

DEP SPECIFICATION

ELECTRICAL ENGINEERING DESIGN

DEP 33.64.10.10-Gen.

February 2011

DESIGN AND ENGINEERING PRACTICE

DEM1



© 2011 Shell Group of companies
All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, published or transmitted, in any form or by any means, without the prior written permission of the copyright owner or Shell Global Solutions International BV.

PREFACE

DEP (Design and Engineering Practice) publications reflect the views, at the time of publication, of Shell Global Solutions International B.V. (Shell GSI) and, in some cases, of other Shell Companies.

These views are based on the experience acquired during involvement with the design, construction, operation and maintenance of processing units and facilities. Where deemed appropriate DEPs are based on, or reference international, regional, national and industry standards.

The objective is to set the recommended 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.

The information set forth in these publications is provided to Shell companies 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 Units 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 such use, including the quality of their work and the attainment of the required design and engineering standards. In particular, for those requirements not specifically covered, the Principal will typically expect them to follow those design and engineering practices that will achieve at least 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.

The right to obtain and to use DEPs is restricted, and is typically granted by Shell GSI (and in some cases by other Shell Companies) under a Service Agreement or a License Agreement. This right is granted primarily to Shell companies and other companies receiving technical advice and services from Shell GSI or another Shell Company. Consequently, three categories of users of DEPs can be distinguished:

- 1) Operating Units having a Service Agreement with Shell GSI or another Shell Company. The use of DEPs by these Operating Units is subject in all respects to the terms and conditions of the relevant Service Agreement.
- 2) Other parties who are authorised to use DEPs subject to appropriate contractual arrangements (whether as part of a Service Agreement or otherwise).
- 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.

Subject to any particular terms and conditions as may be set forth in specific agreements with users, Shell GSI disclaims any liability of whatsoever nature for any damage (including injury or death) suffered by any company or person whomsoever as a result of or in connection with the use, application or implementation of any DEP, combination of DEPs or any part thereof, even if it is wholly or partly caused by negligence on the part of Shell GSI or other Shell Company. The benefit of this disclaimer shall inure in all respects to Shell GSI and/or any Shell Company, or companies affiliated to these companies, that may issue DEPs or advise or require the use of DEPs.

Without prejudice to any specific terms in respect of confidentiality under relevant contractual arrangements, DEPs shall not, without the prior written consent of Shell GSI, be disclosed by users to any company or person whomsoever and the DEPs shall be used exclusively for the purpose for which they have been provided to the user. They shall be returned after use, including any copies which shall only be made by users with the express prior written consent of Shell GSI. The copyright of DEPs vests in Shell Group of companies. Users shall arrange for DEPs to be held in safe custody and Shell GSI may at any time require information satisfactory to them in order to ascertain how users implement this requirement.

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

TABLE OF CONTENTS

1.	INTRODUCTION	5
1.1	SCOPE	5
1.2	DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS	5
1.3	DEFINITIONS	5
1.4	CROSS-REFERENCES	10
1.5	SUMMARY OF MAIN CHANGES	11
1.6	COMMENTS ON THIS DEP	11
2.	DESIGN AND ENGINEERING PRINCIPLES	12
2.1	STANDARDS, CODES, REGULATIONS AND TECHNICAL ASSURANCE	12
2.2	OPERATIONAL SAFETY AND RELIABILITY	12
2.3	PROTECTION AGAINST EXPLOSION AND FIRE HAZARDS	12
2.4	STANDARDISATION OF EQUIPMENT AND MATERIALS	14
2.5	CERTIFICATES, DECLARATIONS AND TEST REPORTS	14
3.	ELECTRICAL SYSTEM DESIGN	15
3.1	GENERAL	15
3.2	ELECTRICAL LOADS AND ELECTRICITY CONSUMPTION	16
3.3	SYSTEM VOLTAGES AND FREQUENCY	18
3.4	SYSTEM POWER FACTOR	19
3.5	SUPPLY CAPACITY	20
3.6	SHORT CIRCUIT RATINGS	24
3.7	ELECTRICAL PROTECTION	26
3.8	SYSTEM EARTHING	26
3.9	ELECTRICITY SUPPLY FOR VITAL SERVICES	27
4.	DESIGN AND SELECTION REQUIREMENTS FOR EQUIPMENT AND CABLES	32
4.1	GENERATORS	32
4.2	SWITCHGEAR	33
4.3	POWER TRANSFORMERS	34
4.4	UPS EQUIPMENT	35
4.5	CAPACITORS	36
4.6	ELECTRIC MOTORS	36
4.7	Electrical Network Monitoring and Control (ENMC)	38
4.8	CABLES, WIRES AND ACCESSORIES	39
4.9	OVERHEAD LINES	42
4.10	LIGHTING AND SMALL POWER EQUIPMENT	44
4.11	ELECTRIC HEATING EQUIPMENT	46
5.	ENGINEERING AND INSTALLATION REQUIREMENTS	48
5.1	GENERAL	48
5.2	MAIN EQUIPMENT	48
5.3	CABLING AND WIRING	50
5.4	LIGHTING AND SMALL POWER INSTALLATIONS	56
5.5	EARTHING AND BONDING	59
6.	DESIGN AND ENGINEERING REQUIREMENTS FOR PARTICULAR INSTALLATIONS	62
6.1	SUBSTATIONS	62
6.2	ADDITIONAL REQUIREMENTS FOR OFFSHORE INSTALLATIONS	66
6.3	OVERHEAD LINES	69
6.4	LABORATORIES	72
6.5	ANALYSER BUILDINGS	72
6.6	JETTIES	72
6.7	NON-INDUSTRIAL BUILDINGS	73
6.8	PLANT LIFT INSTALLATIONS	73
6.9	TEMPORARY ELECTRICAL INSTALLATIONS	74
7.	DOCUMENTS AND DRAWINGS	77
7.1	GENERAL	77

