

DEP SPECIFICATION

FIELD COMMISSIONING OF ELECTRICAL INSTALLATIONS AND EQUIPMENT

DEP 63.10.08.11-Gen.

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DESIGN AND ENGINEERING PRACTICE



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1 INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for field commissioning of electrical installations and equipment.

This DEP covers the pre-commissioning and commissioning of new electrical installations and equipment, or the re-commissioning of equipment following a major overhaul.

Following section (6) Bibliography, there are a series of inspection forms, which precede the appendices.

This is a revision of the DEP of the same number dated August 2000; 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. Application in other facilities may also apply

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 word **should** indicates a recommendation.

1.3.2 Specific Definitions

Term	Definition
Authorised Electrical Person	A competent person who is appointed by Management to supervise or to carry out specific work on electrical equipment and operations in power systems. The appointment may include the authority to issue and cancel permits to work on electrical equipment.
Certificate	Document issued by a recognised authority certifying that it has examined a certain type of apparatus and, if necessary, has tested it and concluded that the apparatus complies with the relevant standard for such apparatus.
Certificate of Conformity	Certificate stating that the electrical apparatus complies with the relevant standards for apparatus for potentially explosive atmospheres.
Declaration of compliance	Document issued by the Manufacturer declaring that the electrical apparatus complies with the requirements of IEC 60079-15.
Electrical Commissioning	Putting into service a piece of equipment or system AND demonstrating that the equipment or system is fit for the purpose for which it was intended. It is the last verification point prior to the official acceptance of that portion of the installation. Commissioning therefore consists of on-load, on-line performance and functional tests.
Electrical Pre-commissioning	Those activities which are carried out after equipment erection and prior to energising and performance checks. Pre-commissioning is therefore concerned with the verification of the state of the equipment, quality of installation work and compliance with requirements and codes.
Electrical Network Monitoring and Control (ENMC) System	Computerised system which is dedicated to monitoring and controlling defined aspects of an electrical network.
Inspection	Ascertaining the general running condition of a piece of equipment by sight, sound, smell and touch. (This may involve the opening of covers).
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).
Ohm	A unit of electrical resistance.
Rectifier	A converter for conversion from a.c. to d.c.
SF6	Sulphur hexafluoride gas
Switchgear	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, 441-11-02, IEC 60050.
Test and Measurement	Verifying by means of instruments and tools the condition and the functioning of an item of equipment and to measure its parameters. (This may include re-calibration).
Zone 0	An area in which an explosive gas atmosphere is present continuously, or is present for long periods(in the classification of hazardous gas areas), 426-03-03, IEC 60050.

Term	Definition
Zone 1	An area in which an explosive gas atmosphere is likely to occur in normal operation. (in the classification of hazardous gas areas), 426-03-04, IEC 60050
Zone 2	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(in the classification of hazardous gas areas), 426-03-05, IEC 60050.

1.3.3 Abbreviations

Term	Definition
a.c.	Alternating Current
ATEX	French ATmospheres EXplosives
AVR	Automatic Voltage Regulator
CT	Current Transformer
d.c	Direct Current
DGA	Dissolved Gas Analysis
FAT	Factory Acceptance Testing
HV	High Voltage
HVAC	High Voltage Alternating Current
IEC	International Electrotechnical Commission
IR	Insulation Resistance
LV	Low Voltage
UPS	Uninterruptible Power Supply
VSDS	Variable Speed Drive System
VT	Potential Transformer

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 (5).

1.5 SUMMARY OF MAIN CHANGES

This DEP is an extensive revision of the DEP of the same number dated August 2000. The following are the main, non-editorial changes.

Old Section	New Section	Change
Part II	Forms and Appendices	All maintenance sections and appendices removed to a separate maintenance practise document.
Section 1.3	Section 1.3	Deletion of reference to Yellow guide for electrical safety, now replaced with DEP 80.64.10.10 -Gen.
Section 2.1.1	Section 2.1.1	New section
Section 2.1.2	Section 2.1.2	New section
Section 2.2	Section 2.2	Fully revised
4.1.1	4.1.1	Fully revised
4.1.2	4.1.2	Addition of ATEX certificates
4.3	4.3	Inserted text from DEP 33.64.10.12–Gen.
4.3.1.2.3	4.3.1.2.3	Revised
4.3.1.4	4.3.1.4	Deleted
4.5.1	4.5.1	Use of digitally controlled test sets recommended. Requirement for relay data download included
4.7.1	4.7.1	Requirement for equipment set point and parameters download included
4.8	4.8	Fully revised
4.9.1	4.9.1	Max protection clearance times included
4.9.3	4.9.3	Details on sample tests included
4.10	4.10	Need for compliance to local regulations included
N/A	4.12	New section added on EMCS and IMCS commissioning
Form 12	Form 12	Reduced test requirements for IMCS relays added
All Appendices	All Appendices	Appendix 4, 5, 6 & 7 deleted, Appendix 10 transferred to RMP 63100850. Remaining appendices re-numbered
Appendix 16	Appendix 10	Addition of DGA testing as normal requirement
	Appendix 11	New appendix for flick testing added

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. FIELD COMMISSIONING PROCEDURES, RESPONSIBILITIES AND DOCUMENTATION

2.1 PROCEDURES AND RESPONSIBILITIES

Testing and commissioning requirements shall be initially addressed at an early point in the design to ensure all testing requirements are identified, and the stage at which each test is best carried out is determined (i.e., FAT, Pre-commissioning or Commissioning). This then ensures all tests are covered in the most cost effective manner and without unnecessary duplication.

