

DEP SPECIFICATION

**FIELD COMMISSIONING OF ELECTRICAL
INSTALLATIONS AND EQUIPMENT FOR GLOBAL
APPLICATION**

DEP 63.10.08.11-Gen.

February 2017

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 for global application. It covers the pre-commissioning and commissioning of new electrical installations and equipment, or the re-commissioning of equipment following a major overhaul.

This DEP is for global use and is harmonised with the Project Guide 14b (Commissioning and Start-up).

Project Guide 14b has two major milestones applicable to electrical systems and equipment:

- Mechanical Completion (Handover 1), where systems and equipment are handed over having been tested in a de-energised state (for the electrical systems and equipment this means having tests done such as continuity and insulation resistance but without being initially energised).
- Pre-Commissioning (Handover 2), where systems are handed over ready to be started up without the introduction of process hydrocarbons (for the electrical systems and equipment this means having tests done after initial energisation such as light run of motors, check of switchgear operation when energised). This then allows the commissioning and start-up team to operate systems by running pumps etc., run utility systems.

The corresponding inspection and test forms are in DEP 63.10.08.91-Gen. (Appendix A) provides an overview of the forms. Where activities are likely to be done outside the normal time frame (e.g., tests that have to be completed with equipment under load, which can only be done after commissioning of systems or even start-up of the plant), these are identified separately.

This is a revision of the DEP of the same number dated February 2015; 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. Application in other facilities may also apply.

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.

In general, references to IEC standards do not apply to North American (NA) applications.

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 word **should** indicates a recommendation.

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

1.3.2 Specific definitions

Term	Definition
Authorised Electrical Person	A Competent Electrical Person approved by the Principal, to supervise or to carry out specified operations on high and low voltage electrical power systems and work on electrical equipment. The authorisation may include the authority to receive a sanction for test, issue and cancel limitations of access and perform the necessary safety procedures associated with such work or testing.
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
Electrical Network Monitoring and Control (ENMC)	A computerised system that is dedicated to monitoring and controlling defined aspects of an electrical network.
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-line functional, load and performance tests.
Electrical 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.
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.
GoCCMS	Construction and commissioning certification management system that enables the monitoring of the inspected, tested and commissioned status of individual tagged items of equipment, sub-systems or full plant systems.

Term	Definition
Handover	Transfer of responsibility and/or ownership from one party to another. Also known as take-over or turnover . See Project Guide 14b.
Inspection	Physical examination to determine the condition of a piece of equipment. This may involve sight, sound, smell and touch and 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).
Inverter	A converter for conversion from DC to AC.
Nomogram	Any graphic representation of numerical relationships.
Rectifier	A converter for conversion from AC to DC.
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).

1.3.3 Abbreviations

Term	Definition
AC	Alternating Current
AIS	Air Insulated Switches
AMB	Active Magnetic Bearings
ASD	Adjustable Speed Drive
ATEX	French ATmospheres EXplosives
AVR	Automatic Voltage Regulator
CT	Current Transformer
DC	Direct Current
DGA	Dissolved Gas Analysis
ENMC	Electrical Network Monitoring and Control
ETA	Electrical Technical Authority
FAT	Factory Acceptance Test
HOA	Hand/ Off/ Auto Switch
HV	High Voltage – IEC above 1000 V (NA above 38,000 V)
IEC	International Electrotechnical Commission
IMCS	Integrated Motor Control System
IR	Insulation Resistance
LV	Low Voltage (Voltage levels up to 1000 V)
MCC	Motor Control Centre
MV	Medium Voltage (NA definition above 1000 V and less than or equal to 38,000 V)
NA	North America
PI	Polarization Index
RCU	Remote Control Unit
TTR	Transformer Turns Ratio
UPS	Uninterruptable Power Supply
VLF	Very Low Frequency

Term	Definition
VSDS	Variable Speed Drive System (same as ASD system)
VT	Voltage Transformer

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section or clause number is shown in brackets (). Other documents referenced by this DEP are listed in (5).

1.5 SUMMARY OF MAIN CHANGES

This DEP is a full revision of the DEP of the same number dated February 2015. 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

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://www.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.

