

DEP SPECIFICATION

ELECTRICAL ENGINEERING DESIGN FOR NORTH AMERICAN APPLICATION

DEP 33.64.20.10-Gen.

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DESIGN AND ENGINEERING PRACTICE

DEM1



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PREFACE

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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 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.

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1. INTRODUCTION

1.1 SCOPE

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

This DEP excludes facilities located outside North America. Refer to DEP 33.64.10.10-Gen.

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

This is a revision of the DEP of the same number dated February 2013; see (1.5) regarding the changes.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorized 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 authorized access to DEPs does not for that reason constitute an authorization to any documents, data or information to which the DEPs may refer.

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

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

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

1.3 DEFINITIONS

1.3.1 General definitions

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

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

The **Principal** is the party that initiates the project and ultimately pays for it. The Principal may also include an agent or consultant authorized to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The capitalized term **SHALL [PS]** indicates a process safety requirement.

The word **should** indicates a recommendation.

The word **may** indicates a permitted option.

1.3.2 Specific definitions

Term	Definition
Accredited Certification Organization (ACO)	An organization that has been accredited by the Standards Council of Canada, in accordance with specific criteria, procedures and requirements, to operate, on a continuing basis, a certification program for electrical equipment. When a reference is made to a NRTL in this DEP, this also includes the Accredited Certification Organization in Canada.
Authority Having Jurisdiction (AHJ)	Organization, office, or individual responsible for enforcing the local regulatory requirements. Consult with the Principal for the applicable AHJs for the specific installation.
Derogation	Authorized variance or exemption from a Process Safety requirement, with specified conditions.
Location	The site where the new electrical facilities will be installed and operated.
Nationally Recognized Testing Laboratory (NRTL) Program	Part of OSHA's Directorate of Technical Support and Emergency Management. The Program recognizes private sector organizations as NRTLs, and recognition signifies that an organization has met the necessary qualifications specified in the regulations for the Program. The NRTL determines that specific equipment and materials ("products") meet consensus-based standards of safety to provide the assurance, required by OSHA, that these products are safe for use in the U.S. workplace.

1.3.3 Technical basic definitions

Term	Definition
Backup Time (of a battery)	The duration for which the battery can supply its rated load within its specified voltage limits, following a prolonged period of battery float-charge operation.
Electrical Network Monitoring and Control (ENMC)	A computerised system that is dedicated to monitoring and controlling defined aspects of an electrical network.
Electrical services (criticality)	• Vital Services are services 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. Vital Services ensure a safe and orderly shutdown of the facility, safety of personnel, and protection of the environment. Emergency services represent a subset of the Vital services that are deemed as “emergency” by the authority having jurisdiction. <i>Vital service can also be referred to as critical service.</i> • Essential Services are services which, if it fails in operation or when called upon, will affect the continuity, quality or quantity of the product or could result in equipment damage or extended downtime, but would not harm people or the environment. • Non-essential Service is any electrical service that is neither vital nor essential. Non-essential service can also be referred to as normal service.
Electro-magnetic Compatibility	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 when the supply to the normal lighting fails.
Escape lighting	Part of the emergency lighting that is provided to ensure that the escape route is illuminated at all times. Also referred to as egress lighting
Hazardous Area	For definitions of hazardous (classified) areas, refer to DEP 80.00.10.13-Gen.
Islanding	Disconnecting the external (public utility) grid supply, so that all or part of the plant electrical system will operate in an “island” with the main on-site generators as the source of supply.
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.

Term	Definition
Proven Equipment	Equipment of which at least three units of similar type, size and specific loading have together accumulated a minimum of 24,000 hours of comparable satisfactory service.
Public utility	Third party provider of electrical power, this can be a publically owned network/grid or a privately owned company.
Substation	Area or group of equipment containing switches, circuit breakers, buses, and transformers for switching power circuits and for transforming power from one voltage to another or from one system to another.
Voltage classes	• Low voltage (LV) Voltages less than or equal to 1000 V. • Medium voltage (MV) Voltages above 1000 V but less than or equal to 38 kV. • High voltage (HV) Voltages above 38 kV.

Definitions in accordance with IEEE 100 are used in this DEP unless replaced or supplemented by those listed below.

1.3.4 Abbreviations

Term	Definition
AHJ	Authority Having Jurisdiction
ASD	Adjustable Speed Drive
CFR	Code of Federal Regulations
DDP	Discipline Delivery Plan
EMC	Electro Magnetic Compatibility
MBS	Maintenance Bypass Switch
OSHA	Occupational Safety and Health Administration
SAFOP	Safety and Operability Review
UPS	Uninterruptable Power Supply
USCG	United States Coast Guard

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 February 2013. The following are the main, non-editorial changes.

Section/Clause	Change
All	Restructured and clarified requirements, enforced use of shall/should/may for normative statements.
All	Definitions for 'Electrical Service Criticality' changed to align definition with DEPs applied in the rest of the world and those published by Rotating Equipment.
All	'Electrical Technical Authority' changed to 'Principal' to align with DEPs applied in the rest of the world.
All	Use of data sheet, DEP 33.64.20.90-Gen. changed. Source for requirements is the BfD however DEP 33.64.20.90-Gen. should be used to define requirements.
2.1	Use of design class added. DEP requirements meet Design Class 3.
3.2.1	New section added to align with DEP 33.64.10.10-Gen. and provide addition clarification to change in Electrical Service Criticality'.
3.9.1	SHALL [PS] requirement for Vital services aligned with revised SHALL [PS] requirements in DEP 33.64.10.10-Gen. (3.9.1).
3.9.4.1	SHALL [PS] requirement for batteries revised. Autonomy times aligned with DEP33.64.10.10-Gen.
4.15.1	SHALL [PS] requirements for lighting removed as requirements are already covered in DEP 80.00.10.13-Gen.
4.15.5	SHALL [PS] requirement for special lighting (navigation aids) revised.
5.3.4	Complete section including SHALL [PS] requirements deleted as they are already included in the NEC & CEC.
6.1.3.2	SHALL [PS] requirements for HVAC separated from non-Process Safety requirements.
6.2.4	SHALL [PS] requirements for navigation aids revised.
6.6	SHALL [PS] requirement for jetties added and aligned with SHALL [PS] requirements in DEP 33.64.10.10-Gen. (6.6).

1.6 COMMENTS ON THIS DEP

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

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

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

1.7 DUAL UNITS

This DEP contains both the International System (SI) units, as well as the corresponding US Customary (USC) units, which are given following the SI units in brackets. When agreed by the Principal, the indicated USC values/units may be used.

1.8 NON NORMATIVE TEXT (COMMENTARY)

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

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

1.9 DATA SHEET

The Data Sheet for this DEP is DEP 33.64.20.90-Gen. This Data Sheet should be used to better define the design requirements for a project in conjunction with this DEP.

2. DESIGN AND ENGINEERING PRINCIPLES

2.1 GENERAL REQUIREMENT

1. Electrical equipment and material shall be suitable for the application and installed in accordance with the Manufacturer's/Supplier's ratings, approvals, recommendations, and instructions.
2. The electrical installation shall be suitable for the site conditions as specified by the Principal.
3. Refer to Standard Forms DEP 00.00.07.75-Gen. and DEP 00.00.07.96-Gen. for guidance on application of Design Class to electrical installations. Electrical installation design per this DEP meets the requirements of Design Class 3 as specified in DEP 00.00.07.75-Gen. and DEP 00.00.07.96-Gen. (standard form).

If specified by the Principal, a (different) Design Class may be given for the design of the electrical installation.

4. The design of the electrical facilities shall meet the specific design criteria, philosophy and/or objective stated in the project definition phase, (e.g., in the basis of design (BfD) document or project specification), relating to a particular location.
 - a. Within this DEP, where options or requirements have to be specified in the basis of design document or project specification, the Data Sheet (DEP 33.64.20.90-Gen.) should be used to better define the design requirements for a project in conjunction with this DEP.

The data sheet may require updating as the projects passes through the design stages i.e., SELECT, DEFINE or EXECUTE.
5. The design and selection of electrical equipment should take into consideration optimizing capital and operating costs.
 - a. Total life cycle cost calculation should be included in the design for assets that have a design life of 15 years or longer.

2.2 STANDARDS, CODES, AND REGULATIONS

This DEP is based on publications from the following organizations:

- American National Standards Institute (ANSI);
- National Equipment Manufacturer's Association (NEMA);
- Institute of Electrical and Electronic Engineers (IEEE);
- American Petroleum Institute (API).

Where relevant, the specific publications are referenced in this DEP.