Electrical installations and equipment in plants engineered and/or erected by Contractors and, in general, any equipment which has been completed and is ready for operation, shall be subject to certain take-over procedures which shall have been agreed between the Contractor and the Principal.

Further the take-over procedures shall state clearly the relevant responsibilities of Contractor and Principal to provide an orderly transition during early pre-commissioning/early energisation and commissioning transitional period.

The organisation and execution of pre-commissioning and commissioning activities shall be the responsibility of the Contractor. Unless otherwise agreed by the Principal, complex electrical systems (e.g., HV/LV switchgear, generators, AVRs, VSDs, UPSs) shall be commissioned with the assistance of the Manufacturer. The extent and level of such assistance will be dependent on the experience and expertise of the site-commissioning teams.

The steps required to connect an electrical system, prior to its initial energising, to an existing electrical network, shall be jointly agreed by the authorised electrical persons responsible for each electrical network.

Where site conditions prevent full performance tests (e.g. power output, temperature rise), agreement should be reached between the Principal and Contractor on the need for such tests at a later date.

If applicable, the Principal should have internal procedures for equipment acceptance by Operations/Maintenance departments from Engineering/Construction departments.

2.1.1 Safety

The necessity of safety precautions during work on electrical equipment cannot be over-emphasised. Attention is therefore drawn to DEP 80.64.10.10-Gen. on which local safety codes and practices shall be based.

2.1.2 Flawless Project Delivery

Analysis of past start-ups indicates a very strong correlation between successful, timely start-ups and the extent of start-up planning activities. Based on the lessons learnt from numerous projects and the common failure modes that occur during the commissioning, start-up and initial operating phases a Flawless Start-Up program has been developed and successfully applied in many projects.

The recommendations for commissioning activities contained in this DEP are consistent with, and support a Flawless Start-Up programme.

2.1.3 Maintenance Management System Data

The Contractor shall provide to the Principal, in an electronic database, all relevant data and information associated with the electrical equipment installed. The format and content of the data shall be agreed in advance with the Principal. The data is intended to be used to populate the computerised maintenance management system with electrical equipment data.

2.2 DOCUMENTATION

The Contractor shall complete the Inspection Forms found in Forms section. The forms shall be pre-loaded with the data as recorded in the electrical equipment electronic database and part of the commissioning procedures shall be to verify that this data is correct. Use may be made of the forms attached to this DEP, or forms generated directly from the database. In the latter case such forms contain, as a minimum, the same information as those attached to this DEP.

In cases where differences are found to exist with the as-installed equipment, the commissioning forms shall be updated with correct information. The contractor shall then upload any changes reported into the electronic database, having first checked that the changes do not invalidate any part of the design.

For pre-commissioning and commissioning, 'Form 1' is applicable to all equipment; subsequent forms shall be used as required.

The Contractor shall develop additional inspection forms for equipment not covered, or not fully covered in this DEP.

All deviations from requirements shall be documented on an "exception list" which shall be presented to those responsible for the installation work for their agreement and action. Any errors in the installation shall be corrected before installation is finally handed over.

The above documentation, including the updated electronic database, shall form part of the official hand-over of plant and equipment.

3. TESTING AND COMMISSIONING METHODS

For suitable test instruments, refer to DEP 70.08.10.13-Gen.

3.1 INSULATION TESTING

Insulation tests shall be carried out at the pre-commissioning stage and prior to the energising of equipment and cables.

The following two methods shall be used:

- a) insulation resistance (IR) testing for motors, generators, transformers, LV switchgear and all equipment other than those items susceptible to damage by over-voltage (e.g., electronic components);
- b) high voltage a.c. or d.c. testing for HV switchgear and HV cables.

Refer to (Appendix 5) and (Appendix 6) for recommended test voltages and insulation resistance values. When re-commissioning existing equipment, reduced test voltages apply. Refer to RMP 63.10.08.50-Gen. for advice on test voltages and insulation values when re-commissioning existing equipment.

3.1.1 Insulation Resistance (IR) Tests

IR testing shall be carried out by applying a "d.c." voltage from an insulation tester at voltage levels given in (Appendix 5).

3.1.2 High Voltage Tests

Before high voltage tests are executed, insulation resistance tests shall be carried out.

High-voltage testing of electrical equipment, except LV cables, shall have been carried out at the Manufacturer's works with a.c. at voltage levels in accordance with the relevant DEP or International Standards.

Repeated high voltage pressure tests may introduce weak points in the insulation of windings, and therefore such tests shall **not** be applied at site to generators, motors or transformers.

If, however, for special reasons these tests are considered to be necessary, they shall be carried out only after consultation with the Manufacturer.

3.1.3 Polarisation Index (PI)

PI testing shall be carried out on all high voltage motors. Value obtained should be greater than 2 for new machines. Note that PI values may be significantly affected by presence of moisture in the atmosphere. Tests should ideally be completed on warm dry windings.

3.1.5 Insulating Oil Tests

High voltage withstand tests shall be carried out using a standard oil testing apparatus, with 25 mm diameter mushroom-shaped electrodes placed at a distance of 2.5 mm from each other.