2. PROCEDURES, RESPONSIBILITIES AND DOCUMENTATION

2.1 PROCEDURES AND RESPONSIBILITIES

2.1.1 General

1. Testing and commissioning requirements shall be initially addressed at an early point in the design (DEFINE) 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).

- a. Testing and commissioning requirements should form part of the Electrical Safety and Operability Review (SAFOP) review.

This ensures all tests are covered in the most cost effective manner and without unnecessary duplication.

- b. Refer to section 2.1.2 of DEP 33.64.10.10-Gen., or (section 2.3 of DEP 33.64.20.10-Gen. for NA applications) for requirements for a SAFOP.
2. 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 a handover/turnover procedure approved by the Principal before pre-commissioning.
3. The handover procedures shall state the relevant responsibilities of Contractor and Principal to provide an orderly transition during early pre-commissioning/early energisation and commissioning transitional period.
4. The organization and execution of pre-commissioning and commissioning activities shall be the responsibility of the Contractor.
 - a. Unless otherwise agreed by the Principal, complex electrical systems (e.g., switchgear, generators, AVRs, VSIDS/ASDs, UPSs) shall be commissioned with the assistance of the Manufacturer/Supplier or 3rd party Contractor as appropriate.
5. Hold/witness points shall be agreed between the Contractor and the Principal in the procedures.
6. 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.

The Principal may have internal procedures for equipment acceptance by Operations/Maintenance departments from Engineering/Construction departments.

2.1.2 Operational Safety

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

- a. Refer to DEP 80.64.10.10-Gen. for electrical safety rules.

2. Electrical work shall be inspected for compliance with applicable codes by the Authority having jurisdiction or its delegate, in accordance with the laws of the jurisdiction.

For example: For projects in Alberta and British Columbia Canada, the electrical work requires inspection 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 and the British Columbia Safety Authority.

3. Since it is likely that the whole electrical system cannot be energized at one time, the electrical system should be tested and commissioned in sub-systems of manageable size with physical controls of the boundaries e.g., application of padlocks.

- a. For safety reasons it is important to energize only a part of the electrical network that can be controlled so that neighbouring systems can be worked on safely.

4. Work shall not continue nor equipment be energized until the relevant documentation has been signed off by the Contractor and the Authorised Electrical Person.

5. The steps required to connect an electrical system, prior to its initial energizing, to an existing electrical network, shall be jointly agreed by the authorized electrical persons (Contractor and Principal) responsible.

2.1.3 Protection against Explosion and Fire Hazards

1. Before starting field inspection, the Contractor shall provide documentation of the qualifications and competence of the personnel carrying out inspection of electrical equipment in hazardous (classified) areas.

- a. Such qualification can include the CompEx or IECEx schemes.

2. The requirements for competence of the personnel should be embedded in a Quality System.

2.1.4 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. 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.

2.1.5 Maintenance management system data

1. The Contractor shall provide to the Principal, in an electronic database, all relevant data and information associated with the electrical equipment installed.

- a. The format and content of the database shall be subject to approval of the Principal.

The data is intended to be used to populate the computerized maintenance management system with electrical equipment data.

2.2 DOCUMENTATION

1. The Contractor shall complete the inspection and testing requirements specified on the forms listed in (Appendix A).
 - a. Standard Form DEP 63.10.08.91-Gen. should be used for this purpose.
2. The forms shall be pre-loaded with the data as recorded in the electrical equipment electronic database.
 - a. As part of the commissioning procedures, this data shall be verified to be correct.
3. Use should be made of the forms listed in (Appendix A), or forms generated directly from the database.
 - a. If the forms are generated directly from the database, they shall contain, as a minimum, the same information as those contained in Standard Form DEP 63.10.08.91-Gen.
4. In order to align with the Shell Certification and Completion Management System (GoCCMS), the forms in the DEP 63.10.08.91-Gen. have been split to differentiate tests conducted during the Mechanical Completion (A tests) and during the pre-commissioning (B tests).
 - a. If the test is to be performed during start-up, they are classified as C tests.
5. In cases where differences are found to exist with the as-installed equipment, the commissioning forms shall be updated with correct information.
 - a. 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.
6. For pre-commissioning and commissioning, 'Form 1 and Form 3' in (Appendix A) should be used for all equipment and subsequent forms used as required.
 - a. Manufacturer/Supplier test documentation should be available on-site during the inspection and testing of equipment.
7. The Contractor may develop additional inspection forms for equipment not covered, or not fully covered in this DEP.
 - a. Any Contractor developed inspection forms shall be subject to approval by the Principal.
8. All deviations from requirements shall be documented on an "exception list" which shall be subject to approval by the Principal before official handover.
9. The documentation required in (2.2, items 1 through 8), including the updated electronic database, shall form part of the official handover of plant and equipment.

