.1.3.2 Switchgear in plant rooms

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

In general only LV switchboards and, where required, associated indoor transformers shall be installed in these rooms in accordance with (7.1.3.1), but subject to the following additional requirements.

The switchboards shall be installed back to the wall with at least 1.5 m free space in front for safe operational and maintenance access.

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

7.1.3.3 Battery installation and battery rooms

When the total capacity of vented batteries exceeds 20 000 VAh, a separate battery room shall be provided in the substation and have an access door from within the substation.

Vented batteries with a total capacity not exceeding 20 000 VAh, and valve-regulated batteries of any capacity, do not require a separate battery room.

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

All battery rooms shall be provided with one equipment access door, and large rooms, exceeding 6 m in length, shall also be provided with a personnel access door. All doors shall be lockable and fitted with an internal panic bolt. The ceiling shall be flat. A water tap, eye-wash basin, sink and drain shall be installed in the room.

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

Heating, ventilation and/or air-conditioning of battery rooms shall be included in the HVAC system of the building and shall be in accordance with DEP 31.76.10.10-Gen.

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

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

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

Batteries installed outside battery rooms, e.g. in switchrooms, should be installed in cabinets. These cabinets shall be naturally ventilated and either house the battery alone or the battery in combination with the associated battery charger.

Battery stands (tiers) shall comply with DEP 33.65.50.31-Gen. or DEP 33.65.50.32-Gen.

The civil requirements of the battery room shall comply with DEP 34.17.00.32-Gen.

7.1.4 Package substations

Package substations may be used for temporary or permanent installation.

Temporary package substations should be used for temporary construction supplies and comprise LV distribution boards and, optionally, transformers and HV ring main switchgear. Reference shall be made to Appendix 5.

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

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

NOTES: 1. The IP classification of the switchgear itself shall be in accordance with DEP 33.67.01.31-Gen. or DEP 33.67.51.31-Gen. for indoor mounting.

2. Dry-type transformers may be mounted en suite with the LV switchgear or in a separately fenced enclosure in the LV switchgear compartment (6.2.3).

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

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

7.2 ADDITIONAL REQUIREMENTS FOR OFFSHORE INSTALLATIONS

7.2.1 General

Reference should be made to (4.10), which covers the general requirements for the electrical system design for offshore installations and which forms the basis of these engineering and installation requirements.

7.2.2 Main equipment

Generators and distribution switchgear shall be monitored for fire by smoke detection systems. Local offshore safety legislation may dictate tripping of non-essential loads upon fire detection. Liquid-filled transformers shall be installed in outdoor enclosures which have a watertight floor and shall be bunded to hold the total volume of transformer coolant. Drain facilities shall be provided.

7.2.3 Cabling and wiring

7.2.3.1 Cable selection and sizing

Cable selection shall be governed by the locations and environments through which the cable will be routed. The cables shall satisfy the requirements of (5.8.7). Cables installed in the drilling areas shall also have increased resistance to oil and/or mud contamination in accordance with BS 6883.

7.2.3.2 Cable identification, routing and segregation

The whole of the cabling on an offshore platform (i.e. cabling for the electrical, instrumentation and telecommunications disciplines) shall be designed to form one integrated system, so as to ensure suitable cable routing and adequate segregation (for reasons of safety, circuit integrity and interference) of the different cable types.

Cable routes shall be selected, as far as is practicable, such as to facilitate installation of as much cable as possible onshore in order to minimise offshore hook-up time.

Cables should be segregated and suitably identified in the applicable cable category, i.e.

- Power (HV and LV),
- Instrumentation (DCS and safeguarding),
- Fire and gas (detection and protection),
- Telecommunications (CCTV and security systems).

The above-mentioned categories shall be further sub-divided into normal and intrinsically safe circuits.

Within the power cable category, cable separation shall be as stated in (6.3.4), except that HV multicore cables may be laid in one layer touching and LV multicore cables in up to a maximum of two layers touching with the applicable group rating factor applied, and a maximum of 25% spare rack capacity.

Where there is a large concentration of cables in an outdoor area, consideration shall be given to the provision of heat and smoke detection in the area, so as to give early warning in case fire fighting measures are required.

Cables shall be arranged such that the density of combustible material in an array does not exceed the recommended loading in relation to the reduced flame propagation classification (IEC 332-3). When the proposed cable routing cannot be made to accommodate those requirements, the hazards should be reduced to an acceptable level by one or more of the following:

- alternative cable routing,
- alternative means of escape,
- screening the cables to keep escape routes clear of smoke or fumes,
- installing fire protection or detection systems for the cables.

When cables are to be routed through restricted openings, care must be taken to ensure that fire is not intensified or readily channelled along the cable route. In general all bulkheads and deck penetrations shall be fitted with 1 h (A60) rated multi-cable transits. This arrangement shall particularly apply to:

- fire walls,
- walls between hazardous and non-hazardous areas,
- through walls, roofs and floors to the open air.

7.2.4 Lighting and small power

7.2.4.1 General lighting

General lighting shall provide the required level of illumination within the utility, production, deck areas and walkways in accordance with Appendix 4. It shall be fed from the normal platform power supply and shall comply with (6.4.1) except that maximum use shall be made of floodlights where possible.

The preferred type of floodlights is high pressure sodium, which shall be used except where instant relight is required, e.g. on helidecks (5.10.1). Typical areas where floodlights can be employed in preference to fluorescent luminaires are open or high-bay production and utility areas, wellheads, cranes, overside legs and moorings, underside and obstructions. Consideration shall also be given to the use of floodlight luminaires which illuminate the sea beneath the lifeboats and vent stack structure.

7.2.4.2 Emergency lighting

Emergency lighting shall provide sufficient level of illumination to permit minimum operation of the platform. The emergency lighting luminaires shall comprise up to 25% of the total number of luminaires. They shall be fed from the emergency switchboard but shall also have a stand-by supply from an independent source with battery back-up to avoid complete darkness during the start-up time of the emergency generating set.

Emergency lighting shall be provided to allow limited operational lighting for inspection, testing, emergency support, and the starting of the emergency generator. Typical applications are obstruction lights on vent stacks and crane booms, perimeter lights on helidecks, and key operational areas such as the control room, radio room, and crane access ladders. The luminaires shall be suitable for Zone 1 areas.

Emergency lighting shall also be installed in main switchgear and generator rooms, accommodation and workshop areas.

Portable emergency lighting units shall be provided at the exit doors of all non-hazardous area modules, e.g. installation control centre, switchrooms, utility areas, and emergency team muster points. Each unit shall comprise a fixed wall-mounted battery charger and hand lamps suitable for use in Zone 1 areas. The unit shall be kept on float charge when not in use and be fed from the emergency lighting switchboard. The battery shall be rated to energise the hand lamp for not less than 6 h.

7.2.4.3 Escape lighting

Escape lighting shall form part of the emergency lighting system and be located such as to illuminate the escape routes, ladders and walkways to allow safe movement of personnel to the muster points, lifeboats, etc. Additionally, platform status lights shall be provided at strategic locations to be defined by the Principal to indicate the state of platform security. Escape lighting shall be fed and equipped in the same fashion as the rest of the emergency lighting except that, for normally unmanned installations, a central uninterrupted maintained power supply should be provided with battery back-up for a 24 h autonomy time.

Escape luminaires shall be installed at the following locations:

- every exit doorway;
- every sleeping cabin;
- external escape ways (stairways and walkways);

- internal escape ways (escape routes in modules or deck areas, accommodation area corridors, and galley);
- embarkation areas (access to helideck and survival craft stations);
- muster areas (helicopter waiting room, cinema, lounge, dining room and the emergency response team muster points).

Escape luminaires installed in sleeping cabins shall only illuminate on loss of the a.c. supply to the integral battery charger.

Escape lighting shall be suitable for Zone 1 areas.

7.2.4.4 Navigational aids

Navigational aids shall be provided on all offshore structures and shall comply with DEP 33.80.00.30-Gen.

7.2.4.5 Power and convenience outlets

Power and convenience outlets shall be suitable for Zone 1 areas, fitted with padlocking facilities and trip interlocked with the fire and gas shutdown system. Power and convenience outlets shall be equipped with 4-pole or double pole switches respectively.

In non-hazardous indoor areas (e.g. utility areas, switchrooms, etc.), convenience outlets of the industrial type shall be installed where required.

Domestic pattern convenience outlets shall only be fitted in the accommodation areas.

7.2.5 Earthing and bonding

The steel deck and structure of an offshore installation is an inherently very low impedance structure capable of conducting earth fault currents without giving rise to sparks or dangerous potential differences. Good electrical continuity is achieved by intimate metal to metal contact through equipment fixing bolts, clamping, rivetting or by welding, such that earth bonding cables need not be used between pieces of non-electrical equipment and between equipment and the steel deck.

Earthing conductors are required to bond the main components of the generation and distribution systems (namely HV and LV generators, transformers, reactors, switchboards, motors and UPS units) to the platform steelwork. They shall be individually identified, and recorded on drawings.

For a typical installation reference shall be made to Standard Drawing S 68.031.

The metallic sheath and armour of a submarine cable shall be solidly bonded to the platform steelwork at both ends of the cable.

7.3 OVERHEAD LINES

7.3.1 General

The design of the overhead lines shall be carried out by a specialist Contractor, approved by the Principal. These guidelines apply to HV lines up to 145 kV. For the design of lines at higher voltages, advice shall be sought from the local public utility and/or a specialist Contractor. The Contractor shall produce a fully detailed design, based on a detailed route survey (7.3.6).

7.3.2 Conductor sizing

The required conductor sizing shall be determined taking account of:

- the thermal short circuit withstand requirement of both phase and earth conductors;
- the maximum permissible voltage drop;
- the maximum continuous load current;
- the maximum conductor temperature appropriate to the conductor material (typically 75 °C);
- the maximum ambient temperature;
- the maximum solar radiation;
- the minimum wind speed (typically 0.5 m/s).

NOTE: The maximum continuous current rating may vary seasonally and may depend on outage conditions.

7.3.3 Type of construction

Single circuit construction is preferred.

With double circuit construction, the circuits shall be on opposite sides of the support and spaced sufficiently far apart that maintenance can be carried out on one circuit while the adjacent circuit is still live.

Lines shall be divided into sections by straight line section supports or deviation supports, so as to minimise the extent of the damage in case of failure of a support or of one or more conductors. This should be done every ten spans or 2 km line length, whichever is the shorter.

7.3.4 Factors of safety

The minimum factors of safety shall be as follows:

ITEM			FACTOR OF SAFETY
Phase and earth conductor tension at maximum wind speed and minimum ambient temperature, including, if relevant, ice loading			2.5, based on UTS
Phase and earth conductor tension at everyday temperature and still air			5.0, based on UTS
Supports	wood poles		3.0, based on UFS
	steel towers or poles	intermediate straight line supports	2.0, based on UTS
		other supports	2.5, based on UTS
Support foundations against overturning or uplift at maximum wind speed and maximum conductor tension		intermediate straight line supports	2.0
		other supports	2.5
Staywire foundations		intermediate straight line supports	2.0
		other supports	2.5
Crossarms		intermediate straight line supports	2.0, based on UTS
		other supports	2.5, based on UTS
Insulators			3.0
Midspan or dead end joints			2.5, based on elastic limit

NOTE: UFS = Ultimate Fibre Strength

UTS = Ultimate Tensile Strength

The number of broken conductors which can be tolerated without failure of the supports shall be specified, typically two conductors on one side of a section or deviation support and one conductor at an intermediate support. Under broken conductor conditions, some of the factors of safety stated above will be reduced, but not to less than 1.25.

7.3.5 Line route

The initial line route shall be established by the Contractor and agreed by the Principal. This route shall form the basis of the detailed route survey.

Line routes shall be accessible, and should make maximum use of existing roads and tracks for both construction and maintenance access.

NOTE: In this context access will normally require the use of four wheel drive vehicles.

Where line routes run parallel to existing roads and tracks, a minimum clearance of 20 m shall be maintained between the nearer edge of the road or track and the centreline of the overhead line.

Where two lines run parallel with one another, they shall be spaced sufficiently far apart that a falling support from one line could not damage the adjacent line, i.e. a clear space not less than the height of the taller line supports.

Where two lines cross one another, the higher voltage line shall be erected over the lower voltage line, or the lower voltage line shall be run in underground cable for at least 20 m on either side of the crossing.

Lines should not be routed parallel to, and in close proximity with, metal pipelines, telephone lines, etc., such that the maximum voltages which can be induced in the parallel service exceed the acceptable levels laid down by national or international standards, e.g. CCITT 'Directives'.

Lines shall not be routed through production or process areas; they should be routed at least 50 m outside the boundary fence or plot limit. Lines feeding such facilities should be terminated at least 20 m from the boundary fence with a cable connection to the plant substation.

Lines shall be routed clear of wellheads, etc., by at least 50 m, so as not to obstruct maintenance access.

Lines shall not be routed over buildings.

Additionally, an access track at least 5 m wide should be cleared immediately adjacent to the line route, wherever possible.

7.3.6 Line route survey

The line route shall be surveyed in sufficient detail to produce the line route plans and line profile drawings, typically at a scale of 1:2000 horizontally and 1:200 vertically. The drawings shall locate all supports and all obstructions, and show the profile of the lowest conductor (7.3.8).

The position of all supports shall be pegged. A soil survey shall be carried out to determine the foundation design parameters for both the supports and the staywire anchors, if required.

7.3.7 Ground clearance

The minimum ground clearance at any point in a span shall not be less than the minimum value prescribed in the national or local regulations for the relevant line voltage. The clearance shall in any event exceed 6 m.

For road crossings, the minimum ground clearance shall be increased to suit the type of traffic expected (typically 12 m) or the line may be cabled underground.

NOTE: The ground clearance is determined relative to the lowest conductor at maximum conductor temperature and in still air. An allowance for long-term creep, e.g. over a period of 10 years, should also be included.

7.3.8 Sag and tension

Sag and tension tables shall be prepared for the conductor(s) being used, covering the range of spans required:

- at maximum conductor temperature, so as to design the line profile,
- over the range between the maximum and minimum ambient temperatures, so as to tension up the conductors correctly during erection.

During erection the conductors shall be overtensioned for a short period (about one hour) to minimise creep prior to making them off permanently.

7.3.9 Earthing and bonding

All lines shall be provided with one or two overrunning earth conductors, which should provide a shielding angle of not more than 30°.

NOTE: The earth conductor can be omitted for wood pole lines at voltages of 36 kV and below.

