

DEP SPECIFICATION

FIELD COMMISSIONING AND TESTING OF ELECTRICAL INSTALLATIONS AND EQUIPMENT FOR NORTH AMERICAN APPLICATION

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DESIGN AND ENGINEERING PRACTICE



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1 INTRODUCTION

1.1 SCOPE

This new DEP specifies requirements and gives recommendations for field commissioning of electrical installations and equipment for North American Applications.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

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

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

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

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

1.3 SAFETY

The necessity of safety precautions during work on electrical equipment cannot be over-emphasised.

For projects in Alberta Canada, the electrical work shall be inspected for compliance using applicable safety codes as required by the Shell Quality Management Plan (Electrical Regulatory Management Plan (ERMP)) as approved by the Alberta Safety Codes Council, Electrical Technical Council.

For projects in other jurisdictions, electrical work shall be inspected for compliance with applicable codes in accordance with the laws of the jurisdiction.

1.4 DEFINITIONS

1.4.1 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.

1.4.2 Specific definitions

Term	Definition
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 Technical Authority	The discipline engineer appointed by the Principal responsible for all technical decisions associated with the work. The Electrical Technical Authority is responsible for technical integrity.
Inspection	Ascertaining the general running condition of a piece of equipment by sight, sound, smell and touch. (This may involve the opening of covers).
Pre-commissioning	Those activities which are carried out after equipment erection and prior to energizing 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.
Nomogram	Any graphic representation of numerical relationships.
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).

1.4.3 Abbreviations

Term	Definition
AC	Alternating Current
ASD	Adjustable Speed Drive
AVR	Automatic Voltage Regulator
CT	Current Transformer
DC	Direct Current
DGA	Dissolved Gas Analysis
FAT	Factory Acceptance Test
IR	Insulation Resistance
LV	Low Voltage
MV	Medium Voltage
PI	Polarization Index
TTR	Transformer Turns Ratio
UPS	Uninterruptable Power Supply
VLF	Very Low Frequency

1.5 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).

1.6 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.

1.7 TESTING FORMS

The applicable form shall be completed and returned to the Electrical Technical Authority.

1.8 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.

2. PROCEDURES, RESPONSIBILITIES AND DOCUMENTATION

2.1 PROCEDURES AND RESPONSIBILITIES

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 turnover procedures which shall have been agreed between the Contractor and the Principal before the pre-commissioning stage.

Furthermore, the turnover procedure should state clearly the relevant responsibilities of the Contractor and the Principal.

The organization 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., switchgear, generators, ASDs, UPSs, etc.) shall be commissioned with the assistance of the Manufacturer/Supplier or 3rd party Contractor as appropriate.

Hold/witness points shall be agreed to between the Contractor and the Principal.

Work shall not continue nor shall equipment be energized until the appropriate documentation has been signed off by the Contractor and the Electrical Technical Authority or delegate.

The steps required to connect an electrical system, prior to its initial energizing, to an existing electrical system, shall be jointly agreed by the Contractor and the Electrical Technical Authority responsible for each electrical system.

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 turnover procedures for equipment acceptance by Operations/Maintenance departments from Engineering/Construction departments.

2.2 DOCUMENTATION

The Contractor shall complete the inspection and testing forms listed in (Appendix 1) or an equivalent form with the same information. Use of alternate forms requires approval from the Electrical Technical Authority.

The Contractor shall develop additional inspection forms for equipment not fully covered by those listed in (Appendix 1).

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.

The above documentation shall form part of the official hand-over of plant and equipment.

3. TESTING AND COMMISSIONING METHODS

3.1 INSULATION TESTING

Insulation tests shall be carried out at the pre-commissioning stage and prior to the energizing 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 potential AC or DC testing for MV switchgear, and MV cables.

Refer to (Appendix 4) and (Appendix 5) for recommended test voltages and insulation resistance values.

3.1.1 Insulation resistance (IR) tests

IR testing shall be carried out by applying a DC voltage from an insulation tester at voltage levels given in (Appendix 4).

For correct comparative interpretation of test data, subsequent IR tests should be carried out at the same voltage level as the initial test.

The measured resistance value is also dependent on the temperature of the insulation and shall be corrected with the use of the nomogram in (Appendix 2).

As a guide, the IR of windings reduces by approximately 50 % for each 10°C (50°F) rise in temperature.

3.1.2 High potential tests

Before high potential tests are executed, insulation resistance tests shall have been carried out.

High potential testing can be carried out by applying AC (power frequency), very low frequency (VLF) or DC voltage at a level above the operating voltage.

High potential testing of electrical equipment, except LV cables, shall have been carried out at the Manufacturer's/Supplier's facility at voltage levels in accordance with the relevant equipment DEP or ANSI standards.

Repeated high potential 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.