7.2	SUMMARY OF ELECTRICAL ENGINEERING	77
7.3	DEP STANDARD REQUISITION SHEETS	77
7.4	DESIGN DRAWINGS	77
7.5	EQUIPMENT AND CABLE NUMBERING	80
8.	REFERENCES	81

APPENDICES

APPENDIX 1	SELECTION OF ELECTRICAL APPARATUS FOR EXPLOSIVE GAS ATMOSPHERES	89
APPENDIX 2	SYSTEM NEUTRAL EARTHING DIAGRAMS	91
APPENDIX 3	CONTROLS, INSTRUMENTS, INDICATIONS AND ALARMS	92
APPENDIX 4	ILLUMINATION LEVELS	98
APPENDIX 5	ASSESSMENT OF NEED FOR LIGHTNING PROTECTION	100
APPENDIX 6	EQUIPMENT AND CABLE NUMBERING	104
APPENDIX 7	DELIVERABLE DOCUMENTS	106
APPENDIX 8	DECISION PROCEDURE FOR ABOVEGROUND or UNDERGROUND CABLE ROUTING	109

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 January 2010; 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 should be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements 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

Term	Definition
	IEC 60050 shall be used for definitions not listed below
Autonomy time (of a battery)	The autonomy time is the duration for which the battery can supply its rated load within its specified voltage limits, following a prolonged period, i.e., not less than one year, of battery float-charge operation.
Certificate	Document issued by a recognised authority certifying that it has examined a certain type of apparatus and, if necessary, has tested it and concluded that the apparatus complies with the relevant standard for such apparatus.
Certificate of conformity	Certificate stating that the electrical apparatus complies with the relevant standards for apparatus for potentially explosive atmospheres.
Conversion of electricity, 601-01-07, IEC 60050	The changing of the characteristics of the form and frequency of voltage and current by means of a converter.
Declaration of compliance	Document issued by the Manufacturer declaring that the electrical apparatus complies with the requirements of IEC 60079-15.
Distribution of electricity, 601-01-10, IEC 60050	The transfer of electricity to consumers within an area of consumption.
Electrical installation	Civil engineering works, buildings, machines, apparatus, lines and associated equipment used for the generation, conversion, transformation, transmission, distribution and utilisation of electricity.
Electrical power system, 601-01-01, IEC 60050	All installations and plant provided for the purpose of generating, transmitting and distributing electricity.
Electrical Network Monitoring and Control (ENMC)	A computerised system that is dedicated to monitoring and controlling defined aspects of an electrical network.
Electromagnetic Compatibility (EMC), 161-01-07, IEC 60050	The ability of a device, equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment.
Emergency lighting	Lighting provided for use when the supply to the normal lighting fails.
Escape lighting	That part of the emergency lighting, which is provided to ensure that the escape route is illuminated at all material times.
Essential service	A service, which, if it fails in operation or when called upon, will affect the continuity, quality or quantity of the product.
Firm capacity	The installed capacity less the stand-by capacity.
Frequency deviation, 604-01-06, IEC 60050	The difference between the system frequency at a given instant and the nominal value.
Generation of electricity, 601-01-06, IEC 60050	A process whereby electrical energy is obtained from some other form of energy.

Term	Definition
Hazardous area, 426-03-01, IEC 60050	An area in which an explosive gas atmosphere is or may be expected to be present in quantities such as to require special precautions for the construction, installation and use of electrical apparatus. NOTE: This applies equally to hazardous dust atmospheres.
High Voltage (HV), 601-01-27, IEC 60050	The set of voltage levels in excess of low voltage. NOTE: Although not covered by an IEC definition, it has become industry practice to use the term Medium Voltage (MV) for voltages from 1 kV up to 52 kV.
Installed capacity	The sum of the rated powers of equipment of the same kind (generators, transformers, converters, etc.) in an electrical installation.
Instrumented Protective Function (IPF)	A function comprising the initiator function, logic solver function and final element function for the purpose of preventing or mitigating hazardous situations. (Ref: 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 a.c.
Nominal value, 151-04-01, IEC 60050	A suitable approximate quantity value used to designate or identify a component, device or equipment.
Non-essential service	A service that is neither vital nor essential.
Non-hazardous area, 426-03-02, IEC 60050	An area in which an explosive gas atmosphere is not expected to be present in quantities such as to require special precautions for the construction, installation and use of electrical apparatus.
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.
Rated value, 151-04-03, IEC 60050	A quantity value assigned, generally by the Manufacturer, for a specific operating condition of a component, device or equipment.
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 that which may be withdrawn from service under planned or unplanned circumstances.