3. TESTING AND COMMISSIONING METHODS

3.1 INSULATION TESTING

3.1.1 General

1. Insulation tests shall be performed at the pre-commissioning stage and prior to the energizing of equipment and cables.
2. The two methods that may be used are:
 - 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 (0.1 Hz [VLF] up to power system frequency) or DC testing for MV (NA) and HV switchgear and MV (NA) and HV cables.
 - i. High potential DC tests should not be done on XLPE cables.
3. Refer to (Appendix E) and (Appendix G) for recommended test voltages and insulation resistance values for NA applications.
 - a. For other locations, use voltage and insulation resistance values from (Appendix F) and (Appendix H).

3.1.2 IR tests

1. Perform IR testing by applying a DC voltage from an insulation tester at voltage levels given in (Appendix E) for NA applications and (Appendix F) for other locations.
2. For correct comparative interpretation of test data, carry out subsequent IR tests at the same voltage level as the initial test.
3. 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 B).
4. As a guide, the IR of windings reduces by approximately 50% for each 10°C (20°F) rise in temperature.

3.1.3 Polarization Index (PI)

1. PI testing shall be performed on all motors rated above 1000V.

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 min / R 1 min).
2. (Appendix C) shows typical curves for variations of insulation resistance and the values for the Polarisation Index.

3.1.4 Interpretation of results – IR and PI

1. Where obtained IR or PI values fall below the minimum values given in (Appendix H), equipment should not be energized or subjected to high potential testing.
2. Appropriate action should be taken to normalize the figures.
3. Where 'flash-over' occurs during testing, then the test shall be deemed to have failed and appropriate measures taken (e.g., cleaning, drying, repair) to eliminate the cause.
 - a. On completion of rectification measures re-testing shall take place.
 - b. The AEP shall be informed of test failures and approve re-testing.

3.1.5 High potential tests

1. Before high potential tests are executed, insulation resistance tests (3.1.2) shall be carried out.
2. High potential testing of electrical equipment, except LV cables, shall have been carried out at the Manufacturer's/Supplier's works with AC at appropriate voltage levels.
 - a. Refer to the relevant DEP or International Standards for requirements.
3. Repeated high potential pressure tests shall not be applied at site to generators, motors or transformers.
 - a. If, repeated high potential pressure tests are considered to be necessary, they shall be carried out only with approval of the Manufacturer/Supplier.

Repeated high potential pressure tests may introduce weak points in the insulation of windings.
4. 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.
 - a. On completion of rectification measures, re-testing shall take place.
 - b. The AEP shall be informed of test failures and approve re-testing.

3.1.6 Bearing insulation tests

1. 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.
2. 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.
 - a. An ohmmeter applied across the insulation shall indicate a resistance of > 10 kΩ or the Manufacturer's/Supplier's recommendations.
 - b. Values below 10 kΩ shall be investigated.
3. If the bearings have internally insulated 'shells' or insulated shafts, carry out measurements with the machine uncoupled (and stopped).
 - a. If, 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.
4. 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 EARTH (GROUND) RESISTANCE TESTS

3.2.1 Conductivity tests

1. Conductivity tests shall be carried out on all field-made switchgear busbar connections and switchgear earth (ground) system joints and a sample of factory-tested joints with a high-current micro-ohmmeter test set in order to establish their tightness and condition.
2. For identical connections, the measured values should not differ by more than 20% from each other.

3.2.2 Earth (ground) resistance tests

3.2.2.1 General

1. For values and method of earth resistance tests, see (4.13) and (Appendix Ia) and (Appendix Ib).

3.2.2.2 Earth (ground) electrodes

1. All earth (ground) electrodes shall be tested by measuring the electrode resistance against the mass of earth, using a purpose-made test set as outlined in (Appendix Ia).
 - a. Verification of the connection of the earthing electrode to foundation earthing should be done as part of the civil scope of works.

