

DEP SPECIFICATION

ELECTRICAL ENGINEERING DESIGN

DEP 33.64.10.10-Gen.

February 2014

DESIGN AND ENGINEERING PRACTICE

DEM1



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The objective is to set the standard for good design and engineering practice to be applied by Shell companies in oil and gas production, oil refining, gas handling, gasification, chemical processing, or any other such facility, and thereby to help achieve maximum technical and economic benefit from standardization.

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1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations 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.

This DEP excludes facilities located in North America. Refer to DEP 33.64.20.10-Gen., Electrical engineering design for North America Application.

This DEP contains mandatory requirements to mitigate process safety risks in accordance with Design Engineering Manual (DEM) 1 – Application of Technical Standards.

This is a revision of the DEP of the same number dated February 2011; see (1.5) regarding the changes.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI, the distribution of this DEP is confined to Shell companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them. Any authorised access to DEPs does not for that reason constitute an authorization to any documents, data or information to which the DEPs may refer.

This DEP is intended for use in facilities related to oil and gas production, gas handling, oil refining, chemical processing, gasification, distribution and supply/marketing. This DEP may also be applied in other similar facilities.

When DEPs are applied, a Management of Change (MOC) process shall be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements could 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 with regards to the safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this 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, the objective being to obtain agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

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

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

The **Principal** is the party that initiates the project and ultimately pays for it. 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 capitalised term **SHALL [PS]** indicates a process safety requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

Refer to IEC 60050 for definitions not listed below.

Term	Definition
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.
Declaration of compliance	Document issued by the Manufacturer declaring that the electrical apparatus complies with the requirements of IEC 60079-15.
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 Network Monitoring and Control (ENMC)	A computerised system that is dedicated to monitoring and controlling defined aspects of an electrical network.
Emergency lighting	Lighting provided for use at emergency response locations when the supply to the normal lighting fails.
Escape lighting	Part of Emergency Lighting provided to ensure that the escape route is illuminated in the event of a major incident.
Essential service	A service, which, if it fails in operation or when called upon, will affect the continuity, quality or quantity of the product.
Firm capacity	The installed capacity less the stand-by capacity.
High Voltage (HV), 601-01-27, IEC 60050	The set of voltage levels in excess of low voltage. NOTE: Although not covered by an IEC definition, it has become industry practice to use the term Medium Voltage (MV) for voltages from 1 kV up to 52 kV.
Installed capacity	The sum of the rated powers of equipment of the same kind (generators, transformers, converters, etc.) in an electrical installation.
Instrumented Protective Function (IPF)	A function comprising the initiator function, logic solver function and final element function for the purpose of preventing or mitigating hazardous situations. (Ref: DEP 32.80.10.10-Gen) NOTE: Previously the term safeguarding was used.
Interruptible, maintained electricity supply	A source of electrical power which is backed up by a second (emergency) source of power, such as to provide a supply of electricity that may be interrupted for no more than 15 s.
Low Voltage (LV), 601-01-26, IEC 60050	A set of voltage levels used for the distribution of electricity and whose upper limit is 1000 V AC
Non-essential service	A service that is neither vital nor essential.

Term	Definition
Non-hazardous area, 426-03-02, IEC 60050	An area in which an explosive gas atmosphere is not expected to be present in quantities such as to require special precautions for the construction, installation and use of electrical apparatus.
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.
Process Safety	Process Safety is the management of hazards that can give rise to major accidents involving the release of potentially dangerous materials, release of energy (such as fire or explosion) or both.
Safety Switch	A switch in the vicinity of a consumer used to disconnect the equipment for safeguarding purposes.
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 equipment which may be withdrawn from service under planned or unplanned circumstances.
Test report	Document prepared by the Manufacturer indicating in detail the tests and verifications to which the electrical apparatus has been subjected, and their results.
Uninterruptible, maintained electricity supply	A source of electrical power which is backed up by a second (emergency) source of power, such as to provide a supply of electricity that may be interrupted for no longer than 0.5 ms. AC uninterruptible, maintained electricity supplies incorporate 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. DC uninterruptible, maintained electricity supplies are derived from battery-rectifier units (DC UPS units) or from rectifier units energised from one or more AC uninterruptible, maintained supply sources (AC UPS units).
Very toxic (substances)	Substances very hazardous for the environment or human health, as specified in DEP 01.00.01.30-Gen. (which also identifies "toxic" substances by reference to chemical substances databases).
Vital service	A service which, if it fails in operation or when called upon, can cause an unsafe condition of the process and/or electrical installation, jeopardise life, or cause major damage to the installation. NOTE: In Marine and Offshore applications, some services defined here as "vital" may be referred to as "Essential services".
Zone 0 (in the classification of hazardous gas areas), 426-03-03, IEC 60050	An area in which an explosive gas atmosphere is present continuously, or is present for long periods.

Term	Definition
Zone 1 (in the classification of hazardous gas areas), 426-03-04, IEC 60050	An area in which an explosive gas atmosphere is likely to occur in normal operation.
Zone 2 (in the classification of hazardous gas areas), 426-03-05, IEC 60050	An area in which an explosive gas atmosphere is not likely to occur in normal operation and if it does occur it will exist for a short period only.
Zone 20 (in the classification of hazardous dust areas), 426-03-23, IEC 60050	An area in which combustible dust, as a cloud, is present continuously or frequently, during normal operation, in sufficient quantity to be capable of producing an explosive concentration of combustible dust mixed with air, and/or where layers of dust of uncontrollable and excessive thickness can be formed.
Zone 21 (in the classification of hazardous dust areas), 426-03-24, IEC 60050	Areas not classified as Zone 20, in which a combustible dust cloud is likely to occur during normal operation, in sufficient quantities to be capable of producing an explosive concentration of combustible dust mixed with air.
Zone 22 (in the classification of hazardous dust areas), 426-03-25, IEC 60050	Areas, not classified as Zone 21, in which combustible dust clouds may occur infrequently, and persist for only a short period, or in which accumulations or layers of combustible dust may be present under abnormal conditions and give rise to combustible mixtures of dust in air. Where, following an abnormal condition, the removal of dust accumulations or layers cannot be assured, the area shall be classified Zone 21.

1.3.3 Installation and equipment definitions

Term	Definition
Bus coupler circuit breaker , 605-02-40, IEC 60050	In a substation a circuit breaker which is located between two busbars and which permits the busbars to be coupled; it may be associated with selectors in case of more than two busbars.
Bus section circuit breaker (= switched busbar circuit breaker), 605-02-41, IEC 60050.	In a substation a circuit breaker, connected in series within a busbar, between two busbar sections.
Distributed Control System (DCS)	A configurable microprocessor-based (process) control system.
Distribution substation / switchboard	A substation/switchboard mainly used for distributing power to several plant substations.
Sub-distribution switchboard	A switchboard, fed by a distribution switchboard, used for distributing low voltage power to a number of users.

Term	Definition
Intake substation / switchboard	A substation/switchboard at which the supply provided by the public utility is interconnected with the site's electrical distribution system. NOTE: An intake substation and a power plant substation may be combined as a single substation.
Integrated Motor Control System (IMCS)	A system comprising control modules, central unit(s), a serial bus connecting the control modules to the central unit and a communication facility enabling connection of the central unit to a distributed control system (DCS) and/or a Supervisory Control and Data Acquisition System (SCADA).
Inverter	A converter for conversion from DC to AC
Plain feeder	A feeder, which consists of a cable or an overhead, line only and does not have an interconnected transformer.
Plant substation / switchboard	A substation/switchboard mainly used for feeding one process or utility plant.
Power plant substation / switchboard	A substation/switchboard to which generators and outgoing feeders are connected. NOTE: An intake substation and a power plant substation may be combined as a single substation.
Rectifier	A converter for conversion from AC to DC
Remote Control Unit (RCU)	A control device in the vicinity of a consumer for operation of the remotely installed controlgear of the consumer.
Switchroom	A room in a substation or building intended exclusively for the installation of one or more switchboards, distribution switchboards etc.
Variable Speed Drive System (VSDS)	A line-fed AC to AC conversion system consisting of all facilities required to operate its electric motor at variable speeds.

1.3.4 Abbreviations

Term	Definition
A/G	above ground
swbd	switchboard
U/G	underground

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section or clause number is shown in brackets (). Other documents referenced by this DEP are listed in (8).