The minimum withstand voltage shall be 30 kV. The test sample shall be tested 6 times without breakdown using the same cell filling. Refer to (Appendix 10) for additional requirements.

3.1.6 Bearing Insulation Tests

If the pedestal bearings or sleeve bearing housings are completely insulated from the body of the machine, the insulation shall be checked with the machine coupled and running at normal speed to establish an oil film in the bearing which will prevent electrical contact between shaft and bearing. An ohmmeter applied across the insulation should indicate a resistance of > 10 kohm. Figures below this shall be investigated.

If the bearings have internally insulated 'shells' or insulated shafts, measurements shall be carried out with the machine uncoupled (and stopped).

Refer to bearing drawings to determine type of test and location of test points.

3.2 CONDUCTIVITY AND EARTH RESISTANCE TESTS

3.2.1 Conductivity Tests

Conductivity tests shall be carried out on switchgear busbar connections and switchgear earth system joints in order to establish their tightness and condition. Conductivity testing shall be carried out with a low-resistance test set, e.g., a 'Ducter' with a 20 A (d.c.) output.

For identical connections, the measured values should not differ by more than 20% from each other.

3.2.2 Earth Resistance Tests

For values and method of earth resistance tests, see (4.9) and (Appendix 8).

3.2.2.1 Earth Electrodes

All earth electrodes shall be tested by measuring the electrode (or electrode group) resistance against the mass of earth, using a purpose-made test set as outlined in (Appendix 9).

3.3 WIRING AND TERMINAL CHECKS

Electrical wiring shall be checked against the schematic diagrams. Factory-tested assemblies such as switchgear should require only sample checks.

The tightness of all terminals shall be verified.

3.4 FUNCTIONAL TESTS

Functional tests shall be carried out to demonstrate the correct operation of complete systems.

- NOTES:
1. Refer to (2.1) about the need for testing to be considered at the design stages.
 2. These considerations shall include functional testing, especially of systems such as Load Shedding, where it will be necessary to consider how satisfactory functional tests may be carried out without adversely affecting a running plant or disrupting the commissioning of another plant.

The functional testing of safety-related systems, such as an auto start of diesel generation on supply failure, shall be mandatory.

Particular attention should be paid to equipment interfaces, where there is a greater likelihood of functional impairment.

In cases where complicated control and/or interlock systems are used, the Contractor shall demonstrate compliance with the design requirements by using special case-by-case functional check lists and system logic diagrams.

4. TESTING AND COMMISSIONING PROCEDURES

4.1 HAZARDOUS AREA EQUIPMENT

(Form 1 and applicable equipment forms)

4.1.1 Installation

All items of electrical equipment installed in a hazardous area shall be subject to an initial detailed inspection in accordance with IEC 60079-17 and information recorded on the above forms.

Bulk ordered material, such as light fittings, junction boxes and RCUs (Remote Control Units), constitutes the largest amount of material to be inspected by numbers of items and may represent a significant inspection burden.

These circuits should be divided into circuits or sub-packages (as dictated by the installation programme) such that they may be inspected as they are completed and before access from temporary scaffolding or similar constraints are removed. Once a circuit or sub-package is inspected they should have readily identifiable labels or tags attached to clearly mark what has or has not been inspected. Any subsequent installation work on that circuit or package requires that the additional works shall be inspected and the tie-in points shall be re-inspected.

During final inspection, one Form No. 1 per plant area is sufficient for each 'bulk material' type. a sample inspection of the installation may be undertaken to prove that no deterioration or interference has taken place since the sub-package inspections.

Particular care shall be taken to ensure that correct cable glands have been fitted correctly and that earthing connections are sound, especially those of braided cables using looping terminals in junction boxes.

4.1.2 Certification

Certificates and declarations relating to equipment used in hazardous areas, are required per DEP 33.64.10.10-Gen. and are outlined below.

Certificates shall be examined to ensure that the installation is in compliance with the certification requirements.

- For electrical apparatus in Zone 0, Zone 1 and Zone 2 areas, a Certificate of Conformity shall be obtained from the Manufacturer. Where applicable ATEX certificates shall be obtained.
- For electrical apparatus in Zone 2 areas, which has type of protection 'n', a Declaration of Compliance may be accepted instead of a Certificate of Conformity, subject to the Principal's approval.

4.2 MOTORS

(Forms 1, and 14 or 16)

It should be noted that the scope of motor testing depends upon the motor type and size, this being indicated on the inspection forms.

Motor vibration shall be measured in a tri-axial direction, i.e.:

- point x axis - side of bearing housing at shaft height
- point y axis - top of bearing housing
- point z axis - axial of bearing housing at shaft height

The measurements shall be carried out with an instrument conforming to ISO 2954 (10-1000 Hz frequency range). With the motor at normal operating temperature, the vibration velocity shall not exceed 2.8 mm/s RMS, or 4 mm/s PEAK, in any direction.

