Guideline for Testing and Commissioning of Small Hydro Power Plant for Feed-in-Tariff (FiT) Projects in Malaysia

SUSTAINABLE ENERGY DEVELOPMENT AUTHORITY (SEDA)

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FOREWORD

The enforcement of the Renewable Energy Act 2011 (Act 725) on 1st December 2011 has enabled the Feed-in-Tariff (FiT) mechanism to be implemented in Malaysia paving for a sustainable for renewable energy (RE) growth trajectory for the RE Industry in Malaysia including small hydro. This RE resource has shown promising development and it can be seen from the number of projects which has benefited from the FiT mechanism. The production of electricity by harnessing the power of flowing water from lakes, rivers, and streams has a huge potential to be tapped for power generation. SEDA Malaysia, being the agency responsible for facilitation of RE growth is playing its role to ensure installations especially those under the FiT mechanism meet and complying to the international standards in terms of quality, reliability and safety which will indirectly impact the performance of the small hydro power plants.

The Guideline for Testing and Commissioning of Small Hydro Power Plant in Malaysia for projects under the FiT mechanism is prepared to provide assistance to the Feed-in Approval Holders (FiAHs) under the small hydro category. It is prepared and deliberated together with the local stakeholders including small hydro developers, consultants, Suruhanjaya Tenaga, Tenaga Nasional Bhd, Sabah Electricity Sdn Bhd, etc. This Guideline is prepared with intent to provide guide in carrying out tests required in ensuring the plants can operate in reliable and optimal manner.

To ensure its effectiveness and relevant to be used, the Guideline was tested and revised to suit the local requirements. Another engagement with the local developers was conducted again for final review. It is dubbed that this is the first ever Guideline for Testing and Commissioning of small hydro power plants available for Malaysia.

I wish to express my gratitude to the stakeholders and beneficiaries who has deliberated and contributed in giving inputs in the process of preparing the Guideline which will be an important document for use by the small hydro industry players under the FiT mechanism.

Catherine Ridu
Chief Executive Officer
SEDA Malaysia

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1.0 OVERVIEW

The Feed in Tariff (FiT) is Malaysia's financial mechanism under the Renewable Policy and Action Plan to catalyse generation of Renewable Energy (RE), up to 30 MW in size. The mechanism allows electricity produced from RE resources to be sold to power utilities at a fixed premium price for a specific duration to enable financial viability of RE plant development.

FiT rates had been introduced through RE Act in 2011 to promote RE technology in Malaysia. One of the RE technology which qualifies for FiT is small hydro - using the energy in flowing water to produce electricity

Hydropower systems use the energy in flowing water to produce electricity or mechanical energy. The water flows via channel or penstock to a waterwheel or turbine where it strikes the bucket of the wheel, causing the shaft of the waterwheel or turbine to rotate. When generating electricity, the rotating shaft, which is connected to an alternator or generator, converts the motion of the shaft into electrical energy.

A small scale hydroelectric facility requires that a sizable flow of water and a proper height of fall of water, called head, is obtained without building elaborate and expensive facilities. The sample of small scale hydroelectric facility using run off river concept are depicted in Figure 1. The overall performance of the power plants depends on the performance of each of this section, indicated by numbers of key performance indicators.

This procedure, therefore, has been prepared with intent to provide guidelines to such team for carrying out testing and commissioning of either horizontal or vertical machines successfully.

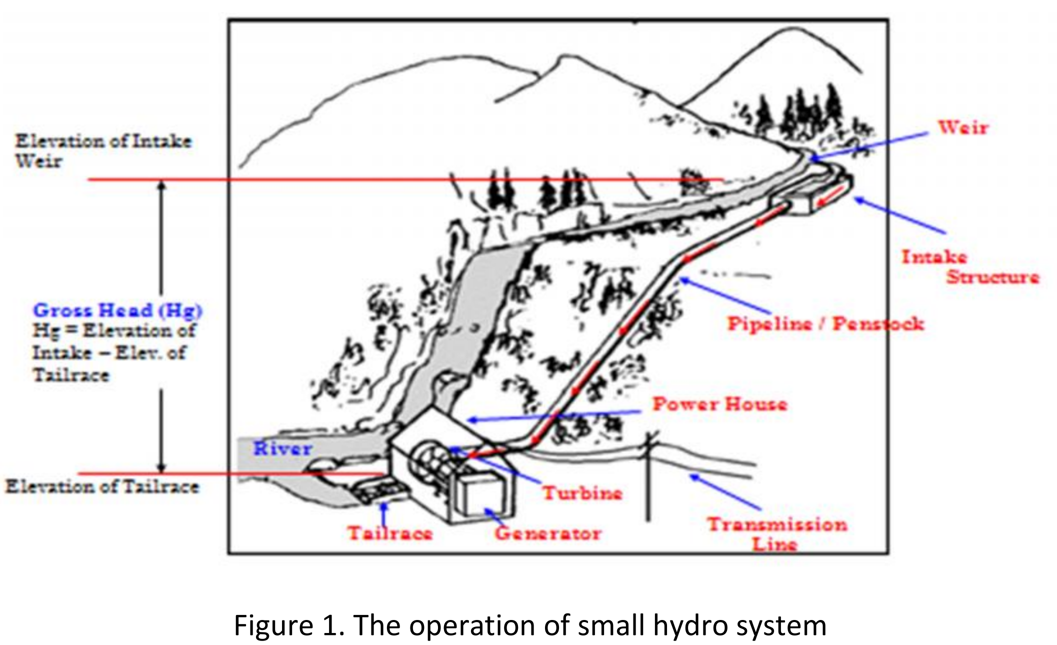

Figure 1. The operation of small hydro system

2.0 REFERENCES AND STANDARDS

1. (IEC) 62006:2010-10 –Hydraulic machines- Acceptance tests of small hydroelectric installation
2. (ASCE) Manuals and Reports on Engineering Practice No.79 – Steel Penstocks (Second Edition)
3. IEEE 1248 – 1998 Guide for the Commissioning of Electrical System in Hydroelectric Power Plant
4. Indian Institute of Technology Roorkee – Guidelines for Small Hydro Development.
5. AWWA Manual M11 – Steel Pipe – A Guide for Design and Installation.
6. Technical Guidebook for the Connection of Generation to Distribution Network by TNB Research – First Edition

3.0 DEFINITION AND ACRONYMS

Alternating current (AC) Electric current that reverses its polarity periodically (in contrast to direct current). In Malaysia the standard cycle frequency is 50 Hz (1 Hz = 1 cycle /sec.)