All conducting support structures shall be earthed at the foot of the support, as shall all apparatus mounted on non-conducting support structures. The earth electrodes should have a maximum resistance of 10 Ω to the general mass of earth.

All non-current-carrying metalwork on non-conducting supports shall be bonded together to prevent pole fires.

7.4 LABORATORIES

Laboratories will usually be located in non-hazardous areas and the quantities of flammable gases present inside these buildings are generally insufficient to constitute a hazard. Therefore, electrical installations may be of normal industrial design. If one of the above conditions is not fulfilled the electrical installation shall at least conform to the installation practice recommended in IEC 79-14.

The electrical installations in bottle wash rooms, drying and fume cabinets, enclosed sample rooms, stores rooms for chemicals and inside closed hoods shall be suitable for Zone 1 areas.

Each work bench shall be equipped with sufficient single phase industrial pattern convenience outlets (5.10.6.3) to supply the test equipment. The outlets shall all be supplied from the same phase and each circuit protected by a 30 mA RCCB. The voltage shall be as stated in (5.10.6.3).

7.5 ANALYSER BUILDINGS

Analyser buildings shall comply with DEP 34.17.00.32-Gen. and HVAC requirements with DEP 31.76.10.10-Gen.

Electrical installations in analyser buildings which are intended to continue operation during an analyser house ventilation failure shall have a type of protection suitable for a Zone 1 hazardous area. All equipment not suitable for Zone 1 areas shall be connected via convenience outlets which shall be automatically isolated by a safeguarding system when a ventilation failure occurs.

7.6 JETTIES

Earthing and bonding of jetties shall be executed in accordance with IEC 79-14 and ISGOTT.

The application of these rules results in electrical isolation between ship and jetty installations, regardless of whether or not the jetties are cathodically protected.

Pipe and/or hose connections between the ship and the jetty shall be provided with insulating flanges or joints, whose minimum insulation resistance after installation shall be 1000 Ω, measured at 1 kV. The maximum insulation resistance shall be 1 MΩ to prevent static build-up.

NOTE: To achieve the minimum insulation resistance of 1 kΩ after installation, experience indicates that a minimum value of 10 kΩ is required before installation.

Gangways shall be insulated from the ship by means of insulated rollers.

Slings shall be fabricated from non-conductive material, e.g. nylon. Steel or similar conductive materials shall not be used.

A ship to jetty bonding cable and a jetty mounted Ex'd' isolating switch shall only be provided for each berth if specifically required by the local authority regulations.

Electrical equipment on the jetty shall be bonded to the shore earthing system regardless of whether or not the jetty is cathodically protected.

The design of the jetty cathodic protection system, if any, shall take account of the leakage current to the shore earthing system.

Breasting dolphins, fenders and the jetty itself, if metallic, shall be insulated from the ship's hull, e.g. by wooden facings.

7.7 MARKETING TERMINALS

Marketing terminals shall comply with the SIPC publication 'Electrical engineering guidelines for marketing facilities'.

7.8 NON-INDUSTRIAL BUILDINGS

Non-industrial buildings comprise all buildings outside the process areas, e.g. workshops, warehouses, canteens, administration buildings, fire stations, training centres, gatehouses, chemical stores, etc.

They shall all be classified non-hazardous with the possible exception of chemical stores, i.e. depending on the chemicals and the method of their storage and handling.

The design and installation of the power, lighting and earthing systems shall comply with IEC 364, the relevant parts of this DEP, and the local regulations in the country of installation, whichever are the most stringent.

The power supply voltage to each building shall be the same as the LV supply to the plant. Except for very small total loads, e.g. less than 15 kVA, a three phase and neutral supply shall be installed.

Normal and interruptible, maintained electricity supplies for lighting and small power should be in accordance with (6.4) and Standard Drawing S 67.022.

Emergency lighting shall be installed in the building switchroom(s). Escape lighting shall be installed along all the emergency exit routes from the building. Escape lighting shall be provided using luminaires with integral 30 minute battery back-up. The selection of luminaires shall be in accordance with (5.10).

Illumination levels shall be as stated in Appendix 4.

Twin outlets of the domestic pattern standard to the country of installation and selected from Group A, B or C in IEC 83 shall be used. Industrial pattern convenience outlets (5.10.6.3) and power outlets (5.10.6.2) shall be provided, e.g. in workshops, as applicable.

Earthing, bonding and lightning protection shall comply with (6.5).

Power supplies to lifts shall be derived directly from the main switchboard.

Power supplies to central air-conditioning units shall be arranged as radial feeders from the main switchboard, and those to fan-coil units from a sub-distribution board of the air-conditioning system. Through-wall air-conditioners should be supplied as radial feeds from the sub-distribution board.

Cabling and wiring shall be installed in accordance with the methods stated in (6.3).

Use should be made of equipment and fittings, etc., given in MESC groups 67, 68, 69 and 70.

7.9 PLANT LIFT INSTALLATIONS

Lift installations shall comply with EN 81, as supplemented by local or national regulations of the country of installation.

Sufficient luminaires shall be connected to an interruptible, maintained electrical supply to permit emergency operation and escape from the lift car up the lift shaft. The lift shaft lighting shall be automatically switched on when opening the lift car escape hatch.

8. DOCUMENTS AND DRAWINGS

8.1 GENERAL

All necessary drawings documents and reports relating to the design of the electrical installation and for its operation, and all necessary drawings required for the installation and interconnection of equipment and cabling shall form part of the design package. The documents, reports and drawings shall be prepared and submitted for approval as shown in Appendix 10. Appendix 10 shows two stages for document preparation and approval, namely 'Project specification' and 'Design and Engineering', which are typically required during the definition and implementation phases of a project, respectively.

Such information shall be updated when alterations to the design are made and shall include additional information that is required during erection or may be required for future maintenance, troubleshooting and operation.

As-built drawings shall be prepared for the project covering all parts of the electrical installation and related civil engineering, mechanical and instrumentation work.

NOTE: The drawings and documents referred to in this section of the DEP shall be prepared by the party responsible for the design.

8.2 SUMMARY OF ELECTRICAL ENGINEERING

A 'Summary of Electrical Engineering', using standard form DEP 05.00.54.84-Gen., shall be prepared as early as possible during the project. Alternative forms, e.g. computer printout, are acceptable provided:

- they contain the same information in the same order,
- they are reproducible on a standard printing machine in A4 or A3 format, as appropriate.

The summary of electrical engineering shall register all engineering documents, detailing references, issues, drawing, document numbers, scheduled publication dates, etc.

The summary of electrical engineering is intended for:

- detailed recording and progress reporting during the engineering, purchasing and erection of the electrical installations of a project,
- giving detailed information and references concerning the electrical installations during erection and after completion of the project.

8.3 DEP STANDARD REQUISITION SHEETS

For the detailed engineering and requisitioning of equipment, the relevant DEP standard requisition sheets shall be used.

The requisition sheets to be used and the procedures to be followed are given in DEP 30.10.01.10-Gen. Amendments/supplements to the DEPs for specific items of electrical equipment shall be specified on the requisition form, or on supplementary requisition form DEP 30.10.00.94-Gen. sheet 2 or 3.

8.4 DESIGN DRAWINGS

8.4.1 General requirements for the production of drawings

The Principal's pre-printed drawing sheets shall be used.

The 'subject index reference' for drawings is:

64 - Electrical schemes,

68 - Cable/lighting layouts.

All drawings shall be suitable for microfilming, and shall comply with the requirements of DEP 02.00.00.10-Gen.

SI units shall be used for the design and on the design drawings.

Symbols and identification of electrical equipment shall be in accordance with IEC 617. Symbols not included in IEC 617 shall be in accordance with Standard Drawing S 64.000.

Wherever possible, Standard Drawings in Groups S 67, S 68 and S 69 shall be adhered to and quoted where applicable, i.e. they should not normally be redrawn.

For the preparation of diagrams, charts and tables refer to IEC 113.

8.4.2 Summary of drawings to be prepared

8.4.2.1 General

Fully detailed construction drawings shall be provided so that the site construction contractor can install all electrical equipment with no additional design effort.

Vendor information and details shall be incorporated in the design package as soon as it becomes available.

Section 2 of the summary of electrical engineering shall be divided into sub-sections for ease of reference and shall contain all the relevant headings from the table in Appendix 10.

One single line diagram and/or schedule shall be produced for each HV switchboard.

For each generator, HV synchronous motor and HV VSDS or group of similar equipment, the following diagrams shall be provided:

- block control and protection diagram,
- single line diagrams for main and auxiliary circuits.

A protection report describing the basic philosophy, and comprising a protection key diagram, relay setting schedules and relay discrimination curves, shall be prepared as stated in (4.7.1).

8.4.2.2 Key line diagram

The key line diagram shall show the complete a.c. electrical generation and distribution system of the plant including all HV feeds, main LV feeds and sub-distribution boards, together with:

- all sources of electric power,
- the principal supply and distribution system interconnections at each voltage level,
- system capacities, equipment ratings and impedances, winding configuration and earthing arrangements.

8.4.2.3 Block diagram

The block diagram shall show the basic control and protection systems defining the protection, control, trip and alarm functions to be fulfilled at the different locations. It shall also indicate the reference signals and controls needed and all the auxiliary supplies required such as air, luboil, cooling water, electrical auxiliary supplies, etc.

8.4.2.4 Single line diagrams

The single line diagrams shall detail the main circuitry and its earthing systems. It shall also indicate the instrument transformers, relays, meters, etc., for the control, protection and operation of the equipment together with electrical data such as voltage, current and impedances.

A single line diagram of a.c. and d.c. interruptible and uninterruptible, maintained electricity supply systems shall be provided. The single line diagram shall detail for each system the system configuration, earthing arrangements, UPS and emergency generator ratings, the equipment number, function, location, nominal voltages, maximum load, number and type of battery cells and battery autonomy time.

8.4.2.5 Switchgear drawings

The following schedule and drawings shall be provided for each HV and LV a.c. switchboard:

- switchboard schedule form: DEP 33.67.01.80-Gen., DEP 33.67.01.81-Gen., DEP 33.67.01.82-Gen. or DEP 33.67.51.80-Gen., as appropriate,
- circuit/schematic or control diagram, showing all circuit details in a schematic form to control a motor or other power device, and all information necessary for the identification and connection of the components and wiring,
- interconnection/connection diagram showing the external connection details of a switchgear panel, relay box, or junction box, etc.,
- block diagram showing the interconnection of the various equipment of a power system in a diagrammatic manner,
- switchboard layout showing the basic information needed for the construction, i.e. the switchboard outline dimensions, and the switchboard front outline layout.

8.4.2.6 Layout drawings

A substation/switchroom layout drawing shows the physical location and the civil provisions to be made for installing all transformers, switchgear and other electrical power, lighting, earthing and auxiliary equipment located in a substation. The cable runs and support systems shall also be shown. Space requirements for future switchgear, correct location and dimensions of transits in the substation floor for existing and future switchgear shall be shown.

Power, lighting, earthing, substation, and trench layout drawings shall identify:

- all major process equipment by their item numbers,
- all electrical equipment and cables by their equipment and cable numbers.

The power layouts shall show all power cabling, identified by cable numbers, lighting supply cables up to the main junction boxes, and the power and convenience outlet distribution board feeder cables.

Lighting layouts shall show all luminaires (normal and emergency), all level gauges, all power and convenience outlet distribution boards, and all junction boxes and cable routing, downstream of the main junction boxes.

NOTE: Luminaires, etc., shall be identified by a support detail reference, circuit reference, fitting/outlet reference. If required for clarity, separate or additional layouts should be prepared for the higher levels (above grade).

Earthing layouts shall show the main earthing grid, branch connections, earth electrodes, earth bars and conductor sizes for both the electrical earthing system and the instrument clean earth system.

The cable trench layout shall show the physical location of all underground cable trenches, underground pipes and ducts.

Cross-sectional arrangement drawings shall be provided for all cable trenches, ducts and above ground cable routes showing the location and number of each cable along the routes.

8.4.2.7 Construction drawings (typical details)

Construction detail drawings shall show typical construction and mounting details of the power, lighting and earthing installations which cannot otherwise be shown on the layouts. Each detail shall have a unique reference.

8.4.2.8 Area classification drawings

The area classification drawings shall show the classification of the areas with respect to gas or vapour or dust explosion hazard, and shall include sectional elevations where needed for clarity. Reference shall be made to Appendix 1.

8.4.2.9 Vendor drawings

Vendor drawings shall be provided to show as a minimum all the information specified in the relevant equipment DEP and the requisition.

8.5 EQUIPMENT AND CABLE NUMBERING

For plants having an existing numbering system, this system shall be followed. Otherwise the equipment and cable numbering systems stated in Appendix 11 shall be used.

9. REFERENCES

In this DEP reference is made to the following publications:

NOTE: Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto.

Amended per Circular 49/99

SHELL STANDARDS

Index to DEP publications and standard specifications	DEP 00.00.05.05-Gen.
Index to Standard Drawings	DEP 00.00.06.06-Gen.
Standard forms (binder)	DEP 00.00.10.05-Gen.
Preparation and microfilming of technical drawings	DEP 02.00.00.10-Gen.
Utility data - electrical	DEP 05.00.10.80-Gen.*
Summary of Electrical Engineering (electrical equipment summary sheets)	DEP 05.00.54.84-Gen.*
General data/requisitioning sheets	DEP 30.10.00.94-Gen.**
Requisitioning (binder)	DEP 30.10.01.10-Gen.
Symbols and identification system - Mechanical	DEP 31.10.03.10-Gen.
Heating, ventilation and air conditioning for plant buildings	DEP 31.76.10.10-Gen.
Instrumentation symbols and identification on Process Engineering flow schemes	DEP 32.10.03.10-Gen.
Instrument signal lines	DEP 32.37.20.10-Gen.
Synchronous a.c. generators 1250 kVA and above	DEP 33.65.11.31-Gen.
Packaged unit a.c. generator sets	DEP 33.65.11.32-Gen.
Power transformers	DEP 33.65.40.31-Gen.
Static d.c. uninterruptible power supply unit	DEP 33.65.50.31-Gen.
Static a.c. uninterruptible power supply unit	DEP 33.65.50.32-Gen.
Electric motors - cage induction and synchronous type	DEP 33.66.05.31-Gen.
Electrical variable speed drive systems	DEP 33.66.05.33-Gen.
Low-voltage switchgear and controlgear assemblies	DEP 33.67.01.31-Gen.
Schedule for LV switchboard	DEP 33.67.01.80-Gen.*
Schedule for lighting distribution switchboard	DEP 33.67.01.81-Gen.*
Schedule for a.c. instrument distribution switchboard	DEP 33.67.01.82-Gen.*
Schedule for d.c. instrument distribution switchboard	DEP 33.67.20.80-Gen.*
High-voltage switchgear and controlgear assemblies	DEP 33.67.51.31-Gen.