1.5 SUMMARY OF MAIN CHANGES

This DEP is a full revision of the DEP of the same number dated February 2011. The following are the main, non-editorial changes.

Section/Clause	Change
General	Statements with “shall” and “should” challenged/verified (for reduction in the number of “shall” statements) Comments from the DEP feedback system are incorporated SHALL [PS] statement added 2.3.2 – 3 for selection, specification and installation of equipment suitable for combustible dust risks SHALL [PS] statement removed 3.9.1, wording incorporated in 3.2.1 – 3 SHALL [PS] statements in 6.6 rationalised to refer to specific ISGOTT requirements
2.3.2	IEC standard for area classification for combustible dust hazards corrected
3.3.1	Requirements for evaluation of 690 V system added
3.5.3	Clarification on dynamic response margin given, with requirement to study in DEFINE phase for large island power systems
3.5.5	Clarification on selection of double busbar systems given
3.8.2	Neutral earthing resistor for HV transformers and directly connected HV generators changed from FLC to 100A, to reduce the risk of machine core damage during earth faults
3.9.2	Duplicate AC UPS requirement changed; options given
3.9.3	Duplicate DC UPS requirement changed; removed “N+1” wording
3.9.4	Clarification on battery autonomy times given
3.10	New Section added to enable retirement of DEP 33.64.10.12-Gen.
4.8.7	Clarification given on standards for cables with increased fire withstand capabilities
4.10.3	Option to consider LED lighting given for control room buildings and non-industrial locations
4.11.	Requirement for separate control and trip switching devices added for directly-fed process heaters
5.1	Minimum IP ratings given for common equipment and locations
5.2.3	Fire walls for intake and large transformers added
5.3.1.1	Section added to show requirements for single core cables
5.3.2.1	Generic statements about cable sizing requirements removed to Informative
5.3.4.1	Advice use metallic cable ties for permanent fixings
5.5	Many requirements moved to EMC DEP 33.64.10.33-Gen.
6.1.3.1	Requirement added to consider very early smoke detection systems for critical air-insulated switchboards
6.1.3.4	Requirements for doors for battery rooms clarified
Appendix 3.7	Section added for monitoring of large HV induction motors

Section/Clause	Change
Appendix 5	"Appendix 5 - Assessment of need for lightning protection" deleted and moved to DEP Informative 5.5.4
Appendix 6	Update to table in Section C) under "Level of congestion within plant area" addressing risk of disturbing/damaging cables if laid U/G.
Appendix 7	Description of deliverable documents clarified SAFOP requirement in DEFINE phase clarified System Commissioning Philosophy added Ex register added Clarified that Area Classification is THSE deliverable

1.6 COMMENTS ON THIS DEP

Comments on this DEP may be submitted to the Administrator using one of the following options:

Shell DEPs Online (Users with access to Shell DEPs Online)	Enter the Shell DEPs Online system at https://www.shelldeps.com Select a DEP and then go to the details screen for that DEP. Click on the "Give feedback" link, fill in the online form and submit.
DEP Feedback System (Users with access to Shell Wide Web)	Enter comments directly in the DEP Feedback System which is accessible from the Technical Standards Portal http://sww.shell.com/standards . Select "Submit DEP Feedback", fill in the online form and submit.
DEP Standard Form (Other users)	Use DEP Standard Form 00.00.05.80-Gen. to record feedback and email the form to the Administrator at standards@shell.com .

Feedback that has been registered in the DEP Feedback System by using one of the above options will be reviewed by the DEP Custodian for potential improvements to the DEP.

1.7 NON NORMATIVE TEXT (COMMENTARY)

Text shown in italic style in this DEP indicates text that is non-normative and is provided as explanation or background information only.

Non-normative text is normally indented slightly to the right of the relevant DEP clause.

2. DESIGN AND ENGINEERING PRINCIPLES

2.1 STANDARDS, CODES, REGULATIONS AND TECHNICAL ASSURANCE

2.1.1 General

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.

1. 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.
2. The electrical installation shall be suitable for the site conditions as specified by the Principal.
3. Where necessary, special attention shall be paid to the selection and installation of electrical equipment suitable for seismic conditions.
4. 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.
5. Electrical equipment and materials shall comply with the relevant DEP specifications, which are supplementary to IEC equipment standards.
6. 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.
7. In the event of contradiction between the requirements of DEP specifications and IEC, CENELEC or national standards, the former shall prevail, provided the statutory obligations in the country of installation are satisfied.
8. 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.
9. As far as is applicable, Standard Drawings in groups S 64, S 67, S 68 and S 69 shall be followed.

2.1.2 Technical assurance

1. The design of electrical installation shall be subjected to a formal technical assurance process.
2. The technical assurance process shall include the requirement for a SAFOP (safety and operability) assessment.

2.2 OPERATIONAL SAFETY AND RELIABILITY

1. Electrical Safety Rules (ESRs) shall be in accordance with DEP 80.64.10.10-Gen.
2. To mitigate the increased risks present in temporary installations, the specific requirements associated with the design and installation of temporary facilities shall be in accordance with (6.9).

2.3 PROTECTION AGAINST EXPLOSION AND FIRE HAZARDS

2.3.1 Flammable gas/vapour hazards

1. To permit the proper selection of electrical apparatus for areas where flammable gas or vapour risks may arise, area classification drawing(s) SHALL [PS] be prepared.
 - Unless otherwise advised by the Principal, IP Model Code of Safe Practice Part 15, Area Classification Code for Petroleum Installations, as amended/supplemented by DEP 80.00.10.10-Gen, shall be used.
2. Control rooms and Substations should be located in non-hazardous areas.
3. Where electrical equipment has to be installed in hazardous areas, equipment with a type of protection suitable for the relevant zones SHALL [PS] be selected, specified and installed.
 - Unless otherwise advised by the Principal, IEC 60079-14 and IEC 60079-17 shall be used.
4. (Appendix 1) summarises the various types of protection of electrical equipment that are permissible in hazardous areas. The specification or procurement of equipment complying with standards different from the above shall require the specific approval of the Principal.
5. The following applies to the final selection for Zone 1:
 - a. LV motors and all inherently non-sparking equipment, (e.g. junction boxes, terminal boxes and luminaires), shall have type of protection 'e'.
 - b. HV motors and all inherently sparking equipment, e.g. switchgear and controlgear, shall have type of protection 'd'.
 - c. Where such type of protection is not available (e.g. large high speed HV motors), type of protection 'p' shall be used.
 - d. HV motors with type of protection 'e' shall not be used.
6. The following applies to the final selection for Zone 2:
 - a. Motors and inherently non-sparking equipment should have type of protection 'n', albeit equipment approved for Zone 1 is also acceptable.
 - b. Inherently sparking equipment shall have type of protection 'd' or 'p', as stated for Zone 1.
 - c. HV motors with type of protection 'n' or 'e' SHALL [PS] not be installed in Zone 2 areas where:
 - i. the motor voltage exceeds 6.6 kV, or
 - ii. the motor drives a centrifugal/screw hydrocarbon and/or hydrogen gas compressor.
 - d. These motors SHALL [PS] have type of protection 'd' or 'p'.
7. For the purpose of commonality of spares and to cater for the possibility of re-classification of areas, the same equipment suitable for use in Zone 2 locations shall be installed within process installations in non-hazardous areas.

NOTE: This applies specifically to motors, luminaires, RCUs and power and convenience outlets. Refer to (4.10.2).
8. Electrical equipment installed indoors, in 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 should be either of the industrial weatherproof type or of the domestic type depending on the function of the area (6.1).

9. Equipment installed in non-hazardous areas outside process installations, e.g. offices, gatehouses, etc. should be of a normal industrial/domestic type in accordance with national standards of the country of installation.

2.3.2 Combustible dust hazards

1. To permit the proper selection of electrical apparatus for areas where combustible dust risks may arise, area classification drawing(s) SHALL [PS] be prepared.
 - Unless otherwise advised by the Principal, IEC 60079-10-2 shall be used.
2. Control rooms and Substations should be situated in non-hazardous areas.
3. Where electrical equipment has to be installed in hazardous areas, equipment with a type of protection suitable for the relevant zones SHALL [PS] be selected, specified and installed.
 - Unless otherwise advised by the Principal, IEC 60079-14 and IEC 60079-17 shall be used.
4. For the purpose of commonality of spares and to cater for the possibility of re-classification of areas, the same equipment suitable for use in Zone 22 locations should be installed within process installations.

