

IEEE Std 1248-1998

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# IEEE Guide for the Commissioning of Electrical Systems in Hydroelectric Power Plants

**IEEE Power Engineering Society**

Sponsored by the Energy Development and Power Generation Committee

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# IEEE Guide for the Commissioning of Electrical Systems in Hydroelectric Power Plants

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**Abstract:** Inspection procedures and tests for use following the completion of the installation of components and systems through to commercial operation are provided. This guide is directed to the plant owners, designers, and contractors involved in the commissioning of electrical systems of hydroelectric plants.

**Keywords:** commissioning, hydroelectric power plant

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# Introduction

(This introduction is not part of IEEE Std 1248-1998, IEEE Guide for the Commissioning of Electrical Systems in Hydroelectric Power Plants.)

This document is a guide for the commissioning of electrical equipment in a hydroelectric power plant. The document was prepared by the Working Group on Powerplant Commissioning of the Hydroelectric Subcommittee of the IEEE Energy Development and Power Generation Committee of the IEEE PowerEngineering Society (PES).

The group was formed at the 1990 IEEE PES Summer Meeting to provide guidance in the commissioning of electrical equipment in a hydroelectric facility. The commissioning includes the installation of a new power plant, the rehabilitation of an existing power plant, or the upgrading of equipment in an existing power plant.

This guide is intended to be used as a reference document for practicing engineers in the hydroelectric industry. The guide includes an index of systems, equipment, and tests that provide information on the checkout and commissioning of electrical equipment in a hydroelectric power plant.

Members of the working group represent a cross section of the hydroelectric industry, including power plant owners, designers, and equipment manufacturers.

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# IEEE Guide for the Commissioning of Electrical Systems in Hydroelectric Power Plants

## 1. Overview

### 1.1 Scope

This guide is directed to the plant owners, designers, and contractors involved in the commissioning of electrical systems of hydroelectric plants. This guide suggests inspection and tests to be used following the completion of the installation of components and systems through to commercial operation. This guide is influenced by general North American terminology and practice. Minor adaptation may be required for particular corporate structures and philosophies.

### 1.2 Introduction

This guide was developed to assist engineers involved in the commissioning of electrical equipment in regard to

- Specific electrical equipment tests; and
- The testing program for placing the equipment in operation.

The commissioning of electrical equipment may be for

- A new hydroelectric plant installation;
- Rehabilitation of an existing hydroelectric plant; or
- Replacement and upgrade of existing electrical equipment.

The guide describes the development of a startup organization, followed by a description of the commissioning phases of a hydropower plant. The principal information is contained in matrix format for each major type of electrical equipment, which identifies the various tests that are associated with the equipment. Information is provided for each specific test, including

- a) A brief description;
- b) Supporting documents;

- c) Equipment required; and
- d) Duration or time required.

Based on the above information, guidance is provided for planning, developing, and documenting a commissioning program.

This guide addresses conventional hydropower. Portions of the guide are relevant to pumped storage plants, but the unique features of pumped storage plants are not specifically addressed.

The guide also contains a bibliography of industry standards, recommended practices, and guides that may be used as resources by the engineer engaged in the commissioning of electrical equipment. The listing is intended to be an aid in preparing for a hydroelectric plant startup or a particular test. Review of relevant documents is encouraged.

## 2. References

All testing should be done in accordance with equipment specifications and contracts with reference to and in conjunction with pertinent industry standards. The latest revision of the standards and guides listed in Annex A should be used. A list of supporting documents, which includes both bibliographic items and general documents, is provided for each test in Clause 9 of this guide.

## 3. Definitions and acronyms

### 3.1 Definitions

**3.1.1 construction testing:** Performing required inspections and tests to ensure that completed installations are in accordance with contract requirements and the latest engineering and design information.

**3.1.2 operational testing:** All testing required to verify system operation in accordance with design requirements after the major component is energized or operated.

**3.1.3 performance testing:** Testing conducted to evaluate the compliance of a system or component with specified performance.

**3.1.4 preoperational testing:** All testing required for system components prior to energizing or operating the major system component.

**3.1.5 prestartup testing:** All testing required prior to rotating the generating unit under power (hydraulic or electrical) which is unique to the unit and not associated with system testing.

**3.1.6 startup testing:** All testing of the generating unit from initial-powered rotation to verify suitability for operation.

**3.1.7 subsystem verification (system operational testing):** Testing to verify that all of the systems required for a main generating unit startup have been tested and are operational.

**3.1.8 system testing:** Preoperational testing to verify components of the system, and operational testing to verify the coordination of the system components for proper design operation of the system functions.

**3.1.9 turbine/generator testing:** Consists of four testing phases: sub-system verification, prestartup, startup, and performance testing.

## 3.2 Acronyms and abbreviations

BHP: brake horse power

CT: current transformer

EMC: electromagnetic compatibility

EMI/RFI: electromagnetic interference/radio frequency

EUT: equipment under test

LCI: load commutating inverter

LTE: lead test engineer

MCC: motor control cubicle

NFPA: National Fire Protection Association

O&M: operations and maintenance

OEM: original equipment manufacturer

PCB: polychlorinated biphenyl

PMG: permanent magnetic generator

RF: radio frequency

RPM: revolutions per minute

RTD: electronic digital type resistance temperature detector

SWC: surge withstand capability

THF: total harmonic factor

TIF: telephone influence factor

UPS: uninterruptible power supply

## 4. Startup organization

### 4.1 General

Administrative procedures clarify the roles of all participants in the organization involved in the project test program. Once the role of these parties is identified, a plan for the turnover of equipment/systems from the

contractor to the owner should be developed. Schedules of construction completion dates and all testing should be included with the administrative procedures. The startup organization described herein is based on the owner, engineer, and contractor having an active role in the startup and commissioning activities. The responsibility of the various entities may shift slightly depending on their contractual relationship. In general, the following description is a guide to those responsibilities.

Generic test procedures are typically prepared for the contractors for equipment testing during installation referred to as the *construction testing phase*. These generic procedures describe electrical, mechanical, and instrumentation verification that are discussed in Clauses 7, 8, and 9. Data sheets should be included in the procedures to record test results and provide baseline data for later use when equipment maintenance is performed by the plant staff.

Preoperational test procedures are used during the preoperational testing phase that follows the construction testing phase. These procedures provide all tests and checks necessary to ensure that each plant system is functional before startup testing of the overall integrated plant commences. The purpose of these procedures is to verify that each system performs in accordance with design requirements.

Operational test procedures are used during the final phase of the plant startup. These procedures outline tests to be performed on the major plant systems and components such as turbine-generator, governor and controls, voltage regulator and excitation systems, relays and protection equipment, and the various modes of starting, loading, and stopping each unit. This phase should be coordinated with the vendor's representatives supplying major components and with the operating authority for the plant.

The typical role of the participants of the startup organization is described below.

## 4.2 Owner

The owner is usually the operator and provides the operating and maintenance personnel that participate in the commissioning program. The owner's representative usually

- a) Reviews administrative, construction, preoperational and operational programs, and schedules;
- b) Witnesses testing activities, as necessary, in support of the commissioning program;
- c) Provides coordination with offsite operating, dispatching, or interfacing agencies, as required;
- d) Conditionally accepts equipment and systems for operation during the preoperational testing phase;
- e) Accepts equipment, systems and facilities, subsequent to successful testing of these items, and provides final acceptance of the project;
- f) Operates all permanent plant equipment to support the start-up schedule; and
- g) Makes final decisions in areas of disputes relating to test activities performed during the test program.