Ampere (amp) A unit of electric current or rate of flow of electrons. One volt cross 1ohm of resistance causes a current flow of 1 ampere.

Bifurcation A section of pipeline where the pipe is divided into two branching pipelines.

Bus bar A heavy metal conductor used to carry a large current.

Butterfly valve A valve designed for quick closure that consists of a circular leaf, slightly convex in form, mounted on a transverse shaft carried by two bearings and wholly enclosed in a circular pipe, which may be opened and closed by an external lever. Often operated by a hydraulic system.

Bypass valve Bypass (or turbine bypass) valve opens in step with closure of turbine wicket gates to divert flow from the turbine to a bypass pipe, thus allowing the turbine to be closed quickly without provoking excessive water hammer pressure rise on load rejection. Upon completion of a load adjustment the bypass valve closes slowly. This option provides good protection against water hammer resulting from load rejection but can only permit load acceptance at a slow rate. (*Alternative to surge tank*).

Capacity The load for which an electric generating unit, other electrical equipment or power line is rated.

Circuit

The complete path of an electric current, including the generating apparatus or other source; or, a specific segment or section of the complete path.

Circuit breaker

A safety device in an electrical circuit that automatically shuts off the circuit when it becomes overloaded. The device can be manually reset.

Conductor

A substance, body, device, or wire that readily conducts or carries electrical current.

Current (I)

The movement of electrons through a conductor, measured in amperes.

Cycle

A completed round of regularly recurring events or phenomena.

Dewatering

Removal of water from foundation excavations by pumping, drainage ditches etc.

Direct current (DC)

Electrical current flowing in one direction only and essentially free from pulsation.

Discharge

Volume of water that passes a given point within a given period of time.

Efficiency

Ratio of useful energy output to total energy input, usually expressed as a percent. Effective operation as measured by a comparison of production with cost.

Energy

The capacity for doing work as measured by the potential for doing work (potential energy) or the conversion of this potential to motion (kinetic energy). Work, measured in Newton-meters (or Joules). Energy has several forms, some of which are easily convertible and can be changed to another form useful for work. Most of the world's convertible energy comes from fossil fuels that are burned to produce heat that is then used as a transfer medium to mechanical or other means in order to accomplish tasks. Electrical energy is usually measured in kilowatt hours and represents power (kilowatts) operating for some period of time period (hours), while heat energy is usually measured in British thermal units. 1 kWh = 3.6 × 103 Joules.

Exciter

Device on a generator for controlling generator power factor and generator output voltage.

Flow

Quantity of water per second (m3/s) flowing at a given location. May be expressed as:

- Base flow, low/dry season flows sustained by contributions from ground water

- Mean flow – flows averaged over discrete periods typical, daily, monthly or yearly.
- Firm flow (or dependable flow) is determined as the flow available 90% to 100% of the time.
- Secondary flow, flow in excess of firm flow that may be used to generate additional (secondary) energy in periods of high inflows in interconnected systems.
- Peak flow, maximum flow due to a flood.

Flow duration curve Distribution curve showing flow versus percent of time equaled or exceeded for specified periods.

Flushing A method used to clean water distribution lines by passing a large amount of water through the system.

Frequency Refers to the rate of current reversals in AC electrical systems. The common system frequencies are 50 Hz.

Gate Movable devices in steel that are used to control water level and flow in headworks (intakes and spillway), canals, tunnels, powerhouse intakes and outlets, etc. Gates of the following types are common on hydropower projects:

- Vertical lift gate (wheeled type or sliding type)
- Radial gate in the form of a sector of a circle rotating about at trunnion.
- Pneumatic or rubber gate in the form of an inflated tube attached to the crest of a dam (weir). Gates may be raised or lowered using wire cables, chain hoists, screw jacks or hydraulic pistons.

Gate valve A valve with a circular-shaped closing element that fits securely over an opening through which water flows.

Gauge Device for registering water level, discharge, velocity, pressure, etc. Thickness of wire or sheet metal.

Gauge pressure Absolute pressure minus atmospheric pressure. The pressure within a closed container as measured with a gauge.

Generation The process of producing electric energy by transforming other forms of energy; also, the amount of electric energy produced, usually expressed in kilowatt hours (kWh).

Generator A machine that converts mechanical energy into electrical energy.

Governor Device for controlling turbine operation, there are three conventional types of governor:

- Speed governor, operates to keep turbine operating at the design rotational speed.
- Water level control operates to keep forebay water level constant (between prescribed limits).
- Load control governor operates to keep turbine operating at a selected load. All three functions may be provided in a single modern digital governor.

Grid A system of interconnected power lines and generators that is managed so that output of the generators is dispatched as needed to meet the requirements of the customers connected to the grid at various points.

Gross Head (Hg) Difference in elevation between the water levels of the fore bay and Tailrace.

GWh Giga Watt hour is a unit of energy equal to a million kWh or 10^9 Wh.

Head Differential of pressure causing flow in a fluid system, usually expressed in terms of the height of a liquid column that pressure will support.

Head loss The energy lost from a flowing fluid due to friction, transitions, bends, etc.

Hertz (Hz) The number of complete electromagnetic cycles or waves in one second of an electrical or electronic circuit.

Hydraulic Powered by water. Having to do with water in motion.

Hydraulic efficiency Efficiency of a pump or turbine to impart energy to or extract energy from water. The ability of hydraulic structure or element to conduct water with minimum energy loss.

Installed capacity A measure indicating the nominal generating capability of a project or unit, as designated by the manufacturer. Also termed *nameplate capacity.*

Intake A structure controlling entry of water from the river into the water conductor system or from a canal into a flume or pipeline.

Intake structure Concrete portion of an outlet works, including trash racks and/or fish screens, upstream from the tunnel or conduit portions.

Kaplan turbine Similar to propeller turbine but with adjustable runner blades and adjustable guide vanes, thus double-regulated.