For bearings fitted with proximity probes, the unfiltered peak-to-peak value of vibration (including shaft 'run-out') at any load between no load and full load, shall not exceed the following values:

- 50 µm for two-pole motors
- 60 µm for four-pole motors
- 75 µm for six-pole or higher motors

Bearing temperature rise limits as given in DEP 33.66.05.31-Gen. following a 'heat run' of 3.5-4 hours, are as follows:

Rolling bearings:

- outer ring measurement max. 90°C
- temperature rise from ambient max. 50°C

Sleeve bearings:

- oil temperature max. 90°C
- bearing temperature rise by RTD max. 50°C
- lub. oil temperature rise from ambient max. 30°C (for forced lub. oil systems).

When commissioning or re-commissioning motors, precautions shall be taken to avoid excessive vibration caused by the phenomenon known as 'soft foot'; i.e., feet which do not have solid **flat** contact with the base **prior** to the tightening of the holding-down bolts.

This may be measured and rectified during installation (or detected during running) by the loosening of each holding-down bolt in turn while measuring motor vibration.

Refer to (Appendix 4).

4.3 GENERATORS

(Forms 1, 16 and 17)

4.3.1 Base Load Generators

A detailed commissioning plan shall be developed before tests are commenced. Details of a test programme shall be agreed between the Principal and the Contractor/Manufacturer.

The following tests shall be carried out in order to prove the satisfactory performance of the generator and its governor, automatic voltage regulator and synchronising and protection systems.

4.3.1.1 Pre-Commissioning Checks (Prior to Running)

All electrical pre-commissioning work shall have been satisfactorily completed, i.e., all possible tests shall have been carried out, prior to the equipment being run and energised.

Protection relays should be tested in accordance with (4.5); however some tests may only be possible with the generator running. See (4.3.1.2.4).

4.3.1.2 Pre-Synchronising Checks (Generator Running, No-Load)

4.3.1.2.1 Open Circuit Tests

Verify the excitation system and generator characteristics by gradually increasing excitation and plotting generator-output voltage against excitation current.

4.3.1.2.2 Generator Phase Rotation

Verify phase rotation of generator by means of an LV phase rotation meter connected as shown in (Appendix 3), to generator VTs, the VTs being fed either from the busbars (test 1) or the generator (test 2).

4.3.1.2.3 Synchronising Circuit Checks

During the above test 2, verify that operation of the synchroscope, voltmeter, auto and check synchronising relays follows the 'beat frequency', i.e., the difference between generator and network frequency and voltage.

During the above test 1, verify in-phase indication on all of above devices and verify synchronising relay operating parameters and close command.

As a last check, verify, using the capacitive voltage indication on generator breaker, that the synchronising relay 'close' command coincides with the in-phase condition when comparing the generator output with a capacitive voltage indicator, measuring the busbar voltage. This will require a phasing out instrument from the same vendor as supplies the capacitive voltage indication unit.

If such indicators are not fitted, then high voltage 'phasing sticks' may be used across the open generator breaker spouts provided that a risk assessment is completed and, if found necessary, suitable, additional, personal protection equipment is worn.

Capacitive voltage measurement method shall be used in every instance where it is practical to do so.

4.3.1.2.4 Protection Tests

a) In the absence of suitable 3-phase primary injection test sets, differential relay in-zone operation and out-of-zone stability may be verified by using the generator as a current source.

b) Differential Relay Stability Check:

- A 3-phase short circuit shall be applied at a suitable point **outside** of the differential protection zone.
- The generator shall subsequently be run up to speed and excited.
- The generator excitation shall be adjusted from zero to a low figure so that no more than full load current may flow. Refer to Manufacturer's test data.
- Differential Relay Sensitivity Check: A 3-phase short circuit is applied at a suitable point **inside** the differential protection zone. Proceed further as for the stability check.

c) Other items of protection and indication equipment may also be verified at this time if not already done by primary current injection, e.g., overcurrent, neutral displacement, negative sequence relays.

d) Overspeed Check: Operation of mechanical and electronic overspeed trip devices shall be verified.

4.3.1.3 Synchronising and Operational Checks (Generator Running, Loaded)

4.3.1.3.1 Synchronise to Grid

The network to which the generator will be initially synchronised should be configured so that the risk of a disturbance to normal plant operations is minimised.

4.3.1.3.2 Function Tests

The following shall be confirmed:

- a) auto and manual synchronising;
- b) control of power factor over full range of power generation;
- c) control of load;
- d) 'bumpless' change-over from Auto AVR to Manual and vice versa;
- e) change-over of AVR from power factor to voltage control (when changing from coupled to 'island operation')

4.3.1.3.3 Protection Tests

The operation of the Reverse Power relay shall be verified by decreasing the governor setting.

The operation of the Field Failure relay shall be verified by decreasing the excitation at minimum load.

4.3.1.3.4 Dynamic Tests

(See Test Form 17)

Dynamic tests shall comprise:

- a) active load rejection,
- b) reactive load acceptance,
- c) active load sharing
- d) reactive load sharing tests
- e) 'Island' proving tests, if applicable.

Test of load rejection/acceptance should be at 100% of generator rating if suitable active load blocks are available.

The following parameters shall be measured on a suitable recorder: (1) generator voltage/time, (2) current/time and (3) speed (or frequency)/time.

The test acceptance criteria shall be:

- no tripping of any protection device;
- no parameter shall exceed 80% of the difference between nominal value and trip set points;
- transient response shall be within the design parameters.