## 4.3 Contractor

The contractor typically furnishes, installs, and tests the equipment and systems under the terms and conditions of the contract. Tests performed by the contractor may be witnessed by the engineer or owner. The contractor usually

- a) Performs construction and preoperational testing on contractor-furnished equipment and systems in accordance with test requirements contained within the contract;
- b) Performs construction testing on owner-furnished equipment in accordance with the contract;

- c) Records test data results during construction and preoperational testing, distributes to the engineer, and incorporates into the system turnover package;
- d) Implements tagging and work clearances on systems and equipment under the jurisdiction of the contractor in accordance with the commissioning program tagging procedure prior to turn over to the owner;
- e) Schedules completion of construction work and construction test activities to support the overall commissioning program;
- f) Provides the engineer with status of contractor-furnished equipment and systems deficiency list items; advises the engineer when turnover for preoperational testing will occur on contractor-furnished equipment and owner-furnished equipment;
- g) Provides craft personnel required during construction and preoperational testing by the contractor, and in support of preoperational and operational testing performed by the engineer;
- h) Participates in the development of schedules for all phases of the commissioning program;
- i) Provides system deficiency list with equipment turnover and resolves all deficiencies; and
- j) Notifies the engineer of any engineering or construction deficiencies that will not allow for proper testing and operation of any system.

## 4.4 Engineer

### 4.4.1 Project engineering

The engineer typically provides the design documents to install and test the equipment based on the manufacturer's recommendations. The engineer usually

- a) Provides all engineering documents and information necessary for completion of construction and testing; and
- b) Furnishes engineers on-site to provide assistance on design and engineering problems.

### 4.4.2 Lead test engineer

The engineer typically provides a lead test engineer (LTE) with overall responsibility for the conduct of pre-operational and operational testing of owner-furnished equipment and the operational testing of contractor-furnished equipment under coordination of the owner.

The LTE should prepare the procedures required to implement the program and give final approval to these procedures prior to owner review and approval. These procedures should be incorporated into a commissioning manual. In addition, the LTE should

- a) Coordinate the need for vendor representatives during the operational testing phase;
- b) Resolve design questions encountered during the commissioning program;
- c) Participate in the development of schedules for construction and preoperational testing of contractor-furnished equipment and systems;
- d) Develop, in conjunction with the owner, schedules for preoperational and operational testing of contractor-furnished equipment and systems;
- e) Accept owner-furnished equipment and systems that have been tested by the contractor in accordance with construction test procedures;
- f) Perform preoperational and operational testing of owner-furnished equipment and systems; and
- g) Perform operational testing of contractor-furnished equipment and systems.

The following test procedures are recommended:

- Administrative
- Electrical
- Mechanical
- Instrument
- Preoperational
- Operational

The LTE usually directs all activities to ensure a smooth, effective commissioning program and is typically responsible for the overall conduct of the commissioning program for all project equipment and systems. The LTE usually has primary responsibility for scheduling and directing the efforts of those assigned to the performance of the commissioning activities. The LTE typically coordinates the interface activities of the contractor for construction and the owner's personnel required to accomplish the commissioning program.

#### 4.5 Manufacturer/vendor

In addition to factory tests to be performed on manufacturer-furnished equipment, tests are typically performed during the installation phase in accordance with the contract. These tests are performed in support of the commissioning program and in keeping with the schedules for preoperational and operational testing. Typical manufacturer tests include

- a) Unit alignment;
- b) Rotational runout checks;
- c) Rotor diameter measurement;
- d) Rotor roundness measurement;
- e) Stator bore diameter measurement;
- f) Stator roundness measurement;
- g) Airgap measurement;
- h) Bearing alignment and clearances;
- i) Verification of temperature devices;
- j) Current transformer polarity checks;
- k) Braking system;
- l) Bearing oil lubrication system;
- m) Stator and rotor winding resistance measurements;
- n) Open circuit saturation test;
- o) Short-circuit test;
- p) Phase sequence test;
- q) Heat run;
- r) Overspeed tests; and
- s) Load rejection tests.

## 5. Commissioning program

### 5.1 Commissioning program phases

The commissioning program is usually divided into three phases: the construction test phase, the preoperational test phase, and the operational test phase.

#### 5.1.1 Construction test phase

The construction contractor usually performs required inspections and tests to ensure that completed installations are in accordance with contract requirements and the latest engineering and design information. The results of construction testing should be documented by the construction contractor and turned over with release of equipment to the preoperational testing group. Construction testing generally includes

- a) Electrical
  - 1) Insulation resistance testing of electrical equipment and cables;
  - 2) Continuity tests to verify cable routing;
  - 3) Initial operation of motors uncoupled (phase rotation check);
  - 4) Inspection and testing of motor control centers and switchgear; and
  - 5) Verification of cable terminations in accordance with design documents.
- b) Mechanical (including piping)
  - 1) Hydrostatic testing of piping systems;
  - 2) Mechanical equipment alignment;
  - 3) Initial lubrication of mechanical equipment;
  - 4) Tank cleaning and piping cleaning (flushing);
  - 5) Inspection of mechanical equipment and piping systems; and
  - 6) Mechanical test procedures implementation.
- c) Instrumentation
  - 1) Testing of pneumatic instrument lines for leaks;
  - 2) Verification of proper grounding of shielded cables;
  - 3) Installation of instrumentation in accordance with design documents;
  - 4) Continuity tests to verify cable routing;
  - 5) Verification of cable terminations in accordance with design documents; and
  - 6) Instrument test procedures implementation.

#### 5.1.2 Preoperational test phase

Preoperational testing generally includes but is not limited to

- a) Insulation resistance testing of electrical equipment, to be done prior to terminations (power cables);
- b) Checkout of electric motors;
- c) Checkout of motor operated valves, dampers and gates;

- d) Checkout and verification of electrical control circuitry through functional testing;
- e) Calibration of electrical relays and meters;
- f) Checkout and trip check tests of switchgear, motor control centers, and molded case breakers;
- g) Flushing of mechanical systems/subsystems;
- h) Blowdown of station/instrument air lines;
- i) Verification of instrument calibration;
- j) Loop calibration of all instrument loops;
- k) Functional loop checkout of all instrument loops;
- l) Preoperational testing in accordance with approved preoperational test procedures;
- m) Vendor testing of supplied equipment and systems;
- n) Vibration testing of driven equipment;
- o) Visual inspection of all systems and equipment; and
- p) Verification of polarity and integrity of instrument transformer circuits.

### 5.1.3 Operational test phase

Operational testing generally includes but is not limited to

- a) Hydraulic operation of spiral case shut-off valves and proper setting of closing and opening times;
- b) Wicket gate or nozzle alignment and verification of proper opening and closing times;
- c) Governor control setting verification;
- d) Verification of proper lubrication of generator and turbine bearings;
- e) Final check of unit braking system;
- f) Initial operation of the turbine-generator and bearing run in;
- g) Electrical and mechanical overspeed trip tests;
- h) Final setting of vibration shutdown sensors;
- i) Voltage regulator and excitation system tests;
- j) Verification of proper generator to system synchronization;
- k) Testing and verification of electrical protection systems with load;
- l) Load rejection tests;
- m) Performance runs at prescribed loads;
- n) Operation and monitoring via plant control systems (local and remote); and
- o) Coordinated testing with all plant units.