Kilowatt (kW)	Unit of electric power equal to 1,000 watts or about 1.34 horsepower. For example, it's the amount of electric power required to light 10 100-watt light bulbs.
Kilowatt-hour (kWh)	The unit of electrical energy commonly used in marketing electric power; the energy produced by 1 kilowatt acting for one hour. Ten 100-watt light bulbs burning for one hour would consume one kilowatt hour of electricity.
Kinetic energy	The energy of a body with respect to the motion of the body.
Level	To make level or to cause to conform to a specified grade. Any instrument that can be used to indicate a horizontal line or plane.
Load(Electric)	The total customer demand for electric service at any given time. Or Amount of electrical capacity or energy delivered or required at a given point. Synonymous with electrical demand.
Megawatt (MW)	One million watts of electrical power (capacity).
Net head (Hn)	Net head is equal to gross head less all hydraulic losses between Intake to tailrace except those chargeable to the turbine.
Ohm	The unit of electrical resistance to current flow. The resistance in a conductor in which one volt of potential difference produces a current of one ampere.
Outage	The period during which a generating unit, transmission line, or other facility is out of service.
Output	The amount of power (or energy, depending on definition) delivered by a piece of equipment, station or system.
Over speed	The maximum speed a runner reaches when, under design conditions, all external loads are removed and turbine wicket gates are closed at the prescribed rate.
Peak load	The maximum power load in a stated period of time.
Penstock	Pressurized pipeline supplying water to the turbine from the Fore bay tank or reservoir. For low pressure pipelines at other locations in the water conductor system the term "pipeline" is preferred.
Plant	Station where mechanical energy is converted into electric energy.
Plant factor	Ratio of average energy production of a plant to the production obtained assuming the plant was operated continuously at its installed capacity (for the period under study)

Power	Mechanical or electrical force or energy. The rate at which work is done by an electrical energy or mechanical force, generally measured in kilowatts or horsepower. Also electrical energy generated, transferred, or used; usually expressed in kilowatts.
Power factor	The ratio of the amount of power, measured in kilowatts (kW) to the apparent power measured in kilovolt-amperes (kVA).
Power house	The building that houses electric generating equipment and related auxiliaries.
Power plant	Structure that houses turbines, generators, and associated control equipment.
Project	A single financial entity which can be composed of several units or divisions, integrated projects, or participating projects.
Propeller turbine	An axial flow turbine with adjustable guide vanes and fixed runner blades, thus single regulated.
Rated capacity	That capacity which a hydro generator can deliver without exceeding mechanical safety factors or allowable temperature rise for design head and design flow. In general this is also the *nameplate rating.*
Rated head	Water depth for which a hydroelectric generator and turbines were designed.
Reactive power	The portion of power that is produced by load inductances or capacitances.
Runaway speed	The maximum speed a turbine would reach if the wicket gates remained open after loss of full load (100% load rejection).
Runner	The rotating part of a turbine.
Run-of-river plant	Plant without storage reservoirs where water is used at the rate at which it "runs" in the river. The regulated inflow of one power plant is equal to the outflow from a power plant upstream.
Semi-Kaplan turbine	Fixed guide vanes and adjustable runner blades, single regulated.
Simple Surge tank	A simple surge tank is a tank connected by a short riser to the upstream pressure tunnel (or pipeline). The cross section area of the riser should be equal or greater than the cross section area of the tunnel (or pipeline).
Sluice	An opening for releasing water from below the static head elevation.

Sluice gate	A gate that can be opened or closed by sliding in supporting guides.
Specific weight	The weight per unit volume.
Specific speed	From consideration of flow, dynamic and geometric similitude it can be shown that runners having similar specific speeds will have similar geometries and operating characteristics. Specific speed is a parameter defined as Ns = No $\frac{\sqrt{P}}{H_4^5}$ where: Ns = specific speed No = design (synchronous speed (rpm) P = power in kW (or horsepower) H = Net head (m) Selection of type of turbine and synchronous speed (Ns is normally, based on empirical equations giving Ns as a function of H.
Speed	Refers to the rate of rotation of a generator in rotations per minute (rpm). The following formula gives the relationship between generator speed and (electric) system frequency.
Static head	The difference in elevation between the pumping source and the point of delivery. The vertical distance between two points in a fluid.
Stator	That portion of a generator which contains the stationary (non-moving) parts that surround the moving parts (rotor).
Stator windings	The armature or stationary winding of a synchronous generator.
Substation	Facility equipment that switches, changes, or regulates electric voltage.
Surge	A rapid increase in the depth of flow.
Surge tank	A surge tank provides protection against excessive water hammer pressure rise on load rejection and provides a volume of water for facilitating turbine start up on load acceptance. Types: - Simple type with minimal flow restriction in riser - Restricted orifice type with orifice in riser to dissipate energy orifice may have different loss characteristics for inflow and outflow. - Differential type with main tank and central riser with port holes (intermediate in behavior between simple and orifice types).
Switchyard	Area holding power transformers and outdoor equipment, etc.

Tailrace	The channel located between a hydroelectric powerhouse and the river into which the water is discharged after passing through the turbines.
Tail water level	The water level immediately downstream of a powerhouse.
Transformer	Device for increasing (stepping up) or decreasing (stepping down) line voltage between generator to transmission line and transmission line to distribution line.
Trash rack	Grating installed at the entrance to an intake to prevent floating debris from entering the water conductor (waterway) system or penstock.
Turbine	A machine for generating rotary mechanical power from the energy of flowing water. Turbines are of the following types: - Francis, radial flow to runner - Kaplan, axial flow to runner - Pelton, impulse type with 1-6 jets impinging a series of runner wheel buckets. - Cross-flow, a variant of the impulse type where jet impinges on entry and exit to the runner.
Unit	A turbine and connected generator that work together as a unit.
Uplift	The upward pressure in the pores of a material (interstitial pressure) on the base of a structure.
Valve	A device used to control the flow in a conduit, pipe, or tunnel that permanently obstructs a portion of the waterway.
Velocity	Rate of flow of water expressed in feet per second or miles per hour.
Volt(V)	The unit of measurement of electromotive force or electric pressure, akin to water pressure in pounds per square inch.
Voltage (E)	Electrical pressure, i.e. the force which causes current to flow through an electrical conductor.
Volt-ampere (VA)	A unit of apparent power in an ac circuit containing reactance.
Volt-amperes reactive (VARS)	The unit of measure for reactive power.
Water conductor system	System of canals, aqueducts, pipelines, tunnels - etc. for transporting water from intake to turbine. Sometimes termed *"waterway".*
Water hammer	Water hammer is a pressure wave produced in water piping system due to rapid valve opening or closing. This phenomenon sometimes produces audible "thumping" sounds in a piping system.