Term	Definition
Test report	Document prepared by the Manufacturer indicating in detail the tests and verifications to which the electrical apparatus has been subjected, and their results.
Transformation of electricity , 601-01-08, IEC 60050	The transfer of electricity through a power transformer.
Transmission of electricity , 601-01-09, IEC 60050	The transfer in bulk of electricity from generating stations to areas of consumption.
Uninterruptible, maintained electricity supply	A source of electrical power which is backed up by a second (emergency) source of power, such as to provide a supply of electricity that may be interrupted for no longer than 0.5 ms.
Very toxic (substances)	Substances that are 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.
Voltage deviation , 604-01-17, IEC 60050	The difference, generally expressed as a percentage, between the voltage at a given instant at a point in the system, and a reference voltage such as nominal voltage, a mean value of operating voltage, or declared supply voltage.
Voltage dip , 604-01-25, IEC 60050	A sudden reduction of the voltage at a point in the system, followed by voltage recovery after a short period of time, from a few cycles to a few seconds.
Voltage surge , 604-03-14, IEC 60050	A transient voltage wave propagating along a line or a circuit and characterised by a rapid increase followed by a slower decrease of the voltage.
Zone 0 (in the classification of hazardous gas areas), 426-03-03, IEC 60050	An area in which an explosive gas atmosphere is present continuously, or is present for long periods.
Zone 1 (in the classification of hazardous gas areas), 426-03-04, IEC 60050	An area in which an explosive gas atmosphere is likely to occur in normal operation.
Zone 2 (in the classification of hazardous gas areas), 426-03-05, IEC 60050	An area in which an explosive gas atmosphere is not likely to occur in normal operation and if it does occur it will exist for a short period only.
Zone 20 (in the classification of hazardous dust areas), IEC 61241	An area in which combustible dust, as a cloud, is present continuously or frequently, during normal operation, in sufficient quantity to be capable of producing an explosive concentration of combustible dust mixed with air, and/or where layers of dust of uncontrollable and excessive thickness can be formed.

Term	Definition
Zone 21 (in the classification of hazardous dust areas), IEC 61241	Areas not classified as zone 20, in which a combustible dust cloud is likely to occur during normal operation, in sufficient quantities to be capable of producing an explosive concentration of combustible dust mixed with air.
Zone 22 (in the classification of hazardous dust areas), IEC 61241	Areas, not classified as Zone 21, in which combustible dust clouds may occur infrequently, and persist for only a short period, or in which accumulations or layers of combustible dust may be present under abnormal conditions and give rise to combustible mixtures of dust in air. Where, following an abnormal condition, the removal of dust accumulations or layers cannot be assured, the area shall be classified Zone 21.

1.3.3 Installation and equipment 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.
Controlgear , 441-11-03, IEC 60050	A general term covering switching devices and their combination with associated control, measuring, protective and regulating equipment, also assemblies of such devices and equipment with associated interconnections, accessories, enclosures and supporting structures, intended in principle for the control of electric energy consuming equipment.
Converter , 551-02-01, IEC 60050	An operative unit for electronic power conversion comprising one or more electronic valve devices, e.g. thyristors, associated firing and control circuits and, if necessary, filters and auxiliaries.
Distributed Control System (DCS)	A configurable microprocessor-based (process) control system.
Distribution substation/switchboard	A substation/switchboard mainly used for distributing power to several plant substations.
Generating set , 602-02-01, IEC 60050	A group of rotating machines transforming mechanical or thermal energy into electricity.
Generator , 411-02-01, IEC 60050	A machine, which converts mechanical power into electrical power.
Intake substation/switchboard	A substation/switchboard at which the supply provided by the public utility is interconnected with the site's electrical distribution system. NOTE: An intake substation and a power plant substation may be combined as a single substation.
Integrated Motor Control System (IMCS)	A system comprising control modules, central unit(s), a serial bus connecting the control modules to the central unit and a communication facility enabling connection of the central unit to a distributed control system (DCS) and/or a Supervisory Control and Data Acquisition System (SCADA).

Term	Definition
Inverter	A converter for conversion from d.c. to a.c.
Plain feeder	A feeder, which consists of a cable or an overhead, line only and does not have an interconnected transformer.
Plant substation/switchboard	A substation/switchboard mainly used for feeding one process or utility plant.
Power plant substation/switchboard	A substation/switchboard to which generators and outgoing feeders are connected. NOTE: An intake substation and a power plant substation may be combined as a single substation.
Power station (power plant), 602-01-01, IEC 60050	An installation whose purpose is to generate electricity and which includes civil engineering works, energy conversion equipment and all the necessary ancillary equipment.
Power transformer, 421-01-01, IEC 60050	A static piece of apparatus with two or more windings which, by electromagnetic induction, transforms a system of alternating voltage and current into another system of voltage and current usually of different values and at the same frequency for the purpose of transmitting electrical power.
Rectifier	A converter for conversion from a.c. to d.c.
Remote Control Unit (RCU)	A control device in the vicinity of a consumer for operation of the remotely installed controlgear of the consumer.
Substation (of a power system), 605-01-01, IEC 60050	The part of a power system, concentrated in a given place, including mainly the terminations of transmission or distribution lines, switchgear and housing and which may also include transformers. It generally includes facilities necessary for system security and control, e.g. the protective devices.
Switchgear, 441-11-02, IEC 60050	A general term covering switching devices and their combination with associated control, measuring, protective and regulating equipment, also assemblies of such devices and equipment with associated interconnections, accessories, enclosures and supporting structures, intended in principle for use in connection with generation, transmission, distribution and conversion of electric power.
Switchroom	A room in a substation or building intended exclusively for the installation of one or more switchboards, distribution boards etc.
Variable Speed Drive System (VSDS)	A line-fed a.c. to a.c. conversion system consisting of all facilities required to operate its electric motor at variable speeds.

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section 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 revision of the DEP of the same number dated January 2010. The following are the main, non-editorial changes.