## 6. Commissioning implementation

### 6.1 General

Throughout the construction and installation of the plant systems, construction supervisors and engineers should perform the necessary inspections to ensure that completed installations are in accordance with the latest engineering and design information.

During the construction phase, the construction contractor usually performs required inspections and tests. The results of construction testing should be documented by the construction contractor and turned over with release of equipment to the preoperational test group.

### 6.2 Construction completion phase

#### 6.2.1 Electrical

All electrical equipment should be installed in accordance with design documents. Testing during the construction phase should, at a minimum, include the tests listed in a) of 5.1.1.

#### 6.2.2 Mechanical

All mechanical equipment should be installed in accordance with design documents. Testing during the construction phase should, at a minimum, include the tests listed in b) of 5.1.1. Final coupling alignment should be performed after startup engineers have operated the associated equipment satisfactorily. All equipment lubrication should be done during this construction phase before turnover. The lubrication and alignment forms attached to this procedure should be used to record the applicable data. Rotating equipment operational problem corrective actions should be the responsibility of the construction group.

#### 6.2.3 Piping

All piping should be installed in accordance with design documents. Testing during the construction phase should, at a minimum, include the piping system tests listed in b) of 5.1.1. Piping changes that are required should be completed by the contractor.

#### 6.2.4 Instrumentation

All instrumentation devices and piping should be installed in accordance with design documents. Testing during the construction phase should, at a minimum, include those instrumentation system tests listed in c) of 5.1.1. Instrumentation changes that are required should be completed by the contractor.

### 6.3 Preoperational testing phase

The LTE and staff should supervise the checkout and testing during this phase. They should ensure that tests performed during this phase of the commissioning are conducted in accordance with approved procedures prior to commencing with the next phase, which is operational testing.

#### 6.3.1 Electrical

All system preoperational testing should be done during this phase by the construction contractor and should include, at a minimum, those electrical system tests listed in 5.1.2. During verification of control circuitry, drawings should be marked to indicate checkout is complete.

### 6.3.2 Mechanical

All mechanical equipment should be checked and tested by the construction contractor and should, at a minimum, include those mechanical system tests listed in 5.1.2.

### 6.3.3 Piping

All piping should be checked out and tested by the construction contractor and should, at a minimum, include those piping system tests listed in 5.1.2.

### 6.3.4 Instrumentation

All final instrument calibration and testing should be done during this phase and should, at a minimum, include those instrumentation system tests listed in 5.1.2. Loop checkout includes checking each loop from the field device to the control board or final control device. This is normally done by the startup group's instrument test technician.

## 6.4 Unit startup and operational phase

The unit startup and operational phase should be accomplished by the LTE, the owner's plant organization, and the vendors' representatives necessary to ensure satisfactory operation of the equipment being commissioned. This phase includes all tests and checks that are necessary to ensure satisfactory station commercial operation (see 5.1.3). This phase should include placing all systems in operation and ultimately operating the unit being commissioned at full load.

The unit startup and operational phase should be coordinated by the LTE and the owner's representative. Support services are normally arranged according to the following procedures:

- a) Contractors normally provide craft labor as requested by the LTE in support of construction and pre-operational activities.
- b) The owner normally provides operations and maintenance (O&M) personnel to support the startup preoperational and operational activities.
- c) Construction contractors requiring vendor service support should coordinate their requests with the LTE.
- d) The LTE normally has responsibility for determining vendor service support required for startup.

Results of operational testing are reviewed by the owner's representative, and if acceptable, the unit is declared commercially operational and turned over for normal operation. The warranty period for the major plant components usually begins at this time.

## 7. Application of this guide

### 7.1 General

This clause provides a method for preparing and executing the commissioning of electrical and other major systems in a hydroelectric plant.

Clause 8 identifies the equipment and systems in a hydroelectric facility in a matrix format. Each matrix lists all tests that are typically performed on a particular piece of equipment or system to verify its readiness for operation. This information along with Clause 9, which provides a brief description of each test, are the keys

for planning commissioning activities. Using the matrices and test descriptions, an engineer should be able to identify and schedule the required tests for installing, checking, and verifying operational status of electrical equipment in the plant.

Typically, the LTE and contractors develop a schedule for the design, delivery, and installation of equipment that will ultimately be commissioned in the plant. When the design is completed and the equipment purchased, necessary information becomes available for developing test procedures used for the installation checkout and operational verification. An equipment test schedule should be developed in conjunction with the construction schedule for equipment and system installation. Once the equipment and systems are identified, the matrices in Clause 8 list suggested tests to be performed on various systems and equipment.

## 7.2 Using this guide to develop a test program

After the equipment and systems that are to be commissioned are identified, the material in Clauses 8 and 9 is then applied to develop the test program. An example of a simple application is used to illustrate the process.

The example assumes that the existing unit exciters in the plant have been replaced with new bus fed static excitation systems. The test matrix for a static excitation system (see 8.1.17) is used to develop a test schedule and test procedure to commission the new excitation systems. The test matrix from 8.1.17 is reproduced in Figure 1 with key components of the matrix highlighted. An examination of the matrix shows major components of the static excitation system listed under the column titled “Equipment/system.” The major components for the static excitation system include the air cooling system, the rectifier bridge, the water cooling system (if employed), the field breaker/leads, the controls, and the excitation transformer. Also included on the matrix are a number of specialized tests used for verifying the readiness of the component or subsystem for operation. For example, the controls system is highlighted in Figure 1 and shows marks that are placed in the test columns for visual inspection, circuitry checkout, and functional checks indicating that these tests are recommended for verifying that the controls of the excitation system are ready for operation. Descriptions of the specific tests listed for checkout of the controls of the excitation systems are contained in Clause 9.

One of the specific tests to be performed on the control system for the static excitation system, the visual inspection test (see 9.1.82) is reproduced in Figure 2 with key elements of the test highlighted.

As can be seen, information about the test provides specifics on the description of the test, test references, equipment required, and the time required to perform the test. It was compiled by extracting the test descriptions from Clause 9 that correspond to the specific tests noted on the equipment matrix and appending any equipment supplier recommendations and industry standard procedures associated with the specific equipment.

The information in Clause 9 briefly describes the test requirements. Supplemental information may be required to completely describe the test requirements. The supplemental information may include the original equipment manufacturer’s (OEM) recommendations or other industry standards. All tests checked in the test matrix should be performed to verify the readiness of the controls of the excitation system for operation.