Waterways	*See* water conductor system.
Watt	Basic unit of electrical power produced at one time.
Watt hour(Wh)	An electrical energy unit of measure equal to one watt of power supplied to, or taken from, an electrical circuit steadily for one hour.
Weir	An overflow structure built across an open channel to raise the upstream water level and/or to measure the flow of water.
Wicket gate	In hydropower applications a gate which pivots open around the periphery of a turbine or pump to allow water to enter.

4.0 STARTUP – OWNER, CONTRACTOR, ENGINEER, MANUFACTURER

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.

Pre-commissioning test is to ensure all tests and checks necessary of each plant system are functional before startup of commissioning testing of the overall integrated plant commences. The purpose of these procedures is to verify that each system performs in accordance with design requirements.

Commissioning 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 pre-commissioning 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 pre-commissioning testing on contractor-furnished equipment and systems in accordance with test requirements contained within the contract;
b) Performs commissioning testing on owner-furnished equipment in accordance with the contract;
c) Records test data results during construction and pre-commissioning 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 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 pre-commissioning testing will occur on contractor-furnished equipment and owner-furnished equipment;

g) Provides craft personnel required during testing by the contractor, and in support of all 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;
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 Engineer

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

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 or 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 run-out checks;

c) Rotor diameter measurement;

d) Rotor roundness measurement;

e) Stator bore diameter measurement;

f) Stator roundness measurement;

g) Air-gap 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) Over-speed tests; and

s) Load rejection tests.

5.0 TESTING AND COMMISSIONING SMALL HYDRO POWER PLANTS

There are two phases of testing and commissioning of a small hydro power plant which are:

a) Pre-Commissioning Test

b) Commissioning Test

5.1 Pre-Commissioning Testing

The contractor required to performs inspections and tests to ensure all the installation are in accordance with the contract requirement. The results of this testing should be documented by the contractor and submitted to the pre-operational testing group. The Pre-Commissioning Testing includes:

5.1.1 Civil and Structure Works – Civil And Pipeline

5.1.1.1 Watering – Up

The watering of the waterway system such as intake and pipeline represents significant readiness of the overall system. This section describes the initial watering and the subsequent steps and activities

The initial watering is crucial as it is the first time the whole waterway system under full water loading. As such, proper procedures must be adopted. These must be done under slow rates and controlled conditions. If the system has Pressure Relief Valves or Plunger Valves, they should be commissioned in isolation to ensure opening set points, opening times and closing times are per design.

i. Start-up procedures
   The following documents shall be furnished;

a) Inspection procedure document relates to the method statement of conducting the pre-commission checking/inspection on the civil and pipeline structures. The structures shall be the intake system, pipeline, surge tank and the fittings/appurtenances.

b) Civil monitoring program document that illustrates the critical civil facilities to be monitored; before, during, and after watering-up or start-up, their frequency, their acceptance criteria, the responsible personnel, communication and sign-off (accountability) for all components.

ii. Before watering

The following works are to be completed and the supervising engineer shall truly endorsed:

a) Baseline survey shall be taken of monuments or significant features to be used for short- and long term measurement
b) The measurement must be taken using appropriate equipment such as theodolite, dumpy levels, etc.
c) Emergency closure systems (ECS) must be complete, dry tested and functional. Such equipment is sluice valve, gate valve or other similar apparatus that are designed to close (manual or automatic) under flow conditions and to stop water from flowing downstream.
d) Where possible interior of the penstock has been inspected, to ensure construction debris and tools are removed and all personnel have vacated the system.
e) The exterior of the system have been inspected to ensure all manholes and gate valves have been closed and air valves are open. The air vent usually installed at the beginning of the pipeline is free of blockage.
f) Communication and clearances with the start-up engineer/supervisor must be signed off to verify that the system is ready for watering-up.
g) Check operability of all gates and valves
h) Check that hillside drainage is appropriate and that drains are clear of debris and vegetation.

Figure 2. Intake Civil Features

iii. During watering-up

The works to be conducted, completed or performed during the watering-up of the water pipeline are:

a) A slowing filling shall be initiated so as to ensure full control of the system. An operator shall be stationed at the ECS during the entire watering-up process in event that a manual closure of the system is required. It suggested that the initial rate be set at about 6 to 15m at this stage, which is sufficient to allow for full control in the filling operations.
b) A system must be set up to provide effective communication with inspection crew, start-up engineer and all other operators
c) The filling should be done during the daylight hours. This is to provide safety to the personnel involved in the operation and inspection. It also allows better visibility so that problem areas can be identified and acted quickly. If possible 4 – 6 hours of daylight should be available after completion of filling. During the nighttime hours, intake gates and ECS must be closed for safety reasons.
d) After the waterway system is completely filed up, the intake/head gates are usually closed and system is allow to rest for 24hours before any operational testing of the powerhouse equipment. This would allow for the porous material to absorb water in controlled and observed condition and to stabilize and monitor the water loss. Inspection must be done to identify any problem. During initial filling process, items such as expansion joints, couplings, valves and other bolted fittings/appurtenances may require retorquing to stop leaks. This must be done according to manufacturer instructions.

e) For buried pipelines that have been fully pressurized, the intake gate/sluice valve shall be closed and monitored the for any pressure drops to verify that there is no leaks or the leaks are within acceptable values.

f) After completion of the CFMP procedures, the start-up engineer start-up procedures must be signed off, indicating the penstock is complete and ready for operational testing.

iv. Recommended Inspection checks

The recommended inspection checks, where, applicable are as follows:

a) Read appropriate water levels at intake, surge tank and tailrace
b) Inspect fittings and appurtenances, such valves, manholes, expansion joints or coupling and air-vacuum valves for leakages
c) Read gauges and meters
d) Check for settlements in foundation
e) Check for cracks and distortions in the pipeline support system
f) Check for any leaks or wet soils, any increase in groundwater in the pipeline system
g) Compare movements or deflections against analysis
h) Survey elevations
i) Check that the river intake flushing gate works (if applicable)
j) Check that sediment basin is clean

Figure 3. Pipeline Features

5.1.1.2 Dewatering Rates

The dewatering rates for inclined pipeline should be limited to the following;

a) 50% of the air valve capacity or
b) 33 vertical m/hr, whichever is lower

5.1.1.3 Subsequent Watering-Up

Subsequent watering-up is not as critical as the initial operation, as the system has already been tested and observed under controlled conditions. Usually, there would be rather long outages, where by the waterway is under dewatered condition, the watering-up must be done under slow rates and controlled conditions. This is due to the fact that the filings/appurtenances may have dried out, such as expansion joints and couplings, or shifted due to thermal changes.