Schedule for HV switchgear and controlgear assemblies	DEP 33.67.51.80-Gen.*
Electric heating system for frost heave prevention of refrigerated hydrocarbon storage tanks	DEP 33.68.30.31-Gen.
Electrical trace heating	DEP 33.68.30.32-Gen.
Navigational aids for offshore structures	DEP 33.80.00.30-Gen.
Minimum requirements for design and engineering of buildings	DEP 34.17.00.32-Gen.
Field inspection of electrical installations and equipment	DEP 63.10.08.11-Gen.

NOTES: * These Standard Forms are included in binder DEP 00.00.10.05-Gen.

** These Data/Requisition sheets are included in binder DEP 30.10.01.10-Gen

Technical specification for electric heater and associated power controllers	Drwg. T-1.706.053
Technical specification for integrated motor control systems (IMCS)	Drwg. T-2.238.761
Electrical engineering guidelines for marketing terminals	SIPC
Materials and Equipment Standards and Code Groups 65, 67, 68, 69 and 70	MESC 65, 67, 68, 69 and 70
Recommendations for electrical safety	Shell HSE Committee
Static electricity, technical and safety aspects	Shell HSE Committee

STANDARD DRAWINGS

NOTE: The latest edition of Standard Drawings can be found in DEP 00.00.06.06-Gen.

Concrete foundations and structures, plant paving, trenches, trench covers, etc.	**Group S 19**
Electrical and instrument cable trenches in concrete paved areas	S 19.001
Cable routing in unpaved, brick-paved or tiled areas and crossing roads	S 19.002
Electrical Engineering General	**Group S 64**
Electrical symbols (additional to IEC 617)	S 64.000
Instrument power supplies, switchgear, protection and control diagrams	**Group S 67**
Schematic diagrams of control circuits for LV motors	S 67.004
Typical instrument electricity supply systems with static components	S 67.006
Single line diagrams of LV switchboard panels	S 67.019
Single line diagram and control circuits for lighting	S 67.022

distribution switchboards

Schematic diagram and control circuits for a.c. instrument distribution switchboard	S 67.024
Schematic diagram of d.c. distribution switchboard for process control and safeguarding systems	S 67.025
Schematic diagrams of control circuits for HV motors (contactor starters)	S 67.028
Typical HV single line diagram, motor controlled by contactor	S 67.045
Typical HV single line diagram, motor controlled by circuit breaker	S 67.046
Typical HV single line diagram, large synchronous motor	S 67.047
Typical HV single line diagram, motor with unit transformer	S 67.048
Typical HV single line diagram, HV/LV transformer ≤ 1600 kVA, controlled by contactor	S 67.049
Typical HV single line diagram, HV/LV transformer ≤ 1600 kVA, controlled by circuit breaker	S 67.050
Typical HV single line diagram, HV/LV transformer including feeder cable ≤ 250 m	S 67.051
Typical HV single line diagram, HV/LV transformer including feeder cable > 250 m	S 67.052
Typical HV single line diagram, parallel plain feeder	S 67.053
Typical HV single line diagram, single plain feeder	S 67.054
Typical HV single line diagram, generator directly connected (≤ 11 kV)	S 67.055
Typical HV single line diagram, generator with unit transformer (> 11 kV)	S 67.056
Typical HV single line diagram, VSDS with synchronous motor	S 67.057
Typical HV single line diagram, submerged motors	S 67.058
Typical HV single line diagram, overhead line circuits (33 - 150 kV)	S 67.059
Typical HV single line diagram, public utility intake	S 67.060
Schematic diagram of control circuits for LV emergency generator	S 67.070
Schematic diagram of control circuits for HV motors (circuit breaker starters)	S 67.071
Typical instrument supply systems with d.c. uninterruptible power supply unit	S 67.080

Earthing, cables, wires and accessories	**Group S 68**
Typical mounting details of earth connectors	S 68.003
Typical arrangements of cables in trenches in plant areas	S 68.009
Clamps for unarmoured single core cables, EPR insulated, PVC sheathed (3800/6600 V grade)	S 68.021
Typical earthing arrangements for substations, field auxiliary rooms and control rooms	S 68.030
Typical earthing arrangements for offshore installations	S 68.031
Typical plant connection details	S 68.032
Typical drawing for electrical substation	S 68.040
Luminaires and accessories	**Group S 69**
Construction and fastening of lamp post for fluorescent lighting fittings	S 69.001
Typical lighting details	S 69.003

AMERICAN STANDARDS

API:

Classification of locations for electrical installations in petroleum refineries	API RP 500 A
Recommended practice for classification of locations for electrical installations at drilling rigs of land and on marine fixed and mobile platforms	API RP 500 B
Classification of locations for electrical installations at pipeline transportation facilities	API RP 500 C

Issued by:
American Petroleum Institute
Publications and Distribution Section
1220 L Street, N.W.
Washington D.C. 20005
USA.

IEEE:

Guide for Safety in AC Substation Grounding

Issued by:
Institute of Electrical and Electronic Engineers Inc.
445 Hoes Lane
Piscataway
New Jersey 08854
USA.

NFPA:

Centrifugal Fire Pumps	NFPA 20
National electrical code	NFPA 70

Intrinsically safe process control equipment for use in Class I hazardous locations	NFPA 493
Purged and pressurised enclosures for electrical equipment in hazardous locations	NFPA 496

Issued by:
National Fire Protection Association
470, Atlantic Avenue
Boston, Mass. 02210
USA.

UL:

Electric motors and generators for use in hazardous (classified) locations	UL 674
Industrial control equipment for use in hazardous (classified) locations	UL 698

Issued by:
Underwriters Laboratories Inc.
207, East Ohio Street
Chicago, Ill. 60611
USA.

BRITISH STANDARDS

BASEEFA:

Special protection	SFA 3009

Issued by:
Certification Support Unit
HSPE
Harpur Hill
Buxton, Derbyshire SK17 9JN
England, United Kingdom.

BSI:

Specification for hot dip galvanised coatings on iron and steel articles	BS 729
Wood poles for overhead power and telecommunications lines	BS 1990
Part 1 - Specification for softwood poles	BS 1990-1
Specification for aluminium alloy stranded conductor for overhead power transmission	BS 3242
Code of practice for the selection, installation and maintenance of electrical apparatus for use in potentially explosive atmospheres (other than mining applications or explosive processing and manufacturing)	BS 5345
Electrical apparatus for potentially explosive atmosphere	BS 5501
Part 1 - General requirements	BS 5501-1
Part 2 - Oil immersion 'o'	BS 5501-2
Part 3 - Pressurised apparatus 'p'	BS 5501-3

Part 4 - Powder filling 'q'	BS 5501-4
Part 5 - Flameproof enclosure 'd'	BS 5501-5
Part 6 - Increased safety 'e'	BS 5501-6
Part 7 - Intrinsic safety 'i'	BS 5501-7
Part 8 - Encapsulation 'm'	BS 5501-8
Part 9 - Specification for intrinsically safe electrical systems 'i'	BS 5501-9
Lead-acid stationary cells and batteries	BS 6290
Part 4 - Specification for lead-acid valve regulated sealed type	BS 6290-4
Code of practice for protection of structures against lightning	BS 6651
Elastomer insulated cables for fixed wiring in ships and on mobile and fixed offshore units	BS 6883
Specification for electrical apparatus for explosive atmospheres with type of protection N	BS 6941
Code of practice for design of high-voltage open-terminal stations	BS 7354

Issued by:
British Standards Institution
389 Chiswick High Road
London W4 4AL
England, United KIngdom.

ELECTRICITY ASSOCIATION:

Engineering recommendation S.34 A guide for assessing the rise of earth potential at substation sites	S.34

Issued by:
Engineering and safety division
The Electricity Association
30 Millbank, London
SWIP 4RD, England
United Kingdom.

ELECTRICAL RESEARCH ASSOCIATION:

Current rating standards for distribution cables	ERA 69-30

Issued by:
Electrical Research Association
Cleeve Road
Leatherhead, Surrey KT22 7SA
England, United Kingdom.

INSTITUTE OF PETROLEUM:

IP Model Code of Safe Practice Part 15: Area classification code for petroleum installations	IP 15

International safety guide for oil tankers and terminals	ISGOTT

Issued by:
Institute of Petroleum
61, New Cavendish Street
London W1M 8AR
England, United Kingdom

EUROPEAN STANDARDS

Safety rules for the construction and installation of lifts and service lifts	EN 81
Electrical apparatus for potentially explosive atmospheres:	
General requirements	EN 50014
Oil immersion 'o'	EN 50015
Pressurised apparatus 'p'	EN 50016
Powder filling 'q'	EN 50017
Flameproof enclosure 'd'	EN 50018
Increased safety 'e'	EN 50019
Intrinsic safety 'i'	EN 50020
Encapsulation 'm'	EN 50028
Intrinsically safe electrical systems 'i'	EN 50039
Voltage characteristics of electricity supplied by public distribution systems	EN 50160

Issued by:
CENELEC,
2, Rue Brederode
B-1000 Brussels
Belgium

Copies can also be obtained from national standards organizations

GERMAN STANDARDS

Recommendations for the calculation of short-circuit currents; Three-phase installations with rated voltages of up to 1000 V	DIN 57102-2
Erection of power installations with rated voltages exceeding 1 kV	DIN VDE 0101
Electrical apparatus for potentially explosive atmospheres General requirements	DIN VDE 0170/0171
Electrical apparatus for potentially explosive atmospheres General requirements	DIN-EN 50014
Oil immersion 'o'	DIN-EN 50015
Pressurised apparatus 'p'	DIN-EN 50016
Powder filling 'q'	DIN-EN 50017

Flameproof enclosure 'd'	DIN-EN 50018
Increased safety 'e'	DIN-EN 50019
Intrinsic safety 'i'	DIN-EN 50020
Encapsulation 'm'	DIN-EN 50028
Intrinsically safe electrical systems 'i'	DIN-EN 50039

Issued by:
Beuth Verlag GmbH
Burggrafenstrasse 6
D-1000 Berlin 30
Germany

BBC Switchgear Manual *Issued by:* *Brown Boveri A.G.,* *Mannheim, Germany, 1978.*	BBC Switchgear Manual: 1978

INTERNATIONAL STANDARDS

ICAO (INTERNATIONAL CIVIL AVIATION ORGANISATION)

Annex 14 to the Convention on International Civil Aviation Aerodromes	ICAO July 1990

Issued by:
International Civil Aviation Organisation
ICAO
International Aviation Building
1080 University Street, Montreal
Canada.

IEC (INTERNATIONAL ELECTROTECHNICAL COMMISSION):

Rotating electrical machines	IEC 34
Part 1 - Rating and performance	IEC 34-1
IEC standard voltages	IEC 38
International electrotechnical vocabulary	IEC 50
High-voltage alternating-current circuit-breakers	IEC 56
Insulation co-ordination	IEC 71
Power transformers	IEC 76
Part 5 - Ability to withstand short circuit	IEC 76-5
Electrical apparatus for explosive gas atmospheres	IEC 79
Part 0 - General requirements	IEC 79-0
Part 1 - Construction and verification test of flameproof enclosures of electrical apparatus	IEC 79-1

Part 2 - Electrical apparatus type of protection 'p	IEC 79-2
Part 5 - Sand-filled apparatus	IEC 79-5
Part 6 - Oil-immersed apparatus	IEC 79-6
Part 7 - Increased safety 'e'	IEC 79-7
Part 11 - Construction and test of intrinsically safe and associated apparatus	IEC 79-11
Part 13 - Construction and use of rooms or buildings protected by pressurisation	IEC 79-13
Part 14 - Electrical installations in explosive gas atmospheres (other than mines)	IEC 79-14
Part 15 - Electrical apparatus with type of protection 'n'	IEC 79-15
Part 18 - Electrical apparatus with type of protection 'm'	IEC 79-18
Plugs and socket-outlets for domestic and similar general use	IEC 83
Lightning arresters	IEC 99
Part 1 - Non-linear resistor type arrester for a.c. systems	IEC 99-1
Diagrams, charts, tables	IEC 113
Dimensions of ball and socket couplings of string insulator units	IEC 120
Polyvinyl chloride insulated cables of rated voltages up to including 450/750 V	IEC 227
Electrical relays	IEC 255
Part 4 - Single input energising quantity measuring relays with dependent specified time	IEC 255-4
A.C. metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV	IEC 298
Plugs, socket-outlets and couplers for industrial purposes	IEC 309
Tests on electric cables under fire conditions	IEC 332
Part 3 - Tests on bunched wires or cables	IEC 332-3
Electrical installations of buildings	IEC 364
Part 2 - Fundamental principles	IEC 364-2
Part 3 - Assessment of general characteristics	IEC 364-3
Tests on insulators of ceramic material or glass for overhead lines with a nominal voltage greater than 1000 V	IEC 383
Characteristics of string insulator units of the long rod type	IEC 433
Low-voltage switchgear and controlgear assemblies	IEC 439

Part 4 - Particular requirements for assemblies for construction sites (ACS)	IEC 439-4
Degrees of protection provided by enclosures (IP Code)	IEC 529
Classification of electrical and electronic equipment with regard to protection against electric shock	IEC 536
High-voltage fuses for the external protection of shunt power capacitors	IEC 549
Internal fuses and internal overpressure disconnectors for shunt capacitors	IEC 593
Graphical symbols for diagrams	IEC 617
Vented nickel-cadmium prismatic rechargeable single cells	IEC 623
Electrical measuring transducers for converting a.c. electrical quantities into d.c. electrical quantities	IEC 688
Part 1 - General purpose transducers	IEC 688-1
Isolating transformers and safety isolating transformers	IEC 742
Electromagnetic compatibility for industrial-process measurement and control equipment	IEC 801
Guide for the selection of insulators in respect of polluted conditions	IEC 815
Shunt power capacitors of the self-heating type for a.c. systems having a rated voltage up to and including 1 kV	IEC 831
Shunt capacitors for a.c. power systems having a rated voltage above 1 kV	IEC 871
Stationary lead-acid batteries. General requirements	IEC 896
Part 1 - Vented types	IEC 896-1
Part 2 - Sealed type (under preparation)	IEC 896-2
Low voltage switchgear and controlgear	IEC 947
Part 2 - Circuit-breakers	IEC 947-2
Electromagnetic compatibility (EMC) Part 5 - Mitigation methods and installation guidelines Section 2 - Earthing and cabling	IEC 1000-5-2
Round wire concentric lay overhead electrical stranded conductors	IEC 1089
Electrical apparatus for use in the presence of combustible dust	
Part 1 - Section 1 - Specification for apparatus	IEC 1241-1-1
Part 1 - Section 2 - Selection, installation, and maintenance	IEC 1241-1-2

Part 2 - Section 1 - Test Methods (Ignition temperature)	IEC 1241-2-1
Part 2 - Section 2 - Test Methods (Electrical resistivity)	IEC 1241-2-2

Issued by:
Central Office of the IEC, (Sales Dept)
3, Rue de Varembé
1211 Geneva 20
Switzerland

Copies can also be obtained from national standards organizations

ISO (INTERNATIONAL ORGANISATION FOR STANDARDIZATION):

Quality management and quality assurance standards - guidelines for selection and use	ISO 9000

Issued by:
Central Secretariat of ISO
1, Rue de Varembé
1211 Geneva 20
Switzerland

Copies can also be obtained from national standards organizations

APPENDIX 1 SELECTION OF ELECTRICAL APPARATUS FOR HAZARDOUS GAS AREAS

A1.1 SUITABILITY OF ELECTRICAL APPARATUS

In order to select the appropriate electrical apparatus for hazardous areas the process engineer will classify the hazardous area, and specify the ignition temperature(s) and the apparatus group(s) relating to the substances being processed, handled or stored.