1. Specific for onshore USA and state waters
 - a. Occupational Safety and Health Administration (OSHA) Jurisdiction – All facilities onshore in the US and in state waters, refer to the National Electrical Code (NEC) and OSHA standards.
 - b. National Fire Protection Association (NFPA).

2. Specific for offshore USA:
 - a. The Bureau of Ocean Energy Management of the United States Department of the Interior (BOEM) Jurisdiction (Primarily Fixed Facilities in Federal Waters) - All fixed facilities in federal waters, refer to the United States Code of Federal Regulations Title 30 Part 250. The BOEM also references API RP 14F and API RP 14FZ.
 - b. USCG Jurisdiction (primarily floating facilities in federal waters)-All floating facilities in federal waters and any other facilities under the jurisdiction of the USCG refer to API RP 14F and USCG regulations.
 - c. National Fire Protection Association (NFPA)
3. Specific for Canada:
 - a. Canadian Standards Association (CSA)

2.3 OPERATIONAL SAFETY AND RELIABILITY

1. Refer to CSA Z462 and/or NFPA 70E for safety requirements of the facilities.
2. Design of electrical facilities shall ensure that:
 - a. they provide a safe supply of electricity at all times;
 - i. this includes normal operating conditions, including those associated with startup and shutdown of plant and equipment, and throughout the intervening shutdown periods.
 - b. all operating and maintenance activities can be performed safely;
 - c. they permit periods of continuous operation of at least five years.
 - i. for non-spared equipment in vital or essential duty, the period of continuous operation shall be at least 6 years.

The period of continuous operation is determined by the major shutdown intervals of the associated plant.
3. Design should not consider the simultaneous failure of two pieces of equipment.
4. Insulating and dielectric materials used in all electrical equipment shall be non-toxic and not contain compounds that are persistent and/or hazardous environmental contaminants, (e.g., polychlorinated biphenyls (PCBs)).
 - a. Refer to DEP 01.00.01.30-Gen. for definitions and requirements for hazardous materials.
5. Equipment that has electro-magnetic emission should be provided with external caution notices to warn heart pace-maker wearers of the risks of electro-magnetic sources. The notices should be:
 - a. installed at the perimeter of the area that is considered dangerous for pace-maker wearers;
 - b. state the minimum approach distance to the particular equipment; and
 - c. be verified with the Manufacturer/Supplier for each individual equipment installation.

The types of equipment known to be a source of electro-magnetic emission include variable adjustable speed drive systems, particularly larger units installed in modularized or containerized packages.
6. Temporary facilities can present increased risk to safety. Refer to (Appendix 2) for the specific requirements associated with the design and installation of temporary facilities required for the erection of permanent installations.

7. If specified by the Principal, a safety and operability study (SAFOP) shall be performed. Refer to (Appendix 1) for requirements.

2.4 HAZARDOUS AREA CLASSIFICATION

1. Refer to DEP 80.00.10.13-Gen. for area classification and electrical spacing requirements.
2. Refer to the following documents (where applicable) for installation of equipment in hazardous area:
 - a. NFPA 70;
 - b. CSA C22.1;
 - c. IEEE 45;
 - d. API RP 14F (or 14FZ).
3. Equipment in hazardous areas complying with other standards shall be subject to approval by the Principal.

2.5 STANDARDIZATION OF EQUIPMENT AND MATERIALS

Standardization of materials and equipment is desired.

1. Equipment of similar nature and incorporating similar or identical components and of similar or identical construction should be of the same Manufacturer/Supplier, (e.g., power and convenience outlets, luminaries, junction boxes, and switches).
2. Equipment that will become obsolete in the near future should not be installed.
3. When the project work is on an existing facility, the design and equipment should match the existing facility.

This DEP does not preclude use of alternative designs or methods resulting from new technologies and sound engineering principles that reflect: simplicity of operation; improved safety; improved reliability/maintainability; improved performance; and, reduced costs.

4. The use of new and unproven technology shall be subject to approval by the Principal.

2.6 CERTIFICATES, DECLARATIONS AND TEST REPORTS

1. The Contractor shall obtain the Manufacturer's/Supplier's test reports in accordance with the equipment DEP specifications, (e.g., for generators, HV motors, VSDS, HV and LV switchgear, UPS equipment, and transformers).
2. Equipment shall be approved, listed, certified, or otherwise determined to be safe by a NRTL in accordance with nationally recognized product safety standards for the application and the environment in which the equipment is installed (e.g., hazardous locations, wet locations).

2.7 QUALITY ASSURANCE AND CONTROL

1. Contractors and Manufacturers/Suppliers shall demonstrate to the Principal that they implement quality control and assurance systems that conform to the ISO 9000 series.

3. ELECTRICAL SYSTEM DESIGN

3.1 GENERAL

1. Design of the electrical facilities shall meet the specific design criteria, data sheet, philosophy and/or objective stated in the project definition phase, (e.g., in the Basis of Design document and/or project specification) relating to a particular plant or facility.
For instance, it may be defined by plant lifetime, skill of operating and maintenance personnel, operational flexibility, extension possibilities, noise limitations, etc.
The philosophies to be employed will depend on the size and complexity of the installation.
2. Refer to Standard Forms DEP 00.00.07.75-Gen. and DEP 00.00.07.96-Gen. for guidance on application of Design Class to electrical installations.
Electrical installation design per this DEP meets the requirements of Design Class 3 as specified in DEP 00.00.07.75-Gen. and DEP 00.00.07.96-Gen. (standard form).
If specified by the Principal, a (different) Design Class may be given for the design of the electrical installation.
3. The following alternatives for the electricity supply should be considered:
 - a. own generation;
 - b. public utility;
 - c. a combination of these, within the limits and possibilities given by the Principal.
4. If specified by the Principal, power system studies shall be undertaken to explore alternative methods of providing power to users.
5. The primary power system shall have provisions that permit inspection and maintenance of the primary equipment without interrupting power to the secondary distribution system.
6. Modularization should be considered in the design of electrical facilities.

3.1.1 Utility interface

1. Final configuration of the primary circuits, including equipment short circuit capacity, service voltage transformation, interconnections, and relaying shall be determined in conjunction with the public utility company.
2. If multiple primary sources are provided by the public utility, the primary switchgear arrangements shall provide a means to continue serving the load without interruption when one primary source has lost voltage or has been faulted.
3. An analyzer that is capable of being programmed to detect and record power system disturbances shall be provided.
 - a. The analyser should be located at the PCC.

3.1.2 Generation

1. The main power generating sets should be in an electrically centralized location and the distribution system arranged radially.
 - a. Ring distribution systems should be considered for facilities requiring high reliability and located at relatively large distances from the power source or from each other.
2. The requirement for islanding schemes including load shedding shall be addressed where onsite generation and utility power is available.

3.1.3 Distribution system

1. Distribution system design (e.g., voltage rating, system configurations), shall be specified in the BfD.
 - a. Data Sheet, DEP 33.64.20.90-Gen. should be used to define requirements.
2. Modifications or additions to existing distribution system design should take into account the following:
 - a. existing distribution system design at the location;
 - b. maintenance philosophies of the location.
3. Layout and circuit arrangement shall permit inspection and maintenance of the distribution system without a total system shutdown.
4. Vital loads shall be supplied by double-ended substations with power being supplied from two independent services.
5. For offshore or remote installations, distribution systems should be fed in a radial manner.
6. For large integrated plants where the level of reliability requires multiple sources of power and the loads might have different maintenance intervals, distribution substations should be double-ended with single or redundant bus tie-breakers.
7. If a distribution substation serves radial loads that cannot be interrupted for maintenance, use of a maintenance bus design shall be provided.
8. Individual process unit loads may be served by radial distribution systems.

3.1.4 Power system studies

1. Power system studies and protection schemes shall be provided in support of the design using a computer based power system studies program approved by the Principal.
 - a. The scope and timing of the power system studies shall be specified by the Principal.

Timing of the power system study is typically during DEFINE however an initial study may be done in SELECT.
 - b. Scenarios and system parameters shall be approved by the Principal.
 - c. SKM Power Tools for Windows is an approved computer based power system studies program.
2. Preliminary power system studies shall be performed to enable purchase of equipment.
 - a. The power system studies shall be updated as the design proceeds.
3. Final studies showing that the design requirements have been met, shall be submitted at the conclusion of the project to the Principal
 - a. Refer to (7) and (Appendix 1) for additional study requirements and documentation.
4. If there is a public utility interconnection, the power system study requirements of the public utility shall be included within the scope of the power system studies.
 - a. The power system studies shall include minimum and maximum three-phase and single-phase fault contribution and X/R ratios from the public utility at the point of common coupling.
5. Each power circuit breaker and fuse within the distribution system shall function in a predetermined and fully coordinated manner with all associated circuit breakers, fuses and motor starter overcurrent devices.