Governor Tests

- a) Load acceptance and rejection: transient response shall be measured by the switching IN and OUT of active load blocks.
- b) Droop settings in "island condition": speed change between zero and full load shall be measured.
- c) Active load sharing. It shall be verified that the load is shared equally (or for different ratings, pro rata) between the generator being commissioned and all other combinations of generators. It shall be verified that the load continues to be shared during changes in total load.

- d) It shall be verified that electrical load variations are within agreed limits during the change-over of fuels.

AVR Tests

- a) Transient response: the recovery of generator voltage shall be measured during the reactive load acceptance and the load rejection tests. This is done to verify that it is within the limits of time and terminal voltage.
- b) Voltage droop*: it shall be verified that voltage droop is proportional to reactive load or is according to design.
- c) Reactive load sharing: the ability of the generator being commissioned to run at the same power factor as parallel-connected generators shall be verified. It shall also be verified that the power factor remains equal during changes in reactive load.
- d) Current boost*: (for AVRs whose supply is derived from their own terminal voltage), it shall be verified from design data, that generator terminal voltage is sufficiently maintained to allow operation of protective devices in the event of a short circuit.

NOTES: 1. For items marked *, factory test results are acceptable.
2. 'Block load' values shall be such as to demonstrate the equipment's compliance with its design.

4.3.1.5 Load Trials

Load trials shall be carried out as agreed between Contractor and Principal and will normally follow satisfactory completion of all the above tests and the completion of construction and testing of the various systems and sub-systems peripheral to the generator and prime mover.

4.3.2 Emergency and Standby Generators

Where relevant, the tests described in (4.3.1.1) through (4.3.1.5) shall be carried out. The testing methods and procedures shall be subject to agreement between the Principal and the Contractor.

Generators of the 'automatic start on mains failure' type shall be tested with associated switchgear as a complete unit. Additional functional tests shall be carried out to prove that the unit functions as intended.

Where an emergency generator system is designed to withstand severe accident conditions of fire, explosion and strong vibration, this capability shall be verifiable from tests and inspection. These performance requirements are application specific and the standards to be followed shall be defined in the equipment specification.

4.3.3. Additional Tests

4.3.1.1 General

The tests are intended to demonstrate the capabilities of systems rather than of the single major components. During testing, the configurations of the network should be kept as similar as possible to the operational configuration. The requirement for these tests to be carried shall be confirmed by the Principal.

4.3.1.2 Generating Units

Generating units shall be tested to demonstrate their capabilities of operating for a sufficient time period under deviating operational conditions. In theory, voltage and frequency deviations should be tested simultaneously but in practice this may lead to insurmountable difficulties. Therefore, tests with off-nominal voltages and frequencies may be performed separately.

The test acceptance criteria shall be:

- no tripping of the generator;
- no tripping of any protection device.

4.3.1.3 Frequency Deviations

A network connection does not allow for any frequency deviations. These tests may be executed in island operation and shall then be limited to the generating unit and its auxiliaries. The following test shall be executed running at 95% of the rated frequency during 10 minutes while supplying the connected auxiliaries;

4.3.4 Prime Movers

To evaluate their dynamic performance, the primary governor control systems of generating units, classified as P1, P2 and P4, shall be tested for their response to small signals. The test shall be executed at rated speed and rated voltage and at 20% and 80% initial loading by a stepwise increase of the reference value of the frequency or power control leading to an increase of output power of approximately 20%. The results of the test shall be given as time responses to step changes, indicating the following performance values of the active power output:

- rise time (t_r)
- overshoot (d)
- time to reach peak value (t_p)
- settling time (t_s)

The following parameters shall be plotted against time on a suitable recorder:

- a) generator output active and reactive power
- b) generator terminal voltage
- c) changed reference value

The Manufacturer/Supplier shall provide the Principal with a diagram in the time domain showing the complete model of the primary frequency and power control system including the prime mover and all parameters necessary to perform dynamic simulations. It shall also include all applicable ceiling values.

To evaluate the maximum rate of change of the electrical power output, a test shall be carried out by increasing the output power from the minimum to the maximum value. As a minimum, the quantities given under previous points a) and b) shall be recorded relative to time.

4.3.5 Excitation Systems

To evaluate its dynamic performance, the primary excitation control system of each synchronous generator shall be tested for its response to small signals in accordance with IEC 60034-16-3. The test shall be executed at rated speed and rated voltage. The results of the test shall be given as time responses to step changes indicating the following performance values of the terminal voltage:

1. rise time (t_r);
2. overshoot (d);
3. time to reach peak value (t_p);
4. settling time (t_s).

The impressed step change of the reference voltage shall amount to +10%. Because the responses may be asymmetric, compound excitation systems shall also be tested for a step change of -10%. The following time responses shall be measured on a suitable recorder:

- exciter or generator field voltage;
- generator terminal voltage;
- changed reference voltage.

The Manufacturer/Supplier shall provide the Principal with a diagram in the time domain showing the complete model of the excitation system and its parameters necessary to perform dynamic simulations. It shall also include all applicable ceiling voltages.

4.3.5 Auxiliaries

Auxiliaries shall be tested for their ability to withstand short voltage interruptions. Prior to the test the generating unit shall be loaded to rated active and reactive power.

The test consists of a forced voltage interruption for one second of the supply to the main auxiliary switchboard. The interruption shall be obtained by opening and reclosing the appropriate breaker.