NOTE: For further information on the classification of hazardous areas, and the properties of flammable liquids, vapours and gases, reference shall be made to IEC 79 and EN 50014.

Electrical apparatus with the following types of protection may be permitted to be installed in the zones indicated below:

	Hazardous areas			Non-hazardous area
	Zone 0	Zone 1	Zone 2	
Type of protection of electrical apparatus	i_a s	d e i_b m o p q s Apparatus suitable for Zone 0	n Apparatus suitable for Zone 0 or Zone 1	Normal industrial apparatus

A1.2 CONSTRUCTION STANDARDS FOR ELECTRICAL APPARATUS

Electrical apparatus of the different types of protection shall comply with the relevant standards tabulated below.

Equipment in accordance with other standards is acceptable when the same level of safety is obtained in the given circumstances. Such equipment shall, however, be subject to the Principal's approval.

Some recognised construction standards for electrical apparatus for explosive gas atmospheres:

Type of protection	IEC	CENELEC	UK	Germany	USA	Notes
General requirements	79-0	EN 50014	BS 5501 Part 1	DIN VDE 0170/0171 DIN-EN 50014		
d	79-1	EN 50018	BS 5501 Part 5	DIN-EN 50018	UL 674 UL 698	
e	79-7	EN 50019	Part 6	DIN-EN 50019		
i	79-11	EN 50020	Part 7	DIN-EN 50020	NFPA 493	Apparatus Systems
		EN 50039	Part 9	DIN-EN 50039		
m	79-18	EN 50028	Part 8	DIN-EN 50028		
n	79-15		BS 6941			
o	79-6	EN 50015	Part 2	DIN-EN 50015		
p	79-2 79-13	EN 50016	Part 3	DIN-EN 50016	NFPA 496	Apparatus Buildings
q	79-5	EN 50017	Part 4	DIN-EN 50017		
s			BASEEFA SFA 3009			

NOTE: The British and German standards are identical to the corresponding CENELEC standards listed, but are only technically similar to the corresponding IEC recommendations.

A1.3 NORTH AMERICAN PRACTICE

The classification of hazardous (classified) areas is covered by three API standards: RP500A, RP500B and RP500C. The requirements for electrical installations in hazardous areas are covered by NFPA 70.

Hazardous areas are classified according to the type of hazardous product being processed or handled:

- Class I : flammable gases or vapours
- Class II : ignitible dusts
- Class III : ignitible fibres or flyings

Class I is sub-divided into divisions, which are defined as follows: "A Class I Division 1 location is a location: (1) in which ignitible concentrations of flammable gases or vapours can exist under normal operating conditions; or (2) in which ignitible concentrations of such gases or vapours may exist frequently because of repair or maintenance operations or because of leakage; or (3) in which breakdown or faulty operation of equipment or processes might release ignitible concentrations of flammable gases or vapours, and might also cause simultaneous failure of electrical equipment."

NOTE: This covers both Zone 0 and Zone 1 areas according to European practice.

"A Class I, Division 2 location is a location: (1) in which volatile flammable liquids or flammable gases are handled, processed, or used, but in which the liquids, vapours or gases will normally be confined within closed containers or closed systems from which they can escape only in case of accidental rupture or breakdown of such containers or systems, or in case of abnormal operation of equipment; or (2) in which ignitible concentrations of gases or vapours are normally prevented by positive mechanical ventilation, and which might become hazardous through failure or abnormal operation of the ventilating equipment; or (3) that is adjacent to a Class I, Division 1 location, and to which ignitible concentrations of gases or vapours might occasionally be communicated unless such communication is prevented by adequate positive-pressure ventilation from a source of clean air and effective safeguards against ventilation failure are provided."

NOTE: This corresponds to Zone 2 areas according to European practice.

The nature of the Class I hazards is sub-divided into groups, as follows:

"Group A: Atmospheres containing acetylene."

"Group B: Atmospheres containing hydrogen, fuel and combustible process gases containing more than 30 percent hydrogen by volume, or gases or vapours of equivalent hazard such as butadiene, ethylene oxide, propylene oxide, and acrolein."

"Group C: Atmospheres such as cyclopropane, ethyl ether, ethylene or gases or vapours of equivalent hazard."

"Group D: Atmospheres such as acetone, ammonia, benzene, butane, ethanol, gasoline, hexane, methanol, methane, natural gas, naphtha, propane or gases or vapours of equivalent hazard."

NFPA 70 states rules on the materials and the installation methods which may be used for the divisions defined above, and requires that all equipment should be 'approved by the authority having jurisdiction'.

APPENDIX 2 RESTARTING/RE-ACCELERATION OF ELECTRIC MOTORS

The magnitude of the maximum voltage dip at switchgear busbars, that corresponds to the minimum permissible voltage of 80% of rated equipment voltage at consumer terminals during motor starting/re-acceleration, will depend on various interrelated technical and economic considerations which have to be taken into account in determining the required electricity supply capacity, source impedance, switchgear short circuit rating, motor cable conductor sizes and motor start/re-acceleration requirements, etc. Consequently, switchgear busbar voltage dips require to be established for each switchboard individually. Nevertheless, the design shall be such that the maximum voltage dip at the switchboard busbars due to the starting or re-acceleration of motors does not exceed 10%.

The following criteria shall apply with respect to voltage dips or interruptions such as those arising as a consequence of system short circuits or disturbances from grid intake supplies:

- Voltage dips resulting in consumer terminal voltages down to 80% of rated equipment voltage shall not affect plant operations.
- Voltage dips resulting in consumer terminal voltages below 80% of rated equipment voltage for a duration of not more than 0.2 s shall, on voltage restoration, result in the instantaneous re-energisation of consumers performing an essential and/or vital service to the extent that is achievable within the constraints imposed by the electrical system.
- Voltage dips resulting in consumer terminal voltages below 80% of rated equipment voltage for a duration between 0.2 and 4 s shall, on voltage restoration, result in a sequential re-energisation of selected consumers.

For control circuits to effect the above requirements, refer to (4.7.7) and Standard Drawing S 67.004, S 67.028 or S 67.071.

The above requirements with respect to auto-restarting should be fulfilled by electronic restart modules (ERM) in conjunction with contactors. For process-controlled consumers time delayed restart modules (TDRM) shall be applied. Alternatively microprocessor-based integrated auto-restarting units may be applied, particularly in the case of more complex requirements. Subject to the Principal's approval, alternative auto-restarting schemes using latched or delayed trip contactors may be used.

NOTE: In the following paragraphs, voltages dips (to less than 80% rated voltage) also include power supply interruptions.

The above requirements with respect to voltage dips resulting in terminal voltages of less than 80% of rated equipment voltage apply principally to electric motor and other power supply circuits controlled by contactors. When for technical or commercial reasons, and subject to approval by the Principal, circuit breakers are used as a means of motor control, alternative means of effecting re-acceleration of such motors following voltage dips may be permitted, e.g. as may be achieved by the application of adjustable time-delayed undervoltage trip/reclosing circuits.

Normally, plant operations can ride through voltage dips of up to 4 s, depending on the type of process involved. Although causing process upsets, the dips would not necessarily always require crash shutdown of plants. Since the latter depends on the correct functioning of process safeguarding systems and other vital services, 'crash' shutdowns should consequently be avoided as far as is reasonably practicable.

Experience has shown that electrical systems can be economically designed to accept transient voltage dips of limited magnitude, as may occur because of the direct-on-line starting of large motors or other load variations. It has also been found feasible to overcome the effects of very severe voltage dips of short duration, such as those occurring as a consequence of electrical system short circuits, by permitting at the instant of voltage restoration a simultaneous re-energisation of relatively large concentrations of decelerating rotating equipment.

The magnitude of electric motor load that can be simultaneously re-energised on a particular system will depend on the cause, extent and duration of the voltage dip and the characteristics of motor and driven equipment to be accelerated.

Consequently, the incidence of certain, more severe short circuits that cause widespread voltage dips of a duration corresponding to the upper limit of 'instantaneous' protection operating time may be such as to prevent the successful re-acceleration of all essential drives simultaneously, particularly when the driven equipment comprises a significant proportion of reciprocating compressors, for example. A detailed study of the entire electrical system (4.7.1), in conjunction with an evaluation of the probability of the incidence of these more severe faults, may indicate that only certain essential drives of more importance need be considered for re-acceleration. Alternatively, that the risk of unsuccessful system recovery in the event of such conditions arising be accepted in view of the benefits arising from the more extensive application of instantaneous restart control circuitry and the adoption of more probable, but less onerous, fault criteria.

After voltage dips of duration in excess of 0.2 s, it is usually not possible to re-accelerate all rotating equipment simultaneously, and sequential re-starting in sufficiently small groups will have to be considered on economic aspects and process requirements. A study of the dynamic performance of the system to establish, for example, the magnitude and number of restarting groups and restart time intervals may be required in such cases.

Voltage dips of duration in excess of approximately 4 s generally make 'crash' shutdowns of plant unavoidable.

Electric motors which comply with DEP 33.66.05.31-Gen. will withstand re-energisation at the instant of maximum residual motor voltage being in anti-phase to the supply voltage. Under such circumstances the transient torques which may be exerted on the coupling and shaft of certain items of driven equipment may be excessive and a time delay between the incidence of a voltage dips and re-starting may be necessary to permit residual voltages to decay sufficiently. The necessity for such measures shall be ascertained for each project individually.

APPENDIX 3 LOAD SHEDDING

For the determination of the magnitude, type and sequence of loads to be shed, the following guidelines apply:

- A fault over a fault, e.g. the simultaneous shutdown of two supply units due to failure, shall not be catered for by automatic load shedding. The total amount of load to be shed therefore need not exceed the capacity of the largest supply unit.
- Non-essential services (2.2) shall be shed first.
- If further load shedding is required, part of the essential services (2.2) of less importance, e.g. loading pumps, shall be tripped as a second stage.
- If the amount of load in the above cases is not sufficient, a choice has to be made by the Principal as to which of the remaining essential services shall be tripped to safeguard supplies to the more important units. Utility plant and other vital services (2.2) shall be considered as the most important units, and their electricity supply shall be safeguarded above all other consumers.

For systems incorporating own generation operating in parallel with a supply derived from the public utility, bulk load shedding facilities may be required based on the magnitude of imported power.

The type of load shedding systems which should be considered are:

- an underfrequency load shedding scheme, which automatically sheds low, medium and, if necessary, high priority loads to prevent the system frequency falling below typically 95% of nominal frequency. The priority group staging should be based on discrete frequency and time delay settings. Rate of change of frequency relays may also be used, especially in power systems with limited on-site generation operating in parallel with a public utility supply.
- an integrated load shedding scheme, whose operation is based on power supply availability and load status. The scheme shall have the flexibility to permit alteration of the load shedding priorities and also the provision to inhibit the starting of large motors under conditions of reduced power supply capacity.

Reference shall also be made to (4.7).

APPENDIX 4 ILLUMINATION LEVELS

The required illumination levels, measured at the working plane or 1 m above the floor level in a horizontal plane, are shown in the table below. These values shall be used as a basis for the design of new installations unless higher illumination levels are required in accordance with national or local regulations in the country of installation. The tabulated illumination levels apply when the luminaires are dirty, i.e. after taking account of the following fouling factors:

Location	fouling factor
Plant areas (both indoor and outdoor):	0.80
Non-plant areas (outdoor):	0.80
Non-plant areas (indoors):	0.85

REQUIRED ILLUMINATION LEVELS

Location		**Lux**	**Notes**
CONTROL ROOMS			
General, including front of panel		300/500	1, 7
Rear of panels		150	
Auxiliary rooms		150/300	2
Outside, near entrances		150	
PLANT AREAS			
Operating areas requiring regular operator intervention	pumps, compressors, generators, drivers, valves, manifolds, loading arms, etc.	150	3
Local control and monitoring points	indicating instruments, gauges and control devices	75	
Level gauges (see-through) to be lit from behind by single tube fluorescent luminaires			
Access ways:	walkways, platforms, stairways, ladders, module roofs (offshore)	25	
Plant and jetty approaches and road intersections		5	
Non-operational areas with limited attendance, e.g. tank farms without equipment requiring regular operator intervention.		0.5	
Loading gantries:	top loading, walkways and top of tankers	150	
	bottom loading (coupling handling area)	150	
Road tanker parking area		25	

Location		Lux	Notes
NON-PLANT AREAS			
Switchrooms, including relay and auxiliary rooms		150	
Workshops and garages	indoor general	250	3
	local on workbenches and machine tools	400	4
	outdoor storage and handling areas	50	
Warehouses and stores	indoor between storage racks	150	
	bulk storage	50	
	outdoor storage areas	5	
Laboratories and analyser rooms		400	
Street lighting and fence lighting	Lit by twin 40 W fluorescent or single 70 W HP sodium (SON) luminaires on standard 8 m poles at, typically, 50 m centres		5, 6
NON-INDUSTRIAL AREAS			
Canteens (dining areas)		100	
Car parks		1	
Catering areas (food preparation and serving)		300	
Communications rooms		400	
Computer rooms		400	7
Conference rooms		400	
Corridors and stairways		100	
Drawing offices		400	7, 8
First aid rooms		400	
Libraries and reading rooms		400	
Lifts		100	
Offices		400	
Plant rooms		150	
Print rooms		250	
Reception areas		150-400	
Recreation rooms and lounges		300	
Store rooms		150	
Toilets and locker rooms		100	

NOTES:

1. 300 lux applies at night and 500 lux during the daytime. Control of the illumination level down to 100 lux should be possible either by switching off rows/groups of luminaires, or by use of electronic dimmers, or both.
2. 150 lux applies for normal access and 300 lux for maintenance activities. Control of the illumination level should be achieved by switching each lamp in a twin fitting from separately controlled circuits or by switching alternative fittings.
3. Where overhead travelling cranes are installed, floodlights should be fitted under the crane beam to provide an illumination level of 400 lux for better illumination during maintenance.
4. In areas where very fine work is carried out, local lighting with higher illumination levels may be required, e.g. 750 - 1000 lux on an instrument workshop bench.
5. Higher illumination levels apply where security fence lighting is required, e.g. for use with video camera surveillance. These shall be specified to be compatible with the video system utilised.
6. At the security barrier and check point in front of site entrance gatehouses, higher illumination levels may be required.
7. In rooms where VDUs are permanently installed, the lighting shall be designed to avoid reflections and glare from the screens.
8. Local lighting shall be provided to give an illumination level of 700 lux on drawing boards.