NOTE: This applies specifically to motors, luminaires, RCUs and power and convenience outlets. Refer to (4.10.2).

2.4 STANDARDISATION OF EQUIPMENT AND MATERIALS

1. Equipment of similar nature and incorporating similar or identical components and of similar or identical construction should be from the same Manufacturer (e.g. power and convenience outlets, luminaires, junction boxes, RCUs, switches etc.).

2.5 CERTIFICATES, DECLARATIONS AND TEST REPORTS

1. 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.
2. 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:
 - a. For electrical apparatus in Zone 0, Zone 1 and Zone 2 areas, a certificate of conformity shall be obtained from the Manufacturer.
 - i. In addition for EU regions, electrical apparatus with a category indication 1 or 2, a certificate of a Notified Body and a CE Declaration of conformity shall be obtained from the Manufacturer.
 - b. 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.
 - i. In addition for EU regions, electrical apparatus with a category indication 3, a certificate of an independent authorisation authority and a CE Declaration of conformity shall be obtained from the Manufacturer.
3. The Contractor shall obtain the Manufacturer's requirements for installation from the certificate or declaration of conformity and incorporate these in the design and engineering for installation.

3. ELECTRICAL SYSTEM DESIGN

3.1 GENERAL

3.1.1 Design philosophy

1. The design shall meet the specific design criteria, philosophy and/or objective stated in the project definition phase, e.g. in the basis of design document and/or project specification, relating to a particular plant or facility.

For instance, it may be defined by plant lifetime, skill of operating and maintenance personnel, operational flexibility, extension possibilities or noise limitations, etc.

2. If specified by the Principal, the design of the electrical installation shall comply with the project Design Class. Refer to DEP 00.00.07.10-Gen.
3. 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.
4. The conceptual designs and philosophies relating to the electrical system shall be documented by a system design description, a key line diagram, basic layout drawings and functional/outline specifications.

The overall design intent is a suitably robust system, with reduced energy consumption through the selection and utilisation of efficient electrical equipment.

5. When electrical power systems are designed, the following alternatives for the electricity supply should be considered: own generation, public utility supply, or a combination of these within the limits and possibilities given by the Principal.
6. Generating sets should normally be in an electrically centralised location with a radial distribution system. Ring distribution systems are preferred for residential/industrial facilities located at relatively large distances from the power source or from each other.
7. A key line diagram of the electrical power system shall be prepared and kept up-to-date.
8. System studies and protection reports, including software files etc., shall be provided in support of the design, for approval by the Principal. Depending on the type, size and complexity of the installation, such studies may comprise the following as listed in (Appendix 7):
 - a. Load flow studies;
 - b. Short circuit studies complying with IEC 60909 Parts 0, 1, 2, 3, 4.
 - c. System dynamic stability (transient stability) studies under three phase fault conditions;
 - d. Dynamic performance studies under motor starting and/or loss of generation conditions;
 - e. Protection grading studies, including relay setting schedules; an arc flash study should be carried out for low voltage switchboards and for high voltage switchboards only if the protection grading studies show that arcing faults cannot be cleared within the Internal Arc Classification time of the switchgear.
 - f. Harmonic analysis studies;
 - g. Motor re-starting and re-acceleration;
 - h. Vital Supply recovery following total power failure, including emergency diesel generator(s), UPS, instrumentation, DCS and IMCS.
10. The scope and timing of the system studies shall be defined by the Principal and agreed with the Contractor before their commencement.

11. The Vital Supply Recovery Study shall document the principle of recovery from total power failure and must identify vital drives and circuits that must be restored and the source of the restoring supply or command. Examples of restoring sources include:
 - a. Emergency diesel generator systems;
 - b. Process control (DCS), safeguarding (IPF), integrated motor control (IMCS);
 - c. UPS, battery supplies;
 - d. Manual operation.

3.1.2 Islanding

1. Before implementing a facility for transition to island operation, an assessment shall be made demonstrating clearly the expected increase in availability and the economic benefits.
2. Where statistical analysis is needed, it shall be based on sufficient local data to make such an analysis valid.
3. As a minimum, the assessment should address the following:
 - a. The effects and expected frequency of voltage dips and their duration caused by disturbances in the external network. The duration will be obtained from the settings of protective devices in the external network while the frequency distribution of voltage dips will be acquired from statistical analysis.
 - b. The effects and expected frequency distribution of outages of the power supply from the external network. The frequency distribution will be acquired from statistical analysis.
 - c. The technical and economic consequences of unplanned failures of the power supply caused by external faults.
 - d. An analysis of the expected system behaviour during and after external disturbances.
 - e. The expected success rate of island initiation after a transient disturbance.
 - f. The expected technical and economic benefits gained by the implementation of a control and protection system for the transition to island operation.

3.2 ELECTRICAL LOADS AND ELECTRICITY CONSUMPTION

3.2.1 Classification of loads

3.2.1.1 General

1. Electrical loads SHALL [PS] be classified as performing a service, which is 'vital', 'essential', or 'non-essential', as defined in (1.3.2).
2. An electrical power system of enhanced reliability and having duplicate energy sources SHALL [PS] be provided to energise loads forming part of vital services; refer to (3.2.1.2) and (3.9).
3. An electrical power system of suitable reliability shall be provided for 'essential', or 'non-essential' services; refer to (3.2.1.3) and (3.2.1.4).

3.2.1.2 Vital service

1. For vital services, complete duplication of the energy source, of the lines of supply and of the equipment is necessary.

Examples:

- *Boiler feed water supply system by means of one electrically driven and one steam driven pump, or two electrically driven pumps supplied from independent sources;*

- *Life support systems, e.g. electric motor driven fire pumps on offshore installations supplied from independent sources;*
- *One or more uninterruptible power supply (UPS) units to provide electrical supply to protection systems and process control systems;*
- *Emergency lighting and escape lighting.*

NOTE: The economic consequences of electricity supply interruptions to essential services generally justify the provision of stand-by feeder capacity to facilitate the isolation of individual circuits for the purpose of equipment maintenance (of on-load tap-changers, circuit breakers, etc.), functional testing (of protective relays and trip circuits, etc.) and possible repair (of cables and cable terminations, etc.) while maintaining electrical services operational.

3.2.1.3 Essential service

1. For essential services, the economics of partial or complete duplication of the energy source, of the lines of supply or of the equipment, or the introduction of automatic restarting or changeover facilities etc. shall be evaluated in relation to the consequences of service interruptions.

Examples:

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

3.2.1.4 Non-essential service

Examples of non-essential services are power and lighting supplies to offices, warehouses, residential areas, etc.

3.2.2 Load assessment and electricity consumption

1. 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.
2. Above schedule of loads shall be prepared and updated regularly throughout the design phases of the project and will form the basis for provision of the necessary electricity supply and distribution system capacity (3.5).
3. During the early phases of a project development, a separate allowance shall be made to account for an increase in the electrical load owing to uncertainties in the process design.

NOTE: This is particularly important where own generation is the main source of electricity. Refer also to (3.5.2). Typically, this allowance may be in the order of 10 % to 25 %, depending on how much of the process design is based on existing operating experience. The allowance is normally reduced at distinct project phases as the design develops.

4. 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

5. Values of the diversity factors (x, y, and z) shall be appropriate to the type of plant and shall be determined by the Principal.
6. Values of the diversity factors (x, y and z) shall take account of the individual drives or consumers which make up the continuous, intermittent and stand-by loads, respectively. For example, y(%)F or z(%)G cannot be less than the largest individual intermittent or stand-by drive or consumer.
7. The various loads shall be classified as follows:

E - "Continuous"	All loads that may continuously be required for normal operation, including lighting and workshops
F - "Intermittent"	Loads required for intermediate pumping, storage, loading, etc.
G - "Stand-by"	All loads required in emergencies only, such as fire-water pumps or those of normally not running electrically driven units in stand-by mode for normally running steam-driven ones, e.g. charge pumps, boiler feed pumps, etc. Spare pumps etc., e.g. the "B" pump of an A-B combination, are <u>not</u> to be considered as "Stand-by" loads.
8. Even though not to be considered as stand-by loads, the largest motor of the spare duty shall be considered in the motor start studies in (3.1) with the duty motor running.
9. Subject to the above considerations, the following default values may be used for initial load assessments, or if the diversity factors have not been finalised:

x	=	100 %.
At rated plant throughput all driven equipment is assumed to be operating at its duty point. However, some diversity may be applied to non-process loads, e.g. offices and workshop power and lighting, typically 90 %.		
y	=	30 %.
z	=	10 %.
10. 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.
11. All loads to be shed during an underfrequency condition shall be identified as such in the 'remark' column.
12. All loads to be automatically restarted after a voltage dip shall be identified as such in the 'restarting' column.
13. Where a group of drives operate as a unit, it shall be considered as an individual consumer.
14. The power consumption of electric motors shall be based on motors rated in accordance with the requirements of DEP 33.66.05.31-Gen.