If the supply to the auxiliaries is safeguarded by an ACO, it shall only be kept in operation during the test provided that the stand-by power supply is fully independent of the main supply.

The test is successful if the generator is not tripped and regains its initial power output.

4.3.6 Control Systems

This test covers the primary, secondary and tertiary voltage and reactive power control and the primary, secondary and tertiary frequency and power control. It shall demonstrate the capabilities of the whole control system for meeting the required performance levels.

The specific tests and protocols required shall be developed as part of the functional specification of the control system.

4.4 SWITCHGEAR

(See Forms 1, 3, 4, 10, 10a and 11.)

Requirements for Gas Insulated Switchgear (GIS) shall be obtained from the Manufacturer. Commissioning of this type of (HV) switchgear shall normally be carried out by or under supervision of the Manufacturer.

4.4.1 Conductivity Tests

All bolts and nuts in the power current-carrying circuits shall have been tightened with a torque wrench to the factory recommended figures before conductivity tests are carried out. Random checks shall be carried out to verify compliance with factory torque figures.

Switchboard 'droppers' shall be considered as part of the busbar system.

Conductivity tests shall be carried out between adjacent, cubicle spouts (See 3.2.1).

The measured values shall be interpreted on a comparative basis and according to the Manufacturer's statements as to variation in conductance that may be expected.

4.4.2 Insulation Tests

High voltage switchgear components (busbars, contactors and circuit breakers) shall be subjected to high-voltage tests at the pre-commissioning stage.

In general high voltage tests are carried out with d.c. and the test voltage shall be limited to 70% of the peak value of the relevant a.c. voltage levels given in IEC 60694. Refer to (Appendix 5) for test voltages and durations.

For HV cast, resin-insulated switchgear, the Manufacturer shall recommend appropriate testing methods.

Low voltage switchgear components (busbars, contactors and switches) shall be subjected to IR tests at the pre-commissioning stage.

4.4.3 Functional Tests

In addition to all checks as given in the appropriate test forms, a full check shall be carried out to demonstrate that all features of the switchboard function as intended.

For complex installations, the Contractor shall develop specific, functional check-lists, based upon control schematic diagrams, to demonstrate compliance with the design requirements.

4.5 PROTECTION

(See Forms 5, 6, 7, 8, 9 and 12)

4.5.1 Testing General

Relays shall be tested and commissioned in accordance with the Manufacturer's instructions. Consideration should be given to requiring Manufacturer's representative to attend or carry out commissioning if there is insufficient knowledge or experience amongst the commissioning team.

Use should be made of the standard test forms in this DEP, but where these prove to be inadequate, e.g. for multi-function microprocessor-based relays, specific forms shall be developed.

The use of digitally controlled test sets which can be configured to self-document the test results and avoid the need to generate project-specific forms is recommended. Such information may also then be extracted in a digital form and may be more easily uploaded into record systems.

All relay operations; indications and logic schemes shall be checked and results recorded on test forms

CT and VT polarity may be proven by flick tests – refer to (Appendix 11).

All CT ratios shall be verified by primary current injection. CT connections once proven by primary injection should not be removed without being retested. Break-in to CT circuits should subsequently only be made at test links provided for the purpose. Under no circumstances shall a CT primary be energised while the secondary is open-circuited.

All protection relays shall be tested by means of primary current injection at (wherever possible) the normal settings to verify their operating parameters.

Overload relays of Ex'e' motors shall be tested to verify that the tripping time of a 'warm' relay is less than the t_E time shown on the motor rating plate when a current equivalent to the motor starting current is injected.

Relay testing shall include verification of the operation of the switching device's tripping mechanism and all alarms and intertrips.

Motor restart relays and systems shall be tested to verify that their settings are as recommended by a "motor restart/re-acceleration" study.

After each test, it shall be verified that the actual relay setting is in accordance with the setting as laid down in the overall protection scheme of the power system.

The last test date shall be indicated on the relay, and a download of the settings file for numeric relays shall be performed. This shall be identified as the "as-built" record of the relay settings and shall form part of the documentation at hand over of the installation.

4.5.2 Equipment

Equipment used to test relays shall have sufficient capability to drive the relay loads.

Electro-mechanical relays generally have non-linear impedance characteristics and may impose high burden on the test set.

Use of test sets with inadequate drive capacity can lead to significant timing errors and invalidate the test results. For these reasons current source secondary test sets with sufficient burden handling capability shall be used.

Attention is drawn to the fact that modern protection schemes generally use 1 amp secondary currents but existing schemes may use a mixture of 1 amp or 5 amp secondary currents. If the

test set is to be used with all relays at a facility, then it shall be rated to meet the higher load demands of existing protection relays as well.

Test equipment shall be calibrated by an authorised test laboratory and be capable of providing accurate test current and voltages applicable for the devices under test. A current calibration certificate shall be in force.

4.5.3 Electronic Relays

Care shall be taken that electronic relay components are touched only under controlled conditions, i.e., in a workshop equipped with anti-static facilities.

Electronic relays shall be removed or short circuited during IR tests on connected circuits.

4.5.4 Communications

Testing of communication shall be proven at a Factory Integration Test and before equipment is delivered to site.