A set of tests or a “test package” as shown in Figure 3 is recommended for use by test personnel to verify operational readiness of the controls of the excitation system. Similarly, “test packages” are developed for each of the other elements comprising the static excitation system. By combining the requirements of each of these test packages for the various elements of the static excitation system, the engineer should be able to develop a comprehensive test procedure for the entire system, have knowledge of special test equipment and resources required for the entire checkout, and be able to develop an accurate estimate of the time required to conduct the excitation system checkout.

| 8.1.17<br>EXCITATION SYSTEMS |      | Recommended tests<br>Static excitation<br>Systems controls |                |                    |              |                  |                     |                       |                       |                   |                   |
|------------------------------|------|------------------------------------------------------------|----------------|--------------------|--------------|------------------|---------------------|-----------------------|-----------------------|-------------------|-------------------|
| EQUIPMENT/SYSTEM             | Test | Visual inspection                                          | High potential | Circuitry checkout | Leak testing | Temperature rise | Harmonic distortion | DC winding resistance | Insulation resistance | Functional checks | Initial operation |
|                              |      |                                                            |                |                    |              |                  |                     |                       |                       |                   |                   |
| Rotating excitation system   |      |                                                            |                |                    |              |                  |                     |                       |                       |                   |                   |
| Three-phase ac/dc exciter    |      | X                                                          |                |                    |              | X                |                     | X                     | X                     | X                 |                   |
| Rectifier bridge             |      | X                                                          |                |                    |              | X                |                     |                       |                       | X                 |                   |
| Air cooling system           |      | X                                                          |                | X                  | X            | X                |                     |                       |                       | X                 |                   |
| Water cooling circuits       |      | X                                                          |                | X                  | X            | X                |                     |                       |                       | X                 |                   |
| Field breaker/leads          |      | X                                                          | X              | X                  |              |                  |                     |                       |                       | X                 |                   |
| Controls                     |      | X                                                          |                | X                  |              |                  |                     |                       |                       | X                 |                   |
| Static excitation system     |      |                                                            |                |                    |              |                  |                     |                       |                       |                   |                   |
| Rectifier bridge             |      | X                                                          |                |                    |              | X                |                     |                       |                       | X                 |                   |
| Air cooling system           |      | X                                                          |                | X                  | X            | X                |                     |                       |                       | X                 |                   |
| Water cooling system         |      | X                                                          |                | X                  | X            | X                |                     |                       |                       | X                 |                   |
| Field breaker/leads          |      | X                                                          | X              | X                  |              |                  |                     |                       |                       | X                 |                   |
| Controls                     |      | X                                                          |                | X                  |              |                  |                     |                       |                       | X                 |                   |
| Excitation transformer       |      | X                                                          |                |                    |              | X                |                     | X                     | X                     |                   |                   |

Equipment components, static excitation system  
"X" means recommended test for component

Figure 1—Example of equipment test matrix

### 7.3 Coordinating commissioning tests of systems and units

Using all of the appropriate test descriptions, a complete testing program can be developed to commission the electrical systems. Once the station and unit systems are tested and verified for operation, the commissioning of a unit may begin. Refer to Figure 4 as a guide for developing a plant-specific commissioning program. A hydroelectric unit includes the turbine/generator and all support equipment for operating the units and delivering the electrical power to the utility system. The tests for unit startup are included with the turbine and generator equipment matrices.