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

3.3 SYSTEM VOLTAGES AND FREQUENCY

3.3.1 General

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

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

2. On 50 Hz systems the nominal LV power supply voltage for new plants of shall be 400/230 V three phase and neutral as recommended in IEC 60038. This voltage should be used for extensions to existing plants requiring new LV distribution systems.
3. A study should be carried out during the SELECT or early in the DEFINE phase of the project for the possible selection of 690 V for supply of large numbers of larger LV motors, once the number and size of drivers is known.

NOTE: 690 V / 60 Hz is a permissible voltage / frequency combination for offshore facilities.

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

3.3.2 Deviations in supply voltage and frequency

1. 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 %.
2. The combined voltage and frequency deviations shall lie within Zone A as described in IEC 60034-1.
3. All loads should be distributed (balanced) so that the negative phase sequence components of voltage and current at any point in the system do not exceed the values quoted in IEC 60034-1.
4. 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.
5. Transient voltage deviations occurring at switchgear busbars during motor or group motor starting/reacceleration shall be such as to maintain a minimum of 85 % voltage on switchgear busbars, and at least 80 %, but not more than 110 %, of rated equipment voltage on all other consumers.
6. 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.
7. 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.
8. The following criteria 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:
 - a. Voltage dips resulting in consumer terminal voltages down to 80 % of rated equipment voltage shall not affect plant operations;
 - b. Voltage dips resulting in consumer terminal voltages below 80 % of rated equipment voltage for a duration of not more than 0.2 s shall result in the ride-through of selected consumers performing a vital and/or essential service;

- c. Voltage dips resulting in consumer terminal voltages below 80 % of rated equipment voltage for a duration between 0.2 s and 4 s shall, on voltage restoration, result in a sequential re-start of selected consumers.
9. Ride-through and re-start requirements are to be agreed with Process and Utility disciplines. Implementation of sequential re-energisation may be done using the DCS or IMCS. The constraints imposed by the electrical system will determine the extent to which ride through and re-starting may be applied.

3.3.3 Deviations and variations in supply waveform

1. 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.
2. Two levels of distortion are recognised:
 - a. The distortion level for extensions to an existing electrical system:
 - i. The Total Harmonic Distortion (THD) and individual harmonic voltage distortions at any point of the system up to a voltage of 36 kV shall not exceed the levels as defined in IEC 61000-3-6 Table 1.

NOTE: IEEE 519 standard and the harmonic values contained therein may be substituted by the Principal.
 - b. The distortion level for new projects or developments
 - i. For new projects the planning levels for Total Harmonic Distortion (THD) and individual harmonic voltage are defined in IEC 61000-3-6 Table 2. THD for system voltages up to 36 kV shall not exceed 6.5 %. THD for system voltages higher than 36 kV shall not exceed 3 %.
3. Equipment, which produces a continuous DC component in the AC supply system, shall not be utilised.

3.4 SYSTEM POWER FACTOR

1. The overall system power factor, inclusive of reactive power losses in transformers and other distribution system equipment, should not be less than 0.8 lagging at rated design throughput of the plant.
2. The power factor shall be determined at:
 - a. the terminals of the generator(s), when power is supplied from own generation,
 - b. the PCC, when power is supplied from a public utility. The plant power system shall be designed so that the power factor stated by the public utility is achieved with a design margin of at least 2 %. The measured power factor is an average value determined over the metering integration period, typically 15 min or 30 min.
3. Any improvement of power factor beyond that necessary to achieve the above should be considered on an economic basis, e.g. reduction in distribution system equipment ratings, reduction in kVAr charges.
4. The requirement for power factor correction shall be agreed with the Principal at the DEFINE phase of the project.
5. Where necessary, power factor correction shall be done by one or more of the following methods, which are stated in order of preference. The method selected depends on reliability and economic considerations.
 - a. Variation of the excitation of synchronous generators.
 - b. Variation of the excitation of synchronous motors.

- c. Permanently energised static capacitor banks connected to distribution switchboards or group motor control centres via suitably protected switching devices (4.5).

3.5 SUPPLY CAPACITY

3.5.1 General

1. The distribution system shall be capable of supplying continuously the peak load, assessed according to the applicable load data (3.2.2).
2. The design of new facilities shall ensure that the firm capacity of the main HV distribution system (power plant switchgear, and/or grid intake transformers, distribution switchgear and interconnecting cabling, excluding process plant) has spare capacity as indicated in Figure 1, unless otherwise instructed by Principal.

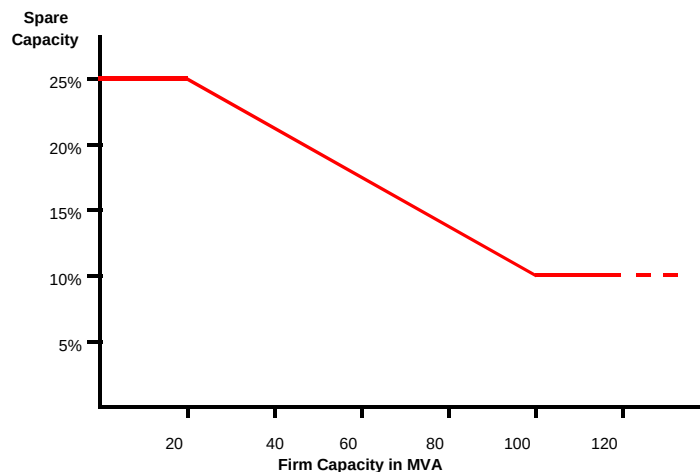


Figure 1 Spare capacity requirements

3. The spare capacity at Plant Substations shall be a minimum of 10 % of peak load at the end of the EXECUTE phase, unless otherwise instructed by the Principal.
4. The provision of stand-by capacity shall be considered in relation to safety, reliability and the requirements with respect to continuity of plant operations.
5. Moreover, the reliability of distribution systems shall be at least comparable to that of their supply systems, each incorporating sufficient stand-by capacity to enable maintenance work, tests and inspection checks to be carried out.
6. Electrical system maintenance requirements should be considered in relation to plant shutdowns for overhaul of process units.
7. General rules relating to the provision of necessary spare and stand-by capacity, and to the rating of supply and distribution equipment for each part of the electrical system, are given in subsequent sections.

3.5.2 Grid intake systems

1. Grid intake circuits shall be controlled by circuit breakers, fitted with the protection, control, alarms, instruments and meters specified below and in (Appendix 3).
2. The overall design of grid intake circuits shall be carried out in close liaison with the public utility, so that both parties' requirements, including provision for disconnection, isolation and earthing, are satisfied. For typical single line and protection diagrams, refer to Standard Drawing S 67.060.
3. 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.

4. 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-bus override. These synchronising controls should be located with the frequency and voltage controls of the generators.
5. Where applicable, the requirements for an islanding system shall be incorporated in the design, with provision for re-synchronisation of islanded system with grid.

3.5.3 Power generation

1. Stand-by capacity (spinning reserve) shall be incorporated to fulfil the requirement of the peak load with the largest generating set out of service.
2. The number of generating sets and their individual ratings shall be approved by the Principal. This depends on many factors, e.g. maintenance requirements, economic size, future load development pattern, unit reliability, etc.
3. In order to ensure a stable electrical power system after trip of the single largest generating unit, spinning reserve shall be available.
4. To achieve the preferred operating philosophy of "N+1", the maximum operating electrical load, in MW, should be as follows:

$$\text{maximum operating electrical load} \leq \frac{(\text{OGC} \times A) - \text{LUO}}{D}$$

Where:

OGC = Max. Operating Generation Capacity (Prime mover and generator), in MW.

LUO = Largest unit operating that may trip, in MW.

A = Availability Factor:

Fraction of the maximum generation capacity that is available to quickly ramp up in case of a trip of a generator. Normally 1.00, but may be constrained by limit on prime mover by process.