Old section	New section	Change
General		Re-formatting DEP into specification & informative. Previous appendix 2,3,4,5,7 & 14 moved to DEP Informative, appendix 13 moved to section 6.9. All appendix re-numbered.
3.3.2		Voltage dip during motor starting increased to 85%
3.7		Most of section moved to DEP 33.64.10.17
4.7		New section for ENMC
Appendix 7		Amended previous appendix 12 to include DECAF requirements

1.6 COMMENTS ON THIS DEP

Comments on this DEP may be sent to the Administrator at standards@shell.com, using the DEP Feedback Form. The DEP Feedback Form can be found on the main page of "DEPs on the Web", available through the Global Technical Standards web portal <http://www.shell.com/standards> and on the main page of the DEPs DVD-ROM.

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.

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

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

In the event of contradiction between the requirements of this 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.

2.1.2 Technical assurance

The design of electrical installation shall be subjected to a formal technical assurance process.

The technical assurance process shall include the requirement for a SAFOP (safety and operability) assessment.

2.2 OPERATIONAL SAFETY AND RELIABILITY

Electrical Safety Rules (ESRs) shall be in accordance with DEP 80.64.10.10-Gen.

Special attention should 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 (6.9), shall be adhered to.

2.3 PROTECTION AGAINST EXPLOSION AND FIRE HAZARDS

2.3.1 Flammable gas/vapour hazards

To permit the proper selection of electrical apparatus for areas where flammable gas or vapour risks may arise, area classification drawing(s) SHALL [PS] be prepared based on

the IP Model Code of Safe Practice Part 15, Area Classification Code for Petroleum Installations, as amended/supplemented by DEP 80.00.10.10-Gen.

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

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 in accordance with relevant parts of IEC 60079.

(Appendix 1) summarises the various types of protection of electrical equipment that are permissible in hazardous areas. The specification or procurement of equipment complying with other standards different from the above requires the specific approval of the Principal.

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

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

HV motors with type of protection 'n' or 'e' SHALL [PS] not be installed in Zone 2 areas where:

- 1) the motor voltage exceeds 6.6 kV,
- or 2) the motor drives a centrifugal/screw hydrocarbon gas compressor.

These motors SHALL [PS] have type of protection 'd' or 'p'.

- c) 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.

- d) 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 should be either of the industrial weatherproof type or of the domestic type depending on the function of the area (6.1).
- e) 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

Area classification and the selection of apparatus for use in areas where there is a combustible dust hazard SHALL [PS] be in accordance with IEC 61241.

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

The ingress protection as defined in IEC 60529 shall be:

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

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

2.4 STANDARDISATION OF EQUIPMENT AND MATERIALS

Equipment of similar nature and incorporating similar or identical components and of similar or identical construction should be of the same manufacture (e.g. power and convenience outlets, luminaries, junction boxes, RCU's, switches etc.).

2.5 CERTIFICATES, DECLARATIONS AND TEST REPORTS

For all major equipment, the Contractor shall obtain at least the Manufacturer's test reports in accordance with the equipment 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:

- a) For electrical apparatus in Zone 0, Zone 1 and Zone 2 areas, a certificate of conformity shall be obtained from the Manufacturer.
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 can be accepted instead of a certificate of conformity.
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. ELECTRICAL SYSTEM DESIGN

3.1 GENERAL

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

The philosophies to be employed will depend on the size and complexity of the installation; those approved for a specific project shall be set down clearly during the project definition phase.

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.

Overall design intent should be reduction in energy consumption through the selection and utilisation of efficient electrical equipment. The use of high efficiency/power factor electric drives, the use of VSDS for speed, flow or power control, the selection of low loss transformers, etc. should be evaluated during the detail design and equipment procurement stages of a project.

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

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

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:

- a) Loadflow studies;
- b) Fault level studies complying with IEC 60909 Parts 0, 1, 2, 3, 4;
- c) 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;
- f) Harmonic distortion studies;
- g) Motor restarting and re-acceleration;
- h) Vital Supply recovery following total power failure, including emergency diesel generator(s), UPS, instrumentation, DCS and IMCS.

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

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

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

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

3.1.1 Islanding

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. Where statistical analysis is needed, it shall should be based on sufficient local data to make such an analysis valid. As a minimum, the assessment ~~shall~~ 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

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

An electrical power system having a degree of reliability commensurate with vital service SHALL [PS] be provided

An electrical power system having a degree of reliability commensurate with 'essential', or 'non-essential' service shall be provided.

3.2.1.1 Vital service

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

- Examples
1. 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;
 2. Life support systems, e.g. electric motor driven fire pumps on offshore installations supplied from independent sources;
 3. One or more uninterruptible power supply (UPS) units to provide electrical supply to systems, and process control systems;
 4. Emergency lighting and escape lighting.

3.2.1.2 Essential service

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

Examples:

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

3.2.1.3 Non-essential service

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

3.2.2 Load assessment and electricity consumption

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

During the early stages 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.

This is particularly important where own generation is the main source of electricity. Refer also to 3.5.2.

Typically, this allowance can be in the order of 10 % to 20 %, 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.

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.

The various loads are classified as follows:

- a) E - "Continuous"; all loads that may continuously be required for normal operation, including lighting and workshops;
- b) F - "Intermittent"; the loads required for intermediate pumping, storage, loading, etc.;

- c) 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, e.g. the "B" pump of an A-B combination, is **not** be considered as a "Stand-by" pump.