3.3 WIRING AND TERMINAL CHECKS

1. Electrical wiring shall be checked against the schematic diagrams.
 - a. Factory-tested assemblies such as switchgear should require only sample checks.
 - b. Wiring done on site shall be checked.
2. The tightness of all field-made terminations shall be verified as follows;
 - a. For North American applications, refer to (Appendix M).
 - b. For all other locations, in accordance with Manufacturer/Supplier torque specifications.

3.4 FUNCTIONAL TESTS

1. Functional tests shall be performed to demonstrate the correct operation of complete systems.

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.
2. The functional testing of safety-related systems shall be performed (e.g., an auto start of diesel generation on supply failure).
3. Attention should be paid to equipment interfaces, where there is a greater likelihood of functional impairment.
4. In cases where interlocked control systems are used, the Contractor shall demonstrate compliance with the design requirements.
 - a. Demonstrating compliance with design requirements may be achieved using system logic diagrams and functional check sheets to demonstrate each case.

3.5 PHASING TESTS

1. Confirmation of phase rotation for switchgear and generator operation shall be done using voltage indication units.
 - a. 'Phasing sticks' shall not be used.
2. For LV systems, phasing should not be done across main busbars but using a visible wiring check and test downstream/after the short-circuit protection (fuse/MCB) of the voltmeters.

3.6 POST COMMISSIONING TESTS

If procedures require that the equipment be tested against operating conditions, for example motor load tests, then the tests may need to be performed during the start-up or even operational phase.

1. Equipment that has to be tested against operating conditions should be identified early in the preparation of the project commissioning planning.
 - a. The list of equipment to be tested against operating conditions shall be subject to approval by the Principal.

4. TESTING AND COMMISSIONING PROCEDURES

4.1 GENERAL

1. All items of electrical equipment except bulk ordered equipment (e.g., light fittings, junction boxes and RCUs/HOAs) shall be inspected and tested.
 - a. Refer to the relevant DEP and the Inspection and Testing Forms in (Appendix A) or DEP 63.10.08.91-Gen. for requirements.
2. All electrical equipment tags shall be verified for compliance with the relevant drawings and specifications, i.e., equipment nameplates.

4.2 HAZARDOUS (CLASSIFIED) AREA EQUIPMENT

Refer to (Appendix A) or DEP 63.10.08.91-Gen., Form 4 and applicable equipment forms.

4.2.1 Installation

1. All items of electrical equipment installed in a hazardous (classified) area shall be subject to an initial detailed inspection and information recorded on the forms listed in (Appendix A).
 - a. For North American applications, refer to NFPA 70, CSA C22.1, IEEE 45, API RP 14F (or API RP 14FZ) where applicable for requirements.
 - b. In all other locations, refer to IEC 60079-14 / IEC 60079-17 for requirements.
2. Bulk ordered material such as light fittings, junction boxes and RCUs/HOAs should be divided into circuits or sub-packages (as dictated by the installation programme) such that they can be inspected as they are completed and before access from temporary scaffolding or similar constraints are removed.
3. Once a circuit or sub-package is inspected, it should have readily identifiable labels or tags attached to clearly mark what has or has not been inspected.
 - a. Any subsequent installation work on that circuit or package requires that the additional works should be inspected and the tie-in points should be re-inspected.
4. During final inspection, one Form 1 (Appendix A) per plant area is sufficient for each 'bulk material' type.
 - a. A sample inspection of the installation may be undertaken to prove that no deterioration or interference has taken place since the sub-package inspections.
5. The testing Contractor shall ensure that cable connections and terminations have been made according to specifications and by qualified personnel.
6. Purged and pressurized enclosures shall be inspected to verify proper operation of purge and pressurization systems and alarms.

4.2.2 Certification

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

4.2.3 Ex / Hazardous Area Classifications Register

1. The Ex register / Hazardous Area Classifications register shall be completed in order to provide the verification dossier for compliance of the installation with the relevant standards.
 - a. Refer to Appendix G of DEP 33.64.10.10-Gen., or Appendix 1 of DEP 33.64.20.10-Gen., for requirements.