D = Dynamic Response Margin:

e.g. 1.1 to 1.2 for gas turbines. This value may be reduced if confirmed by electrical transient stability studies, but note some smaller gas turbines with dry low-NO_x combustion systems have limited load acceptance capability

- a. Above formula may also be used for networks without an external grid connection, i.e. permanently islanded networks.
 - b. The dynamic response margin of larger systems may be reduced based on experience with similar installations and supported by transient stability studies.
 - c. The dynamic response margin should not be lower than 1.05 to provide an allowance for continuous control of the remaining generators.
 - d. If at any time in normal operation the electrical load exceeds maximum allowed load, then a pro-active controlled load reduction (not load shedding) should be carried out in order to achieve N+1 operation again.
 - e. For systems > 100 MW, the electrical transient stability study shall be done in the DEFINE phase.
5. The following applies for plants with own generation capable of operating in island mode:
 - a. An automatic load shedding scheme should normally be provided.
 - b. Isochronous control should only be used on a single generating unit in a network that has no connection to the public network.

3.5.4 Transmission and distribution systems

1. The stand-by feeder capacity shall enable the largest supply circuit to be withdrawn from service while satisfying the peak load requirements with the margins specified in (3.5.1).
2. The provision of stand-by capacity to non-essential service loads shall be evaluated based on circuit availability for carrying out maintenance, testing and inspection.
3. The maximum rating of transformers feeding plant substations should be such that the rated current of their low voltage winding does not exceed 2500 A. This results in the following maximum transformer ratings:
 - a. 25 MVA, if feeding a 6 kV or 6.6 kV switchboard;
 - b. 12.5 MVA, if feeding a 3 kV or 3.3 kV switchboard;
 - c. 1600 kVA, if feeding an LV (400V) switchboard.
4. In order to keep the level of the prospective short circuit within the range of commercially available switchgear, transformers with higher impedance than specified in DEP 33.65.40.31-Gen. may be considered. Refer to (3.6).
5. 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.
6. Single circuit lines or ring distribution circuits should only be considered for supplies to individual plants or facilities that are periodically shut down for maintenance so as to permit simultaneous maintenance of the feeder circuit.

3.5.5 Switchgear

1. 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.
2. Double busbar systems should be selected for HV switchboards rated > 6.6 kV at grid intake substations and power plant substations as an alternative to the above arrangement.
3. Switchboards with double busbar systems shall incorporate one circuit breaker per circuit.
4. For HV and LV switchboards, the rated short circuit withstand duration corresponding to the rated withstand current shall be 1 s.
5. HV switchboards shall have a maximum of three sections and, consequently, a maximum of two bus section switches.
6. LV switchboards shall have two, three or maximum four sections (in 'H' configuration). Where the LV load exceeds the capacity of a four-section switchboard, additional switchboard(s) shall be installed rather than having switchboards of more than four sections. Special arrangements, e.g. automatic changeover, may be required for switchboards supplying vital services, where an alternative supply is required.
7. For design purposes normal operating position of switchboard bus section switches shall be as follows:
 - a. 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.
 - b. For HV switchboards the bus section switches shall be operated normally closed on switchboards at intake substations, power (generation) plant substations and distribution substations.
 - c. Bus section switches shall be operated normally open on switchboards at plant substations.

8. When a switchboard panel serves a stand-by function to one or more main consumers, it shall be connected to a different busbar section from that to which the main consumer or consumers are connected, provided that there is no possibility of a switchboard incoming circuit or busbar section becoming overloaded as a consequence of selecting any main or stand-by consumers for operational use.
9. The basic configuration for a switchboard supplying essential service loads shall be a 2-section switchboard with two 100 % rated incoming circuits and one bus section switch:

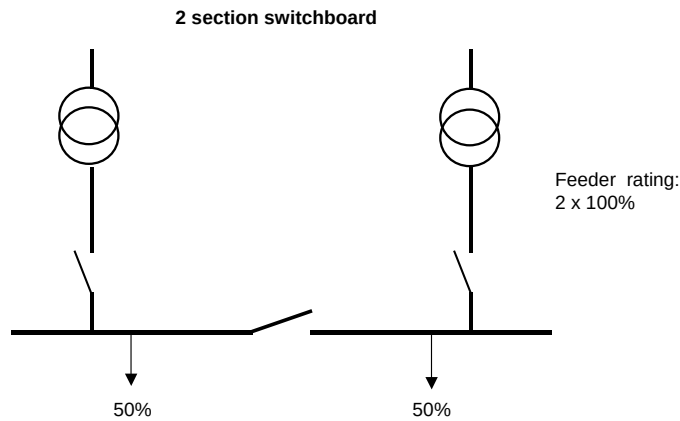


Figure 2 2-section switchboard

10. The transformer sizing to maintain firm capacity for 3-section switchboards shall be as shown below:

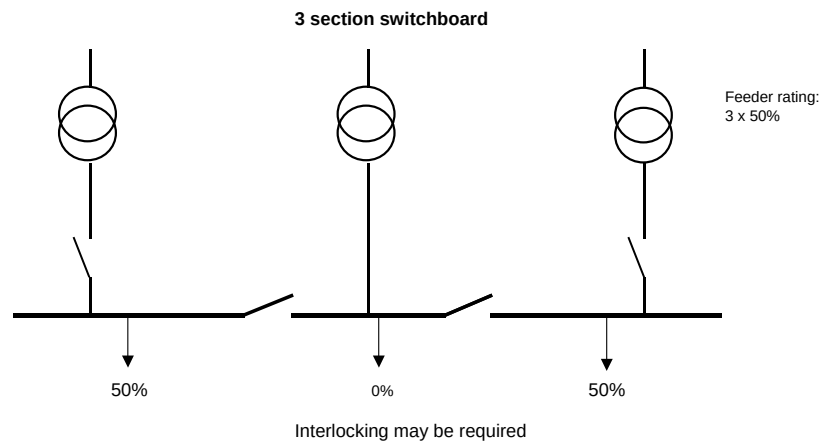


Figure 3 3-section switchboard

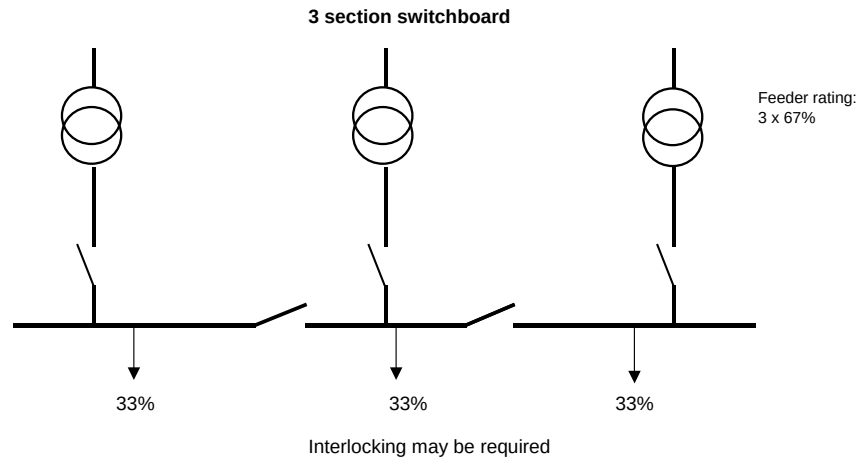


Figure 4 3-section switchboard (option)

11. Normally open bus section switches and/or interconnectors that may have to be operated simultaneously in the closed position, shall be rated so as to permit the largest incoming circuit feeder to be withdrawn from service without the necessity to de-energise any switchboard busbar section or consumer circuit.
12. The configurations of intake, power plant and distribution switchboards shall permit one switchboard section to be taken out of service while still maintaining normal downstream plant operations.

3.5.6 Electric motors

1. 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.
2. 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.