3.1.3 Polarisation index (PI)

The PI is the ratio between the insulation resistance measured after one minute and after 10 minutes of continuous testing at the appropriate voltage ($PI = R_{10 \text{ min}} / R_{1 \text{ min}}$).

(Appendix 3) shows typical curves for variations of insulation resistance and the values for the Polarisation Index.

3.1.4 Interpretation of results

Should the obtained IR or PI values fall below the minimum values given in (Appendix 5), then the equipment should not be energized or subjected to high potential testing.

Appropriate action should be taken, e.g., drying, to normalize the figures.

Should 'flash-over' occur during high potential testing then the test shall be deemed to have failed and appropriate measures taken (e.g., cleaning, drying, repair) to eliminate the cause, following which a re-testing shall take place. The Electrical Technical Authority or delegate should be made aware of test failures and approve re-testing.

3.1.5 Bearing insulation tests

The method of insulating bearings as a means of controlling shaft current depends upon the type of construction and methods employed to support the bearings.

If the pedestal bearings or sleeve bearing housings are completely insulated from the body of the machine, the insulation may 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 $> 10 \text{ k}\Omega$ or the Manufacturer's/Supplier's recommendations. 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). If, however, only one bearing is insulated (contrary to DEP requirements for motors and generators), verification is limited to the inspection of Manufacturer's/Supplier's QC documentation.

Where double insulation is applied to pedestal bearings, i.e., they are insulated around the bearing 'shell' and at the pedestal base, IR measurement of the 'mid section' with respect to ground will indicate if either insulation is bridged.

3.2 CONDUCTIVITY AND GROUND RESISTANCE TESTS

3.2.1 Conductivity tests

Conductivity tests shall be carried out on switchgear bus bar connections and switchgear ground system connections 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 at least a 20 A (DC) output.

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

3.2.2 Ground resistance tests

For values and method of ground resistance tests, see (4.14).

3.2.2.1 Ground electrodes

All ground 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 (4.13) and (Appendix 7). If approved by the Electrical Technical Authority, ground electrode resistance to earth may also be measured by a clamp on ground resistance meters.

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 terminations should be verified. See (Appendix 9) for required torque values.

3.4 FUNCTIONAL TESTS

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

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 GENERAL

All items of electrical equipment (except bulk ordered equipment) shall be inspected and tested in accordance with the relevant DEP, this DEP and the Inspection and Testing Forms in DEP 63.10.08.91-Gen.

All electrical equipment tags shall be verified for compliance with the relevant drawings and specifications, i.e., equipment nameplates, etc.

4.2 HAZARDOUS (CLASSIFIED) AREA EQUIPMENT

Electrical equipment, capable of igniting flammable atmospheres (except bulk ordered equipment) installed in a hazardous (classified) area, shall be inspected for compliance with the area classification.

Spot checks shall be carried out on bulk ordered material.

Purged and pressurized enclosures shall be inspected to verify proper operation of purge and pressurization systems and alarms.

4.3 GENERATORS

(Forms - 29, 30 and 31)

4.3.1 Base load generators

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

The following tests shall be carried out in order to prove the satisfactory performance of the generator, governor, automatic voltage regulator (AVR) and synchronizing/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 tests should have been carried out prior to the equipment being energized.

4.3.1.2 Pre-synchronizing checks (generator running, no-load)

4.3.1.2.1 Open circuit tests

The excitation system and generator function should be verified. Verify that voltage is produced.

4.3.1.2.2 Generator phase rotation

Phase rotation on main bus should be checked using a phase rotation meter.

4.3.1.2.3 Utility phase rotation (if applicable)

Phase rotation on main bus should be checked using a phase rotation meter.

4.3.1.2.4 Synchronizing circuit checks

Synchronizing system indicating out of sync and a voltage difference for an incoming system should be verified. After adjustments, either automatic or manual, the system shall indicate in sync and no voltage difference as appropriate.

4.3.1.2.5 Protection systems tests

Protection relays should be tested in accordance with (4.7).

4.3.1.3 Post synchronising checks (generator running, loaded)

4.3.1.3.1 Synchronize to grid

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

4.3.1.3.2 Function tests

Function tests shall be developed for the system purchased. Function tests, for example, should include:

1. Auto and manual synchronizing;
2. Control of power factor over full range of power generation;
3. Control of load;
4. 'Bumpless' change-over from auto AVR to manual and vice versa;
5. Change-over of AVR from power factor to voltage control (when changing from coupled to 'island operation').

4.3.1.3.3 Dynamic tests

(Form 30)

Dynamic tests shall comprise:

- Active load rejection and reactive load acceptance, active load sharing and reactive load sharing tests and 'Islanding' shall be function tested where applicable.

Active load rejection and reactive load acceptance shall be confirmed at FAT.

Active load sharing and reactive load sharing tests shall be confirmed to be within the Manufacturer's/Supplier's specifications.

The following parameters should be measured on a suitable recorder:

- a) Generator voltage/time, current/time and speed (or frequency)/time.