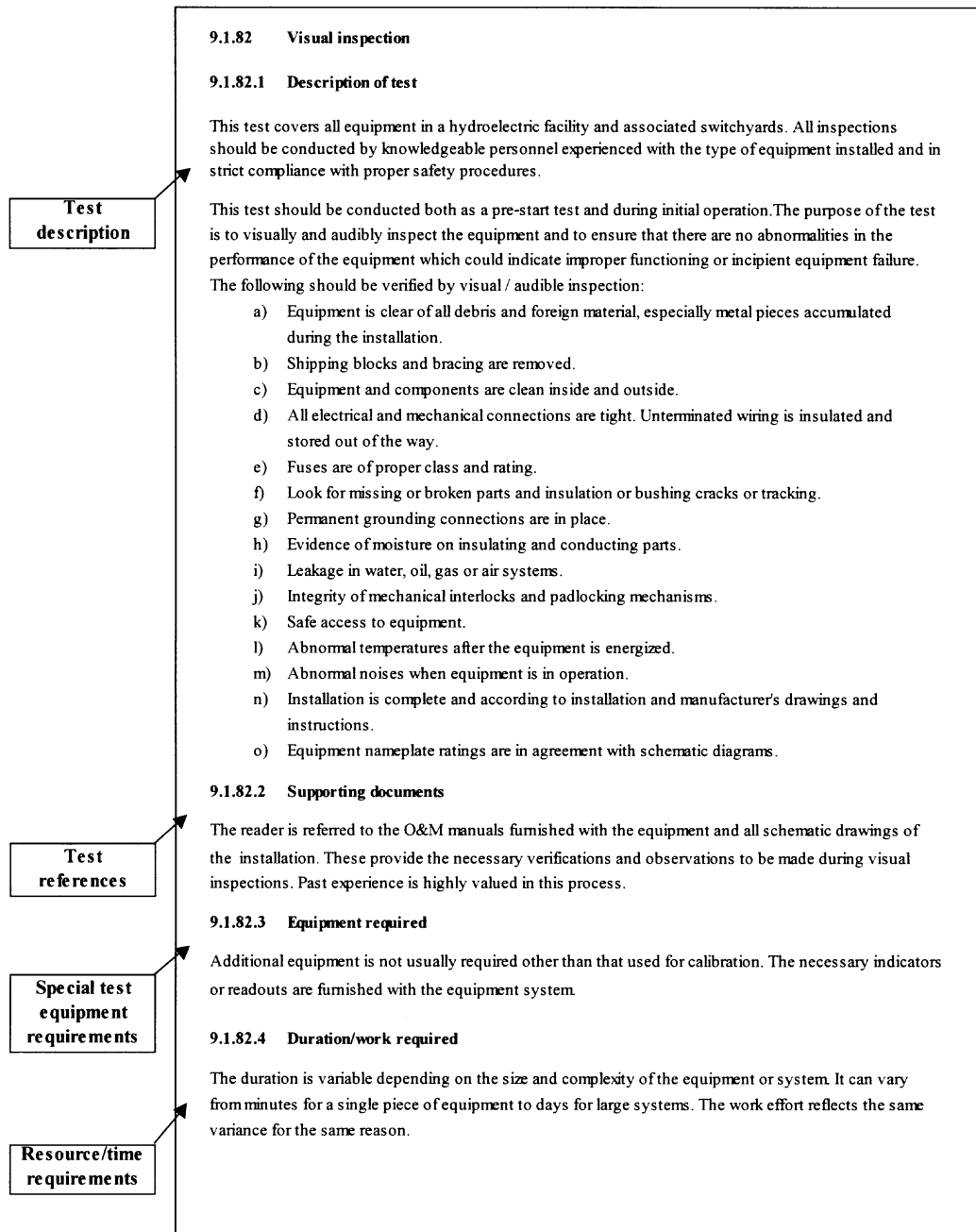


Figure 2—Example of a test description

## 8. Plant equipment

### 8.1 List of equipment and test matrixes

8.1.1 AC POWER—Low and medium voltage switchgear

8.1.2 AC POWER—Motor control centers (600 V class)

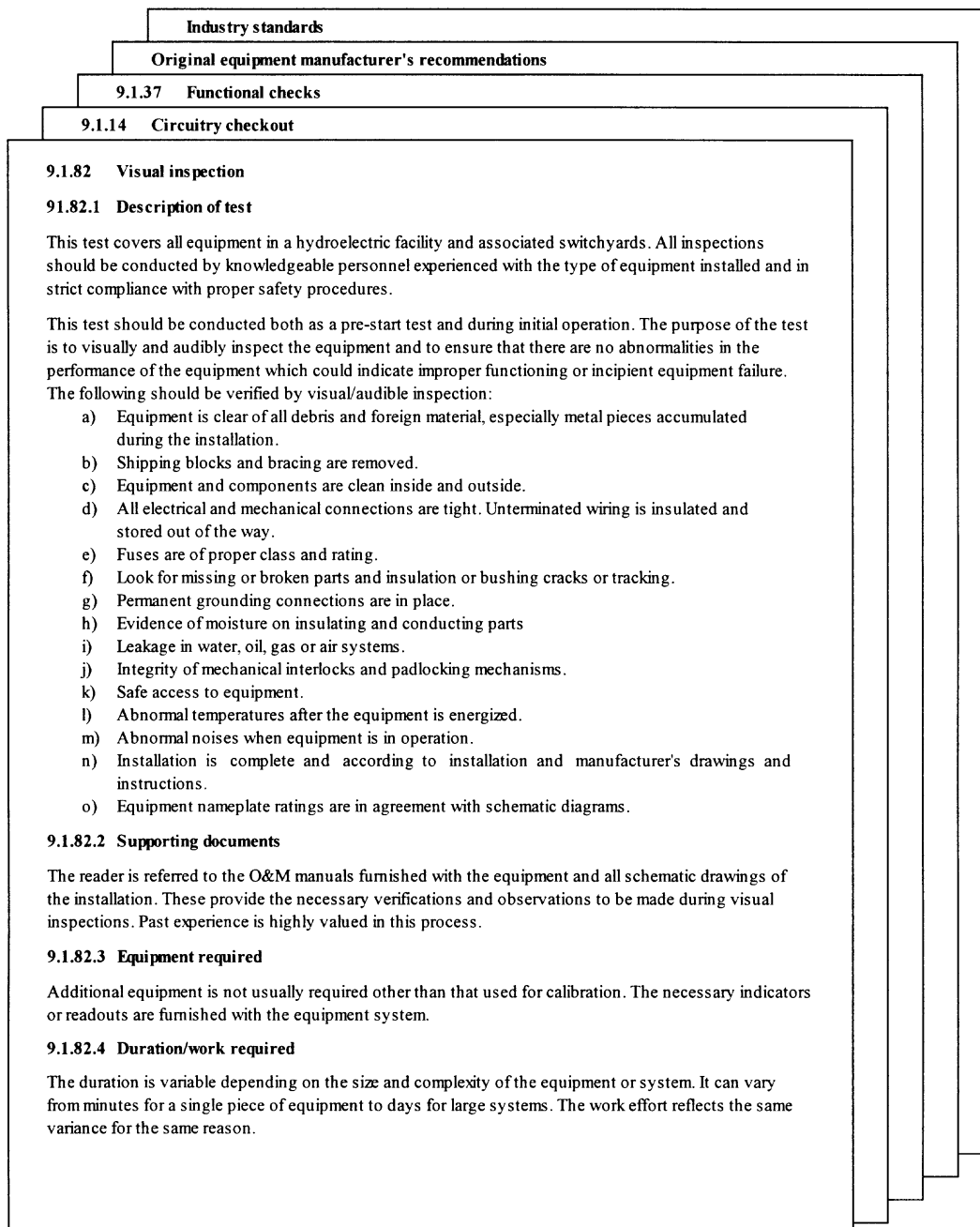
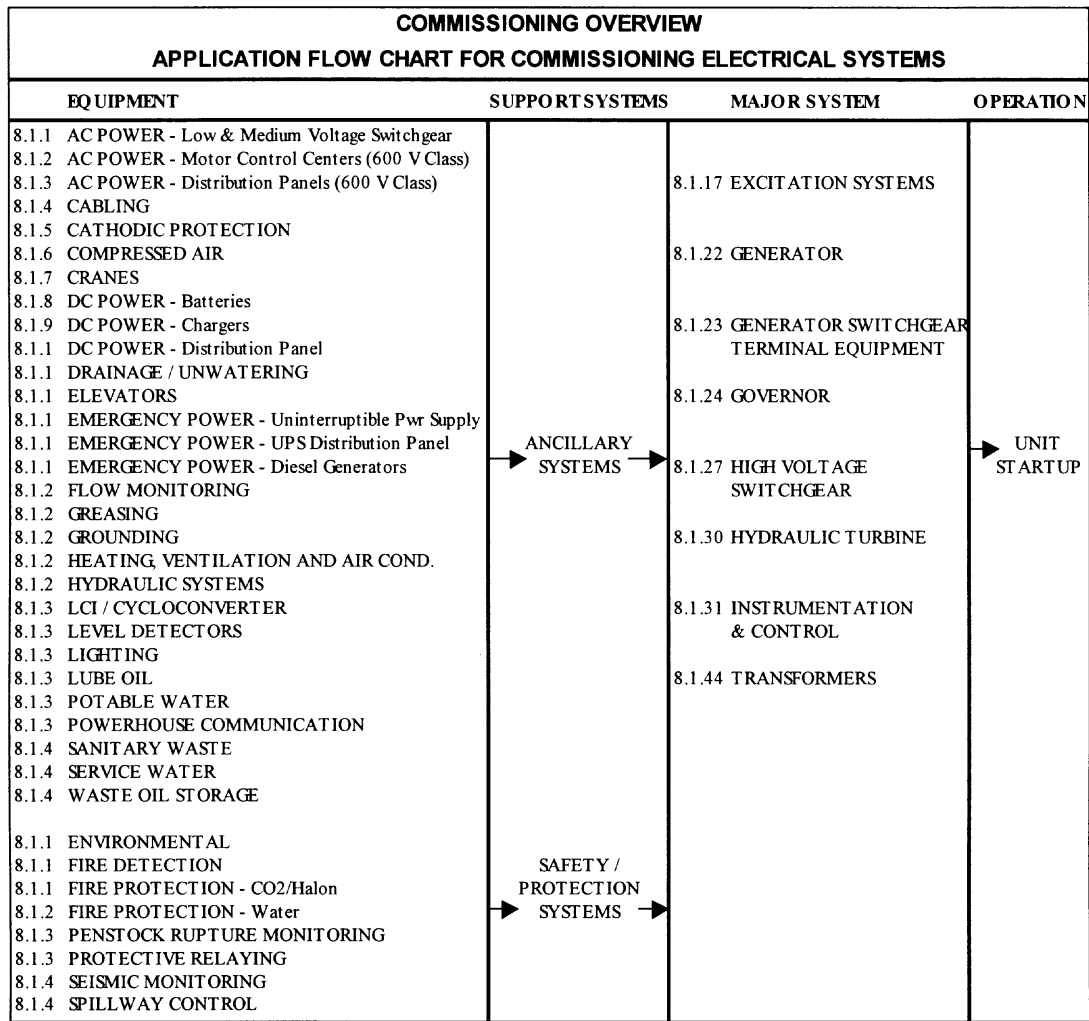


**Figure 3—Test package, excitation system control**

- 8.1.3 AC POWER—Distribution panels (600 V class)
- 8.1.4 CABLING
- 8.1.5 CATHODIC PROTECTION
- 8.1.6 COMPRESSED AIR
- 8.1.7 CRANES
- 8.1.8 DC POWER—Batteries
- 8.1.9 DC POWER—Chargers
- 8.1.10 DC POWER—Distribution panel
- 8.1.11 DRAINAGE/UNWATERING