4.3 MOTORS

4.3.1 General

Refer to (Appendix A) or DEP 63.10.08.91-Gen., Forms 1, 3, 23, 24, 25, 26.

The scope of motor testing depends upon the motor type and size indicated on the inspection forms.

4.3.2 Insulation tests

1. Typically, final motor insulation resistance testing is completed with the feeder cable attached.
 - a. Where acceptable insulation resistance test values cannot be achieved or where capacitors and surge arresters are connected in the motor terminal box, the motor and feeder should be disconnected and testing completed on the individual components.

Appropriate test voltages and pass criteria are shown in (Appendix E) and (Appendix G) for NA applications with values for other locations in (Appendix F) and (Appendix H).
2. Unless otherwise specified, polarization index testing test duration shall be ten minutes.
3. If specified in DEP 33.66.05.98-Gen for North American applications, HV and MV motors shall be subjected to high-potential tests (DC).
4. Insulation resistance tests shall be performed on the exciter and field winding of synchronous motors, including the exciter solid state components.

4.3.3 Vibration tests

1. Motor vibration shall be measured in a tri-axial direction, i.e.,
 - a. point x axis - side of bearing housing at shaft height;
 - b. point y axis - top of bearing housing;
 - c. point z axis - axial of bearing housing at shaft height.
2. The measurements shall be performed with an instrument conforming to ISO 2954 (10 Hz-1000 Hz frequency range).
 - a. With the motor at normal operating temperature, the vibration velocity shall not exceed 2.8 mm/s (0.11 in/s) RMS, or 4 mm/s (0.16 in/s) PEAK, in any direction.
3. 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:
 - a. 50 μ m (0.002 in) for two-pole motors;
 - b. 60 μ m (0.0024 in) for four-pole motors;
 - c. 75 μ m (0.003 in) for six-pole or higher motors.
4. For North American application, the vibration limits shall be in accordance with:
 - a. API 541, Figure 1 and Figure 2, for MV induction motors.
 - b. API 546 for MV synchronous motors.
 - c. IEEE 841 for LV motors.
5. For motors with active magnetic bearings (AMB), testing and commissioning shall conform to Manufacturer's/Supplier's requirements.

4.3.4 Bearing temperature rise tests

1. Motors shall be operated at no load for at least 1 hour after the bearing temperatures have stabilized.

Stable temperature is defined as a change of not more than 1°C (2°F) in 30 minutes.

2. For bearing temperature rise limits, refer to:
 - a. DEP 33.66.05.31-Gen. for IEC induction motors;
 - b. DEP 33.65.11.31-Gen. for IEC synchronous motors;
 - c. DEP 33.65.11.34-Gen. for NA API 546 synchronous motors;
 - d. DEP 33.66.05.35-Gen. for NA LV induction motors;
 - e. DEP 33.66.05.36-Gen. for NA API 541 motors, and
 - f. DEP 33.66.05.37-Gen. for NA API 547 motors.

4.3.5 Synchronous motors

1. Insulation resistance tests should be performed on the exciter and motor field, including the exciter solid state components.

4.4 GENERATORS

Refer to (Appendix A) or DEP 63.10.08.91-Gen., Forms 1, 3, 29, 30 and 31.

4.4.1 Base load generators / Main power generators

1. A detailed commissioning plan shall be developed before generator tests commence.
 - a. Details of the test plan shall be agreed between the Principal, Contractor and Manufacturer/Supplier.
2. Refer to (4.4.1.1) through (4.4.1.6) for tests to be performed in order to prove the satisfactory performance of the generator, governor, automatic voltage regulator (AVR) and synchronizing/protection systems.

4.4.1.1 Pre-commissioning checks (prior to running)

1. All electrical pre-commissioning work shall have been satisfactorily completed, i.e., all possible tests have been carried out, prior to the equipment being run and energised.
2. Protection relays should be tested in accordance with (4.9).

Some tests are only possible with the generator running. See (4.4.1.2.4).