6. To ensure that current transformers do not saturate during short circuit fault conditions, the current transformer saturation curves shall be checked with respect to the dc offset of fault current.
7. Protective device coordination studies shall be evaluated at both the minimum and maximum available fault currents to verify complete device selective coordination throughout the expected system operating range.
8. If specified by the Principal, a Black Start Study shall be completed to document the principle of recovery from a total power failure.
 - a. The Black Start study shall identify vital equipment and circuits to be reinstated and the methodology for recovery.
9. If specified in the BfD, a protection system description and philosophy document shall be provided.
 - a. Data Sheet, DEP 33.64.20.90-Gen. should be used to define requirements.

3.2 ELECTRICAL LOADS AND ELECTRICITY CONSUMPTION

3.2.1 Classification of loads

3.2.1.1 General

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

3.2.1.2 Vital service

1. Refer to (3.9) for requirements for power supply to 'vital' services.

Examples of 'vital' services are:

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

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

3.2.1.3 Essential service

1. For essential services, the extent 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 shall be determined by the Principal.

Examples of essential services are:

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

3.2.1.4 Non-essential service

1. Non-essential Service is not backed up.

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

3.2.2 Load assessment and electricity consumption

1. A schedule of the installed electrical loads, the maximum normal running plant load, and the peak load, expressed in kilowatts and kilovars and based on the plant design capacity when operating under the site conditions specified shall be prepared.
2. The schedule of installed electrical loads shall be completed and updated throughout the design phases of the project and form the basis for provision of the necessary electricity supply and distribution system capacity (3.5).
3. The method for determining the total electrical load in (Appendix 3) shall be used.

3.3 SYSTEM VOLTAGES AND FREQUENCY

3.3.1 General

1. For modification to existing facilities, nominal system voltages and frequencies for three phase systems shall be selected based on voltage levels and frequencies presently being utilized by the Location.
2. For new locations, nominal system voltages and frequencies for three phase systems shall be selected by the Principal.

Typical voltages and frequencies include one or more of the following:

- Voltages levels: 69000, 34500, 25000, 13800, 12470, 12000, 6900, 4160, 2400, 600 and 480;
- Frequencies; 50Hz or 60Hz.

Voltage and frequency selection may depend upon the public utility.

3. Nominal system voltage(s) and frequency of three phase systems shall be indicated on the overall key one-line diagram.
4. For modification to existing facilities, nominal system voltages and frequencies for lighting and other small utility services shall be selected based on voltage levels and frequencies presently being utilized by the Location.
5. For new locations, nominal system voltages and frequencies for lighting and other small utility service shall be selected by the Principal.

Typical voltages and frequencies include one or more of the following:

- 240/120 V, 208/120 V, 480/277 V or 600/347 V;
- Frequencies; 50Hz or 60Hz.

6. 480/277 V and 600/347 V 4-wire systems should be derived from a separate solidly grounded lighting transformer with a maximum capacity of 75 kVA.

3.3.2 Deviations in supply voltage and frequency

1. During normal system operation, and under steady-state conditions:
 - a. the voltage at generator and consumer terminals shall not exceed –5% or +5% of the rated voltage of the equipment served; and
 - b. the system frequency shall not deviate from the rated frequency by more than 2%.
2. All loads shall be balanced so that the voltage unbalance at any point in the distribution system does not exceed 1%.

3. During starting or reacceleration of direct online motors, either singularly or in a group, the voltage at the motor terminals shall not deviate by more than +10% or -20% from rated equipment voltage, unless otherwise specified in the BfD.
 - a. Data Sheet, DEP 33.64.20.90-Gen. should be used to define requirements.
 - b. If the motor starting voltage is less than 80% of the motor rated voltage, the motor Manufacturer/Supplier shall certify that the driven equipment's starting requirements are satisfied at the motor starting voltage.
4. Motor starting or reaccelerating voltage shall be sufficient to produce the torque required to accelerate the load to rated speed (with a 10% acceleration torque margin).

The requirement in 3.3.2 (Item 4) applies in particular to motors controlled by starters that remain closed during a momentary voltage dip.
5. Transient voltage deviations occurring at switchgear or motor control center busbars during motor or group motor starting/reacceleration shall maintain:
 - a. a minimum of 85% voltage on switchgear or motor control center busbars; and
 - b. a minimum of 80% and a maximum of 110% of rated system nominal voltage on all other consumers.
6. Notwithstanding the above requirements, the limits set by the public utility regarding the maximum voltage deviations that a consumer is permitted to cause at the point of common coupling (PCC), (e.g., due to the starting of electric motors), shall be adhered to.
7. Equipment having special requirements with respect to variations in voltage and/or waveform shall be provided with a power supply that is adequately stabilized and/or filtered.
8. Steady-state voltage drop from the substation bus to the loads supplied from the substation shall not exceed 5% of the nominal system voltage

Steady state voltage drop is typically split as 2% feeder and 3% branch circuit.
9. Transformer secondary side no-load voltage shall rise no more than 8% above the nominal system voltage at the transformer secondary terminals.

3.3.3 Deviations and variations in supply waveform

1. Electrical loads having non-linear characteristics, such as producing voltage and current waveform distortion of a magnitude that is detrimental to the lifetime or performance of system electrical equipment or interferes with other systems such as communications, shall not be utilized, unless appropriate measures are taken to render harmless the effects of such distortion, (e.g., by filtering or phase displacement).
2. Current distortions at the PCC with the utility and when specified by the Principal at locations inside the plant, shall not exceed those listed in IEEE 519 Section 10 for the appropriate Voltage and Short Circuit Ratio.
3. If Telephone Interference is specified in the BfD as an issue, the interference level shall not exceed the defined levels in IEEE 519.
 - a. Data Sheet, DEP 33.64.20.90-Gen. should be used to define requirements.
4. Equipment that produces a sustained DC component (i.e., even harmonics) in the AC supply system shall not be utilized.

3.4 SYSTEM POWER FACTOR

1. Unless specified otherwise in the BfD, the overall system power factor, inclusive of reactive power losses in transformers and other distribution system equipment, shall not be less than the following:
 - a. when connected to a utility, a minimum level of 0.9 lagging at rated design throughput of the plant unless a higher power factor is required by the utility;
 - b. when providing own generation and not connected to the utility, a minimum level of 0.8 lagging at rated design throughput of the plant;
 - c. data Sheet, DEP 33.64.20.90-Gen. should be used to define requirements.
2. The power factor shall be determined at:
 - a. terminals of the generator(s), when power is supplied from the Principal's own generation;
 - b. PCC, when power is supplied from a public utility.
 - i. 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%.

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

3.5 SUPPLY CAPACITY

3.5.1 General

1. Unless otherwise specified in the BfD, 25% spare capacity of the main HV distribution system (power plant switchgear, and/or grid incoming transformers, distribution switchgear, and interconnecting cabling) shall be provided.
 - a. Data Sheet, DEP 33.64.20.90-Gen. should be used to define requirements.
2. Distribution systems shall be capable of supplying continuously at least 125% of the running load, assessed according to the applicable load list (3.2), without exceeding specified voltage and frequency limits (3.3), and equipment ratings, unless otherwise specified on the BfD.
 - a. Data Sheet, DEP 33.64.20.90-Gen. should be used to define requirements.
3. Requirements for the provision of necessary spare and stand-by capacity, and for the rating of supply and distribution equipment for each part of the electrical system, are given in (3.5.2) through (3.5.5).

3.5.2 Power generation

3.5.2.1 General

1. Power generation should have sufficient stand-by capacity to meet the requirement of the peak load with the largest generating set out of service (N+1 design) unless otherwise specified in the BfD.
 - a. For facilities that require a peak demand for a short duration, it may be acceptable, with approval from the Principal, to require operation of a standby generating set to meet peak demand.
 - b. The availability of further stand-by supply capacity to cater for generating set failures during maintenance/repair periods shall be provided if specified in the BfD.

(e.g., where the aggregate maintenance/repair time warrants this).
 - c. For a plant with its own generation capable of operating in island mode, an automatic load shedding scheme should be provided to ensure the load does not exceed the available generating capacity.
 - d. Data Sheet, DEP 33.64.20.90-Gen. should be used to define requirements.
2. If specified in the BfD, space for a future generating set shall be provided to accommodate future load growth.
 - a. Data Sheet, DEP 33.64.20.90-Gen. should be used to define requirements.