APPENDIX 5 TEMPORARY ELECTRICAL INSTALLATIONS

A5.1 GENERAL

All regulations constituting the local law and the following additional regulations are obligatory. However, in the event of inconsistency, the more stringent shall apply. For semi-permanent parts of the site installation such as site offices and ancillary buildings, the local regulations, if any, shall be adhered to. In the absence of local regulations generally accepted standards, e.g. IEE wiring regulations, shall be followed.

A single line diagram and layout drawing shall be prepared for the temporary power system. All equipment and cabling shall be uniquely numbered and clearly marked in a prominent manner.

The whole of the temporary installation, including buried cables, shall be removed on completion of the project construction.

A5.2 SUPPLY ARRANGEMENTS

HV supplies should be in the form of a ring circuit, operated open at one point, with HV switchgear, e.g. ring main unit, local to each transformer.

LV supplies shall be arranged as a TN-S system, with radial feeders from a main distribution board, e.g. local to each transformer or to the generating sets, to sub-distribution boards close to the work areas.

The HV distribution equipment, the transformers and the main LV distribution boards shall be accessible to authorised persons only.

Power supplies shall be provided with Class 2 kilowatt-hour metering at source of supply, except where generating sets are used.

A5.3 GENERATING SETS

The diesel generating sets shall be installed at a single, reasonably central location.

NOTE: Only in the case of a very widespread site may they be installed at more than one location, in which case they shall supply a number of separate temporary power systems.

The generating sets shall be complete with a circuit breaker and all necessary control equipment, and shall be suitable for parallel operation where more than one set is installed.

The generators shall be star connected and their neutral points shall be solidly earthed.

A5.4 HV SWITCHGEAR

The main HV switchboard, if required, shall comply with IEC 298 and have single section busbars with one incoming switch, together with a number of outgoing feeder circuit breakers for ring distribution or fuse switches for radial distribution.

Each outgoing feeder circuit breaker shall be protected with IDMT overcurrent and earth fault protection. The incoming switch should not require any protection. Consideration should be given to switchgear and protection which does not require any d.c. tripping supplies. Circuit earthing facilities shall be provided.

If a ring distribution system is used, HV switchgear at each transformer substation shall comprise a tee-off fuse switch and two ring circuit isolators.

The switchgear shall be suitable for outdoor use or mounted in a packaged weatherproof enclosure, with adequate access for operating/maintenance personnel.

A5.5 TRANSFORMER SUBSTATIONS

Transformers shall comply with IEC 76. They shall be connected delta-star and the LV neutral points shall be solidly earthed.

Consideration should be given to the use of packaged substations complying with (7.1.4).

The transformer, together with the associated HV switchgear and LV main distribution board, whether separate or packaged units, shall be mounted on concrete plinths within a fenced enclosure with padlockable gates. The cornerposts shall protect the substation equipment from vehicle impact. The substation should be located at least 5 m clear from the edge of any road.

A5.6 LV DISTRIBUTION BOARDS

All distribution boards shall comply with IEC 439-4.

Main LV distribution boards supplied by one or more generating sets shall have an incoming switch for each generator. The outgoing circuits shall be protected by fuses or MCCBs having a maximum rating/setting of 355 A.

Sub-distribution boards should additionally comply with the requirements for sub-distribution boards specified in DEP 33.67.01.31-Gen.

Each sub-distribution board shall be provided with one incoming switch. Each outgoing feeder shall be provided with a switching device with short circuit and residual current protection. The maximum outgoing feeder rating shall be 125 A. The sensitivity of the residual current circuit breakers shall be as follows:

- 30 mA for circuits below 125 A
- 300 mA for circuits of 125 A.

Fuses shall be accessible only if the fuse bases are protected to at least IP2X, or if interlocking exists such that the fuse base is electrically isolated first.

A5.7 TEMPORARY CABLING

A5.7.1 General

Temporary cables may be installed above ground or underground, subject to the site circumstances. The method of installation shall in any event be chosen such as to minimise the risk of damage. The temporary cable installation shall comply with the requirements specified below.

A5.7.2 Underground cables

Temporary cables shall not be installed in the same trench as any permanent project cabling or other services. A minimum separation of 2 m should be maintained.

HV and LV cables shall be buried at a minimum depth of 0.8 m and 0.5 m respectively, to avoid being damaged by any disturbance of the ground reasonably likely to occur during the construction period.

Cables should be installed underground at road crossings.

Underground cables shall be provided along the routing with the marking 'Temporary cable', also indicating the applicable project number.

A5.7.3 Above ground cables

Where the use of overhead road and route crossings is unavoidable, the cables shall be erected with the following minimum clear height:

- 6.0 m, where the roads and routes are designated for use by vehicular traffic,
- 3.5 m, where vehicular traffic is prohibited.

Above ground cables shall be fixed on site so that they are clear of building operations or engineering construction work and so that they are not a hazard. Where possible they are to be installed clear of passageways, walkways, ladders, stairs, etc.

Overhead cables when crossing passages, shall be bound with yellow/black coloured tapes. Alternatively freely moving strips of coloured fabric or plastic may be attached to attract attention. In some circumstances protective barriers may be required.

All cables shall be installed in such a way that they are at least 150 mm clear of piped services such as steam, gas and water. Apparatus and accessories other than lampholders shall not be suspended from electric cables.

All cables which are likely to be frequently moved in normal use shall be flexible, of the heavy- duty neoprene rubber type or equivalent.

A5.8 EARTHING

For the purpose of earthing the electrical system and equipment the installation shall have one common earthing grid connected to at least two earth electrodes, which may form part of the permanent earthing system. The resistance to earth of this common earthing grid shall be as low as practicable but shall not exceed 4 Ω.

Earth wires shall be of the standard copper conductor with green/yellow PVC sheathing. They shall be sized to carry the rated fault current of the distribution switchgear for its rated short- time duration. For mechanical reasons main earth wires shall be at least 70 mm^2, branch earth wires 25 mm^2, unless adequate mechanical protection is provided by other means, e.g. wire installations in conduit, or earth conductors forming part of a cable, allowing a smaller size.

The connections between earth electrode and conductors shall be so executed that easy inspection and testing of the earth resistance of each individual electrode, without disconnecting any part from the earthing system, is possible.

The earth bar in each main distribution board and sub-distribution shall be connected with two 70 mm^2 earth wires each suitable for 100% duty to the above-mentioned common earthing grid.

A5.9. SELECTION OF COMPONENTS

The components shall be suitable for their particular application as regards their voltages, rated currents, service life, making and breaking capacities, short circuit strength, etc.

The components having a short circuit strength and/or a breaking capacity insufficient to withstand the stresses likely to occur at the place of installation shall be protected by means of current-limiting devices, e.g. fuses or MCCBs. When selecting current-limiting devices for built-in switching devices, account shall be taken of the maximum admissible values specified by the manufacturer of the apparatus, having due regard to co-ordination.

Power and convenience outlets shall be industrial pattern complying with IEC 309. Plugs of different rated currents or voltages shall not be interchangeable.

All three phase outlets shall be connected with the same phase sequence.

The socket outlets and plugs shall have a degree of protection at least IP 54, both when the plug is removed and when fully inserted.

The requirements of (5.10.5) shall apply to portable lamps and tools.

APPENDIX 6 CONTROLS, INSTRUMENTS, INDICATIONS AND ALARMS

A6.1 GENERAL

This appendix states the typical requirements for controls, instruments and meters, status indications and alarms to be provided both locally and remotely for the various types of electrical plant and equipment. The inclusion of any items identified as optional, and the need for any additional items, shall be determined by the Principal. Protection devices are shown on the relevant Standard Drawing S 67.

The requirements at each location in the following tables are identified as follows:-

A = mandatory, if applicable;
C = common (grouped) alarms, etc.;
I = individual alarms, etc;
O = optional, at the Principal's discretion;
T = close circuit breaker in test position only;
X = mandatory;
(n) = number of signals, e.g. (3) = three ammeters (one per phase).

The locations are as follows:-

CCR = central control room;
CP = control panel;
FAR = field auxiliary room;
LOC = local (e.g. FAR, S/S or on generator skid);
SER = system event recorder;
S/S = substation.

Other abbreviations are as follows:-

BC = bus coupler;
BS = bus section;
CB = circuit breaker;
G/T = generator transformer;
OLTC = on-load tap changer.

A6.2 MAIN GENERATING SETS

Description	CCR	Location S/S HV swbd	LOC Gen. CP	LOC Driver CP
Controls:				
Generating set - normal start				X
Generating set - auto start	X			X
Generating set - fast loading	A			A
Generating set - normal stop	X			X
Generating set - emergency stop	X			X
Generating set - local/remote control selector switch				X
Isochronous/droop control selector switch				A
Generating set - base/peak load selector switch				A
Governor setpoint control	X		X	X
Generator CB control		XT	X	
G/T OLTC - tap raise/lower			A	
Field switch - on/off			X	
Voltage regulator - auto/manual selector switch			X	
Voltage regulator - voltage/p.f. selector switch			A	
Voltage setpoint control - auto			X	
Voltage setpoint control - manual			X	
P.F. setpoint control			A	
Synchronising selector switch			X	
Indications (status):				
Generating set - local/remote control	X			X
Generating set - base/peak load operation	A			A
Isochronous/droop operation				A
Generator CB - open/closed	X	X	X	
Field switch - open/closed			X	
Voltage regulator - voltage/p.f.	O		A	

Description	CCR	Location S/S HV swbd	LOC Gen. CP	LOC Driver CP
Instruments and meters:				
Generator voltage	X	X(3)	X(3)	
Generator frequency	X	X	X	
Generator current	X	X(3)	X(3)	
Generator real power	X	A	X	
Generator reactive power	X		X	
Generator power factor	X		X	
Generator real energy summated		X		X
Generator reactive energy summated		X		
Synchronising instruments			X	
Field voltage			X	
Field current			X	
Stator temperature			X	
Alarms:				
Master trip relay(s)	X		X	X
Stator temperature high alarm	X		X	O
Coolant temperature high alarm	X		X	O
G/T temperature high alarm	A		A	O
G/T Buchholz gas alarm	A		A	O
Excitation system alarm	X		X	O
Rotor earth fault	A		A	O
Auxiliary systems	X		X	O
All protection relays (trip)			I	O
Mechanical non-trip alarms	O		C	I
Mechanical trip alarms	O		C	I

A6.3 GRID INTAKE, POWER PLANT AND DISTRIBUTION SUBSTATIONS

Description	**Location**		
	CCR	**S/S HV swbd**	**LOC CP**
Controls:			
Incoming feeder CB -			
CB control	O	X	X
sync relay & selector switch	O		X
Incoming transformer OLTC -			
tap raise/lower	O		A
AVR setpoint control	O		A
auto/manual selector switch			A
Generator circuit controls		Refer to (A6.2)	
BS/BC CB -			
CB control	O	X	X
sync relay & selector switch	O		A
Outgoing feeder CB -			
CB control	O	X	X
Indications (status):			
All CBs - open/closed	O	X	X
Instruments and meters:			
Busbars (per section) -			
voltage	O	X	X
frequency	O	X	X
Incoming feeder -			
voltage	O	X(3)	X(3)
current	O	X(3)	X(3)
real power	O	X	
reactive power	O	X	
power factor	O	X	
real power summated	O	X	
reactive power summated	O	A	
transformer tap position	O	A	A
Generator circuit		Refer to (A6.2)	
BC current	O	O	
Outgoing feeder -			
current (Note 1)	O	X	
real power	O	O	
reactive power	O	O	
real energy (Note 2)	O	O	

	Location			
Description	**CCR**	**S/S HV swbd**	**LOC Annunciator**	**SER**
Alarms:				
All circuits - master trip relay(s)	O	I	I	I
Switchgear tripping and closing supplies -				
battery/charger (each)		I	I	O
Trip circuit supervision				
(per busbar section)		I	I	C
Loadshedding (per stage)	A			I
Annunciator repeat alarms	C			
Annunciator fault	C		I	
HVAC failure	A		I	
Substation temperature too high/too low	A		I	

NOTES:

1. A thermal maximum demand ammeter may optionally be provided on the switchboard.
2. The real energy integrating meters may optionally be fitted with a maximum demand indicator.
3. Where incoming supplies are metered by a Public Utility, check metering shall be installed on the Shell switchboard.