4.4.1.2 Pre-synchronising checks (generator running, no-load)

4.4.1.2.1 Open circuit tests

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

4.4.1.2.2 Generator / busbar phase rotation

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

4.4.1.2.3 Synchronising circuit checks

1. During the phase rotation test (4.4.1.2.2), for test 1, verify in-phase indication and verify synchronising relay operating parameters and close command.
2. During the phase rotation test (4.4.1.2.2), for 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.
3. 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.
 - a. The phasing out instrument shall be supplied by the same Manufacturer/Supplier who supplied the capacitive voltage indication unit.

4.4.1.2.4 Protection tests

1. 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.
2. Differential relay stability check shall include the following steps:
 - a. A 3-phase short circuit be applied at a suitable point outside of the differential protection zone.
 - b. The generator subsequently be run up to speed and excited.
 - c. The generator excitation be adjusted from zero to a low figure so that no more than full load current may flow.
 - i. Refer to Manufacturer's/Supplier's test data.
3. For a Differential Relay Sensitivity Check, a 3-phase short circuit is applied at a suitable point inside the differential protection zone.
 - a. Proceed further as for the stability check in (4.4.1.2.4, item 2).
4. 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.
5. For the overspeed check, operation of mechanical and electronic overspeed trip devices shall be verified.

4.4.1.3 Synchronizing and operational checks (generator running, loaded)

4.4.1.3.1 Synchronize to grid

1. 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.

4.4.1.3.2 Function tests

1. The following function tests shall be confirmed:
 - a. auto and manual synchronizing;
 - 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')

4.4.1.3.3 Dynamic tests

Refer to (Appendix A) or DEP 63.10.08.91-Gen., Form 30.

1. Dynamic tests shall comprise:
 - a. active load rejection;
 - b. reactive load acceptance;
 - c. active load sharing;
 - d. reactive load sharing;
 - e. 'Island' proving tests, if applicable.
2. Test of load rejection/acceptance should be at 100% of generator rating if suitable active load blocks are available.
3. The following parameters shall be measured on a suitable recorder:
 - a. generator voltage/time;
 - b. current/time;
 - c. speed (or frequency)/time.
4. 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 within the Manufacturer/Supplier design parameters.
5. Governor tests
 - a. Measure load acceptance and rejection: transient response by the switching IN and OUT of active load blocks.
 - b. Measure droop settings in "island condition": speed change between zero and full load.
 - c. Active load sharing: verify that the load is shared equally (or for different ratings, pro rata) between the generator being commissioned and all other combinations of generators. Verify that the load continues to be shared during changes in total load.
 - d. Verify that electrical load variations are within the limits specified in the test procedure during the change-over of fuels.

6. AVR tests

- a. Transient response. Measure the recovery of generator voltage 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. Verify that voltage droop is proportional to reactive load or is according to design.
 - i. For voltage droop, factory test results are acceptable.
- c. Reactive load sharing. Verify the ability of the generator being commissioned to run at the same power factor as parallel connected generators. Also verify 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.
 - i. For current boost, factory test results are acceptable.
- e. 'Block load' values shall be such as to demonstrate the equipment's compliance with its design.
- f. AVR Under and Over excitation (UEL and OEL) limiters shall be checked.

4.4.1.3.4 Protection tests

1. The operation of the Reverse Power relay shall be verified by decreasing the governor setting at minimum load.
2. The operation of the Field Failure relay shall be verified by decreasing the excitation at minimum load.

4.4.1.4 Load tests

1. Load tests shall be performed as agreed between Contractor and Principal.
 - a. Load tests will normally follow satisfactory completion of all the tests in (4.4.1.1 through 4.4.1.3) and the completion of construction and testing of the various systems and sub-systems peripheral to the generator and prime mover.
2. The final tests should be a series of load tests culminating in a protracted run, under design conditions, at maximum power output to demonstrate that the generator, prime mover and all auxiliary equipment meet the designed performance levels while running continuously at full rated load.

4.4.1.5 Utility/Grid compliance tests

1. Tests shall be performed as agreed with the public utility/local grid company.
 - a. The tests may include operation at extremes of real and reactive power, tests at reduced voltage of auxiliary supplies and momentary interruption of supply to auxiliaries. See (4.4.3).

4.4.1.6 Black start generators

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