This testing shall be performed either:

- between intelligent devices and, board mounted interface units, or;
- between DCS or ENMC and the protection relays / switchboard interface units (where fitted)

4.6 CABLES AND POWER TRANSFORMERS

4.6.1 Cables

(See Forms 11, 14, 18 and 19)

Testing of all power cables shall be carried out whilst isolated from both supply and load circuits. This shall include phase allocation verified by continuity checks on cable cores.

Refer to (Appendix 5) and (Appendix 6) for values of test voltage, method and acceptable insulation resistance values.

LV underground cables should be tested prior to cable trench back-filling. HV cables may be tested only after terminations are completed, which generally is after trenches are backfilled. Sheath integrity testing may be carried out after first fill (normally sand) of trench has been completed, provided all cable through joints are completed.

All unterminated and exposed cable ends shall be sealed against moisture ingress.

Heat tracing cable ends shall be kept sealed under all circumstances to prevent moisture ingress which may destroy the temperature regulating characteristic of the cable.

4.6.2 Power Transformers

(See Forms 1 and 13)

Windings of transformers shall not normally be subjected to high voltage testing. Refer to (Appendix 5) and (Appendix 6) for test voltages and acceptable insulation resistance values.

SFRA (Sweep Frequency Response Analysis) should be carried out on large (> 10MW) power transformers to capture the transformer signature for future reference/analysis.

Testing of dry type transformers shall be in accordance with Manufacturer's recommendations.

Refer to (Appendix 10) for transformer oil tests.

Oil testing shall include the following tests and analysis:

- a) electric strength
- b) dissolved gas analysis
- c) moisture content
- d) acidity
- e) colour

Before parallel operation of the transformer is attempted, 'phasing-out' operations shall be carried out to verify that the two supplies are "in-phase". Refer to (Appendix 3).

Refer to (Appendix 9) for examples of Delta/Star Transformer connections.

4.7 POWER ELECTRONICS

4.7.1 General

Power electronic equipment (e.g., UPS, VSDS, excitation controls, heater controls) shall be commissioned fully in accordance with the Manufacturer's instructions. For complex equipment, the Manufacturer's representatives will normally be used to supervise or undertake the commissioning activities.

All protection devices which perform a trip, alarm or control function shall be functionally tested up to and including the operation of the final 'device'.

On completion of commissioning, a list of all equipment set points and parameters shall be recorded and attached to the relevant equipment records in the electrical equipment database.

4.7.2 Variable Speed Drives (VSD)

(See Forms 1, 13, 14, 16 and forms specific to the VSDS type.)

The testing of large variable speed drives should form part of the purchase requisition due to difficulty, cost and complexity of testing. The tests to be carried out on-site should be included in this protocol. Reference should be made to DEP 33.66.05.33-Gen. for more guidance on testing of such systems.

Testing of smaller VSD systems (typically those not covered by DEP 33.66.05.33-Gen.) should follow the Manufacturer's recommendations, but shall include as a minimum:

- setting of site-specific parameters
- full load trials, including auto-restart and voltage dip ride through
- full load noise tests throughout the speed range
- full load vibration tests throughout the speed range

4.7.3 Uninterruptible Power Supply (UPS)

(See Forms 1 and 15)

The commissioning procedure shall follow the Manufacturer's instructions and shall include tests designed to confirm the static and dynamic performance of the equipment, including:

- a) rectifier float charge voltage level
- b) rectifier boost charge voltage level
- c) battery discharge capacity test
- d) battery cell voltage and specific gravity measurements
- e) operation of Inverter and By-pass in synchronism
- f) transfer of load from Inverter to By-pass and return

- g) when the rectifier is switched off, the battery accepts load and the UPS output remains within limits
- h) oscilloscope checks on the equipment's output waveform

4.8 LIGHTING

(See Forms 1 and 11)

Refer to comments on hazardous area equipment inspection in (4.1.1).

Inspection of lighting circuits shall include measurement of earth loop impedance to verify if prospective short circuit current values will allow the protective devices to operate within maximum of 5 seconds for a phase to earth fault. See (4.9.1).

Tests shall be carried out on each circuit at point furthest from supply point. Where circuit has short spurs only with limited numbers of fittings from the main circuit route, it is not necessary to test individual spurs. Where there are significant numbers of junction boxes in spur circuits, then this test shall be repeated from ends of spur circuits as well as at the end of the main circuit.

Points from where tests were made shall be marked up on relevant drawings and form part of hand over documentation. The purpose of the record is to aid repetition of these tests by maintenance staff.

Insulation resistance of circuits shall also be tested. Care should be taken that test voltage applied is within withstand capability of any equipment, e.g., light fittings which will remain in circuit during test, otherwise such equipment shall be isolated.

One Inspection (Form 1) per equipment type and per area shall be completed.

Inspection (Form 11) shall be completed for all circuits.

For hazardous area lighting, 100% checks shall be made as described in (4.1.1).

For lighting in unclassified areas, spot checks on 5% (minimum) of the total shall be carried out. If any faults are found, the inspection shall be suspended and the Installation Contractor asked to check the entire installation and correct any faults found. Inspection may then be restarted with a fresh 5% sample, and if necessary, the cycle repeated.

The operation and autonomy time of all Emergency and Escape lighting systems shall be verified by testing. The results obtained shall be compared with design values downloaded from the electronic electrical equipment database. The database shall be updated with the results of the tests including the date of the test.