A6.4 PLANT SUBSTATIONS (HV SWITCHBOARDS)

	Location			
Description	**CCR**	**S/S HV swbd**	**LOC Annunciator**	**SER**
Controls:				
Incoming feeder CB control		X		
BS CB control		X		
Distribution feeder CB control		X		
Motor control		XT		
Indications (status):				
Incoming feeder and BS CBs - open/closed		X		IO
Distribution feeders - open/closed		X		IO
Motor feeders - open/closed	IO	X		
Motor feeders - operations counter		X		
Instruments and meters:				
Busbar voltage (per section)	O	X		
Incoming feeder voltage		X		
Incoming feeder current	O	X		
BS current	O	X		
Distribution feeder current	O	X		
Motor current	O	X		
Motor hours run meter		X		
Alarms:				
All non-motor circuits - master trip relay	C	I	I	C
Motor circuits - protection operated		I	I	
Switchgear tripping and closing supplies - battery/charger (each)		I	I	O
Trip circuit supervision - (per busbar section)		I	I	C
Annunciator repeat alarms	C			
Annunciator fault	C		I	
HVAC failure	A		I	
Substation temperature too high/too low	A		I	

A6.5 VSDS (HV)

Description	Location CCR	S/S HV swbd	VSDS Converter
Controls:			
Normal start	X		X
Normal stop	X		X
Emergency stop	X	X	X
Local/remote selector switch			X
Supply switch control		X	
Setpoint control	X		X
Indications (status):			
Drive stopped	X		X
Drive running	X		X
Supply switch - open/closed	X	X	
Instruments and meters:			
Supply current	O	X	
Speed	X		X
Process variables	A		A
Output voltage	O		X
Output current	O		X
Output power	X		X
Alarms:			
Master trip relay	X	X	
Protective devices on converter			I
Protection relays on switchgear		I	
Electrical non-trip alarms	I		I
Mechanical non-trip alarms	I		C
Mechanical trip alarms	I		C

A6.6 SYNCHRONOUS MOTORS (HV)

Description	CCR	S/S HV swbd	LOC CP
	Location		
Controls:			
Normal start	X		X
Normal stop	X		X
Emergency stop	X	X	X
Local/remote selector switch			X
CB control		X	X
Excitation setpoint control	X		X
Indications (status):			
Drive stopped	X		X
Drive running	X		X
CB -open/closed	X	X	
Instrument and meters:			
Stator current	X	X	X
Real power	X		X
Reactive power	X		X
Power Factor	X		X
Field voltage			X
Field current			X
Stator temperature			X
Hours run meter			X
Alarms:			
Master trip relay	X	X	
Stator temperature high alarm	X		X
Coolant temperature high alarm	X		X
Excitation system alarm	X		X
Protection relays on switchgear		I	
Electrical non-trip alarms	I		I
Mechanical non-trip alarms	I		C
Mechanical trip alarms	I		C

APPENDIX 7 ASSESSMENT OF NEED FOR LIGHTNING PROTECTION OF STRUCTURES

A7.1 GENERAL

This appendix states the method of assessing the need to provide lightning protection for a structure. It is based on the principles laid down in BS 6651.

The following terms are defined:

P = Risk: the probable number of strikes per year.
Po = Acceptable risk.
Pa = Overall risk
Ng = Lightning flash density: the number of flashes to ground per km^2 per year.
Ac = Collection area of a structure (m^2).

Weighting factors:
A: Use of structure.
B: Type of construction.
C: Contents or consequential effects.
D: Degree of isolation.
E: Type of country.

Wo = Overall weighting factor (A x B x C x D x E).

A structure of exposed metal requires no lightning protection beyond adequate earthing arrangements.

Buildings in plant areas such as analyser houses are usually effectively protected by the nearby steel structures and columns.

A7.2 INTERPRETATION OF ACCEPTABLE RISK (Po)

BS 6651 states:

> "The risk factor method given in this code is intended to give guidance on what can, in some cases, be a difficult problem. If the result obtained is considerably less than 10^{-5} (1 in 100 000) then, in absence of other overriding considerations, protection does not appear to be necessary; if the result is greater than 10^{-5}, say for example 10^{-4} (1 in 10 000), then sound reasons would be needed to support a decision not to give protection."

After due consideration of the above it has been decided that, the acceptable risk (Po) for industrial installations within Shell Group companies should be set at 10^{-4} (1 in 10 000).

A7.3 OVERALL WEIGHTING FACTOR (Wo)

Table 1 gives typical values for the overall weighting factor for various types of buildings and structures. The following aspects have been taken into account:

- Control buildings, substations, FARs and analyser houses are assumed to be located in process plant areas among structures of the same or greater height (D = 0.4). Workshops, warehouses and office blocks are assumed to be located in areas with few other structures of similar height (D = 1).
- The type of country is assumed to be flat (E = 0.3).
- Control buildings, substations, FARs and analyser houses are assumed to be constructed in accordance with the relevant DEPs.

The weighting factors shall be adjusted in accordance with BS 6651, where the actual situation deviates from the above.

TABLE 1 TYPICAL VALUES FOR OVERALL WEIGHTING FACTOR (Wo)

Type of Building	Value
Control buildings	0.048
Substations	0.038
FARs	0.038
Analyser houses	0.038
Workshops, warehouses	
- reinforced concrete, non-metal roof	0.036
- brick, non-metal roof	0.090
- brick/timber, metal roof	0.153
Office blocks	
- reinforced concrete, non-metal roof	0.045
- brick, non-metal roof	0.108
- brick/timber, metal roof	0.183

A7.4 STEPS TO BE TAKEN TO EVALUATE THE NEED FOR LIGHTNING PROTECTION

1) Define the mean number of flashes to ground per km^2 per year (Ng) for the geographic area concerned. This figure is related to the number of thunderstorm days per year. (see Table 2).

   If no accurate site information is available, the number of thunderstorm days can be obtained from the relevant map in BS 6651.

TABLE 2 RELATIONSHIP BETWEEN THUNDERSTORM DAYS PER YEAR AND LIGHTNING FLASHES PER km^2 PER YEAR

Thunderstorm days per year	Flashes per km^2 per year	
	Mean	**Limits**
5	0.2	0.1 - 0.5
10	0.5	0.15 - 1
20	1.1	0.3 - 3
30	1.9	0.6 - 5
40	2.8	0.8 - 8
50	3.7	1.2 - 10
60	4.7	1.8 - 12
80	6.9	3 - 17
100	9.2	4 - 20

NOTES: 1. A thunderstorm day is a calendar day during which thunder is heard at a location.
2. The above data is taken from BS 6651.

2) Define the collection area of the structure (Ac). Figure A7.1 gives some examples.

3) Calculate the risk using the formula: $P = Ac \times Ng \times 10^{-6}$

4) Calculate the overall risk with the formula: $Pa = Wo \times P$

5) Compare Pa with Po and if $Pa \geq Po$ the structure should be protected against lightning.

A7.5 SOME EXAMPLES

A7.5.1 Control Building

Dimensions (l x w x h) : 30 x 15 x 4 m
Collection area:
$Ac = (30 \times 15) + (2 \times 30 \times 4) + (2 \times 15 \times 4) + (\pi\ 4^{2)}) = 860\ m^2$

a) Location: PERNIS, Netherlands

Lightning flash density: Ng = 1.1
$P = Ac \times Ng \times 10^{-6} = 860 \times 1.1 \times 10^{-6} = 946 \times 10^{-6}$
$Pa = Wo \times P = 0.048 \times 946 \times 10^{-6} = 4.5 \times 10^{-5}$
$Po = 10^{-4}$

* Since Pa < Po, lightning protection is not required.

b) Location: SINGAPORE

Lightning flash density : Ng = 9.2
$P = Ac \times Ng \times 10^{-6} = 860 \times 9.2 \times 10^{-6} = 7912 \times 10^{-6}$
$Pa = Wo \times P = 0.048 \times 7912 \times 10^{-6} = 3.8 \times 10^{-4}$
$Po = 10^{-4}$

* Since Pa > Po, lightning protection is required.

A7.5.2 Workshop

A7.5.2.1 Construction: brick, non-metal roof

Dimensions: (l x w x h) : 40 x 18 x 6 m

Ac = (40 x 18) + (2 x 40 x 6) + (2 x 18 x 6) + (π $6^{2)}$ = 1529 m^2

a) Location: STANLOW, U.K.

Lightning flash density: Ng = 0.5
P = Ac x Ng x 10^{-6} = 1529 x 0.5 x 10^{-6} = 765 x 10^{-6}
Pa = Wo x P = 0.09 x 765 x 10^{-6} = 6.9 x 10^{-5}
Po = 10^{-4}

* Since Pa < Po, lightning protection is not required.

b) Location: MIRI, Sarawak

Lightning flash density: Ng = 6.9
P = Ac x Ng x 10^{-6} = 1529 x 6.9 x 10^{-6} = 10550 x 10^{-6}
Pa = Wo x P = 0.09 x 10550 x 10^{-6} = 9.5 x 10^{-4}
Po = 10^{-4}

* Since Pa > Po, lightning protection is required.

A7.5.2.2 Construction: brick, non-metal roof

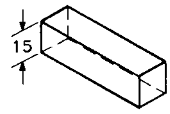
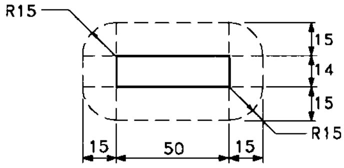
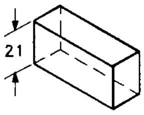
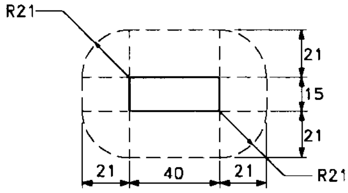
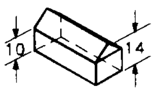
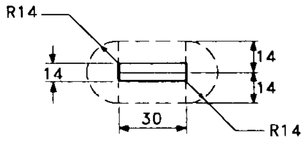
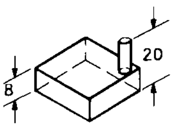
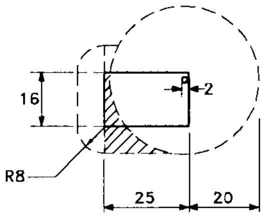
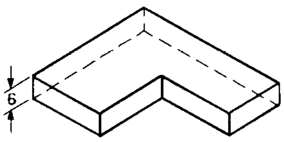
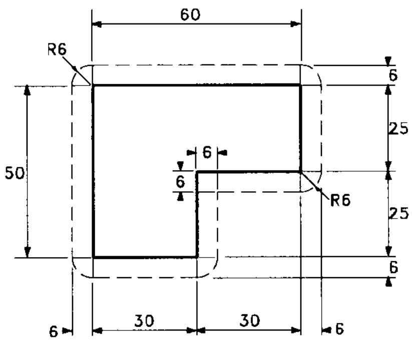
Dimensions (l x w x h) : 65 x 20 x 6 m
Ac = (65 x 20) + (2 x 65 x 6) + (2 x 20 x 6) + ($\pi 6^{2)}$ = 2433 m^2

Location: STANLOW, U.K.

Lightning flash density: Ng = 0.5
P = Ac x Ng x 10^{-6} = 2433 x 0.5 x 10^{-6} = 1217 x 10^{-6}
Pa = Wo x P = 0.09 x 1217 x 10^{-6} = 1.1 x 10^{-4}
Po = 10^{-4}

* Since Pa > Po, lightning protection is required.

FIGURE A7.1 EXAMPLES OF STRUCTURES AND COLLECTION AREAS

General arrangement	Collection area and method of calculation	
		$A_c = 14x50+2(15x50) +2(15x14)+\pi 15^2$ $A_c = 3327 m^2$
		$A_c = 15x40+2(21x40) +2(21x15)+\pi 21^2$ $A_c = 4296 m^2$
		$A_c = \pi 14^2 +2(14x30)$ $A_c = 1456 m^2$
		$A_c = \pi 21^2 +8x16+\pi 8^2 x1/2 +200$ (approx) $A_c = 1814 m^2$
		$A_c = 25x60+25x30+6x60 +6x50+6x25+6x25 +6x30+6x24+5/4x\pi 6^2$ $A_c = 3675 m^2$

APPENDIX 8 PLANT SWITCHBOARD CONFIGURATIONS

A8.1 GENERAL

100% incoming circuit rating refers to the peak load of the whole switchboard plus the 10% margin calculated in accordance with (4.2.2) and (4.5.1).

Where shown dotted in the figures A8.1 - A8.7 inclusive, transformers are omitted when voltages are equal.

NOTE: Interlocks between incoming circuits and/or bus sections shall be mechanical, and are only shown where they may be necessary to ensure the switchgear short circuit rating is not exceeded. Electrical interlocks shall only be used for automatic changeover schemes where an override feature is required, e.g. for testing of emergency generators.

A8.2 VITAL SERVICES

The basic scheme for interruptible, maintained supplies to vital (non-instrument) services requires a single section switchboard with two 100% rated incoming circuits, the normal feeder being derived from the mains power system and the stand-by circuit from an independent source, e.g. an emergency diesel generating set. An automatic changeover system shall be provided to change over to the stand-by circuit in case of mains failure. This configuration is shown in figure A8.1.

In some cases it may be economic to arrange a vital supplies switchboard as an extra section of another switchboard connected through a normally closed bus section switch. The changeover facilities described above shall be provided on that bus section switch. This configuration is shown in figure A8.2.

A8.3 ESSENTIAL SERVICES

The requirement for stand-by incoming circuit capacity to a switchboard supplying essential services necessitates the provision of one or more bus section switches, depending on the total number of incoming circuits. Only one incoming circuit should be connected to each switchboard section, and under normal circumstances, all incoming circuits shall be of equal rating.

The following configurations are designed to ensure that there is no possibility of overloading during either normal operation, or during the scheduled outage of one incoming circuit. To achieve this, three section boards and above require that duplicated (A,B) circuits must be connected to the same busbar section. **This arrangement should not be changed (i.e. A,B drives on different sections) without careful consideration of the overloading possibilities for all sections of the switchboard.**

Except where stated below, these configurations do not provide for outage of a plant switchboard section without interruption of some supplies to the plant.

The most commonly used configuration for a switchboard supplying essential service loads is a two section switchboard with two 100% rated incoming circuits and one bus section switch. This normally satisfies the requirements with incoming circuit ratings up to the maximum recommended continuous ratings stated in (4.5.3). Duplicated (main and stand-by) outgoing circuits shall be connected to different sections of the switchboard. Non-duplicated (i.e. non-essential) outgoing circuits shall be distributed between the busbar sections so as to balance the loads as far as possible. This configuration is shown in figure A8.3, and offers high security, as it permits the scheduled outage of one switchboard section while still continuing to operate the plant normally from the other section.