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:

$$x = 100 \%$$

At rated plant throughput all driven equipment should be operating at its duty point. However, some diversity can be applied to non-process loads, e.g. offices and workshop power and lighting, typically 90 %.

$$y = 30 \%$$

$$z = 10 \%$$

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. 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.

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

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.

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.

3.3 SYSTEM VOLTAGES AND FREQUENCY

3.3.1 General

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

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

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

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

3.3.2 Deviations in supply voltage and frequency

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

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

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

Transient voltage deviations occurring at switchgear busbars during motor or group motor starting/reacceleration shall be such as to maintain a minimum of 85% 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.

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:

- 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, on voltage restoration, result in the instantaneous re-energisation of consumers performing an essential and/or vital service to the extent achievable within the constraints imposed by the electrical system;
- 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-energisation of selected consumers.

3.3.3 Deviations and variations in supply waveform

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

Two levels of distortion are recognised:

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

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

- b) The distortion level for new projects or developments

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

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

3.4 SYSTEM POWER FACTOR

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

- a) the terminals of the generator(s), when power is supplied from the Principal's 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

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

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

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

- 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 (3.7.6).

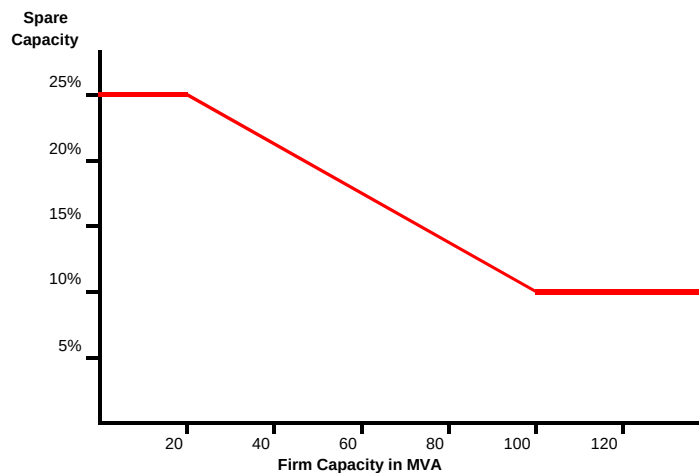
3.5 SUPPLY CAPACITY

3.5.1 General

The distribution system shall be capable of supplying continuously the peak load, assessed according to the applicable load data (3.2.2).

The design of new facilities shall ensure that the firm capacity of the main HV distribution system has spare capacity as indicated in graph below, unless otherwise instructed by Principal.

“Main” distribution is considered to be power plant switchgear, and/or grid intake transformers, distribution switchgear and interconnecting cabling, excluding process plant.



The spare capacity at Plant Substations shall be a minimum of 10 % of peak load at the end of the EXECUTE phase, this 10 % spare capacity being retained for future plant debottlenecking and changes.

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

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

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

3.5.2 Grid intake systems

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

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

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

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

Where applicable, the requirements for an islanding system shall be incorporated in the design. Provision shall be made to allow re-synchronisation of islanded system with grid.

Grid intake circuits shall be provided with the alarm equipment, indicating instruments and integrating meters stated in (Appendix 3).

3.5.3 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. Stand-by capacity (spinning reserve) shall be incorporated to fulfil the requirement of the peak load with the largest generating set out of service.

In order to ensure a stable electrical power system after trip of the single largest generating unit, spinning reserve shall be available. 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. 1.15 to 1.2 for gas turbines. This value may be reduced if confirmed by electrical transient stability studies.

NOTES: 1) This formula can also be used for networks without an external grid connection, i.e. permanently islanded networks.

- 2) The dynamic response margin of larger systems may be reduced based on experience with similar installations and supported by transient stability studies.
- 3) The dynamic response margin should not be lower than 1.05 to provide an allowance for continuous control of the remaining generators.
- 4) If at any time in normal operation the electrical load exceeds maximum allowed load, than a pro-active controlled load reduction (not load shedding) should be carried out in order to achieve N+1 operation again.

The above formula is only for defining the required spinning reserve. The total generation capacity required depends on a number of other factors, e.g. prime mover maintenance requirements, plant reliability, economic assessment, etc.

For plants with own generation capable of operating in island mode

- a) an automatic load shedding scheme should normally be provided.
- b) isochronous control shall 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

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

The provision of stand-by capacity to non-essential service loads should be evaluated based on 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 2500 A. This results in the following preferred 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 switchboard.

Subject to approval from Principal, higher ratings may be considered only if a significant cost saving can be demonstrated.

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

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

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

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.

For HV and LV switchboards, the rated short circuit withstand duration corresponding to the rated withstand current shall be 1 s.

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

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

HV switchboards shall have a maximum of three sections and, consequently, a maximum of two bus section switches.