#### Figure 4—Development of a plant commissioning program

- 8.1.12 ELEVATORS**
- 8.1.13 EMERGENCY POWER**—Uninterruptible power supply (UPS)
- 8.1.14 EMERGENCY POWER**—UPS distribution panel
- 8.1.15 EMERGENCY POWER**—Diesel generators
- 8.1.16 ENVIRONMENTAL**
- 8.1.17 EXCITATION SYSTEMS**
- 8.1.18 FIRE DETECTION**
- 8.1.19 FIRE PROTECTION**—CO<sub>2</sub>/Halon
- 8.1.20 FIRE PROTECTION**—Water
- 8.1.21 FLOW MONITORING**
- 8.1.22 GENERATOR**
- 8.1.23 GENERATOR SWITCHGEAR/TERMINAL EQUIPMENT**
- 8.1.24 GOVERNOR**
- 8.1.25 GREASING**
- 8.1.26 GROUNDING**
- 8.1.27 HIGH-VOLTAGE SWITCHGEAR**
- 8.1.28 HEATING, VENTILATION, AND AIR CONDITIONING**
- 8.1.29 HYDRAULIC SYSTEMS**

- 8.1.30 HYDRAULIC TURBINE
- 8.1.31 INSTRUMENTATION AND CONTROL
- 8.1.32 LOAD COMMUTATING INVERTER/CYCLOCONVERTER
- 8.1.33 LEVEL DETECTORS
- 8.1.34 LIGHTING
- 8.1.35 LUBE OIL
- 8.1.36 PENSTOCK RUPTURE MONITORING
- 8.1.37 POTABLE WATER
- 8.1.38 POWERHOUSE COMMUNICATION
- 8.1.39 PROTECTIVE RELAYING
- 8.1.40 SANITARY WASTE
- 8.1.41 SEISMIC MONITORING
- 8.1.42 SERVICE WATER
- 8.1.43 SPILLWAY CONTROL
- 8.1.44 TRANSFORMERS
- 8.1.45 WASTE OIL STORAGE

| 8.1.1<br>AC POWER<br>Medium- and low-voltage<br>switchgear |      |                   |                     |                       |                   |                |               |        |                |                    |             |              |                    |                   |                               |                                     |                   |  |  |
|------------------------------------------------------------|------|-------------------|---------------------|-----------------------|-------------------|----------------|---------------|--------|----------------|--------------------|-------------|--------------|--------------------|-------------------|-------------------------------|-------------------------------------|-------------------|--|--|
| EQUIPMENT/SYSTEM                                           | TEST | Visual inspection | Bolted joint torque | Insulation resistance | Continuity checks | High potential | Polarity (ac) | Ratios | Phase relation | Circuitry checkout | Calibration | Bus transfer | Contact resistance | Functional checks | Instrument transformer burden | Current transformer (CT) saturation | Initial operation |  |  |
|                                                            |      |                   |                     |                       |                   |                |               |        |                |                    |             |              |                    |                   |                               |                                     |                   |  |  |
| System                                                     |      |                   |                     |                       |                   |                |               |        |                |                    |             | X            |                    |                   |                               |                                     | X                 |  |  |
| Switchgear cubicle                                         | X    |                   |                     |                       |                   |                |               |        |                |                    |             |              |                    |                   |                               |                                     |                   |  |  |
| Circuit breakers                                           | X    |                   | X                   |                       |                   |                |               |        |                |                    |             |              | X                  | X                 |                               |                                     |                   |  |  |
| Vacuum interrupter                                         | X    |                   |                     |                       |                   | X              |               |        |                |                    |             |              |                    |                   |                               |                                     |                   |  |  |
| SF6 interrupter                                            | X    |                   |                     |                       |                   | X              |               |        |                |                    |             |              |                    |                   |                               |                                     |                   |  |  |
| Arc chutes                                                 | X    |                   |                     |                       |                   |                |               |        |                |                    |             |              |                    |                   |                               |                                     |                   |  |  |
| Current transformers                                       | X    |                   | X                   | X                     |                   | X              | X             | X      | X              |                    |             |              |                    |                   | X                             | X                                   |                   |  |  |
| Potential transformers                                     | X    |                   | X                   | X                     |                   | X              | X             | X      | X              |                    |             |              |                    |                   | X                             |                                     |                   |  |  |
| Power cable                                                | X    |                   | X                   | X                     | X                 |                |               |        | X              |                    |             |              |                    |                   |                               |                                     |                   |  |  |
| Control cable                                              | X    |                   | X                   | X                     |                   |                |               |        |                | X                  |             |              |                    |                   |                               |                                     |                   |  |  |
| Bus bar                                                    | X    | X                 | X                   | X                     | X                 |                |               |        | X              |                    |             |              |                    |                   |                               |                                     |                   |  |  |
| Meters                                                     | X    |                   |                     |                       |                   |                |               |        |                | X                  | X           |              |                    | X                 |                               |                                     |                   |  |  |
| Relays                                                     | X    |                   |                     |                       |                   |                |               |        |                | X                  | X           |              |                    | X                 |                               |                                     |                   |  |  |
| Instruments                                                | X    |                   |                     |                       |                   |                |               |        |                | X                  | X           |              |                    | X                 |                               |                                     |                   |  |  |
| Control switches                                           | X    |                   |                     |                       |                   |                |               |        |                | X                  |             |              |                    | X                 |                               |                                     |                   |  |  |
| Selector switches                                          | X    |                   |                     |                       |                   |                |               |        | X              | X                  |             |              |                    | X                 |                               |                                     |                   |  |  |
| Synchronizing panel                                        | X    |                   |                     |                       |                   |                |               |        | X              | X                  |             |              |                    | X                 |                               |                                     |                   |  |  |
| Ground cable                                               | X    | X                 | X                   |                       |                   |                |               |        |                |                    |             |              |                    |                   |                               |                                     |                   |  |  |
| Fuses                                                      | X    |                   |                     |                       |                   |                |               |        |                | X                  |             |              |                    |                   |                               |                                     |                   |  |  |
| Power cable lugs                                           | X    | X                 | X                   |                       |                   |                |               |        |                |                    |             |              |                    |                   |                               |                                     |                   |  |  |
| Surge protectors                                           | X    |                   | X                   |                       |                   |                |               |        | X              |                    |             |              |                    |                   |                               |                                     |                   |  |  |
| Ground sensors                                             | X    |                   |                     |                       | X                 |                |               |        |                | X                  |             |              |                    | X                 |                               |                                     |                   |  |  |
| Circuit interrupter                                        | X    |                   |                     |                       |                   |                |               |        |                |                    |             |              | X                  |                   |                               |                                     |                   |  |  |
|                                                            |      |                   |                     |                       |                   |                |               |        |                |                    |             |              |                    |                   |                               |                                     |                   |  |  |
|                                                            |      |                   |                     |                       |                   |                |               |        |                |                    |             |              |                    |                   |                               |                                     |                   |  |  |
|                                                            |      |                   |                     |                       |                   |                |               |        |                |                    |             |              |                    |                   |                               |                                     |                   |  |  |
|                                                            |      |                   |                     |                       |                   |                |               |        |                |                    |             |              |                    |                   |                               |                                     |                   |  |  |
|                                                            |      |                   |                     |                       |                   |                |               |        |                |                    |             |              |                    |                   |                               |                                     |                   |  |  |

### 8.1.2 AC POWER

Motor control centers (MCCs)  
(600 V class)