Where the incoming circuit ratings would exceed the maximum recommended continuous ratings stated in (4.5.3) if a two section switchboard were used, a three section switchboard with three incoming circuits and two bus section switches can be utilised. This permits doubling of the load which can be supplied by the two section switchboard described above. The central incoming circuit acts as the stand-by circuit to each of the outer two and the incoming circuits can each be rated at 50%. All loads shall be supplied from the outer sections of the switchboard and no loads connected to the centre section. Duplicated outgoing circuits for each 100% rated drive shall be connected to the same section of the switchboard. Non-duplicated (i.e. non-essential) outgoing circuits shall be distributed between the outer busbar sections so as to balance the loads as far as possible. In this configuration, the provision of interlocking may be necessary to prevent simultaneous closure of the two bus section switches if the short circuit rating of the switchgear would otherwise be exceeded. This configuration is shown in figure A8.4, and saves one incoming circuit in comparison with the two two section switchboards, which would otherwise be required to supply the load.

Where use is made of three 50% rated drives (i.e. two duty drives plus one stand-by -A, B, C) and it is required to supply each of these from a separate switchboard section so as to improve the security of supply, such loads can be connected to each of the three sections of a three section switchboard. The remaining loads should be distributed between the three sections so as to balance the loads as far as possible. Duplicated outgoing circuits for each 100% rated drive (A,B) shall be connected to the same section of the switchboard. Each incoming circuit must be rated to supply the load on the centre section plus one outer section of the switchboard, resulting in a maximum rating of 67%. Interlocking of the two bus-section switches may be required, as described for the 3*50% case above. The configuration with interlocking is shown in figure A8.5.

Where the concentration of LV loads exceeds the load which could be supplied by the three section switchboard configuration shown in figure A8.4, the four section double sided switchboard in 'H' configuration can be utilised. The central incoming circuit acts as the stand-by circuit to each of the outer four and the incoming circuits can each be rated at 25%. This permits the load which can be supplied by the two section switchboard described above to be increased by up to four times. Duplicated outgoing circuits for each 100% rated drive (A,B) shall be connected to the same section of the switchboard. Non-duplicated (i.e. non-essential) outgoing circuits shall be distributed between the busbar sections so as to balance the loads as far as possible. In this configuration it is necessary to provide interlocking between the four bus section switches to prevent more than two incoming circuits being paralleled. This configuration is shown in figure A8.6, and saves three incoming circuits in comparison with the four two section switchboards, which could otherwise be used to supply the load.

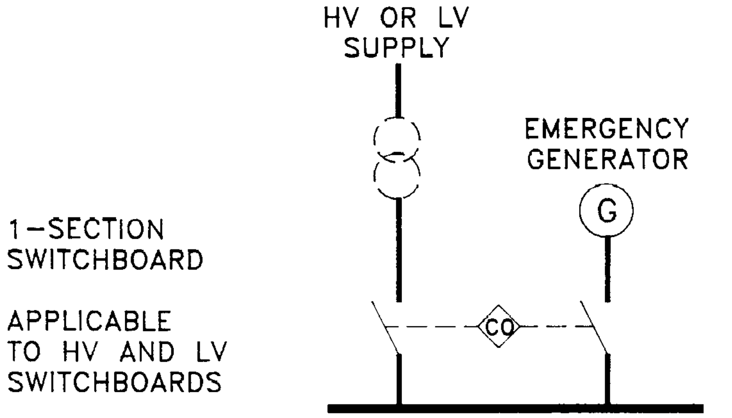
If it is necessary to be able to maintain normal plant operations when one section of the upstream source switchboard (supplying the plant switchboards described above) is taken out of service, then each of the incoming supply circuits to the plant switchboard must be supplied from a separate section of the source switchboard or from two independent source switchboards.

A8.4 NON-ESSENTIAL SERVICES

For non-essential services, a single section switchboard with one 100% rated incoming circuit shall be provided. This arrangement is shown in figure A8.7.

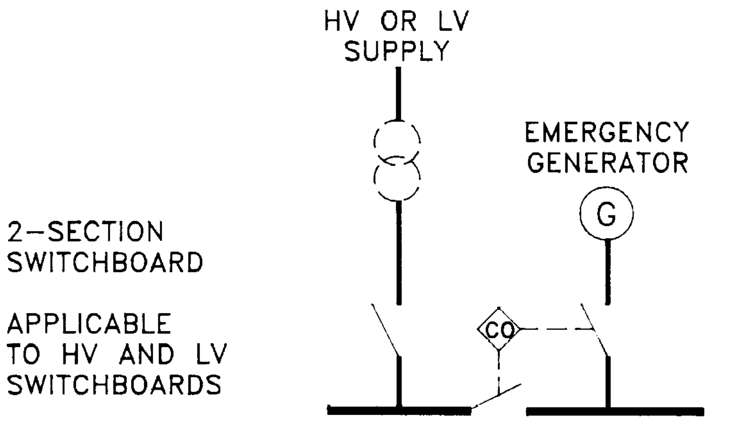
It may be economic to supply non-essential services from essential service switchboards, especially when these loads are small.

FIGURE A8.1



TRANSFORMER/FEEDER RATING: 1x100%
GENERATOR RATING: 1x100%
CO = BREAK-BEFORE-MAKE AUTO-CHANGEOVER

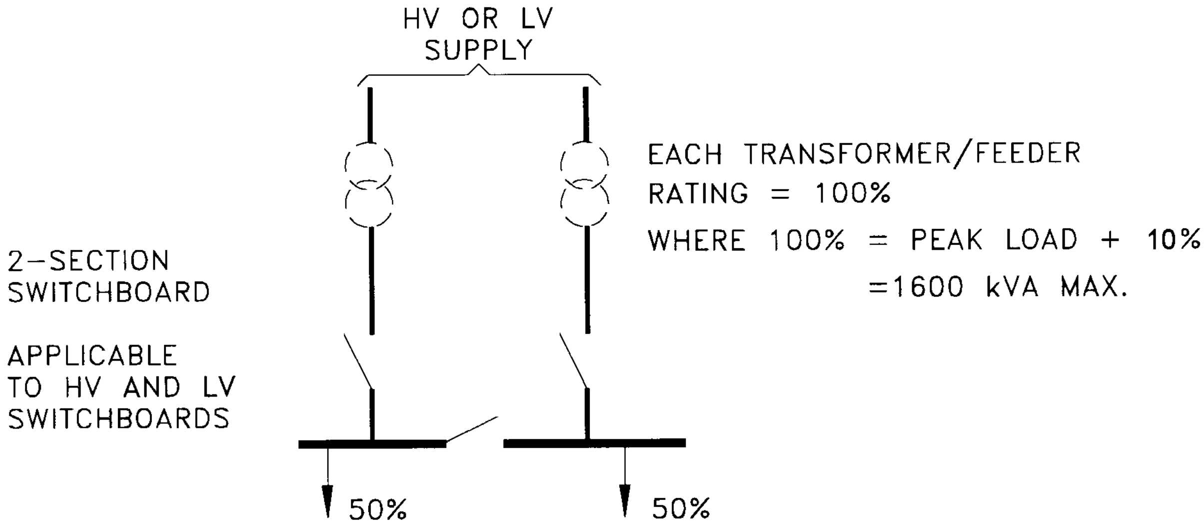
FIGURE A8.2



TRANSFORMER/FEEDER RATING: 1x100% TOTAL LOAD
GENERATOR RATING: 1x100% VITAL SERVICES
OUTGOING CIRCUIT CONNECTIONS: VITAL SERVICES ON RIGHT HAND SECTION
OTHER LOADS ON LEFT HAND SECTION

CO = BREAK-BEFORE-MAKE AUTO-CHANGEOVER

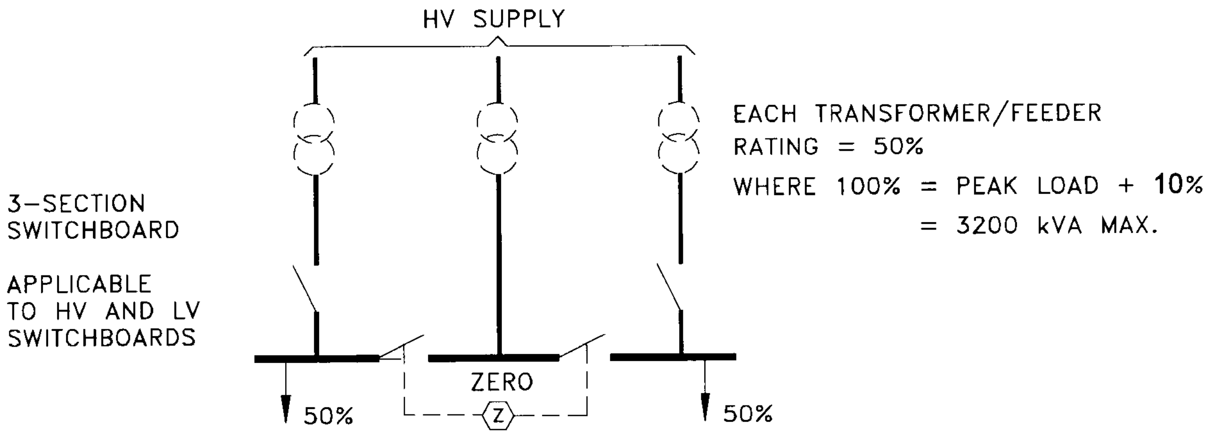
FIGURE A8.3



INCOMER/BUS SECTION INTERLOCKING: NONE

OUTGOING CIRCUIT CONNECTIONS: 'A' AND 'B' DRIVES ON DIFFERENT BUSBAR SECTIONS

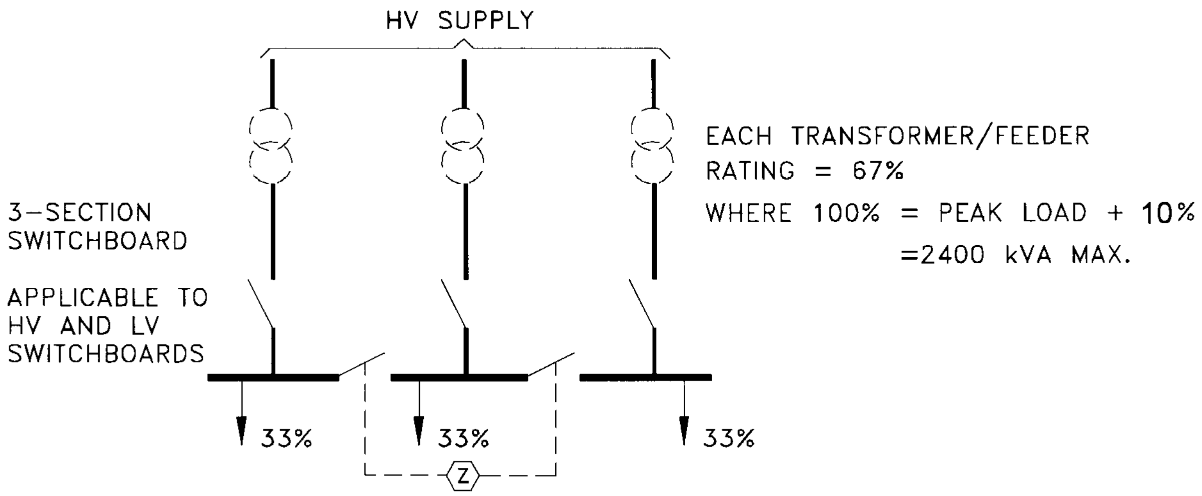
FIGURE A8.4



INCOMER/BUS SECTION INTERLOCKING (Z):1 OUT OF 2 CLOSED

OUTGOING CIRCUIT CONNECTIONS : LOADS EVENLY DISTRIBUTED BETWEEN OUTER SECTIONS.
"A" AND "B" DRIVES ON SAME (OUTER) BUSBAR SECTION
NO LOAD ON CENTRE BUSBAR SECTION