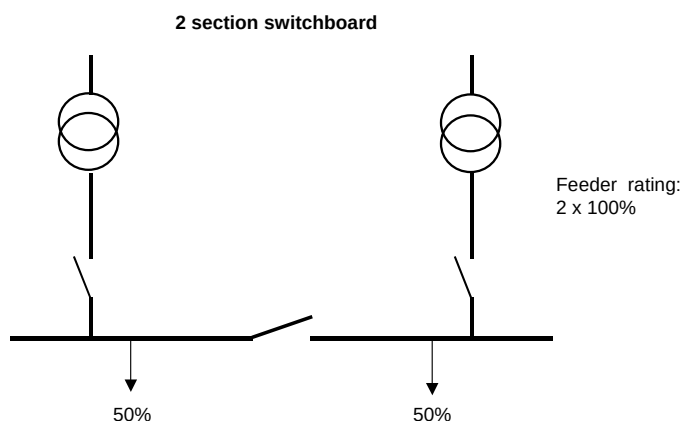
LV switchboards shall have two, three or maximum four sections (in 'H' configuration). Where the LV load exceeds the capacity of a four-section switchboard, additional switchboard(s) shall be installed rather than having switchboards of more than four sections. Special arrangements, e.g. automatic changeover,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

For design purposes normal operating position of switchboard bus section switches shall be as follows:

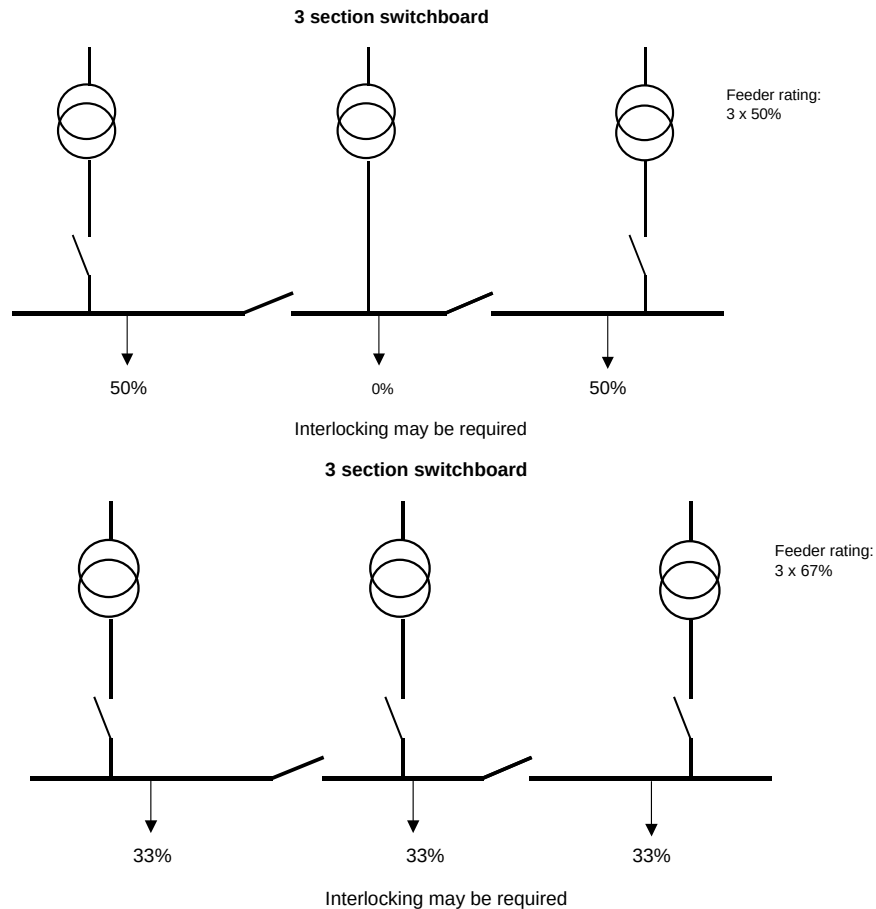
- a) For LV switchboards the bus section switches shall be operated normally open, except on switchboards at the source of supply, i.e., at LV generator switchboards.
- b) For HV switchboards the bus section switches shall be operated normally closed on switchboards at intake substations, power (generation)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

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.

The basic configuration for a switchboard supplying essential service loads is a two section switchboard with two 100 % rated incoming circuits and one bus section switch



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



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

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

3.5.6 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.

3.6 SHORT CIRCUIT RATINGS

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

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

The short circuit ratings of equipment and cables, including the short circuit making and, where relevant, breaking capacity of circuit switching devices, shall be based on the parallel operation of all supplies which can be operated in parallel. Due regard should be 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, break before make automatic supply changeover arrangements, *etc*

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.

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.

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

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

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

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

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

The use of current-limiting reactors, Is-limiters and similar devices intended specifically as a means of limiting the magnitude of short circuit currents are permissible only when they form part of extensions or interconnections with existing installations. The application of the above-mentioned current-limiting equipment should 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.

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

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

Short circuit current contributions from cage induction machines need normally only be taken into account for determining the necessary dynamic withstand rating of equipment and the required making duty of circuit breakers tested in accordance with IEC 60056 62271-100 and IEC 60947-2. However, where reliance is placed on circuit breakers having an enhanced making capacity, the effects of asynchronous machine contributions shall be taken into account in establishing the adequacy of the fault breaking duty of circuit breakers, taking into account the decay of the short circuit current contribution.

A period of 100 ms after the fault shall be taken for establishing adequacy of the breaking capacity of circuit breakers.

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

3.7 ELECTRICAL PROTECTION

3.7.1 General

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

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.- Application of Protective Functions for Electrical Systems.

3.8 SYSTEM EARTHING

3.8.1 General

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

The preferred system earthing arrangements are given in (Appendix 2).

3.8.2 HV systems

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

HV system neutrals shall be earthed at each source of supply (transformer, direct-connected generator) as shown in (Appendix 2).

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

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

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

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

Where generators of dissimilar ratings, characteristics or loadings are to be operated in parallel so as to give rise to circulating currents in the above-mentioned earthing resistors

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

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

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

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

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

3.8.3 LV systems

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

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

3.8.4 UPS systems

A.C. UPS systems shall have their neutrals solidly earthed. This applies equally to single phase and three phase systems.