8.1.3  
AC POWER  
Distribution panels  
(600 V class)

### 8.1.4 CABLING

### 8.1.5 CATHODIC PROTECTION

### 8.1.6 COMPRESSED AIR

| 8.1.7<br>CRANES       |      |                   |                       |                   |                |             |                    |                |           |                 |                   |                   |  |  |  |  |  |  |
|-----------------------|------|-------------------|-----------------------|-------------------|----------------|-------------|--------------------|----------------|-----------|-----------------|-------------------|-------------------|--|--|--|--|--|--|
| EQUIPMENT/SYSTEM      | TEST | Visual inspection | Insulation resistance | Continuity checks | Phase relation | Calibration | Circuitry checkout | Braking system | Load test | Crane operation | Functional checks | Initial operation |  |  |  |  |  |  |
|                       |      |                   |                       |                   |                |             |                    |                |           |                 |                   |                   |  |  |  |  |  |  |
| System                |      |                   |                       |                   |                |             |                    |                | X         | X               |                   | X                 |  |  |  |  |  |  |
| Power cable           |      | X                 | X                     | X                 | X              |             |                    |                |           |                 |                   |                   |  |  |  |  |  |  |
| Crane rail busbar     |      | X                 | X                     |                   | X              |             |                    |                |           |                 |                   |                   |  |  |  |  |  |  |
| Power rail shoes      |      | X                 | X                     |                   |                |             |                    |                |           |                 |                   |                   |  |  |  |  |  |  |
| Disconnect switches   |      | X                 | X                     |                   | X              |             |                    |                |           |                 | X                 |                   |  |  |  |  |  |  |
| Deadman safety switch |      | X                 |                       |                   |                |             | X                  | X              |           |                 | X                 |                   |  |  |  |  |  |  |
| Circuit breakers      |      | X                 | X                     | X                 | X              |             | X                  |                |           |                 | X                 |                   |  |  |  |  |  |  |
| Gear boxes            |      | X                 |                       |                   |                |             |                    |                |           |                 |                   |                   |  |  |  |  |  |  |
| Crane rope            |      | X                 |                       |                   |                |             |                    |                |           |                 |                   |                   |  |  |  |  |  |  |
| Crane hooks           |      | X                 |                       |                   |                |             |                    |                |           |                 |                   |                   |  |  |  |  |  |  |
| Lifting sheaves       |      | X                 |                       |                   |                |             |                    |                |           |                 |                   |                   |  |  |  |  |  |  |
| Bumper stops          |      | X                 |                       |                   |                |             |                    |                |           |                 |                   |                   |  |  |  |  |  |  |
| Limit switches        |      | X                 |                       | X                 |                |             | X                  |                |           |                 | X                 |                   |  |  |  |  |  |  |
| Runway rail alignment |      | X                 |                       |                   |                |             |                    |                |           |                 |                   |                   |  |  |  |  |  |  |
| Alarm bell            |      | X                 |                       |                   |                |             | X                  |                |           |                 | X                 |                   |  |  |  |  |  |  |
| Flashing lights       |      | X                 |                       |                   |                |             | X                  |                |           |                 | X                 |                   |  |  |  |  |  |  |
| Cab controls          |      | X                 |                       |                   |                |             | X                  |                |           |                 | X                 |                   |  |  |  |  |  |  |
| Breaks                |      | X                 |                       |                   |                |             | X                  | X              |           |                 | X                 |                   |  |  |  |  |  |  |
| Pendant cable         |      | X                 | X                     | X                 |                |             | X                  |                |           |                 |                   |                   |  |  |  |  |  |  |
| Pendant controls      |      | X                 |                       |                   |                |             | X                  |                |           |                 | X                 |                   |  |  |  |  |  |  |
| Power cable reel      |      | X                 |                       |                   |                |             |                    |                |           |                 |                   |                   |  |  |  |  |  |  |
| Ground cable          |      | X                 | X                     |                   |                |             |                    |                |           |                 |                   |                   |  |  |  |  |  |  |
| Hoist motors          |      | X                 | X                     |                   | X              |             |                    |                |           |                 | X                 |                   |  |  |  |  |  |  |
| Bridge motor          |      | X                 | X                     |                   | X              |             |                    |                |           |                 | X                 |                   |  |  |  |  |  |  |
| Trolley motor         |      | X                 | X                     |                   | X              |             |                    |                |           |                 | X                 |                   |  |  |  |  |  |  |
| Control panel         |      |                   |                       | X                 |                | X           | X                  |                |           |                 | X                 |                   |  |  |  |  |  |  |
| Relays                |      |                   |                       |                   |                | X           | X                  |                |           |                 | X                 |                   |  |  |  |  |  |  |
| Meters                |      |                   |                       |                   |                | X           | X                  |                |           |                 | X                 |                   |  |  |  |  |  |  |

### 8.1.8 DC POWER Batteries

[illegible]

[illegible]

8.1.10  
DC POWER  
Distribution panel

### 8.1.11 DRAINAGE/UNWATER-ING

### 8.1.12 ELEVATORS

### 8.1.13 EMERGENCY POWER UPS

8.1.14  
EMERGENCY POWER  
UPS distribution panel

| 8.1.15<br>EMERGENCY POWER<br>Diesel generators |      |                   |                  |                       |                   |                |                      |                    |               |        |                |             |              |                   |                               |               |                   |  |  |
|------------------------------------------------|------|-------------------|------------------|-----------------------|-------------------|----------------|----------------------|--------------------|---------------|--------|----------------|-------------|--------------|-------------------|-------------------------------|---------------|-------------------|--|--|
| EQUIPMENT/SYSTEM                               | TEST | Visual inspection | Pressure testing | Insulation resistance | Continuity checks | High potential | Circuit-breaker trip | Circuitry checkout | Polarity (ac) | Ratios | Phase relation | Calibration | Leak testing | Functional checks | Instrument transformer burden | CT Saturation | Initial operation |  |  |
| System                                         |      |                   |                  |                       |                   |                |                      |                    |               |        |                |             |              |                   |                               |               | X                 |  |  |
| Diesel engine                                  | X    |                   |                  |                       |                   |                |                      |                    |               |        |                |             |              | X                 |                               |               |                   |  |  |
| Diesel generator                               | X    |                   |                  | X                     | X                 | X              |                      |                    |               |        | X              |             |              | X                 |                               |               |                   |  |  |
| Fuel oil storage tank                          | X    |                   |                  |                       |                   |                |                      |                    |               |        |                |             | X            |                   |                               |               |                   |  |  |
| Fuel oil day tank                              | X    |                   |                  |                       |                   |                |                      |                    |               |        |                |             | X            |                   |                               |               |                   |  |  |
| Fuel oil pump                                  | X    |                   |                  |                       |                   |                |                      |                    |               |        |                |             | X            | X                 |                               |               |                   |  |  |
| Piping                                         | X    | X                 |                  |                       |                   |                |                      |                    |               |        |                |             | X            |                   |                               |               |                   |  |  |
| Valves                                         | X    | X                 |                  |                       |                   |                |                      |                    |               |        |                |             | X            | X                 |                               |               |                   |  |  |
| Strainers                                      | X    |                   |                  |                       |                   |                |                      |                    |               |        |                |             | X            |                   |                               |               |                   |  |  |
| Exhaust system                                 | X    |                   |                  |                       |                   |                |                      |                    |               |        |                |             | X            |                   |                               |               |                   |  |  |
| Diesel panel                                   | X    |                   |                  |                       | X                 |                |                      | X                  |               |        |                |             |              | X                 |                               |               |                   |  |  |
| Circuit breakers                               | X    |                   | X                |                       |                   | X              |                      |                    |               |        |                |             |              | X                 |                               |               |                   |  |  |
| Current transformers                           | X    |                   | X                | X                     |                   |                |                      | X                  | X             | X      | X              |             |              |                   | X                             | X             |                   |  |  |
| Potential transformers                         | X    |                   | X                | X                     |                   |                |                      | X                  | X             | X      | X              |             |              |                   | X                             |               |                   |  |  |
| Power cable                                    | X    |                   | X                | X                     | X                 |                |                      |                    |               |        | X              |             |              |                   |                               |               |                   |  |  |
| Control cable                                  | X    |                   | X                | X                     |                   |                |                      | X                  |               |        |                |             |              |                   |                               |               |                   |  |  |
| Meters                                         | X    |                   |                  |                       |                   |                |                      | X                  |               |        |                | X           |              | X                 |                               |               |                   |  |  |
| Relays                                         | X    |                   |                  |                       |                   |                |                      | X                  |               |        |                | X           |              | X                 |                               |               |                   |  |  |
| Instruments                                    | X    |                   |                  |                       |                   |                |                      | X                  |               |        |                | X           |              | X                 |                               |               |                   |  |  |
| Control switches                               | X    |                   |                  |                       |                   |                |                      | X                  |               |        |                |             |              | X                 |                               |               |                   |  |  |
| Synchronizing equipment                        | X    |                   |                  |                       |                   |                |                      | X                  |               |        | X              |             |              | X                 |                               |               |                   |  |  |
| Ground cable                                   | X    |                   | X                |                       |                   |                |                      |                    |               |        |                |             |              |                   |                               |               |                   |  |  |
| Fuses                                          | X    |                   |                  |                       |                   |                |                      | X                  |               |        |                |             |              |                   |                               |               |                   |  |  |
| Motors                                         | X    |                   | X                |                       |                   |                |                      |                    |               |        |                |             |              | X                 |                               |               |                   |  |  |
| Transfer switch                                | X    |                   |                  |                       |                   |                |                      |                    |               |        |                |             |              | X                 |                               |               |                   |  |  |
| Starting system                                | X    |                   |                  |                       |                   |                |                      |                    |               |        |                |             |              | X                 |                               |               |                   |  |  |
| Control panel                                  | X    |                   |                  |                       |                   |                |                      | X                  |               |        |                |             |              | X                 |                               |               |                   |  |  |