3.6 SHORT CIRCUIT RATINGS

1. 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.
2. 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.
3. Distribution of short circuit current and the limiting effect of system protective devices or control schemes, e.g. fuse links, IS-limiters, break before make automatic supply changeover arrangements, etc., shall be applied when determining short circuit ratings.
4. Parallel operation includes bus section switches or interconnectors, etc. which are intended for normally open operation and on which no (inter)locking has been provided to prevent simultaneous closure.
5. 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:
 - a. the maximum short circuit level at the point of supply from which the new switchgear will be energised,
 - b. an electrical loading of the new installation such that the nominal capacity of the switchboard is fully utilised,

- c. future planned increases in short circuit level due to the direct or indirect connection of machines or public utility supply.
6. Generally the load of process facilities predominantly consists of induction motors. When no details are known at the time of order, 90 % of the nominal capacity of the switchboard should be taken as motor load.
7. At the time of order, an HV switchboard at intake, power plant or distribution substations shall have a margin of not less than +10 % between the calculated fault level under the above-mentioned conditions and the specified short circuit rating of the equipment.
8. Short circuit calculations shall be based on nominal impedance values of the equipment. The margin specified above is provided to allow for the tolerances permitted for equipment characteristics.
9. 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. The type of interlock provided shall be subject to approval by Principal.
10. Automatic break-before-make changeover arrangements of supply capacity shall not be introduced with the specific aim of justifying the use of equipment having a lower short circuit rating than would otherwise be required for the parallel operation of all available supplies.
11. 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 considered only as a means of achieving system extensions or interconnections, which could not otherwise be practicably or economically realised without the use of such devices.
12. The installation of current-limiting reactors, Is-limiters and similar devices should be evaluated and documented during the conceptual design of the electrical distribution network.
13. When equipment short circuit ratings are determined, the effects of contributions from asynchronous and synchronous machines on the switching duties of switchgear and on the dynamic and thermal loading of the electrical installations in general shall be taken into account.
14. Short circuit current contributions from cage induction machines shall 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 62271-100 and IEC 60947-2.
15. 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.
16. A period of 3 cycles (60 ms for 50 Hz) after the fault shall be taken for establishing adequacy of the breaking capacity of circuit breakers.
17. Any restrictions imposed by the public utility with respect to short circuit current infeed to their supply network shall not be exceeded.

3.7 ELECTRICAL PROTECTION

3.7.1 General

1. The electrical system SHALL [PS] be equipped with automatic protection to provide safeguards in the event of electrical equipment failures or system maloperation.
2. Automatic protective systems shall be designed to achieve selective isolation of faulted equipment with a minimum delay and within a time corresponding to the short circuit

current withstand capability of the equipment, arc flash exposure, system stability limits, and the maximum fault clearing times.

3. The selection, schemes specification and settings of switching and protective devices, control circuits and associated auxiliary equipment shall be in accordance with DEP 33.64.10.17-Gen.

3.8 SYSTEM EARTHING

3.8.1 General

1. The neutral of AC systems shall normally be earthed as stated below. These shall not be designed for unearthed operation, unless they form an extension to an existing unearthed system. The preferred system earthing arrangements are given in (Appendix 2).

3.8.2 HV systems

1. HV electrical systems shall be earthed by means of dedicated earth electrodes connected to the plant main earth grid (5.5.1).
2. HV system neutrals shall be earthed at each source of supply (transformer, direct-connected generator) as shown in (Appendix 2).
3. For grid infeed system voltages above 36 kV, the neutral point of transformers should be solidly earthed, unless otherwise required by the public utility.
 - a. Where circuit breakers have to be connected to an existing solidly earthed system, suitable CTs shall be selected so as to prevent CT saturation under earth fault conditions.
4. Transformer feeders to HV switchboards with a system voltage not exceeding 36 kV shall be resistance earthed.
 - a. Each resistor should be sized so as to limit the earth fault current supplied by the equipment to which the resistor is connected, to approximately 100 A, provided that with such a resistor, sufficient current would flow under each fault condition to ensure positive operation of earth fault protection on all circuits.

NOTES:

1. The above applies equally to the earthing of the neutral point of the HV winding of generator step-up transformers.
2. It may be necessary for HV systems feeding overhead line distribution systems to be solidly earthed so as to allow for detection and tripping of earth faults remote from the source of supply.

5. 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.
 - a. Generator earthing 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.
 - b. Each resistor should be sized so as to limit the magnitude of earth fault current to 100 A. 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.
 - c. The size of resistor provided shall ensure that sufficient current would flow under each fault condition, to ensure positive operation of earth fault protection on all circuits. If this cannot be achieved, 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: When more than 2 generators and/or transformers are directly connected to the same HV switchboard, use of separate earthing transformers in zigzag connection (e.g., 1 per section),

should be evaluated for system neutral earthing, with generator single phase distribution transformers to limit generator earth fault current to a harmless but detectable value e.g. 10 A.

6. Where generators of dissimilar ratings, characteristics or loadings are to be operated in parallel so as to give rise to circulating currents in the above-mentioned earthing resistors that would exceed the thermal rating of the resistors, then the HV system shall be earthed via one earthing resistor only.
 - a. 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.
 - b. 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.
7. 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.
 - a. The resistor shall be rated to limit the generator earth fault current to 10 A, or to $3 \times I_{co}$ where I_{co} is the per-phase capacitive charging current, whichever is the greater.

NOTE: The per-phase capacitive current is that due to the generator stator windings, generator transformer LV winding, and generator main cable/connections.
8. Each earthing transformer and resistor shall be rated to withstand the respective earth fault currents for a duration of not less than 10 s. Longer withstand times may be required, depending on the earth fault protection system applied.
9. 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.
 - a. In such cases, a low value earthing resistor should be installed in parallel with the normal high impedance device so that, if a fault on an outgoing circuit is not cleared within the allowed time, the resistor can be switched in to provide a higher fault current to allow clearance by back-up protection.

3.8.3 LV systems

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

3.8.4 UPS systems

1. AC UPS systems shall have their neutrals solidly earthed. This applies equally to single phase and three phase systems.
2. DC 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.
3. DC supplies for telephone systems shall be solidly earthed at the positive pole in line with normal telecommunication practice. DC supplies for special applications may be earthed as required by the equipment Manufacturer.

3.9 ELECTRICITY SUPPLY FOR VITAL SERVICES

3.9.1 General

1. Supplies shall comply with the requirements in (3.2.1).
2. 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.
3. To meet the above requirements, the electrical power requirements for loads forming part of vital services are classified in three categories as specified in (3.9.2), (3.9.3), and (3.9.5).
4. For typical electricity supply arrangements that fulfil the requirements of each of the following categories, refer to Standard Drawing S 67.006.
5. The design of such systems shall be agreed with the Principal at the SELECT phase of a project.

3.9.2 AC uninterruptible, maintained electricity supply

1. AC uninterruptible, maintained electricity supply shall be either:
 - a. Derived from two 100% rated independent UPS units, each with its own battery, static changeover switch and maintenance bypass switch, as shown in Standard Drawing S 67.006.
 - b. or, for Design Classes 1 and 2, or when the maintenance bypass switch can be used to release the UPS to carry out full testing and maintenance during a shutdown of the associated process plant, a single AC UPS unit may be considered.
- NOTE: Typical intervals for UPS maintenance are 2 yearly.
2. Parallel static units may be used to provide a single source of uninterruptible power with high levels of reliability and availability normally required for large indivisible loads. However, load sharing controls shall not be subject to common mode failure problems. Guidance on the rating and performance requirements of static AC UPS units is given in DEP 33.65.50.32-Gen.
 3. The equipment fed from an AC 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.
 4. For equipment suitable for receiving duplicate supplies:
 - a. Systems or equipment requiring a duplicate AC supply shall derive one supply from each UPS switchboard.
 - b. In order to preserve the high integrity of the redundant supplies shown on Standard Drawing S 67.006, the UPS switchboards shall not be operated in parallel.
 - c. The AC supplies derived from the two UPS switchboards shall also not be operated in parallel since each uninterruptible supply may be of marginally different frequency under certain operating conditions.
 - d. 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 be an integral part of the equipment or system being energised.

5. For equipment suitable for receiving a single supply:
 - a. Equipment requiring a single AC supply shall derive that supply from a distribution switchboard which shall itself be energised from one UPS switchboard, but have an automatic, break-before-make changeover switch to derive a supply from the second UPS switchboard in the event of failure of the first supply.
 - b. The operation of the changeover switch shall create an interruption in supply voltage to the load of not greater than 0.25 s, refer to Standard Drawing S 67.006.
6. To cater for the possible, but unlikely, failure of the output of one UPS unit, loads which have a single AC supply and which have a trip function on loss of the supply voltage shall incorporate a time delay that will prevent tripping during operation of the above mentioned changeover switch.