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

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

3.9 ELECTRICITY SUPPLY FOR VITAL SERVICES

3.9.1 General

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

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

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

The design of such systems shall be agreed with the Principal at the SELECT phase of a project.

3.9.2 A.C. uninterruptible, maintained electricity supply

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

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

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

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

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

a) 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.

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.

b) Equipment suitable for receiving a single electricity supply:

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

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

3.9.3 D.C. uninterruptible, maintained electricity supply

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

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

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

3.9.4 Battery autonomy times

The batteries of UPS units SHALL [PS] be rated to energise the relevant loads for not less than:

For onshore installations:

- a) 30 min for process plant shutdown;
- b) 1 h for utility plants;
- 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 systems;
- f) 8 h for telecommunication and radio systems.

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

If "N+1" spared emergency generators are supplying the UPS systems, the following changes to the battery autonomy time can be made, subject to approval by the Principal:

- 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.

For offshore installations:

- a) 30 min for emergency shutdown and depressurising systems;
- b) 45 min for process monitoring and control systems;
- c) 90 min for helideck lighting, see (6.2.4.5);
- d) 3 h for public address, platform audible alarms and status lights;
- e) 3 h for fire and gas detection and alarm systems;
- f) 3 h for emergency and escape lighting (the latter with 1 h internal battery back up) (refer to 5.4.2);
- g) 24 h for SOLAS (Safety of Life at Sea) communications equipment;
- h) 96 h for navigational aid systems.

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

The above autonomy times for offshore installations may be reduced if "N+1" spared emergency generators are installed that feed the UPS systems, but this is subject to specific approval by the Principal.

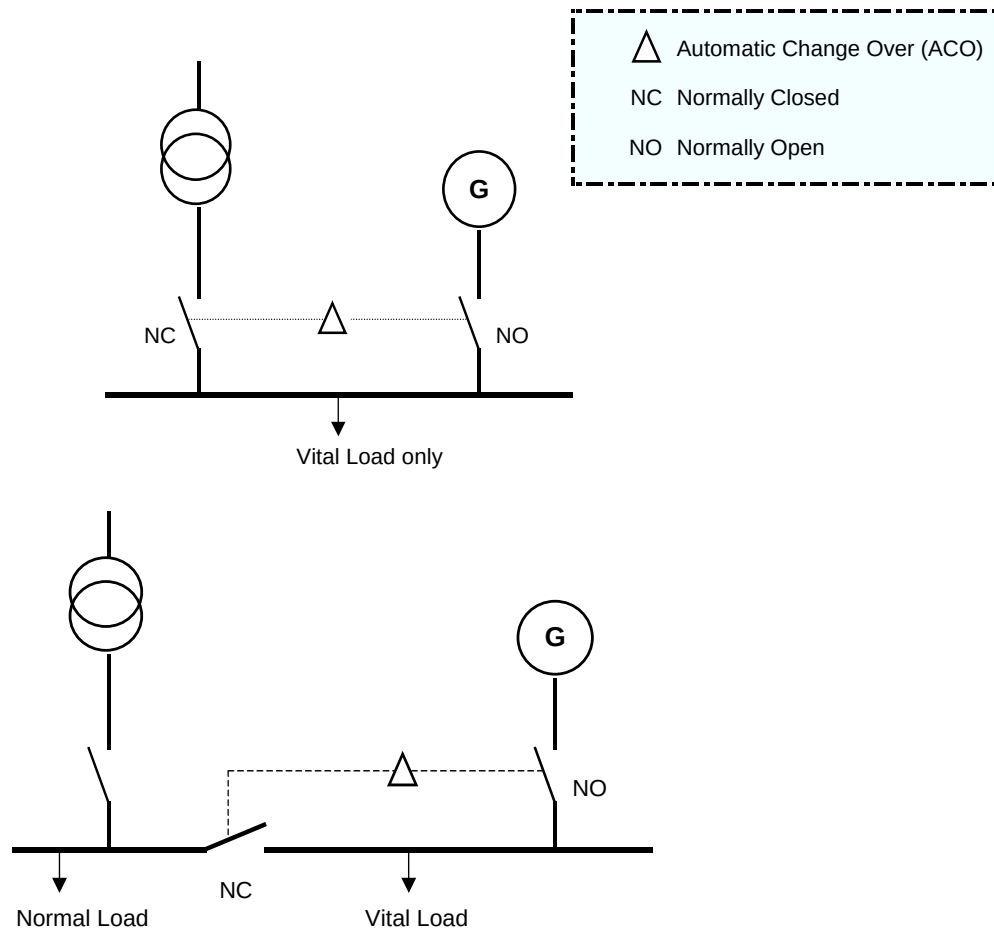
These are minimum autonomy times and can be increased to enable combining of services aiming at a reduction in the number of UPS systems. The use of timers to selectively switch off consumers is not recommended.