The following must be observed for subsequent watering-up operations;

a) A walk-down of the exterior of the exterior shall be done to ensure all manholes and gate valves have been closed and air valves are open. The air vent usually installed at the beginning of the pipeline is free of blockage.
b) The filling rate can be higher. The suggested rate for subsequent can be a about 33 vertical m/hr. However, the maximum if dewatering is then required, the rate must not exceed 50% of the controlling air valve capacities.
c) The initial and subsequent watering reports must be reviewed for occurrence of any unusual events or circumstance.
d) After the system has been fully pressurized but before being returned to operation, the entire system must be walked down, and any abnormal items or conditions must be noted and corrected if necessary.
e) Communication and clearances with the start-up engineer/supervisor must be signed off to verify that the system is ready to return to operation.

Figure 4. Pipeline Fittings/Appurtenances

5.1.2 Mechanical & Electrical

5.1.2.1 Dry Test

These tests are conducted before charging the water-conductor system of the unit. Test at this stage include following:

a) All critical unit clearances and dimensions are checked.
b) Alignment of unit shaft system.
c) Calibration and adjustment of all temperature sensing devices, pressure switches, flow switches, transducers is done If the contractor does not have calibration facility, the same should be done at laboratory approved by the purchaser.
d) Continuity of all cabling and their connection as per cable schedules are checked.
e) Operation of all control system in both energized and de-energized state is checked.
f) Hydrostatic tests of all pressurized fluid system.
g) AC/DC high potential tests.
h) Protection system secondary test injections and tripping test.
i) Control System/Unit PLC functional testing.
j) Hydrostatic tests of generator coolers, bearing coolers and piping.
k) Auxiliary equipment is connected properly.
l) All the instrumentation and safety devices operate correctly.
m) Insulation resistance & dielectric test of generator.
n) Functional checks and adjustment of generator speed switches and pressure switches.
o) Functional checks of wicket gates, and excitation system.
p) The fire protection system is operating.
q) The generator brake and lifting jacks and their interlocks operate as required.
r) The entire unit must be thoroughly inspected before charging with water for tools, other objects which might have been inadvertently left in the unit.
s) Check penstock man hole draft tube manholes are properly closed and tightened after providing proper gasket, o-ring etc.
t) Check working of all hydro-mechanical gates & valves etc. Must be commissioned according to manufacturer's instructions.
u) Check main & auxiliary transformers and their cooling arrangement.
v) Check switchyard & switchyard equipment.
w) Check all unit auxiliaries & station auxiliaries for their proper functioning.
x) Arrange all clearances from in charges of different systems & subsystems.

All tests carried out must be properly documented for each system and subsystem and signed by tests engineers of manufactures and plant owner. This documentation helps the owner to identify potential problem in specific equipment before watering start-up and take remedial measure in advance.

5.1.2.2 Wet Test

These tests are conducted after charging the water conductor system of the unit. Test at this stage include following:

a) The contractor shall carry out detailed inspection of machine to ascertain no abnormality is found during first hour of operation
b) Unit is charged with water, leakages from penstock and man holes, coolers, shaft seals are checked, remedial action, if found necessary, are to be taken.
c) Check penstock pressure, cooling water pressure and availability of water at proper pressure in each cooler
d) Ensure working of flow meters
e) Then machine is rotated for the first time at slow-speed, ensure for any abnormal sounds or interference in machines, take immediate remedial action, if necessary.
f) This is a critical stage as for the first time all equipment components are operating as an integral system at rated head and flow condition
g) The first unit rotation is done at slow speed then machine is run at 25, 50, 75 and final 100% speed

Following tests at this stage are done:

a) Shaft run out
b) Bearing temperatures stabilization (this is called bearing run also)
c) Reliability of start, stop, synchronizing unit is also to be confirmed
d) All protective devices, lock out relays and emergency stop system are checked at low load to ensure that they are functional

All these tests are divided in two categories:

i. No Load Tests

These tests confirm the operation of the generator and powerhouse auxiliaries equipment under no load conditions. These are as follows:

a) Phase rotation check

b) No load saturation test
c) Short circuit saturation test
d) Operational tests, check thermal relays, speed switches, RTDs, flow switches
e) Excitation system checks
f) Continuity Test
g) Insulation resistance tests to check the condition of cable insulation
h) Functional test of each component and the interconnected system of components in both auto and manual mode
i) Test of the software and hardware associated with the computer control system

ii. Load Tests

These tests confirm the operation of generator under load condition. These are as follows:

a) Heat run test to determine maximum temperature rise
b) Load rejection tests
c) Time taken by machine in stopping after application of brakes
d) Measurement of excitation field current at generator rated output
e) Unit capacity test

The load rejection test is performed at 25%, 50%, 75% and 100% rated load which confirm the unit can be safely stopped under any operating condition. During confirm that both of these parameters are within design limit. Any abnormal noise, alarm, high temperature and any unusual or unexpected condition must be thoroughly investigated.

5.1.3 Combined Electrical / Mechanical Review – Dry Condition

a) Review factory & field test certificates for all major pieces of equipment.

- Turbine
- Governor
- Speed increaser
- Intake gates, draft tube gates, spillway gates, inlet valves
- Generators
- Main power transformers
- Generator switch gears (medium voltage)
- Switchgears

b) Unit or plant control switch boards

c) Confirm that manufactures have provided detailed written installation instructions for all major pieces of equipment, including detailed dimensional record sheets and quality assurance plan followed during erection.
d) Review all detailed dimensional record sheets in conjunction with a visual inspection of all major pieces of equipment.

5.1.3.1 Mechanical Review Tasks

a) Verify that hydrostatic tests have been performed on all pressurized fluids systems.
b) Review operational check out sheets for each mechanical system, including calibration sheets for all level switches, flow switches, pressure switches etc.
c) Review unit alignment check out sheets.
d) Review bearing setting, centering, gaps check out sheets.
e) Review generator air gap check out sheets.
f) Review functionality check out sheets for brakes, cooling system, oil pressure unit system, gland seal's repair seals, top cover drainage system, greasing system etc.