3.5.2.2 Essential service power generation for offshore facilities

1. Essential loads are defined by the operating requirements of the facility and may include post lube pumps on compressors, instrument air compressors, methanol pumps, and emergency command center HVAC systems.
2. Essential service power shall operate (e.g., generator space heaters, food freezers, and other vital loads) during evacuation periods when the normal power generation system is not available.
3. Essential service power shall be available for a minimum of 72 hrs. This may be accomplished by using an auto-fill fuel system.
4. An essential service generator on a facility with an emergency generator shall be designed to the same criteria as the emergency generator.
 - a. The essential service generator should not be sized for total connected load.

This minimizes spare parts and improves standardization.
5. Consideration may be given to the designation of a dual fuel primary generator for use as an essential service generator.

3.5.3 Transmission and distribution systems

1. The stand-by feeder capacity shall enable the largest supply circuit to be withdrawn from service while satisfying the peak load requirements with the margins specified in (3.5.1), unless otherwise specified in the BfD.
 - a. Data Sheet, DEP 33.64.20.90-Gen. should be used to define requirements.
2. Transformer secondary capacity ratings shall not exceed the following:
 - a. 2500 A for 480 V and 600 V;
 - b. 3000 A for over 601 V.

3. Subject to approval of the Principal, higher ratings than (3.5.3 Item 2) may be provided if a significant cost saving can be demonstrated and fault and arc flash levels are acceptable.

In order to keep the level of the prospective short circuit within the range of commercially available switchgear, transformers with higher impedance than listed in the relevant ANSI C57 standard may be considered. Reference is also made to (3.6).

4. Overhead power lines should not be installed within process units, production facilities, or product loading and distribution facilities handling flammable or combustible fluids.
5. Overhead power line circuits shall not be used as a means of supplying vital or essential loads.
6. Overhead power line circuits should not be considered for locations susceptible to high wind and high lightning frequency.

3.5.4 Switchgear

1. Switchgear should have a single busbar system and a single switching device per circuit.
2. HV outdoor switchgear or gas insulated switchgear (GIS) at main incoming substations and power plant substations incorporating double busbar systems (e.g., breaker and a half or ring bus arrangements) may be selected.
3. If double-ended switchgear with double busbar systems is specified by the Principal, the switchgear shall incorporate one circuit breaker per circuit.
4. Double-ended switchgear should have one or two bus tie-breakers depending on the maintenance requirements of the supplied equipment. Special arrangements, e.g., automatic changeover, could be required for switchgear supplying vital services, where an alternative supply is required.
5. For facilities connected to the public utility, the configuration of the main incoming and distribution switchgear shall permit one switchgear section to be taken out of service, while maintaining normal downstream plant operations.

3.5.5 Motor control centers

1. Motor control centers should have a single busbar system and contain motor starters and circuit breakers.

3.6 SHORT CIRCUIT RATINGS

1. All equipment shall be capable of withstanding the effects of short circuit currents and associated voltages arising from equipment or circuit faults.

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

2. Fault currents shall be determined using the procedures in IEEE C37.13.1 for equipment rated 600 V and below and in IEEE C37.010 for equipment rated above 600 V.
3. Short circuit ratings of equipment and cables shall be based on the parallel operation of all supplies that can be operated in parallel.
 - a. If a "two-out-of-three main/tie/main" breaker configuration uses a "make-before-break" operational sequence so that all three breakers are closed for a period less than 1 s, the short circuit ratings may be based on non-parallel operation, if an automatic changeover scheme is provided. This requires approval from the Principal.
 - b. The distribution of short circuit current and the limiting effect of system protective devices or control schemes, (e.g., fuse links, Is-limiters, automatic supply changeover arrangements) shall be evaluated.

4. The short circuit rating of the switchgear shall be based on the sum of the short circuit contributions from the following:
 - a. maximum short circuit level at the point of supply from which the new switchgear will be energized;
 - b. induction and synchronous motor contribution;
 - c. if specified by the Principal, future planned conditions (e.g., future motor loads, generation);
 - d. if specified by the Principal future planned increases in short circuit level due to the direct or indirect connection of machines or public utility supply.
5. At the time of order, HV or MV switchgear at the main incoming power plant or distribution substations shall have a margin of not less than 10% between the calculated fault level under the conditions (3.6, Items 4 (a – d)) and the specified short circuit rating of the equipment.

The margin specified is provided to allow for the tolerances permitted for equipment characteristics.
6. Short circuit calculations shall be based on nominal impedance values of the equipment.
7. Mechanical interlocking of switches shall be provided where the equipment short circuit ratings can be exceeded.
8. The use of current-limiting reactors or Is-limiters, as a means of limiting the magnitude of short circuit currents shall be permissible only when they form part of extensions or interconnections with existing facilities that could not otherwise be practicably or economically realized without the use of such devices.
 - a. The use of Is-limiters or reactors shall be subject to the approval of the Principal.
9. When equipment short circuit ratings are determined, the effects of contributions from induction and synchronous machines on the switching duties of switchgear and on the dynamic and thermal loading of the electrical facilities shall be taken into account.
10. Any restrictions imposed by the public utility with respect to short circuit current contribution from the Location to their supply network shall not be exceeded.

3.7 ELECTRICAL PROTECTION AND CONTROL

3.7.1 General

1. The electrical system shall be equipped with automatic protection that provides safeguards in the event of electrical equipment failures or system misoperation.
2. Protection systems for new facilities shall use microprocessor based relays.
 - a. Incorporating relays into an Electrical Network Monitoring and Control System (ENMCS) should be considered. See (3.7.16).
3. Automatic protective systems shall be designed to achieve selective isolation of faulted equipment with a minimum delay that is within a time corresponding to the short circuit current withstand capability of the equipment, arc flash exposure, system stability limits, and the maximum fault clearing times.
4. Arc flash calculations shall be performed in accordance with IEEE 1584.
5. Primary and secondary distribution systems shall be designed to minimize the available incident energy at locations where personnel are expected to operate and maintain equipment while energized.

6. Arc flash incident energy levels shall be kept below 40 cal/cm².
 - a. Arc flash incident energy levels above 40 cal/cm² shall be subject to approval of the Principal.
7. The software approved by the Principal (3.1.4, Item 1) shall be used to calculate the arc flash levels.
8. Selective phase short circuit and ground fault protection shall be provided, with due regard given to the magnitude of short circuit currents and the method of system grounding (3.8). Limited duration overcurrents arising from single or group motor starting/reacceleration are permitted.
9. Protection systems shall be selective and the settings coordinated so that back-up protection is provided to initiate fault clearance in the event of protective system and/or switching device failure.
10. A protection diagram in the form of a one line diagram shall be prepared for the complete electrical power system to indicate the type and location of all protective devices and associated equipment to be provided.
11. Based on the protection diagram, an electrical protection report shall be prepared that demonstrates the adequacy of all protective systems in fulfilling the above requirements.
 - a. The electrical protection report shall be a live document and be kept updated over the lifetime of the installation.
 - b. The electrical protection report shall include, as a minimum, the following:
 - i. a description of the system and of the system operating modes on which the settings are based;
 - ii. short circuit current calculations or computations for specified minimum and maximum generation or supply conditions;
 - iii. single line diagrams for each part of the system, tabulated settings of the individual devices, and coordinated characteristics of the protection devices and fuses, plotted in graphical form;
 - iv. tabulated relay settings for all electronic relay parameters, irrespective of whether the individual functions are used or not.
12. The protection of the interconnections with the outside grid system shall satisfy the requirements in the BfD and the public utility.

3.7.2 Main generators

1. Main generators shall, as a minimum, be equipped with the protection, control, alarm and metering functions specified in (3.7.2, Item 2 through Item 14).
2. If a generator is connected to the system via a step-up transformer, the transformer shall be incorporated into the protection system of the generator.
3. Neutral grounding of the generators shall conform to (3.8).
4. Generators running in parallel with the utility shall comply with the requirements specified by the public utility.
5. Generators that require electrically operated breakers (e.g., when machines have synchronizing capabilities) shall be equipped with power circuit breakers.
 - a. Motor operated, molded case circuit breakers shall not be used, except for generators rated less than 100 kW and subject to approval of the Principal.
6. The applicable modes of control shall be specified on the generator data sheets.
 - a. In cases where an ENMCS is to be installed, refer to (3.7.16).