3.9.3 DC uninterruptible, maintained electricity supply

1. Two 100% rated DC UPS units, including batteries shall be used for DC uninterruptible, maintained electricity supply.
2. Where an AC uninterruptible, maintained electricity supply is available and the DC load does not exceed 15 % of the AC supply capacity, the DC uninterruptible, maintained electricity supply may be derived via duplicate rectifier units fed from the AC UPS distribution switchboards, as shown on Standard Drawing S 67.006.
3. Requirements for DC UPS units in tripping (and closing) service of HV switchgear are specified in DEP 33.67.51.31-Gen.

3.9.4 Battery autonomy times

3.9.4.1 General

1. Requirements for autonomy times for batteries in tripping (and closing) service of HV switchgear are specified in DEP 33.67.51.31-Gen.
2. Battery autonomy times specified in 3.9.4.2 and 3.9.4.3 are minimum and may be increased to enable combining of services aiming at a reduction in the number of UPS systems. Timers shall not be used to selectively switch off consumers.
3. Batteries of UPS units SHALL [PS] be rated to energise the relevant loads per the requirements of the safety case for the installation. In the absence of such requirements, battery autonomy times specified in 3.9.4.2 and 3.9.4.3 shall be used for onshore and offshore installations.

3.9.4.2 Onshore installations

1. Unless otherwise specified, battery autonomy times for onshore installations shall be as follows:

NOTE: Specific offshore country-specific requirements may apply.

 - a. 30 min for process plant shutdown, process monitoring and control systems;
 - b. 1 h for utility plant process monitoring and control systems;
 - c. 1 h for emergency lighting (refer to 5.4.2);
 - d. 10 min for non-process computer installations;
 - e. 8 h for fire-fighting and fire alarm and gas detection systems;
 - f. 8 h for telecommunication and radio systems.
2. If "N+1" spared emergency generators are supplying the UPS systems, the following changes to the battery autonomy time may be made:
 - a. All vital services, with the exception of telecommunication and radio systems, may be supplied via 100 % rated duplicate UPS systems with a battery autonomy time of 30 min;

- b. Telecommunication systems and radio equipment shall be supplied by a dedicated parallel or duplicate UPS system.

3.9.4.3 Offshore installations

1. Unless otherwise specified, battery autonomy times for offshore installations shall be as follows:
 - a. 30 min for emergency shutdown and depressurising systems, process monitoring and control systems;
 - b. 90 min for helideck and obstruction lighting, see (6.2.4.5);
 - c. 3 h for public address, platform audible alarms and status lights;
 - d. 3 h for fire and gas detection and alarm systems;
 - e. 3 h for emergency and escape lighting (the latter with 1 h internal battery back-up) (refer to 5.4.2);
 - f. 24 h for SOLAS (Safety of Life at Sea) communications equipment;
 - g. 96 h for navigational aid systems.
2. The above autonomy times for offshore installations may be reduced if “N+1” spared emergency generators are installed that feed the UPS systems, subject to approval by the Principal.

3.9.5 AC interruptible, maintained electricity supply

1. AC interruptible, maintained electricity supply is a power supply which is derived from the main distribution system but which has back-up power supply, typically from an automatically started, emergency diesel generator. The interruption in voltage on mains supply failure is normally 10 s to 15 s.
2. Switchboard configurations shall typically be as follows:

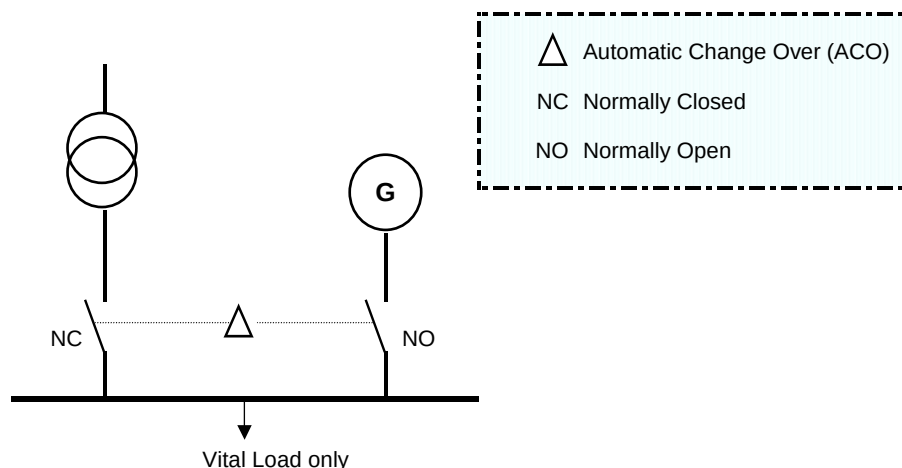


Figure 5 Switchboard arrangement vital loads

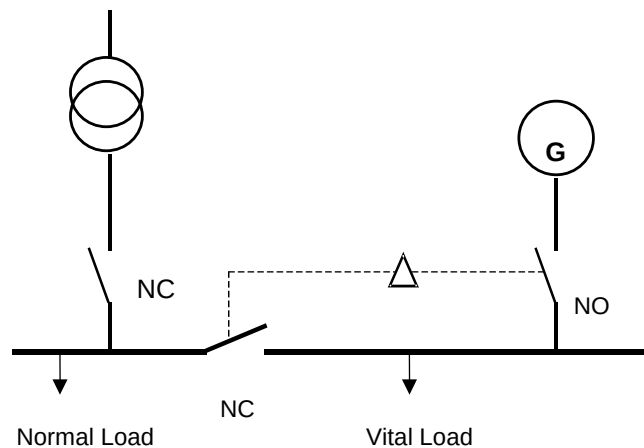


Figure 6 Switchboard arrangement vital loads (option)

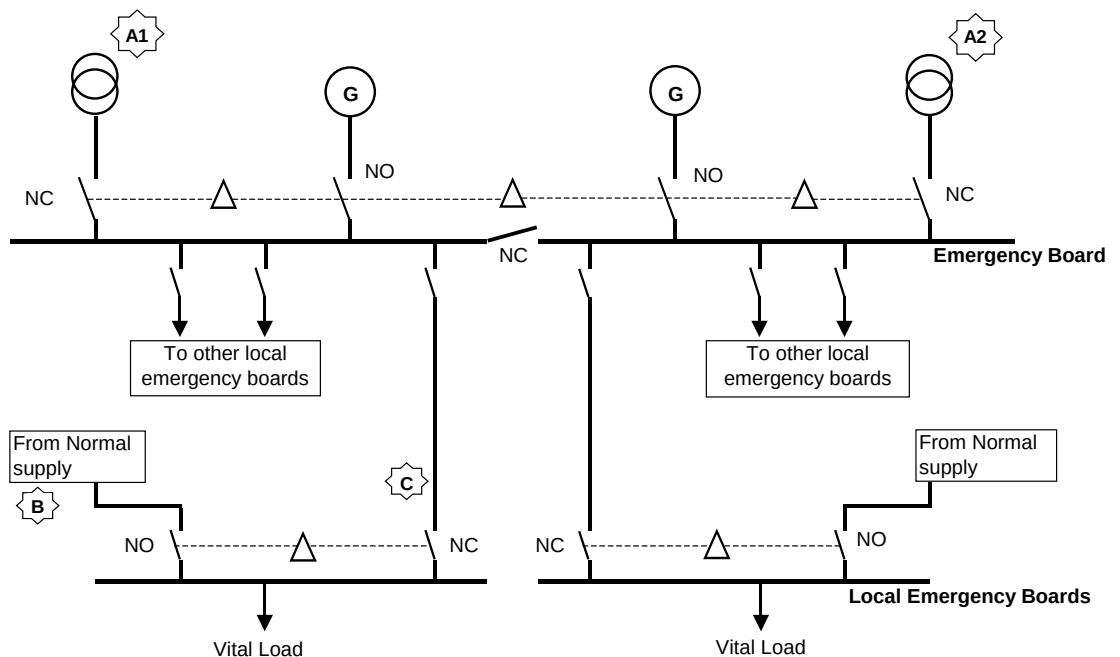


Figure 7 Switchboard arrangement vital loads (option)

3. AC interruptible, maintained electricity supply is used typically for energising electric motors associated with cooling systems of enclosures housing process control and instrument systems, analysers, emergency lighting, etc.
4. Standard drawing S 67.006 shows a typical arrangement of an AC interruptible, maintained electricity supply.
5. If mains electricity failures lasting longer than 1 h are expected to be fairly frequent, then the emergency generator should be used to energise the AC UPS units, thereby extending the duration of the relevant supplies beyond the UPS battery autonomy times mentioned in (3.9.4). Standard drawing S 67.006 shows this alternative arrangement.