5.1.3.2 Electrical Review Tasks

a) Review system ground resistance test certificate and ensure adequate ground connection as per relevant IEEE.
b) Review surge protection of powerhouse/ switchyard.
c) Confirm that phasing check has been performed across generator circuit breaker.
d) Review the station battery/ battery charger arrangement and operational check out sheet.
e) Verify that all relays are bench tested and that the settings are as per design and that CT shorting screws have been removed.

5.1.4 Combined Electrical / Mechanical Review – Wet Condition

5.1.4.1 Mechanical Review Tasks

a) Observe first mechanical rotation of unit.
b) Observe and review results of bearing temperature run.
c) Observe and review results of unit load rejection tests.

d) Observe turbine index test, verify that results are consistent with manufacturers promised performance.
e) Verify unit alignment and balance.
f) Monitor for excessive vibration.

5.1.4.2 Electrical Review Tasks

a) Observe unit manual starts, stops and synchronization.
b) Observe unit automatic starts, stops and synchronization.
c) Observe one manually initiated emergency stop sequence.
d) Observe unit stops by activation of each lock out relay.

5.1.5 Review of PLC Used For Unit Control

a) Identify manufacturer's recommended chassis and logic ground points and see whether they are to be connected collectively or grounded separately. If connected collectively confirm how common mode noise is prevented from entering the PLC.
b) Verify the grounded resistance value for chassis and logic grounds are consistent with the manufacturer's recommendation.
c) Ensure that surge protection are provided on all inputs to the I/O racks that will be susceptible to voltage transients including all cables routed to devices located outside the powerhouse.
d) Ensure that the AC power for PLC is reliable and free of voltage transients usually an inverter fed by station batteries.
e) Confirm that the final PLC software coding has been well documented and that the document is available for future plant maintenance and trouble shooting.

5.2 Commissioning Testing

Commissioning testing generally includes:

1) Head loss measurement in pipeline
   The head loss in the pipe system can be made if the flow measuring devices are located close to the turbine otherwise, reading from pressure gauges can be used. The velocity measurement is described in IEC 62006 in section Annex B under B.3.
2) Pressure variation in pipeline
   Closing times must be confirmed before any load rejection testing and the pressure variations in the pipeline and upstream and downstream of machine as well as the variations in surge tank water levels during the pre-commissioning test should be noted for the following cases;

a) Speed no load (SNL) rejection
b) 25% load rejection and acceptance
c) 50% load rejection (critical case for Francis turbine) and acceptance
d) 75% load rejection and acceptance
e) 100% load rejection and acceptance
f) 100% gate or needle rejection and load acceptance (critical pressure drop for impulse machine)
g) Hill top valve/main inlet valve closure
h) Normal shutdown

3) Discharge measurement in pipeline
IEC 62006 has described 6 types of discharge measurement. These are illustrated as follows;
    a) Velocity area
    b) Pressure time method
    c) Ultrasonic (acoustic) method
    d) Volumetric gauging method
    e) Electromagnetic flow meters
    f) Thermodynamic methods

4) Hydraulic operation of shut-off inlet valves, hill top valve and intake gates and proper setting of closing and opening times
5) Wicket gate or nozzle alignment and verification of proper opening and closing times
6) Governor control setting verification
7) Verification of proper lubrication of generator and turbine bearings
8) Checks on braking system
9) Turbine-generator and bearing run in
10) Electrical and mechanical over speed trip test
11) Final setting of shutdown sensors
12) Voltage regulator and excitation system tests
13) Verification of proper generator to system synchronization
14) Testing and verification of electrical protection system with load
15) Operation and monitoring via control system (local and remote)
16) Forebay surging during startup and shutdown, valve and gate opening and closure
17) Monitor intake submergence (observe vortices)

6.0 ACCEPTANCE TEST

Acceptance test objective is to determine the performance of Electromechanical Equipment as it is part of the contract obligation and also provides strategic input for revisiting the design and manufacturing process. Also reconfirms the accuracy and authenticity of the claimed model tests results. The "performance" of a turbine is quantified generally under the following reference: the efficiency of the machine within specified range of output and head variation should meet the guaranteed efficiency; the turbine power output should meet the guarantee as a function of the net head discharge available. The performance also includes safe operation of the machine without being subject to cavitation or fatigue in the specified head range. The machine behavior under load throw-off condition is also in some cases constitute performance test. In addition to these performance tests done during acceptance, it becomes relevant several times in the operational life of the turbine in the course of operation, as wear and cavitation pitting occur on critical parts of the turbine and as a result efficiency decreases. This test result becomes paramount for the policy decision regarding rehabilitation.

Typically, performance test of a Hydro Power plant includes:

1) Inspection of all components, systems and station auxiliaries.
2) Functional checks of simpler devices and systems
3) Testing of measuring instruments.
4) Secondary injection tests on protective relays.
5) Operational tests on control systems.
6) Measurement of the parameters critical for generation.
7) Measurement of maximum power output of generating units
8) Determination of efficiency of generating units, combined and individually.

<u>Codes/Standards for Acceptance Test</u>

The International Electro technical Commission (IEC) 62006: 2010-10 – "Hydraulic machines-Acceptance tests of small hydroelectric installation" specifies procedures for the measuring methods and contractual guarantee condition for field acceptance tests of the generating machinery in small hydroelectric installation. It applies to installation containing impulse or reaction turbines with power up to about 15MW and reference diameter of about 3 meters. It also contains information about most of the test required such as safety approval test, trial operating and reliability tests, as well for verification of cavitation, noise and vibration.

The American Society of Civil Engineers (ASCE) "Manuals and Reports on Engineering Practice No.79 – Steel Penstocks (Second Edition)" which covers not limited to testing and start-up of steel penstocks including branches, wyes, associated appurtenance and tunnel liners.

Determination of Turbine Efficiency and Measurement involved:

Turbine Efficiency: Mechanical Power Produced-Mechanical Power (Turbine)

$P_m = P_g/\eta_g + P_{th} + P_{gd} + P_{au} + P_{gb}$

Hydraulic Power Available -Hydraulic Power $P_h = g\ H_n\ \rho\ Q$

Where,

•P_g= Generator output

•η_g= Tested generator efficiency.

•P_{th}= Thrust bearing loss corresponding to turbine.

•P_{gd}= Mechanical power dissipated in guide bearing.

•P_{au}= Electrical Power supplied to auxiliary equipment

•P_{gb}= Mechanical power loss in Gear Box

•g= Gravity acceleration.