FIGURE A8.5

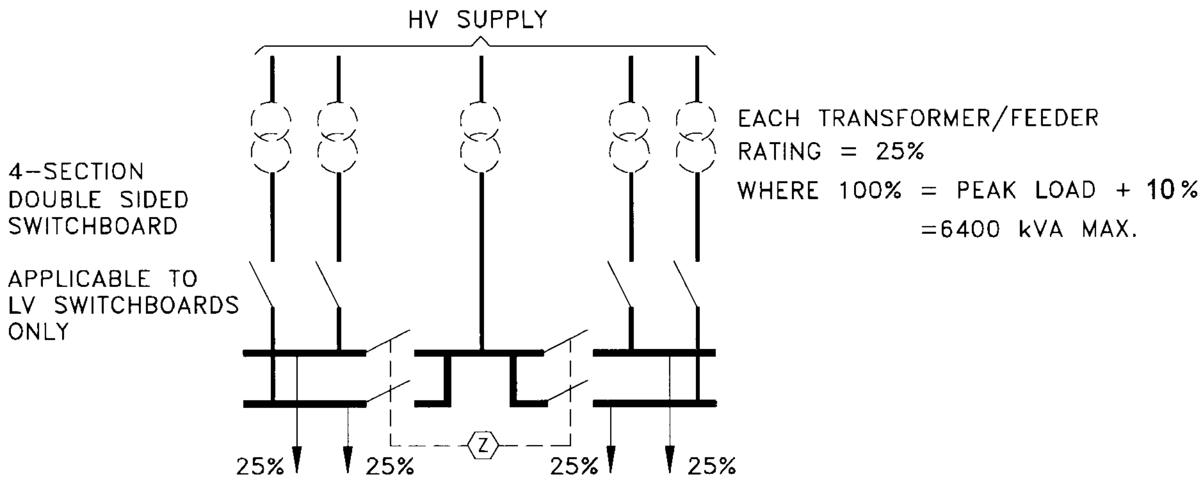


INCOMER/BUS SECTION INTERLOCKING (Z):1 OUT OF 2 CLOSED

LOADS EVENLY DISTRIBUTED BETWEEN THREE SECTIONS

OUTGOING CIRCUIT CONNECTIONS: LOADS EVENLY DISTRIBUTED BETWEEN THREE SECTIONS
'A' AND 'B' DRIVES ON SAME BUSBAR SECTION

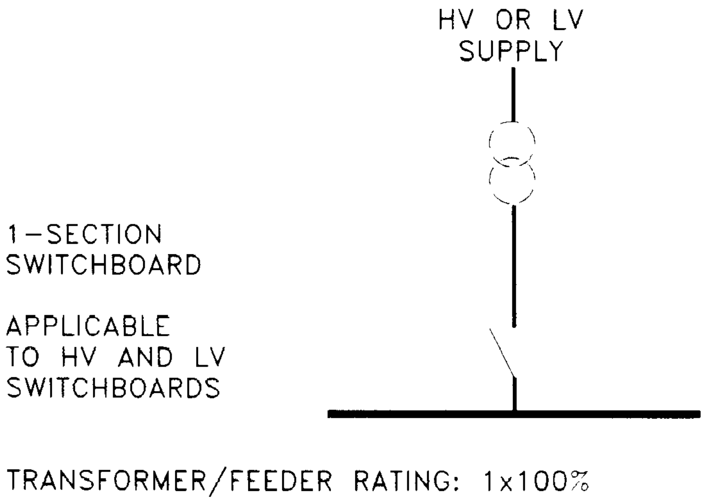
FIGURE A8.6



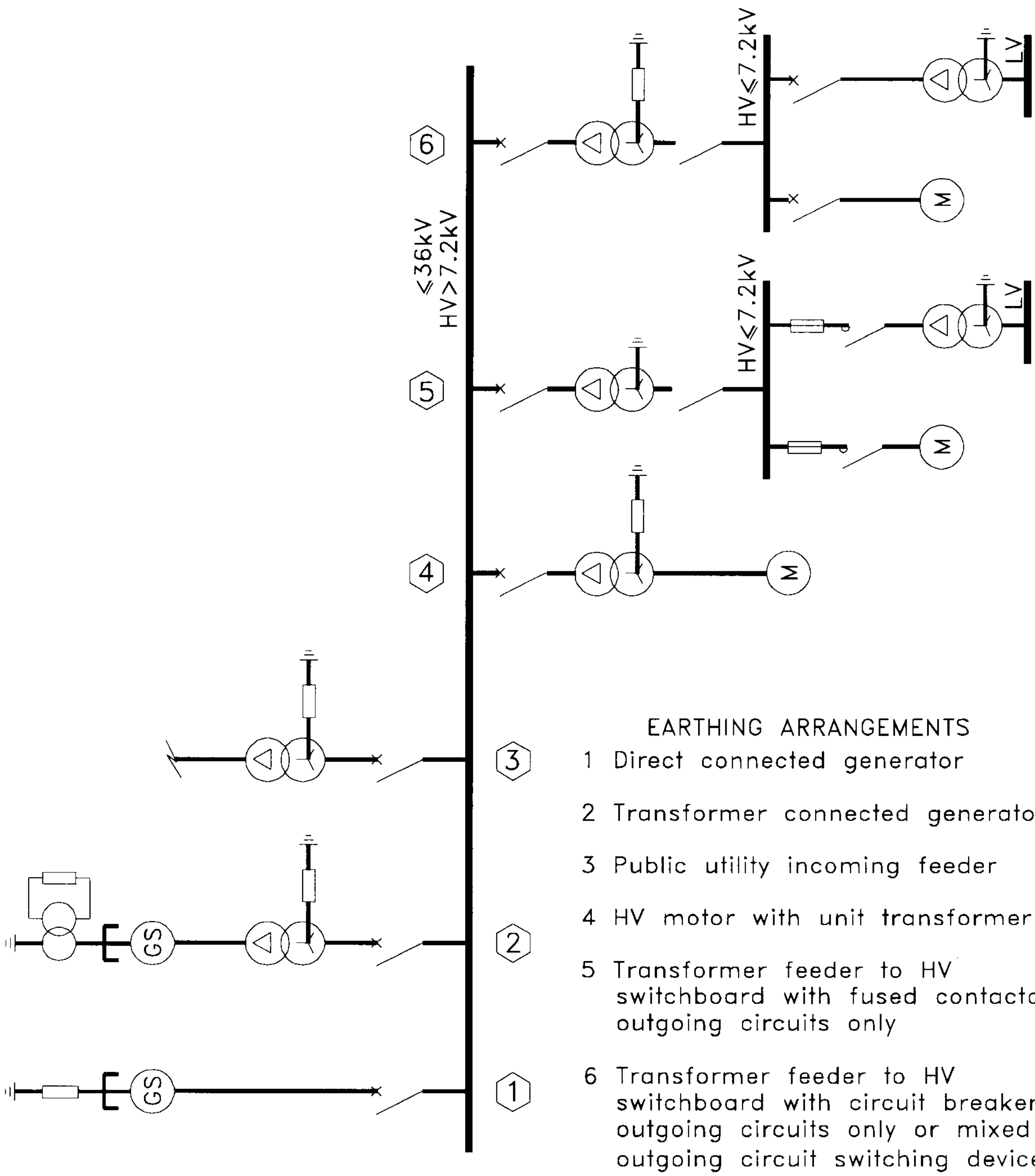
INCOMER/BUS SECTION INTERLOCKING (Z):1 OUT OF 4 CLOSED

OUTGOING CIRCUIT CONNECTIONS: LOADS ON FRONT & REAR OUTER BUSBAR SECTIONS
'A' & 'B' DRIVES ON SAME BUSBAR SECTION
NO LOAD ON CENTRE BUSBAR SECTION

FIGURE A8.7


HV OR LV
SUPPLY
1-SECTION
SWITCHBOARD
APPLICABLE
TO HV AND LV
SWITCHBOARDS
TRANSFORMER/FEEDER RATING: 1x100%

APPENDIX 9 SYSTEM NEUTRAL EARTHING DIAGRAMS



EARTHING ARRANGEMENTS

1 Direct connected generator

2 Transformer connected generator

3 Public utility incoming feeder

4 HV motor with unit transformer

5 Transformer feeder to HV switchboard with fused contactor outgoing circuits only

6 Transformer feeder to HV switchboard with circuit breaker outgoing circuits only or mixed outgoing circuit switching devices

APPENDIX 10 CONTRACTOR PREPARED DOCUMENTS AND DOCUMENTS FOR PRINCIPAL'S APPROVAL

Project documents	Project specification		Detail design and engineering	
Documentation	Contractor preparation	Principal approval	Contractor preparation	Principal approval
DESCRIPTIVE SECTIONS:				
System Description	X	Xv		
System Operation Philosophy	X	X		
Control, Monitoring & Protection	X	X		
Emergency & Vital Supplies	X	X		
Shell Documents:				
Amendments to DEPs	X	X		
Supplements to DEPs	X	X		
List of Recommended Vendors	X	X		
OPCO Requirements	X	X		
STUDIES:-				
Cable sizing calculations			X	X(s)
Harmonic analysis			(X)	X
Illumination levels			X	
Motor restart			(X)	X
Substations (quantity & location)	X	X		
Power factor correction			X	X
Protection settings			X	X
Short circuit	X(p)	X	X	X
System stability & load shedding			(X)	X
VSDS economics	(X)	X		
DRAWINGS:-				
Key line diagram	X	X	X	X
Emergency & vital systems S.L.diagrams	X	X	X	X
HV switchboard single line diagrams			X	
Connection diagrams			X	
Control system block diagram			X	X(s)
Schematic diagrams			X	
Protection & metering key diagrams	X	X	X	X
Protection discrimination graphs			X	X
Area classification layouts and sections	X	X	X	X
Cable routing layouts	X(m)	X	X	X(m)
Earthing layouts			X	
Lighting & LV power layouts			X	
Power layout (motors etc.)			X	
Substation layouts	X	X	X	X
Trace heating system layouts			X	
Cable trench details			X	
Construction details			X	

Project documents	Project specification		Detail design and engineering	
Documentation	Contractor preparation	Principal approval	Contractor preparation	Principal approval
SCHEDULES:-				
Control, alarm & monitoring table	X	X	X	X
HV switchgear	X(t)	X	X	X(s)
LV switchgear	X(t)	X	X	X(s)
Protection relay settings			X	X
Summary of Electrical Engineering (electrical equipment summary sheets)	X(P1&P2)	X	X	X
Utility data (electrical)	X	X	X	X
REQUISITIONS:-				
Generators	X	X	X	X
Luminaires			X	
Motors (HV)	X(t)	X	X	X(s)
Motors (LV)	X(t)	X	X	
Remote control units (RCUs)			X	
Switchgear (HV)	X	X	X	X(s)
Switchgear (LV - MCC)	X(t)	X	X	X(s)
Switchgear (LV - misc.)			X	
Transformers	X(t)	X	X	X(s)
UPS units (a.c.)	X(t)	X	X	X(s)
UPS units (d.c.)	X(t)	X	X	X(s)
VSDS	X	X	X	X(s)
SPECIFICATIONS (as applicable):-			X	
Bulk materials			X	
Cables	X	X(t)	X	X(s)
Motor operated valves (MOVs)	X	X	X	X(s)
Neutral earthing device	X	X	X	X(s)
Power factor correction	X	X	X	X(s)
Package units	X	X	X	X(s)
Process heaters			X	
Trace heating				
MISCELLANEOUS:-			X	X
Construction specification			X	X
Design manual	(X)	X	X	X(s)
Equipment Bid Evaluation (Report)	(X)	X	X	X(s)
Equipment Bid Tabulations (Tech.)			X	X
Operating manuals			X	X
Spare parts list (& SPIR)			X	X
Temporary installation specification			X	X
Test record forms (site)			X	X
Testing procedures (site)			X	X(s)
Vendor drawings			X	X(s)
Vendor equipment certificates				

Legend for Appendix 10:

(X) = If requested by Principal
(m) = Main

(p)	=	Preliminary
(s)	=	Selected
(t)	=	Typical
(P1 & P2)	=	Parts 1 & 2 only of the Summary of Electrical Engineering (electrical equipment summary sheets).

APPENDIX 11 EQUIPMENT AND CABLE NUMBERING

A11.1 EQUIPMENT NUMBERING

A11.1.1 General

Electrical machines shall be identified as stated in DEP 31.10.03.10-Gen.

Electrical distribution and control equipment shall be identified by a number, thus: WWxxxYz, where

- WW is the two letter equipment reference as stated in (A11.1.2),
- xxx is the three digit substation number as determined by the Principal,
- Y is the one letter voltage identification as stated in (A11.1.3), or two letters for transformers, one for each winding voltage,
- z is the one or two digit sequence identification.

NOTES: 1. For greenfield sites the substation number should be as follows:-

The sources of power, i.e. Main Electrical Intake Station and/or Power Station Switchboard shall be identified by alphabetic characters with if applicable an additional sequence number (e.g. MIS, PSS1, PSS2).

HV substations fed directly from these substations shall be identified by a three digit number with a prefix "SS" (e.g. SS-100, SS-200 etc.). The first digit is a sequence number.

HV substations fed from another HV substation shall be identified with a sequence number of the second digit (e.g. SS-110, SS-210 etc.).

LV substations fed from an HV substation shall be identified with a sequence number of the third digit (e.g. SS-111, SS-201 etc.).

2. The sequence identification may be numbers and/or letters. Letters, e.g. A, B should be used as the final character in the identification of several identical items of plant.

A11.1.2 Equipment references

The following references shall be used to identify the function of the equipment:

AP	=	Alarm panel
CA	=	Capacitor bank
CP	=	Control panel
IR	=	Interposing relay box
JB	=	Junction box
RR	=	Resistor (earthing)
RX	=	Reactor
SB	=	Switchboard
TR	=	Transformer
UP	=	UPS unit
VS	=	VSDS

A11.1.3 Voltage identification

The following references shall be used to identify the nominal voltage level(s) of the equipment:

A	=	60 kV and above
B	=	20 kV - 33 kV
C	=	10 kV and 11 kV
D	=	3 kV - 6.6 kV
E	=	LV (interruptible, maintained)
F	=	LV (d.c.) N = LV (essential and non-essential)
V	=	LV (uninterruptible, maintained)
X	=	LV (controls, alarms and indications, a.c. or d.c.)

A11.1.4 Examples

The first 6.6 kV switchboard in substation 110 would be identified as SB110D1.

The third 400 V (a.c.) switchboard in substation 112 would be identified as SB112E3.

The second 33/6.9 kV transformer located at distribution substation 300 would be identified as TR300BD2. The tap change control panel associated with this transformer would be identified as CP300X2.

A11.2 CABLE NUMBERING

Cable numbers shall be listed in the project cable schedule, DEP 05.00.54.84-Gen sheet 4, stating all the information specified. The destinations shall be specific, stating the switchboard and panel numbers, etc.

If it is required to distinguish between cables at different voltages or of differing functions, the sequence identification numbers should be sub-divided into blocks, e.g. 1000-1999 for HV cables, 2000-2999 for LV cables, 3000-3999 for control cables, etc.

A block of cable numbers should be allocated for site use, e.g. 1900-1999, 2900-2999, etc.

APPENDIX 12 CALCULATION OF EARTH LOOP IMPEDANCES

A12.1 Sequence impedances

The values of positive sequence impedances, R and X, are readily available from cable manufacturers' data sheets, and for cables, positive and negative sequence impedances are equal.

The relationship between the zero and positive sequence impedances, R0/R1 and X0/X1, depend on the earthfault return path as follows:

Table 12.1 Zero sequence impedance ratio.

Cross section	R0/R1		X0/X1	
A (mm^2)	a	b	a	b
3 x 2.5	4	1.1	4.0	19
3 x 4	4	1.2	4.0	19
3 x 6	4	1.3	3.9	18
3 x 10	4	1.5	3.9	17
3 x 16	4	1.8	3.8	16
3 x 25	4	2.2	3.8	14
3 x 35	4	2.6	3.7	12
3 x 50	4	3.0	3.7	10
3 x 70	4	3.5	3.6	8
3 x 95	4	4.2	3.6	6
3 x 120	4	4.5	3.5	5
3 x 150	4	4.9	3.5	4
3 x 185	4	5.2	3.4	3
3 x 240	4	5.6	3.4	3
3 x 300	4	6.0	3.3	2
Earthfault returns via: a; Fourth conductor (Size A mm^2) b; Plant's grid (Size 70 mm^2) and Armouring (Size = A/2 mm^2)				

In the above table, the earthfault return path of a plant comprises the combined impedance of the plant's 70 mm^2 earth grid copper conductors and the outer conductor of the cable. The latter comprises, if applicable, lead sheath, steel wire armouring and additional copper wires. These additional wires are used to achieve a total impedance which is approximately equal to an equivalent copper conductor sized A/2 mm^2, where A is the area of the individual cable phase conductors.

A12.2 References

For this subject, reference is made to the following publications:

1. DIN 57 102-2;
2. BBC (Brown Boveri) Switchgear Manual; 6th edition; Table (4-21), Page 84.