6. If the emergency generator is to be used to energise UPS units then the rating of the emergency generator shall be not less than twice the rated output of the UPS.

NOTE This is to account for the magnitude of the harmonic currents required by the rectifier of each UPS and consequent voltage distortion created (non-linear loads).
7. 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.
8. Where required, synchronising and/or synchronising check facilities shall be provided to enable 'make before break' return to normal operation.
9. Facilities shall be provided to permit periodic on-load testing of emergency generators by enabling the generator to start and be synchronised with the mains supply.
10. Each generating set shall have sufficient fuel storage capacity for at least 8 h full load operation. Increased fuel storage capacity may be specified for offshore and remote land installations.
11. For offshore installations, the start sequence of the emergency generator(s) shall be inhibited or the set(s) shut down if gas is detected in the generator room or in the combustion air intake.
12. For onshore installations, the emergency generator should be located in a non-hazardous area.

3.10 CONTROL OF FREQUENCY, VOLTAGE AND REACTIVE POWER

3.10.1 Frequency control

1. Generators in parallel operation with the utility may be controlled as follows:
 - a. MW control, if control of grid import/export is required;
 - b. Back pressure control of steam turbines supplying process steam;
2. Control shall be designed so that upon loss of grid connection, control automatically reverts to island operation.
3. Generators in island operation may be controlled as follows:
 - a. Speed control with a droop characteristic, and a secondary frequency controller to maintain nominal frequency.
 - b. Individual units shall be capable to be switched to fixed MW control, e.g., due to process or equipment constraints. However, sufficient other units shall remain in droop control mode to maintain frequency within limits.
4. Emergency generators should not be included in secondary frequency control.

3.10.2 Voltage control

3.10.2.1 General

1. Voltage control shall be a primary function to maintain the main busbar voltages within narrow, fixed limits under normal operational conditions.
2. The bandwidth shall be such that the allowable voltage deviations within the plant network comply with (3.3.2).
3. Reactive power control is a secondary and tertiary voltage control function and should be used:
 - a. As a secondary function to maintain generators within the operational limits. This function may be extended to provide a constant reactive power output or a constant power factor.
 - b. As a tertiary function to maintain the exchange of reactive power with an external network within a certain bandwidth or to provide a constant power factor to the power exchange.

4. Primary, secondary and tertiary voltage control functions shall be separated hierarchically within a control system. As the three functions will influence each other, stable operation can only be enforced by a distinction in time response - primary control acting fastest and tertiary control slowest.
5. Secondary and tertiary voltage control shall allow for the operational constraints of the controlled unit.
6. Emergency generation units should be excluded from tertiary voltage control.

3.10.2.2 Voltage control – Island operation

1. Voltage control shall be assigned to the generators connected to the main busbar.
2. A secondary control system shall maintain the reactive power distribution between the generators in operation by adjustment of the AVR set points.
3. If additional generators are connected at a lower voltage level, the function of voltage control should be primarily assigned to equipment connected to the main busbar as stated in the previous paragraph.
4. The requirement for secondary voltage control of the additional generators shall be determined by the Principal.

3.10.2.3 Voltage control – Parallel operation (connection to external grid)

1. Voltage control should normally be assigned to the tap changer(s) of the interconnecting grid transformer(s).
2. A control system shall be used to maintain the correct tap position of parallel transformers to eliminate circulating reactive currents (e.g. master-slave).

4. DESIGN AND SELECTION REQUIREMENTS FOR EQUIPMENT AND CABLES

4.1 GENERATORS

4.1.1 General

1. Rating, type and characteristics of the generating set shall fulfil the requirements of the electrical power system, whether operating in island mode, in parallel with other generating sets, in parallel with a public utility or any combination of these.
2. Rating, type and characteristics of the generating set shall take account of factors such as overload capabilities, load acceptance/rejection, real and reactive power sharing, maximum speed deviations, maximum response times, reactances, inertias, etc.
3. The kVA rating of the generator should be selected by the prime mover Manufacturer, in line with the specified requirements, so that the generator does not limit the output of the prime mover over the specified operating temperature range.
4. The generator rated power factor shall be 0.8 lagging, unless otherwise specified.

4.1.2 Synchronous generators ≥ 1250 kVA

1. The generator and its auxiliaries shall comply with DEP 33.65.11.31-Gen., and will normally be used for base load generation services; however, it may also be installed in (centralised) emergency or stand-by systems of large process facilities.
2. Main cable termination arrangements shall be in accordance with DEP 33.65.11.31-Gen.
 - a. For generator ratings requiring more than three cables per phase, use of phase segregated busbar connections between the generator and its transformer or switchgear shall be evaluated.
 - b. For transformer-connected generators, phase segregation shall be maintained for all the cabling and for busbars connected to the generator, so as to minimise the possibility of multi-phase short circuits.
3. Each generating set should be provided with its own LV auxiliary switchboard for the supply and control of all its motor driven auxiliaries. This switchboard shall be treated as an essential services switchboard, (3.5.4) and be provided with a normal and a stand-by incomer.
4. The normal supply should be taken from a utilities switchboard in the power plant.
5. 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.
6. For a plant equipped with its own generation only, a minimum of two or half of the main generating sets should be equipped with a black-start capability.
7. 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.
8. Main generators shall be fitted with the following control equipment:
 - a. Manual and automatic synchronising with a check synchronising relay and a dead-bus override.
 - b. Voltage control equipment consisting of automatic voltage control with a manual control stand-by system.
 - i. The manual control system shall follow the setpoint of the automatic control system to allow for automatic changeover from the automatic to the manual control system without significant voltage transients if the automatic control system fails.

- ii. The voltage control system shall be suitable for island and parallel operation. In island operation the voltage control system shall be designed to maintain the voltage within 0.5 % of the operational value during normal operational conditions.
 - iii. Reactive-Power sharing among sets shall be provided for the voltage control system.
 - iv. Cross-current compensation between generators employing A static Loop Circulating Current should only be considered for extensions to an existing power station where this feature is already provided.
- c. Power factor or reactive power control equipment arranged to adjust the AVR setpoint, so as to keep the generator power factor constant when operating in parallel with a public utility supply.
 - i. For a generator connected via a unit transformer with an on-load tap changer, in general, one AVR unit shall be the master and the other the slave, or one shall be controlled manually while the other is on auto mode, to prevent "voltage hunting".
- 9. Generator control panels shall be fitted with underfrequency and overfrequency tripping devices that are set by the generator Manufacturer to protect the generator and its prime mover.
- 10. There shall be a signal into the control circuits of the generator(s) to signify the change in operating mode from grid connected to island operation, which is normally achieved via the interconnection circuit breaker auxiliary contacts.
- 11. During synchronised operation with the grid, the generator governor and exciter are set to control the generator MW output and power factor or reactive power respectively; during island operation, the same controls will affect the frequency and voltage respectively. This change in operating mode needs to be signalled to the governor control.
- 12. Gas turbine and diesel engine driven generating sets shall be provided with automatic control schemes. This shall include facilities for auto-starting, automatic synchronising and automatic loading.
- 13. Local control of generating sets shall include all the components necessary for commissioning, maintenance of and trouble-shooting the generating sets independently of the rest of the power system.
- 14. Main generators shall be provided with the alarm equipment, indicating instruments and integrating meters stated in (Appendix 3).

4.1.3 Synchronous generators < 1250 kVA (packaged units)

- 1. The generator and its auxiliaries shall comply with DEP 33.65.11.32-Gen. They will normally be used for interruptible, maintained electrical supplies, possibly together with black-starting duties, rather than for base load generation services.
- 2. The rating of these generating sets will normally be within the range of 50 kW to 1000 kW, and supply an emergency LV switchboard. However, for power plant black-start duties and emergency or stand-by systems of large process facilities, sets with a larger rating may be required, possibly supplying an HV system.
- 3. In sizing the generating set, account shall be taken of the related motor starting requirements and UPS loads (3.9).
- 4. The generating sets shall be suitable for unattended operation and for automatic black-starting on detection of failure of the mains supply.

4.1.4 Cage induction generators

- 1. The generator shall comply with DEP 33.66.05.31-Gen.