•H_n= Net Head

•ρ = Water Density

•Q = Water discharge

The measurements involved in determining the efficiency are from IEC 62006:

(1) For determining the Hydraulic power

a) Discharge (Q)

b) Head (m)

c) Acceleration due to gravity (g)

(2) For determining Mechanical Power

a) Electrical Power Output

b) Generator efficiency ....from Generator test report

This also can be referred to IEC 62006 Clause 7 under Performance guarantees and tests.

Discharge measurement in pipeline

IEC 62006 Annex E Table E.1 has described 6 types of discharge measurement. These are illustrated as follows;

Table E.1 – Selection of flow measurement method

Method	Water passage condition	Test preparation
Velocity area	Closed conduit v > 0,4 m/s current meter v > 1 m/s pitot tube D > 1,4 m and D/d > 14 straight pipe L/D > 25 Open conduit v > 0,4 m/s current meter only H > 0,8 m and H/d > 8 straight conduit L > 3,5 m	Rig for velocity meter
Pressure time	$\rho.Q \cdot \left(\int dL/A\right) > 50$ kPa/s Closed conduit between measuring sections L/D > 10 upstream $\Delta L \cdot v > 50$ m²/s $\Delta L > 10$ m	Pressure taps
Acoustic single path	v > 1,5 m/s, D > 0,8 m straight pipe: L/D > 10 upstream L/D > 3 downstream	Surface to mount transducer
Acoustic four paths		Transducer holes
Electromagnetic	straight pipe: L/D > 10 upstream	Flange connections
Volumetric gauge	No condition	Volumetric tank Deflector
Thermodynamic (indirect flow measurement)	Head > 100 m	Tap for probe Rig for temperature distribution

A: penstock area
d: propeller diameter
D: penstock diameter
H: depth of open conduit
L: length of water passage
Q: discharge
v: average velocity
ΔL: distance between measuring sections