The test acceptance criteria shall be:

- a) No tripping of any protection device;
- b) No parameter shall exceed 80 % of the difference between nominal value and trip set points;
- c) 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 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 AVR's 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 should be such as to demonstrate the equipment's compliance with its design.

4.3.1.4 Load trials

Load trials shall be carried out as agreed between the Contractor and the 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.

These final tests should be a series of load tests culminating in a protracted run, under design conditions, at designed maximum power output. This may be performed at FAT.

These final tests will demonstrate that the generator, prime mover and all ancillary equipment meet the designed performance levels while running continuously at full rated load.

4.3.1.5 Black start generators

Where black start capability is required, a suitable commissioning procedure that function tests the system shall be developed.

4.3.2 Emergency and standby generators

Where applicable, the tests described on Inspection and Test Form 31 shall be carried out. The testing methods shall be subject to an agreement between the Principal and the Contractor.

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

4.4 TRANSFORMERS

4.4.1 Power transformers

(Form 9)

Windings of transformers shall be subjected to high voltage testing. Refer to (Appendix 4) and (Appendix 5) for test voltages and acceptable insulation resistance values when testing is specified.

Power transformers are typically tested by a 3rd party Contractor. Test results should be reviewed and accepted by the Electrical Technical Authority. Tests that are typically done by a 3rd party Contractor include:

- Power factor using a Doble (or equivalent) test set
- Transformer Turns Ratio (TTR) test

An oil sample should be taken and laboratory-tested in accordance with ASTM D923. Tests should include:

1. Visual Examination
2. Dissolved Gas Analysis (DGA)

3. Liquid Power Factor
4. Dielectric Strength
5. Acid Neutralization Number
6. Interfacial Tension
7. Colour
8. PPM Water

See (Appendix 8) for transformer oil tests.

After initial energization of a power transformer, it should be put on no-load 'soak' for a few hours (e.g., overnight) before being put on load.

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

Liquid levels shall be verified that they are correct. For transformers with nitrogen or other gas blanket, verify that a positive pressure (in accordance with the Manufacturer/Supplier data) is maintained.

For transformers with auto tap changers, an oil sample should be taken and laboratory-tested separate from the main tank.

4.4.2 Dry type transformers

Prior to initial energizing, small, low-voltage, air-cooled, dry type transformers should have insulation-resistance tests performed winding-to-winding and each winding-to-ground for 1-minute duration.

4.5 BUS DUCT

(Form 11)

The Bus duct shall be inspected, tested and commissioned fully in accordance with the test Form.

The bus duct heaters shall be functionally tested to ensure they are working properly. Verify that the amp meter shows current flow through the heater circuits to ensure that it is continuous and operating.

Check that the bus duct enclosure has adequate drainage to prevent the accumulation of moisture.

Check that wall/floor penetrations are properly installed.

Testing of bus duct will primarily consist of insulation resistance tests. (Appendix 4) and (Appendix 5) show proper test voltages and insulation resistance values.

4.6 SWITCHGEAR

Switchgear shall be inspected, tested and commissioned fully in accordance with the specific test forms.

4.6.1 Air insulated switchgear

(Forms 5, 6 and 7)

4.6.1.1 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. All torqued connections shall be marked to:

- Indicate that they have been properly torqued;
- Show if torque bolts/nuts have been disturbed after the fact.

Random checks shall be carried out to verify compliance with factory torque figures.

Switchgear vertical bus shall be considered part of the bus bar system.

Conductivity tests shall be carried out between adjacent cubicle bus stabs.

The measured values shall be interpreted on a comparative basis.

4.6.1.2 Insulation tests

Switchgear components (bus bars, contactors and circuit breakers) shall be subjected to Insulation Resistance tests.

If it is specified, medium voltage switchgear components (bus bars, contactors and circuit breakers) shall be subjected to high-voltage tests (DC).

Refer to (Appendix 4) for test voltages and durations.

4.6.1.3 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 switchgear function as intended/designed.

For complex installations, the Contractor shall develop specific functional check lists based upon control schematic diagrams in order to demonstrate compliance with the design requirements. Function checks shall be witnessed by an Electrical Technical Authority (or designate).

4.6.2 Gas insulated switchgear (GIS)

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

4.7 PROTECTION

(Forms 33, 34, 35, 36 and 37)

Relays should be tested and commissioned in accordance with the Manufacturer's/Supplier's instructions.

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 energized 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.

Where it is impractical to use a primary injection test set, relays may, subject to the Electrical Technical Authority's approval, be tested by secondary injection.

For generators and generator/transformer combinations, use may be made of the generator as a current source.

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

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

The last test date shall be shown on the relay.

4.8 MOTOR CONTROL CENTRES AND SWITCHRACKS

(Forms 13, 14, 15 and 16)

Motor control centres and switchracks shall be inspected, tested and commissioned fully in accordance with the specific test forms.