7. Gas turbine and diesel engine driven generators shall be provided with automatic control schemes that include auto-starting and automatic synchronizing.
8. Local control of generators shall include all the components necessary for commissioning, maintenance, and trouble-shooting the generators independently of the rest of the power system.
9. Main generators shall be fitted with the following control equipment:
 - a. manual and automatic synchronizing with a sync check relay and a dead-bus override;
 - b. voltage control equipment consisting of automatic voltage control with a manual control stand-by system;
 - i. the manual control system shall follow the set point of the automatic control system to allow automatic changeover from the automatic to the manual control system without significant voltage transients;
 - ii. the voltage control system shall be suitable for island and parallel operation;
 - 1). reactive-power sharing among generators shall be provided for the voltage control system.
 - iii. cross current compensation between generators employing Astatic Loop Circulating Current shall only be applied 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 set point to keep the generator power factor constant when operating in parallel with a public utility supply.
10. The control for generators in parallel operation with the utility shall be specified in the BfD, based on one of the following:
 - a. speed control with a droop characteristic;
 - b. MW control, if control of grid import/export is required;
 - c. back pressure control of steam turbines supplying process steam, automatically switched off when the generators are in island operation.
11. The control for generators in parallel operation with the utility, shall be designed so that upon loss of grid connection, governor control automatically reverts to speed/frequency (isochronous) control.
12. The control for generators in island operation shall be specified in the BfD, based on one of the following:
 - a. speed control;
 - b. Isochronous control of one generator, the remainder by a combination of speed and (if applicable) back pressure control;
 - c. Isochronous control of all sets with load sharing, if all machines are identical.
13. In standby operation, a generator shall automatically start on a power failure.
14. An automatic transfer system (normally break-before-make) shall be used to connect the generator to the emergency power supply bus.
 - a. The retransfer to the utility supply shall be manually initiated and be make-before-break.

15. The following generator protective devices shall be provided:
 - a. ground fault protection;
 - b. differential protection on generators 1 MW and larger;
 - c. voltage regulator with both fully automatic and manual modes of operation.

Refer to IEEE C37.102 for additional guidance on generator protection.

3.7.3 Utility interconnection systems

1. Utility interconnection circuits shall be controlled by circuit breakers that are fitted with the protection, control, alarms, instruments and meters as required by the public utility.
 - a. The overall design of the utility interconnection circuits shall be carried out in cooperation with the public utility.
2. If the utility interconnection circuits include transformer feeders and the transformers are fitted with on-load tap changers, automatic voltage control equipment shall be provided to control the interconnection substation switchgear voltage.
3. Utility interconnection circuits that are required to operate in parallel with the Location's own generation shall be provided with manual synchronizing facilities, a synch check relay, and a dead-bus override.
 - a. These synchronizing controls should be located where control of the frequency and voltage of the generators can be exercised.
4. If specified in the BfD, the requirements for an islanding system shall be incorporated in the design.
 - a. Data Sheet, DEP 33.64.20.90-Gen. should be used to define requirements.
5. If wye-grounded, wye-resistance grounded transformer connections schemes are used, and the Location is provided with onsite generation, ground fault protection shall be coordinated in both directions (from the utility to the Location and from the Location to the utility).

3.7.4 Switchgear

1. Short circuit current, time overcurrent, and ground fault protective devices shall be applied at the supply end of the switchgear incoming circuit feeders.
 - a. The short circuit current, time overcurrent, and ground fault protective devices shall serve as feeder protection, as protection of switchgear busbars in the event of busbar faults, and as back-up to switchgear outgoing circuit protection.
 - b. In transformer circuits, ground fault protection shall also be provided in the transformer secondary neutral-ground connection.
2. In the event of a busbar fault, the operating time of the above-mentioned circuit protection shall be as short as possible.
 - a. It shall, in any event, not exceed the 'through fault' withstand duration of the switchgear corresponding to the switchgear rated short circuit withstand current, regardless of variations in the magnitude of busbar short circuit current.
3. Bus differential protection shall not be provided on LV switchgear.
 - a. Zone selective interlocking, an arc flash reduction maintenance setting system, or other arc flash protection systems may be used for LV switchgear to mitigate high incident energies.
4. If specified in the BfD, bus differential protection shall be provided on MV switchgear.
 - a. Data Sheet, DEP 33.64.20.90-Gen. should be used to define requirements.

5. Manual initiation of the operation of distribution circuit breakers should be accomplished locally, either on the circuit breaker or on an adjoining control panel.
 - a. Automatic, remote trip functions maybe required with certain protection schemes, (e.g., load shedding).
 - b. Remote operation of distribution circuit breakers may be provided, (e.g., large distances from manned control rooms, operation away from the front of the switchgear, mitigation of high incident energy).
6. Necessary safeguarding features shall be provided to prevent unsafe switching operations, (e.g., interlocks with grounding switches).
7. Remote breaker racking facilities should be included whenever practical.

3.7.5 Motor control centers

1. MV motor controllers shall have starters with fused contactors, except where the rated voltage and power of the motor exceeds that of the contactor.
2. MV motors shall have microprocessor-based multifunction relays.
 - a. Control power for the microprocessor-based multifunction relays and motor starters shall be provided from the substation 125 VDC battery power supply. .
3. LV motor controllers shall use combination motor starters.
 - a. If specified in the BfD, motor circuit protectors (MCPs) or fuses shall be used for short circuit protection.
 - b. Low voltage motors shall have current operated overload devices within the motor starter.
4. Control systems should be selected in consultation with the responsible control systems engineer.
5. Motors requiring emergency shutdown (ESD) shall have a hard-wired contact in the control circuit, unless specified by the Principal it may trip all control power to a motor control center (MCC).
6. With the exception of skid mounted or packaged equipment, each motor shall have a separate, independent shutdown device.

3.7.6 Power transformers

1. Power transformers shall be controlled and protected on the primary side by one of the following:
 - a. Circuit breakers in conjunction with phase short circuit and ground fault protection relays.
 - i. Phase short circuit protection by means of overcurrent relays that have inverse time (inverse, very inverse, or extremely inverse) and instantaneous characteristics.
 - ii. Primary side ground fault protection by a residual current relay, set to achieve minimum fault clearance time.
 - b. Metal enclosed, SF6 insulated fused disconnect switches.
 - c. Metal enclosed air insulated disconnect switches.
 - d. Fused contactors (incorporating a latched mechanism) in conjunction with a protective device for overload and ground fault protection (2400 V, 4160 V and 6900 V only).
2. Transformers having secondary voltage ratings greater than 1000V shall have circuit breakers for primary protection.
3. Transformers rated 10 MVA or greater shall be provided with differential protection.

4. Ground fault protection shall be provided on the (grounded) wye connected windings of distribution transformers and generator step-up transformers.
 - a. The protection shall be achieved by means of High Resistance Grounding (HRG) for LV or Low Resistance Grounding (LRG) for MV placed in the neutral-to-ground connection of the power transformer secondary winding. Use of HRG for MV requires approval from the Principal.
 - b. The primary current rating of the CT supplying the ground fault relay shall correspond to 50% of the current rating of the neutral grounding resistor.
 - c. For HRG systems, the ground fault relay shall:
 - i. alarm only on LV systems; and
 - ii. trip the protective device on MV systems.
 - d. For LRG systems, the ground fault relay shall trip the protective device.
5. If multiple transformers having secondary voltage ratings less than 600 V are connected to the same primary feeder, each transformer shall be protected by a dedicated fused primary disconnect switch.
 - a. Unless otherwise specified in the BfD, fused primary switch shall be located indoors.
 - i. Data Sheet, DEP 33.64.20.90-Gen. should be used to define requirements.

3.7.7 Capacitors

1. MV capacitor banks up to and including 1000 kVAR, shall be comprised of individually fused capacitor units.
 - a. Refer to IEEE 18 for fuse requirements.
 - b. The fuses should be easily accessible for inspection and replacement.
2. For large capacitor banks exceeding 1000 kVAR, the capacitors shall be connected in a double wye with unbalance protection monitoring the wye point voltages or with differential current protection across the two halves of the capacitor bank.
 - a. Capacitor failure shall alarm on one capacitor failure and trip on two failures.
 - b. If recommended by the Manufacturer/Supplier, overpressure switches shall be fitted to MV capacitor units and connected to trip the capacitor bank.
3. Individual capacitors shall be controlled by contactors, circuit breakers, or fused switch units (low voltage applications).
 - a. The switching devices shall be approved for this duty by the switchgear Manufacturer/Supplier.
 - b. The switching devices shall be rated for at least $1.5 \times I_n$, and be able to withstand transient inrush currents up to $100 \times I_n$.
4. Contactor or switch controlled capacitor banks should be protected by means of fuses.
 - a. In the case of circuit breaker control, phase fault and ground fault protection relays shall be provided.
5. If a capacitor is connected in parallel with an electric motor, a single switching device and associated relays and/or fuses that control and protect both the motor and the capacitor shall be provided.