[illegible]

### 8.1.17 EXCITATION SYSTEMS

### 8.1.18 FIRE DETECTION

8.1.19  
FIRE PROTECTION  
CO<sub>2</sub>/Halon

| 8.1.20<br>FIRE PROTECTION<br>Water |      |                   |                  |                       |                   |                      |                    |             |                                     |                   |                   |  |  |  |  |  |  |  |  |
|------------------------------------|------|-------------------|------------------|-----------------------|-------------------|----------------------|--------------------|-------------|-------------------------------------|-------------------|-------------------|--|--|--|--|--|--|--|--|
| EQUIPMENT/SYSTEM                   | TEST | Visual inspection | Pressure testing | Insulation resistance | Continuity checks | Circuit-breaker trip | Circuitry checkout | Calibration | Fire code (H <sub>2</sub> O system) | Functional checks | Initial operation |  |  |  |  |  |  |  |  |
| System                             |      |                   |                  |                       |                   |                      |                    |             |                                     |                   | X                 |  |  |  |  |  |  |  |  |
| Penstock valves                    |      | X                 | X                |                       |                   |                      |                    |             | X                                   | X                 |                   |  |  |  |  |  |  |  |  |
| Strainer                           |      | X                 | X                |                       |                   |                      |                    |             | X                                   |                   |                   |  |  |  |  |  |  |  |  |
| Blowdown valve                     |      | X                 | X                |                       |                   |                      |                    |             | X                                   | X                 |                   |  |  |  |  |  |  |  |  |
| Head tank                          |      | X                 | X                |                       |                   |                      |                    |             | X                                   |                   |                   |  |  |  |  |  |  |  |  |
| Piping                             |      | X                 | X                |                       |                   |                      |                    |             | X                                   |                   |                   |  |  |  |  |  |  |  |  |
| Valves                             |      | X                 | X                |                       |                   |                      |                    |             | X                                   | X                 |                   |  |  |  |  |  |  |  |  |
| Sprinkler heads                    |      | X                 | X                |                       |                   |                      |                    |             | X                                   | X                 |                   |  |  |  |  |  |  |  |  |
| Deluge valves                      |      | X                 | X                |                       |                   |                      | X                  |             | X                                   | X                 |                   |  |  |  |  |  |  |  |  |
| Hose stations/hydrants             |      | X                 |                  |                       |                   |                      |                    |             | X                                   |                   |                   |  |  |  |  |  |  |  |  |
| Fire detectors                     |      | X                 |                  |                       |                   |                      | X                  |             | X                                   | X                 |                   |  |  |  |  |  |  |  |  |
| Emergency fire pump                |      | X                 |                  |                       |                   |                      | X                  |             | X                                   | X                 |                   |  |  |  |  |  |  |  |  |
| Jockey pump                        |      | X                 |                  |                       |                   |                      | X                  |             | X                                   | X                 |                   |  |  |  |  |  |  |  |  |
| Motors                             |      | X                 |                  | X                     |                   |                      | X                  |             | X                                   | X                 |                   |  |  |  |  |  |  |  |  |
| Circuit breakers                   |      | X                 |                  | X                     | X                 | X                    | X                  |             | X                                   | X                 |                   |  |  |  |  |  |  |  |  |
| Motor starters                     |      | X                 |                  | X                     | X                 |                      | X                  |             | X                                   | X                 |                   |  |  |  |  |  |  |  |  |
| Power cable                        |      | X                 |                  | X                     | X                 |                      |                    |             | X                                   |                   |                   |  |  |  |  |  |  |  |  |
| Control cable                      |      | X                 |                  | X                     | X                 |                      | X                  |             | X                                   |                   |                   |  |  |  |  |  |  |  |  |
| Instruments                        |      | X                 |                  |                       |                   |                      | X                  | X           | X                                   | X                 |                   |  |  |  |  |  |  |  |  |
| Gauges                             |      | X                 |                  |                       |                   |                      | X                  | X           | X                                   | X                 |                   |  |  |  |  |  |  |  |  |
| Pressure controller                |      | X                 | X                |                       |                   |                      |                    | X           | X                                   | X                 |                   |  |  |  |  |  |  |  |  |
| Ground cable                       |      | X                 |                  | X                     |                   |                      |                    |             | X                                   |                   |                   |  |  |  |  |  |  |  |  |
| Alarm devices                      |      | X                 |                  |                       | X                 |                      | X                  |             | X                                   | X                 |                   |  |  |  |  |  |  |  |  |
|                                    |      |                   |                  |                       |                   |                      |                    |             |                                     |                   |                   |  |  |  |  |  |  |  |  |
|                                    |      |                   |                  |                       |                   |                      |                    |             |                                     |                   |                   |  |  |  |  |  |  |  |  |
|                                    |      |                   |                  |                       |                   |                      |                    |             |                                     |                   |                   |  |  |  |  |  |  |  |  |
|                                    |      |                   |                  |                       |                   |                      |                    |             |                                     |                   |                   |  |  |  |  |  |  |  |  |
|                                    |      |                   |                  |                       |                   |                      |                    |             |                                     |                   |                   |  |  |  |  |  |  |  |  |

### 8.1.21 FLOW MONITORING