The activities shall include a record of measured illumination levels. Luxmeter readings shall be taken at the working plane or 1 m above the floor level in a horizontal plane and entered on a suitable plot or building plan.

The illumination levels shall be as specified in Appendix 4 of DEP 33.64.10.10-Gen. or as specified by the Principal.

4.9 EARTHING AND BONDING

(Forms 20, 21 and (partly) Forms 3, 10, 13, 14)

Refer to (Appendix 7) and (Appendix 8) for testing methods. The test numbers mentioned below are illustrated in (Appendix 7).

4.9.1 Electrical System Earthing (ESE)

All earth electrodes shall be individually measured (with the earth cable disconnected from the electrode). The resistance value of each group of electrodes shall be tested also and shall not exceed 4 ohms (test 1).

All earth connections between the electrode, the supply neutral and the plant earth loop shall be tested for continuity (tests 2 and 3).

All earth connections between Switchboards, Transformers and the Substation earth bar shall be tested for continuity (test 11).

The earth loop impedance of all power and convenience outlets shall be measured using an appropriate 'earth loop tester'.

Where protection is by fuses the impedances measured should allow a maximum 0.4 second disconnection time for portable equipment and a maximum of 5 seconds for fixed installations. Where protection is by earth leakage circuit breakers, test currents and operating times shall be as determined by the circuit breaker characteristics.

4.9.2 Clean Earth (CE)

All earth electrodes shall be individually measured (with the earth cable disconnected from the electrode). Also, the resistance value of each group of electrodes shall be tested and shall not exceed 4 ohms (tests 1 & 4).

All earth connections between the electrode and the instrument clean earth bar and the substation earth bar, shall be tested for continuity (tests 5 and 6).

Note that this test applies to re-commissioning of existing installations. New installations do not include concept of separate Clean Earth.

4.9.3 Equipment External Earth (EE)

4.9.3.1 Process Plant Non-Electrical Equipment

Sample measurements shall be taken (5% of the total) to verify the continuity of the equipment's external earthing cable (with the cable disconnected from the equipment) and any adjacent earthing cable (also disconnected from its equipment) (test 7).

4.9.3.2 Process Plant Electrical Equipment, (Motors, Heaters, etc.)

Measurements shall be made on the earth return path of all electrical equipment having an external earth connection (test 8).

Measurements shall be made with the equipment in operational condition and all cables connected. The earth return impedance shall be measured between the body of the equipment and the substation earth bar, using a conductivity meter and a calibrated cable.

Results shall be evaluated on a comparative basis to identify any abnormal readings. But in any case, earth loop impedance shall be such as to allow the protective device to operate before damage to the cable occurs. For motor circuits with earth leakage protection, this calculation shall be based upon operation of the fuse or mcb protection.

4.9.4 Earth for Lightning and Static Discharge (LPE)

All earth electrode systems used for lightning or static discharge shall be measured with the main earth grid disconnected, and the resistance value of each electrode (group) shall not exceed 10 Ω (test 9).

All earth connections between the electrode and the plant earth loop shall be verified for continuity (test 10).

4.10 BUILDINGS

(See Forms 1, 2, 11, 20; Form 2 for Electrical Buildings only)

Plant buildings and non-plant buildings (i.e., offices, warehouses, gatehouses, workshops, etc.) shall be treated in the same manner as plant equipment and be subject to pre-commissioning and commissioning procedures.

The Contractor shall satisfy himself as to the relevant local regulations applying to the country of the installation and conform to these requirements. Where there are no specific local regulations, then the Contractor shall propose and obtain agreement of the Principal of the testing programme to be followed.

The scope of the pre-commissioning and commissioning activities shall cover all electrical equipment and systems, including the following:

- Lighting shall include normal, emergency and escape lighting systems. Refer to (4.8).
- Switchboards, convenience outlets. Refer to Inspection (Form 11).
- HVAC electrical equipment, refer to sections on Motors, Switchgear etc.
- Earthing. Refer to (4.9).

4.11 HIGH VOLTAGE OVERHEAD LINES

(See Forms 22, 23, and 24)

Inspection criteria and responsibility shall be clearly defined at the time of contract award. Such measurements include:

- a) conductor tension (during and after pulling)
- b) conductor sag
- c) conductor to ground clearance at critical points (e.g., road crossings)
- d) resistance across line compression joints and termination fittings
- e) structural alignment (poles in line and upright)
- f) resistance to earth of static earth wires, guys, structures, lightning arrestors etc.

The measurement shall be recorded in a suitable tabular format.

The Contractor shall be required to submit for the Principal's approval a procedure for stringing/tensioning the line.

Prior to energisation, the entire line and associated equipment shall be checked visually and the insulation resistance of the line recorded. See check list (Form 22, item 7).

4.12 EMNC AND IMCS COMMISSIONING

For guidance on commissioning of EMNC and IMCS systems, refer to following:

- DEP 33.64.10.32-Gen.
- DEP 33.67.01.31-Gen.

In principle, the inter-operation of the components forming the systems shall be proven during Factory Acceptance Testing before erection at site. The site-specific tests are to demonstrate the site installed communication wiring or fibre optic components are operating correctly, and then confirm that the systems are communicating correctly. Thereafter the system testing shall follow recommendations given in the DEPs referred to above.