3.7.8 Electric motors

3.7.8.1 General

1. Induction motors shall be switched directly across the line.
 - a. If this is impractical or uneconomical, current restricting start-up equipment may be used.
2. Unless otherwise specified in the BfD, motors rated 6.6 kV, and higher, shall have partial discharge (PD) monitoring systems.
 - a. Lower voltage motors shall have PD monitoring, if specified on the Data Sheet.
 - b. Data Sheet, DEP 33.64.20.90-Gen. should be used to define requirements.
3. Motors with auxiliary equipment, water cooling, or special detection facilities, e.g., cooling air/water temperature detectors, water leakage detectors, shall be connected to an alarm annunciation system with first failure alarm.

3.7.8.2 Adjustable speed drives

1. Refer to (4.12) for adjustable speed drives (ASDs).

3.7.8.3 Synchronous motors

1. As a minimum, synchronous motors shall be equipped with microprocessor-based, multifunction motor protection relays that have the following protection functions:
 - a. overload;
 - b. winding temperature using 100 Ω Pt RTDs;
 - c. bearing temperature using 100 Ω Pt RTDs;
 - d. pull out (out of step);
 - e. current unbalance;
 - f. multiple starts;
 - g. ground fault;
 - h. differential (1500kW (2000 HP) and above);
 - i. loss of field.
2. Synchronous motors should have control equipment for the following:
 - a. voltage control/excitation control and sequencing;
 - b. controlled start-up, (e.g., via start switch);
 - c. controlled shutdown, (e.g., via normal stop switch);
 - d. crash shutdown as required, (e.g., via emergency stop switch);
 - e. vibration monitoring (Bently Nevada) (when over 1000 kW (1250 HP) and 1200 rpm).
3. As a minimum synchronous motors shall have digital metering equipment for the following:
 - a. stator current and unbalance levels;
 - b. winding and bearing temperatures;
 - c. voltages;
 - d. real power, reactive power and power factor;
 - e. exciter field current;
 - f. diode failure detection.

4. Other control, metering and protection functions shall be provided if specified in the BfD.
 - a. Data Sheet, DEP 33.64.20.90-Gen. should be used to define requirements.
- 3.7.8.4 MV induction motors
 1. As a minimum, MV induction motors shall be equipped with microprocessor-based, multifunction, motor protection relays that have the following protection functions:
 - a. overload;
 - b. winding temperature using 100 Ω Pt RTDs;
 - c. bearing temperature using 100 Ω Pt RTDs;
 - d. current unbalance;
 - e. stall;
 - f. multiple starts;
 - g. ground fault;
 - h. differential (1500 kW (2000 HP) and above).
 2. Induction motors should have control equipment for the following:
 - a. controlled start-up, (e.g., via start switch);
 - b. controlled shutdown, (e.g., via normal stop switch);
 - c. vibration monitoring (Bently Nevada or as specified) (when over 1000kW (1250 HP) and 1200 rpm).
 3. As a minimum, induction motors shall have digital metering equipment for the following:
 - a. stator current and unbalance levels;
 - b. winding and bearing temperatures;
 - c. voltages;
 - d. real power, reactive power and power factor.
 4. Other control, metering, and protection functions shall be provided if specified in the BfD.
 - a. Data Sheet, DEP 33.64.20.90-Gen. should be used to define requirements.
 5. RTD inputs shall be used for temperature indication and alarm only.
 - a. Tripping large, vital motors based on winding temperature may be used only if voting logic is used by the motor protection relay.
 6. If specified in the BfD, a device "86" lock-out relay shall be provided with all medium voltage motor starters.
 - a. Electrical protective functions shall be wired to the "86" relay so that electrical maintenance can verify the cause of a trip (when the "86" trips the starter) before allowing an attempted re-start.
 - b. If specified in the BfD, the overload function shall be wired to trip the contactor directly (not via the "86" relay).
 - c. Data Sheet, DEP 33.64.20.90-Gen. should be used to define requirements.

At locations where operators are allowed to reset a relay that tripped on overload, the overload trip function should not be routed through the "86" relay.

7. For the protection of submerged motors, or if excessively frequent or consecutive starting is possible, (e.g., load pumps or pumps with more than 3 starts/hour), restrictive start relays shall be provided.
 - a. In addition to the restrictive start relay, submerged pumps shall have underload protection.

3.7.8.5 LV induction motors

1. LV induction motors shall be equipped with short circuit protection and current sensing overload protection.
2. Other control, metering, and protection functions shall be provided if specified in the BfD.
 - a. Data Sheet, DEP 33.64.20.90-Gen. should be used to define requirements.

3.7.9 Cable feeders

1. Cable feeders for HV and MV distribution shall be controlled and protected by fused contactors or circuit breakers in conjunction with phase time delay and short circuit, plus ground fault protective devices.
2. Cable feeders for LV distribution shall be controlled and protected by fused disconnects or circuit breakers in conjunction with phase time delay and short circuit.
 - a. In addition, solidly grounded LV systems shall incorporate ground fault protection.
3. The trip rating of a fuse protected LV circuit that is supplied from a distribution switchboard should not exceed 33% of the trip rating of the fuse protected LV circuit that feeds the switchboard.

This ensures that the circuit protective devices are selective in isolating short circuits.

3.7.10 Overhead lines

1. Overhead lines of primary distribution feeders shall be controlled and protected by fuses or circuit breakers in conjunction with phase time delay and short circuit, plus ground fault protective relays.
2. If distance protection is employed, it shall be provided in conjunction with overcurrent and ground fault protection, the latter serving as back-up protection.
 - a. The selection of protection depends on the circuit interconnections, method of system grounding, and general service conditions.
3. Equipment supplied by overhead lines shall be protected against lightning by means of overhead ground wires and lightning arresters (surge arresters) at the point of delivery of power to the loads.
 - a. Subject to approval of the Principal, overhead ground wires may be omitted.
4. Where overhead lines cross roads via underground cables, each side of the overhead line at the road crossing shall be provided with lightning arresters.
5. Three or single-phase auto-reclosure schemes should be considered in relation to the general service conditions.

3.7.11 UPS equipment

1. DC and AC UPS equipment shall be protected by molded-case circuit breakers (MCCBs) that coordinate with the UPS input protection.
2. Sub-distribution circuits fed by DC or AC UPS systems shall be protected against short circuits by current limiting fuses that provide selectivity between upstream and downstream devices, taking into account the limited short circuit current available from the UPS systems.
 - a. If specified in the BfD, circuit breakers shall be provided instead of current limiting fuses, provided the system is capable of providing sufficient short circuit current to trip the breaker under fault conditions.
 - i. Data Sheet, DEP 33.64.20.90-Gen. should be used to define requirements.
3. Panelboards that are connected to the load side of the UPS shall be fused type with blown fuse indication, unless otherwise specified in the BfD.
 - a. Data Sheet, DEP 33.64.20.90-Gen. should be used to define requirements.
4. Fuses shall be of the fast acting type and sized to meet circuit inrush requirements.

3.7.12 Electric process heaters

1. Feeders to the power and control assemblies of process heaters connected directly to the LV system shall be protected by means of a fused switch or a MCCB supplemented with a contactor.
 - a. The protection shall be coordinated with the heater protection.
 - b. For fuse ratings or MCCB trip settings exceeding 100 A, ground fault protection shall also be provided.
2. Refer to DEP 33.68.30.35-Gen. for electric process heaters for North American applications.

3.7.13 Reciprocating engine standby generators

1. Control and protection of LV and MV standby generators shall be specified in the protection philosophy.
2. Facilities shall be provided to enable load tests of the generators during normal plant operation.

3.7.14 Power and convenience outlet circuits

1. LV power and convenience outlet circuits shall be protected by phase time delay and short circuit protective devices plus current-operated ground fault devices that are in accordance with the CEC and/or NEC.

3.7.15 Panelboards

1. Panelboards shall have bolt-on type circuit breakers.
2. Each panelboard fed directly from a transformer should have a main circuit breaker.
3. Panelboards fed from other panelboards do not require a main circuit breaker, but one should be considered as a local disconnect for maintenance.
4. In general, branch circuit breakers for lighting and convenience receptacle circuits should be rated 15 A or 20 A.
5. Large lighting circuits may use circuit breakers rated 25 A or 30 A.
6. Dedicated receptacle circuits, for non-cord-and-plug loads, may use circuit breakers rated above 20 A.