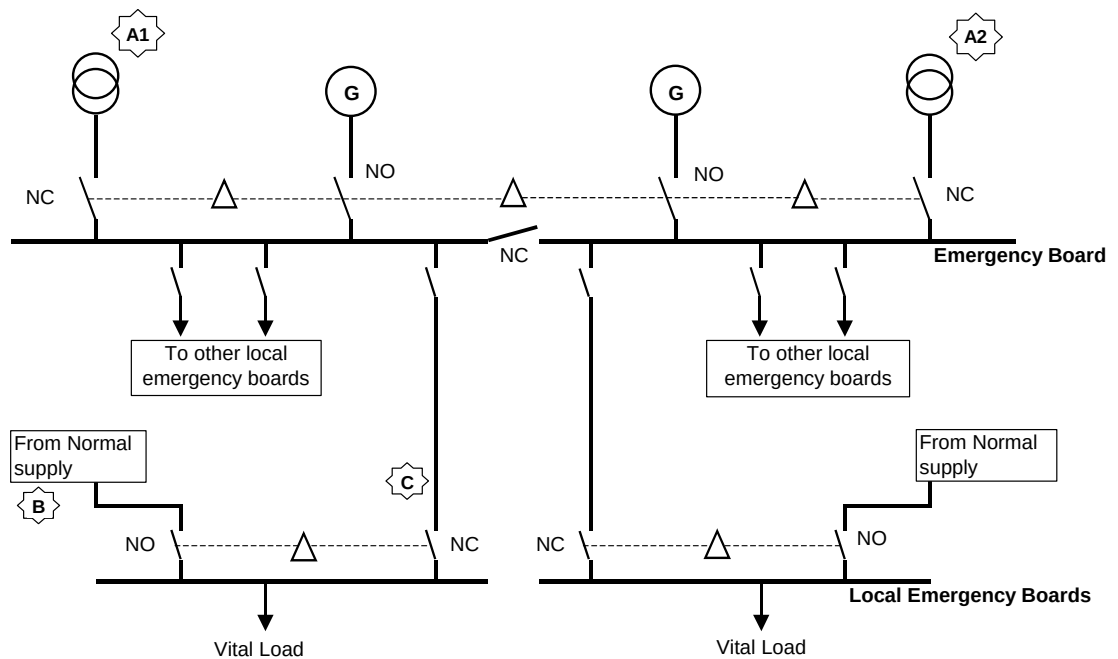
NOTE: Specific offshore country-specific requirements may apply.

3.9.5 A.C. interruptible, maintained electricity supply

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

Switchboard configurations shall typically be as follows:





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

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

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

If the emergency generator is to be used to energise UPS units then 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).

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.

Where required, synchronising and/or synchronising check facilities shall be provided to enable 'make before break' return to normal operation.

Facilities shall be provided to permit periodic on-load testing of emergency generators by enabling the generator to be synchronised with the mains supply. Each generating set shall have sufficient fuel storage capacity for at least 8 h full load operation. Increased fuel storage capacity may be specified for offshore and remote land installations.

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

4. DESIGN AND SELECTION REQUIREMENTS FOR EQUIPMENT AND CABLES

4.1 GENERATORS

4.1.1 General

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

The above requirements should 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.

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

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

4.1.2 Synchronous generators ≥ 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, however, it may also be installed in (centralised) emergency or stand-by systems of large process facilities.

Main cable termination arrangements shall be in accordance with DEP 33.65.11.31-Gen. However:

- a) 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;
- b) for transformer-connected generators, phase segregation should be maintained for all the cabling and for busbars connected to the generator, so as to minimise the possibility of multi-phase short circuits.

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

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

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

Main generators shall be fitted with the following control equipment:

- a) Manual and automatic synchronising with a check synchronising relay and a dead-bar override;
- b) Voltage control equipment consisting of automatic voltage control with a manual control stand-by system. Manual control system shall follow the setpoint of the automatic control system to allow for automatic changeover from the automatic to the manual control system without significant voltage transients if the automatic voltage control system fails. The voltage control system shall be suitable for island and parallel operation. 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. 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;

- 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.
For generator connected via a unit transformer with on-load tap changers, 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 prevent "voltage hunting".
- d) 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.
- e) 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 breakers' auxiliary contacts.

NOTE: 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. Thi change in operating mode needs to be signalled to governor control.

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

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

Main generators shall be provided with the alarm equipment, indicating instruments and integrating meters stated in Appendix 2.

4.1.3 Synchronous generators < 1250 kVA (Packaged Units)

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.

The rating of these generating sets will normally be within the range of 50 kW to 1000 kW, and supply an emergency LV switchboard. However, for power plant black-start duties and emergency or stand-by systems of large process facilities, sets with a larger rating may be required, possibly supplying an HV system. In sizing the generating set, account shall be taken of the related motor starting requirements and UPS loads (3.9).

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

4.1.4 Cage induction generators

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

4.2 SWITCHGEAR

4.2.1 HV switchgear

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

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

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

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

4.2.2 LV switchgear

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

Where generators are directly connected to an LV switchboard the ratio of peak to rms short circuit current is likely to be higher than normal allowance as per IEC standard. In these cases the peak short circuit requirement should be clearly stated in the specification.

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

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

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

4.2.2.1 LV feeders

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. MCCBs and fuses shall co-ordinate with outgoing circuit protective devices on the receiving end sub-distribution switchboard.

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.

4.3 POWER TRANSFORMERS

4.3.1 General

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

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

For primary voltages up to and including 12 kV, fused (latched) contactors shall be used as switchgear for transformer feeders.

Transformers for outdoor use and rated:

- a) up to and including 1600 kVA shall be of the oil filled hermetically sealed type;
- b) 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;
- c) above 3150 kVA shall be of the oil filled conservator type.

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

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

In locations where fire risk must be minimised, e.g. in buildings, on offshore platforms, etc., the dielectric/cooling liquid of transformers shall be synthetic with reduced ignitability and flame-retardant characteristics, e.g. silicone fluid. In the above locations, dry-type transformers having cast resin encapsulated windings may also be used.