3.7.16 Electrical network monitoring and control system

3.7.16.1 General

1. An electrical system design philosophy document specifying the overall monitoring and control philosophy of the electrical supply and distribution system shall be generated during the DEFINE phase of the project and subject to approval by the Principal.
2. Refer to DEP 33.64.10.32-Gen. for additional requirements for an electrical network monitoring and control system (ENMCS).
3. A dedicated ENMCS for the electrical supply and distribution system should be considered where centralized metering and overall electrical system supervisory control and data acquisition is required to provide safe and stable operation of the power system.

3.7.16.2 Mimic panels

1. Mimic panels shall be provided if specified in the BfD.
 - a. The functionality may be part of an ENMCS, a DCS, or a custom built panel.
 - b. Data Sheet, DEP 33.64.20.90-Gen. should be used to define requirements.
2. The panel functionality shall include necessary controls, indicators, and meters to properly perform all switching actions anticipated under normal and emergency conditions.
3. The panel shall be located such that a switchgear failure does not cause physical injury to a person located at the panel.
4. The panel shall be supplied with power from a UPS.
5. For offshore facilities:
 - a. for reasons of safety and operability, a mimic panel shall be provided for all switchgear, unless switchgear can be operated remotely with the facility's DCS or control system;
 - b. the generator main circuit breaker control and indication shall be at the generator control panels;
 - c. the mimic panel should be located as near as possible to the generator control panels.

3.7.16.3 Load shedding

1. If the running load can exceed the rated on-line generating capacity, a load shedding system shall be implemented.
 - a. The amount of load to be shed automatically shall be such that system stability can be maintained.
 - b. The load shedding system shall respond fast enough to not cause the other generators to trip offline (including relay and circuit breaker clearing times).
2. The type of load shedding system shall be selected by the Contractor subject to approval by the Principal.

3. The types of load shedding systems that should be considered are as follows:
 - a. integrated load shedding system whose operation is based on power supply availability and load status;
 - b. an under frequency load shedding system that automatically sheds low, medium and, if necessary, high priority loads to prevent the system frequency from falling below 95% (typically) of nominal frequency;
 - i. The priority group staging should be based on discrete frequency and time delay settings.
 - ii. Rate of change of frequency relays may also be used.
 - c. a turbine temperature monitoring scheme in which generator drivers are monitored for overload and any other preventable shutdown conditions. The system drops loads in order to prevent the shutdown of the unit.
4. Where load shedding is through an integrated system whose operation is based on the power supply available and load status, the system shall have the flexibility to permit alteration of the load shedding priorities and the provision to inhibit the starting of large motors under conditions of reduced power supply capacity.

This system focuses on the available spinning reserve. Based on that spinning reserve and a motor's individual rating, it allows a large motor to be started or not. Typical guideline is 2.7 times the motor rating (for across the line starting) in reserve to allow for starting. This is usually for large motors 150 kW (200 HP) and above.
5. To determine the type, number, and sequence of loads to be shed, the following order shall apply:
 - a. non-essential production loads as prioritized by the Principal (operations);
 - b. other non-essential loads;
 - c. essential loads.
6. Drilling rig loads are normally not shed.
7. Emergency/Vital loads shall not be shed.
8. The power supplied by each generator and the total power available shall be continuously monitored by the control system (i.e., PLC or ENMCS) containing the load shedding software.
 - a. In addition, the control system shall continuously:
 - i. monitor power supplied through feeder breakers located in switchgear and large ASDs;
 - ii. compute which loads can be shed;
 - iii. calculate spinning reserve power available and determine when loads can be restarted.
9. A permissive contact shall be included in the control logic to allow the load to start when adequate power is available.

3.7.17 Generator synchronization

1. Generators requiring manual synchronization shall be provided with a single synchroscope and/or phase indicator lights.
 - a. Synchroscope/lights shall be installed where they are clearly visible from the generator control panels.
2. For medium and high voltage generators, a utility grade sync-check relay shall be utilized to prove synchronization.
 - a. A lesser grade sync-check relay shall only be used for low voltage generators.

3.8 SYSTEM GROUNDING

3.8.1 General

1. Grounding system for electrical facilities shall be in accordance with the following:
 - a. onshore facilities – NEC (US) or CEC (Canada);
Refer to IEEE 142 – Green Book for additional guidance.
 - b. offshore facilities – API RP 14F.
2. The grounding grid shall consist of 20 mm (3/4 in) by 3 m (10 ft) copper-clad steel ground rods and #2/0 AWG minimum insulated or bare copper cables that form a continuous loop or grid.
Cable selection is dependent on local standards and soil conditions.
3. If the size of the ground loops and interconnecting conductors as mentioned in (3.8.1 Item 2) is not sufficient due to the level of available fault currents, the sizes of the loops and interconnecting conductors shall be increased.
4. Outdoor substations rated 15 kV and above, shall have a ground grid or loop that conforms to IEEE 80, the NEC (US) or CEC (Canada).
5. If a substation fence is provided, the grid shall include a perimeter loop located 1 m (3 ft) outside the fence and bonded to the fence and gates.
6. The neutral of AC systems shall be grounded as stated in (3.8.2), (3.8.3), (3.8.4), or (3.8.5).
7. Systems shall not be designed for ungrounded operation, unless they form an extension to an existing ungrounded system.
8. Unless otherwise approved by the Principal, the ground resistance of made electrodes (ground rods, ground wire, and/or ground grid) used for system grounding shall not exceed:
 - a. 1 Ω for solidly grounded systems above 600 V;
 - b. 5 Ω all other systems.
9. Step and touch potentials during ground faults shall not exceed the safe values specified in IEEE 80 (US) or CEC (Canada).
10. Grounding systems shall confirm to Table 1.

Table 1 Grounding Systems

Nominal Voltage	Phase	Wire	Type Grounding
120/240	Single	Three Wire	Solid
208/120	Three	Four Wire	Solid
480	Three	Three Wire	High Resistance
600	Three	Three Wire	High Resistance
2400	Three	Three Wire	Low Resistance
4,160	Three	Three Wire	Low Resistance
6,900	Three	Three Wire	Low Resistance
12,000	Three	Three Wire	Low Resistance
12,470	Three	Three Wire	Low Resistance
13,800	Three	Three Wire	Low Resistance
34,500	Three	Three Wire	Low Resistance

11. For Canada, high-resistance grounded neutral systems are permitted at 2400 V and 4160 V.
12. 4160 V high-resistance grounded neutral systems shall be designed to trip when a ground fault is sensed.
 - a. If systems are designed not to trip when a ground fault is sensed, the following requirements shall be met:
 - i. a cost/benefit, operability, health and safety, or environmental impact analysis demonstrates that the improved availability of 5 kV equipment offered by high-resistance grounded systems justifies their use;
 - ii. shielded cable rated 8 kV, 115 mil insulation thickness (or greater), and determined by the Manufacturer/Supplier to be suitable for high-resistance grounded systems, is used for all feeder and branch circuit conductors on the 4160 V system.

3.8.2 HV and MV systems

3.8.2.1 General

1. HV and MV system neutrals shall be resistive grounded per Table 1 at each source of supply by means of dedicated electrodes that have a direct, low impedance connection to the plant main ground grid.
2. HV and MV system neutrals shall be grounded at each source of supply (transformer, direct-connected generator).
3. The rating of each resistor should limit the ground fault current supplied by the equipment to which the resistor is connected, to a magnitude as low as possible, but at least twice the system charging current.
 - a. If circuit breakers are connected to an existing solidly grounded system, suitable CTs shall be selected so as to prevent CT saturation under ground fault conditions.
4. The requirements in (3.8.2.1, Item 3) shall apply to the grounding of the neutral point of the HV winding of generator step-up transformers.
5. The protection for low resistance ground faults shall be coordinated with the upstream protection devices.

6. Each grounding transformer and resistor shall be rated to withstand the respective ground fault currents for duration of not less than 10 s.

Longer withstand times may be required, depending on the ground fault protection system applied.

3.8.2.2 Generator considerations

1. If generators are directly connected to the main HV switchgear, i.e., not via generator transformers, each generator should be grounded via a dedicated grounding resistor or resistor/transformer connection.
 - a. It shall be verified that the zero sequence, triplen harmonic currents (3rd, 9th, 15th etc.) that could circulate through the resistors under various loading conditions of the generators do not damage the resistors.
 - b. The rating of each resistor should limit the magnitude of ground fault current to as low as possible, but at least twice the system charging current.
 - c. If more than three generators make up the power sources, a zigzag grounding transformer and resistor system should be considered in lieu of dedicated resistors for each generator.
2. If generators of dissimilar ratings, characteristics, or loadings are operated in parallel causing circulating currents in the dedicated grounding resistors to exceed their thermal rating, the generator system shall be analyzed and, if necessary, grounded via one grounding resistor only.
 - a. If only one resistor is used the following are applicable:
 - i. Each generator shall be provided with a suitable switching device, i.e., remotely operated circuit breaker or latched contactor to facilitate connection of any machine to the resistor.
 - ii. During normal operation, only one generator shall be connected to the resistor.
 - 1). If the generator is tripped for any reason, an alarm shall be provided to prompt manual intervention to close the neutral-ground switching device of one of the other operating generators to facilitate grounding of the system.
 - iii. If generators are connected to the main switchgear via individual generator step-up transformers, each generator neutral point shall be individually grounded through a single-phase distribution transformer with a secondary resistor.
 - 1). The resistor shall be rated to limit the generator ground fault current to 10 A, or to $3 \times I_{co}$ where I_{co} is the per-phase capacitive charging current, whichever is greater.

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

3.8.3 LV systems

1. The neutral of LV electrical systems shall be grounded per Table 1 at each source of supply.
2. Relay settings shall be such as to detect and alarm ground fault conditions.
 - a. Relay settings should be set high enough to avoid nuisance alarms.
3. A current-sensing alarm relay shall be wired in the resistor circuit to provide a ground fault detection signal to the facility alarm system.
 - a. The alarm system shall alert operating personnel, allowing for prompt maintenance and orderly shutdown.
 - b. The alarm circuitry shall be latching to alert personnel of intermittent faults.
4. The main secondary breaker shall not be tripped; however the fault shall be alarmed.
5. In sizing the neutral grounding resistor, the lowest value of ground fault current shall be used, giving consideration to capacitive charging current, use of ASDs, and relay coordination.
 - a. The ground fault current shall be at least 2 A and no more than 10 A, which allows uninterrupted system operation underground fault conditions.
6. High resistance grounding units should be provided with a means to determine the location of a ground fault without systematically switching off loads.

3.8.4 UPS systems

1. AC UPS systems shall have their neutrals solidly grounded. This applies equally to single phase and three phase systems.
2. DC UPS systems supplying instrumentation loads shall have their negative lead solidly grounded.
3. DC UPS systems for switchgear shall have their negative lead solidly grounded or be ungrounded with appropriate ground fault detection.
4. DC supplies for telephone systems shall be grounded in line with normal telecommunication practice.
5. DC supplies for special applications shall be grounded as required by the equipment Manufacturer/Supplier.

3.8.5 Instrument systems

1. Instrument systems shall not be designed with an isolated ground system in control rooms and field auxiliary rooms (FARs).
2. Two grounding systems shall be supplied for the control systems hardware:
 - a. AC safety ground;
 - b. reference ground.
3. Separate ground bus bars shall be provided for the AC safety ground and the reference ground.
 - a. The reference ground bus shall be tied to the AC safety ground bus with a solid green insulated wire.
 - b. The location of the reference ground bus shall be accessible.

The reference ground bus is provided for data highway ground wires, reference ground wires and shield wires.
4. The AC safety ground bus shall be tied to the plant electrical ground grid with a #2 AWG green insulated ground wire.

3.8.6 Lightning protection

1. If specified by the Principal, lightning protection shall be designed in accordance with NFPA 780. Refer to IEEE 998, API RP 2003 and API RP 540 for the design of lightning protection systems.
2. Instrument power panel boards feeding DCS systems shall be protected with metal oxide varistor (MOV) surge arrestors for high voltage spike suppression.
 - a. Surge arrestors shall be connected on the load side of each power phase of the main breaker in each breaker panel.
 - b. A spare breaker in the panel shall be utilized for this connection.

3.9 ELECTRICITY SUPPLY FOR VITAL SERVICES**3.9.1 General**

1. An electrical power system having duplicate energy sources, lines of supply and equipment SHALL [PS] be provided to energize loads forming part of 'vital' services.
2. Supplies for 'vital' services SHALL [PS], if required by the load, be uninterrupted on failure of one energy source.
 - a. Loads that can tolerate an interruption in the power supply, but which need restoration of the supply within 1 minute, shall be energised from an interruptible maintained power source. See also (3.9.5).
3. The electrical power requirements for loads shall be classified in three categories as specified in (3.9.2), (3.9.3), or (3.9.5).
4. The design of such systems shall be agreed with the Principal at the SELECT phase of a project.
5. Emergency/vital services shall be sized to handle 100% of the connected load.

The transformer capacity is not considered to be a load.

Loads other than emergency loads may be powered from the emergency generator through a tie-breaker if it can be automatically tripped off-line in the event that the emergency generator becomes overloaded.

3.9.2 AC uninterruptible, maintained electricity supply

1. AC uninterruptible, maintained electricity supply is derived from one or more AC UPS units, each of which incorporates a battery to provide power in the event of failure of the normal power supply. The power supply is uninterrupted in the event of normal supply failure and is maintained throughout the battery discharge period.
2. An AC uninterruptible, maintained supply derived from a single AC UPS unit is normally used where the normal plant power supply is considered reliable.
3. The UPS shall provide power for the specified period of time (3.9.4) upon loss of input power.
 - a. It shall supply transient free power within the power supply specifications for microprocessor or computer based control and monitoring systems and vital instrumentation, control, and shutdown systems.
4. The UPS and battery shall be sized to provide the expected demand plus spare capacity at the beginning of the execute phase as follows:
 - a. 25% for a UPS up to 100 kVA;
 - b. 15% for a UPS over 100 kVA.
5. If high levels of reliability and availability are required, AC uninterruptible, maintained supplies may be derived from two independent UPS units operated in parallel, each with its own battery, static changeover switch, and maintenance bypass switch.

6. Design of UPS system shall take into consideration all inrush currents and their effect on the operation of the UPS.
 - a. Circuits that have high inrush currents can cause the inverter of the UPS to go into current limit and cause the UPS to transfer through the static switch to the alternate power supply. After the inrush currents subside, the UPS should transfer back to normal operation.
 - b. Powering on of circuits shall be staged to the UPS and not be switched on all at one time.

3.9.3 DC uninterruptible, maintained electricity supply

1. DC uninterruptible, maintained electricity supply is derived from rectifier units (DC UPS units). For most applications, the number of rectifier units to be installed should be $n + 1$ with a common battery, where "n" is the number of units required to supply the load.

3.9.4 Battery autonomy (backup) times

3.9.4.1 General

1. Batteries of UPS units (ac or dc) identified as safety critical elements SHALL [PS] be rated to energise the relevant loads as follows:
 - a. per the requirements of the safety case (documented demonstration of ALARP) for the installation, or
 - b. in the absence of a safety case, as specified in (3.9.4.2) and (3.9.4.3).
2. Batteries of UPS units (ac or dc) that are not identified as safety critical elements shall be rated to energise the relevant loads as follows:
 - a. per the requirements of the safety case (documented demonstration of ALARP) for the installation, or
 - b. in the absence of a safety case, as specified in (3.9.4.4) and (3.9.4.5).
3. Battery autonomy times specified in (3.9.4.2), (3.9.4.3), (3.9.4.4) and (3.9.4.5) are minimum and may be increased to enable combining of services aiming at a reduction in the number of UPS systems.
4. Timers shall not be used to selectively switch off consumers.
5. If "N+1" spared emergency generators are supplying the UPS systems, the following changes to the battery autonomy time may be made:
 - a. All vital services, with the exception of telecommunication and radio systems, may be supplied via 100% rated duplicate UPS systems with a battery autonomy time of 30 min.
 - b. Telecommunication systems and radio equipment shall be supplied by a dedicated parallel or duplicate UPS system.

3.9.4.2 Onshore installations (safety critical)

1. Battery autonomy times for onshore installations shall be as follows:
 - a. 30 min for process plant shutdown, process monitoring and control systems;
 - b. 1 h for utility plant process monitoring and control systems;
 - c. 1 h for emergency lighting (refer to 4.15.4);
 - d. 10 min for non-process computer installations;
 - e. 8 h for fire-fighting and fire alarm and gas detection systems;
 - f. 8 h for telecommunication and radio systems.