APPENDIX A: Net Head for various turbine type from IEC62006- Annex B

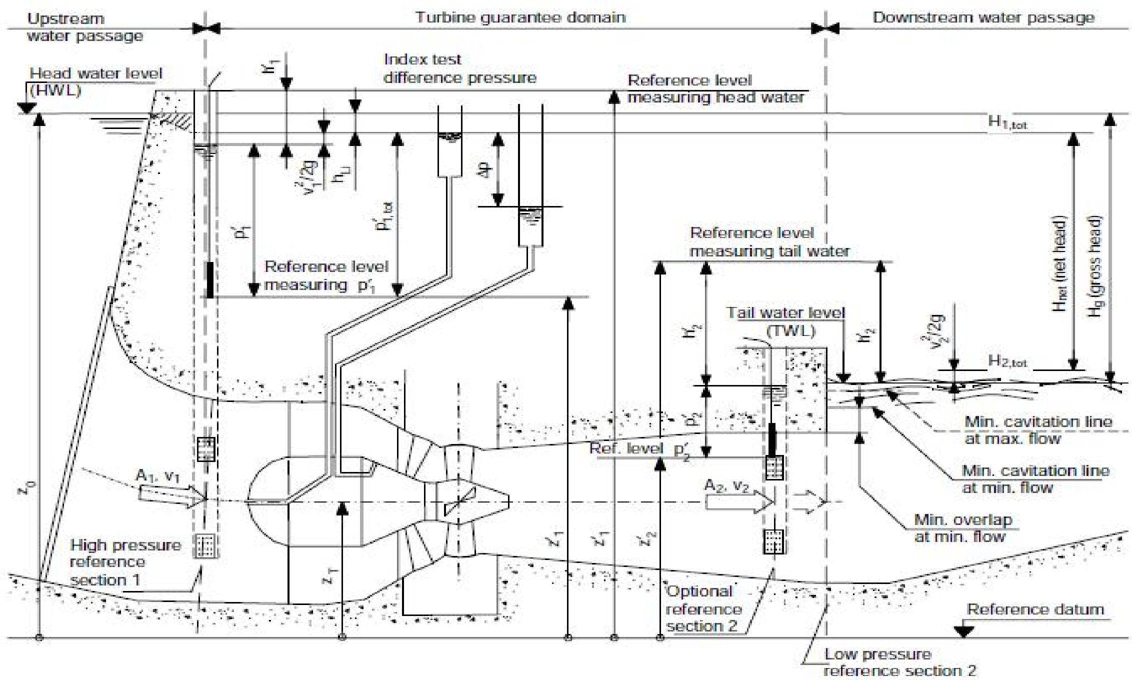

Figure B.5 – Kaplan turbine with horizontal shaft

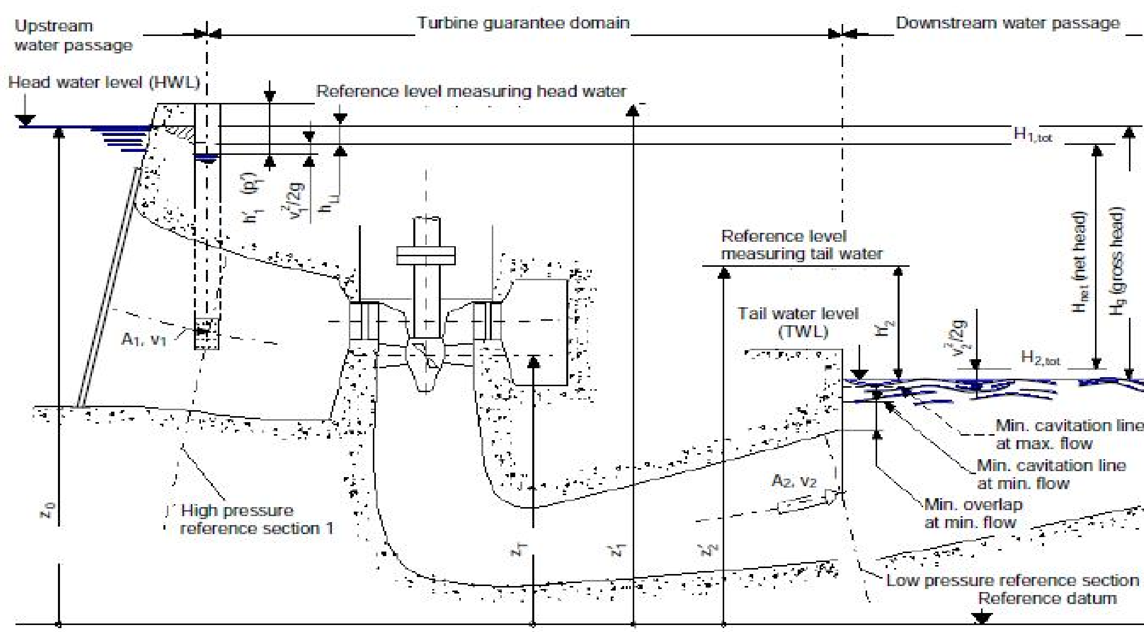

Figure B.6 – Kaplan turbine with vertical shaft

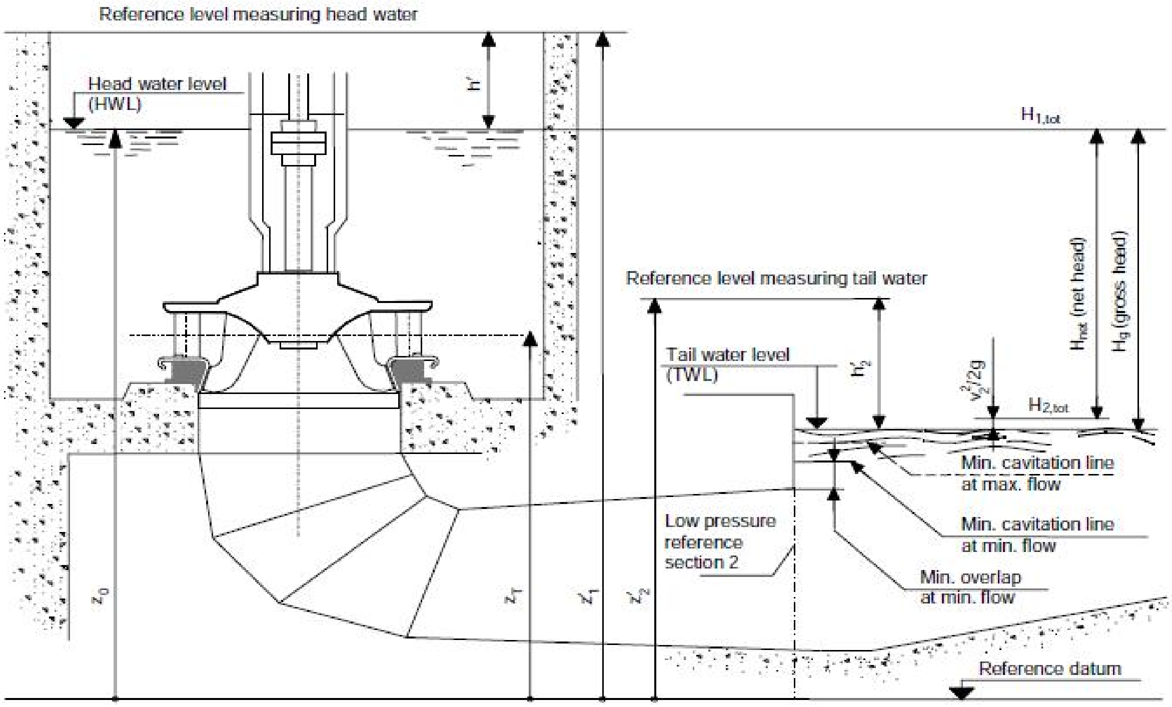

Figure B.7 – Francis open flume turbine with vertical shaft

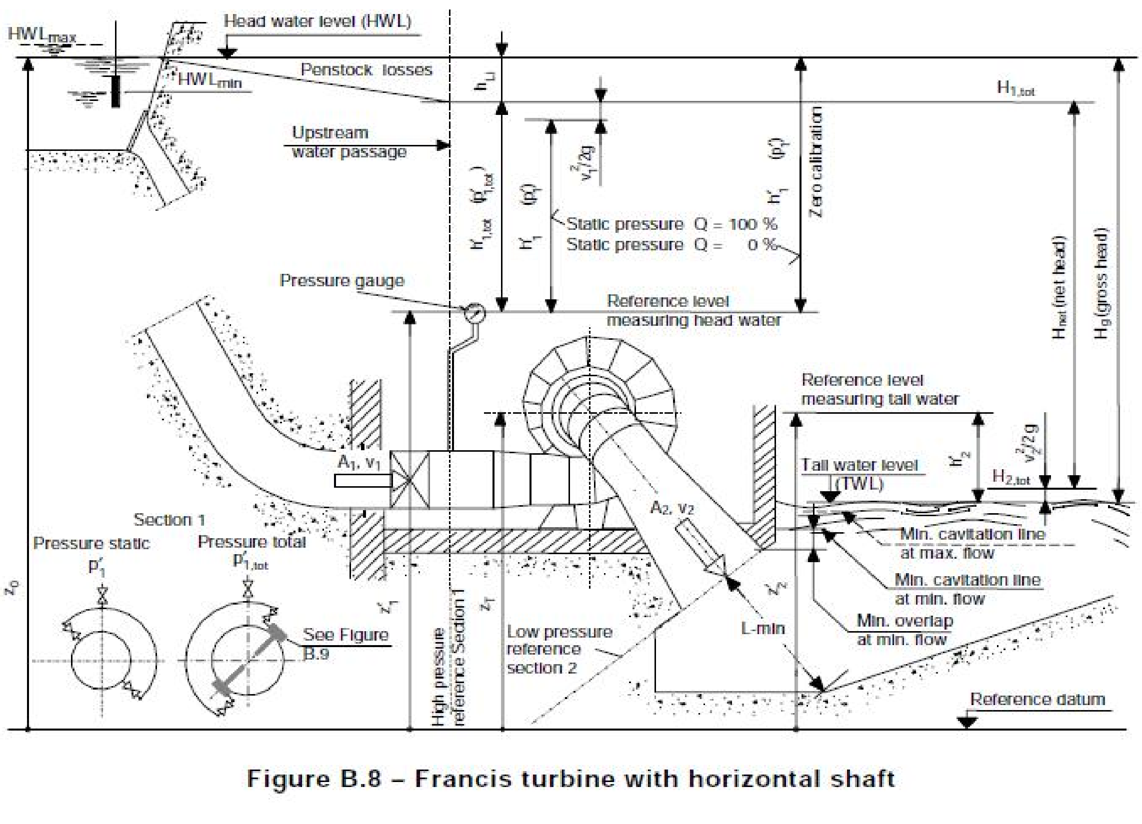

Figure B.8 – Francis turbine with horizontal shaft

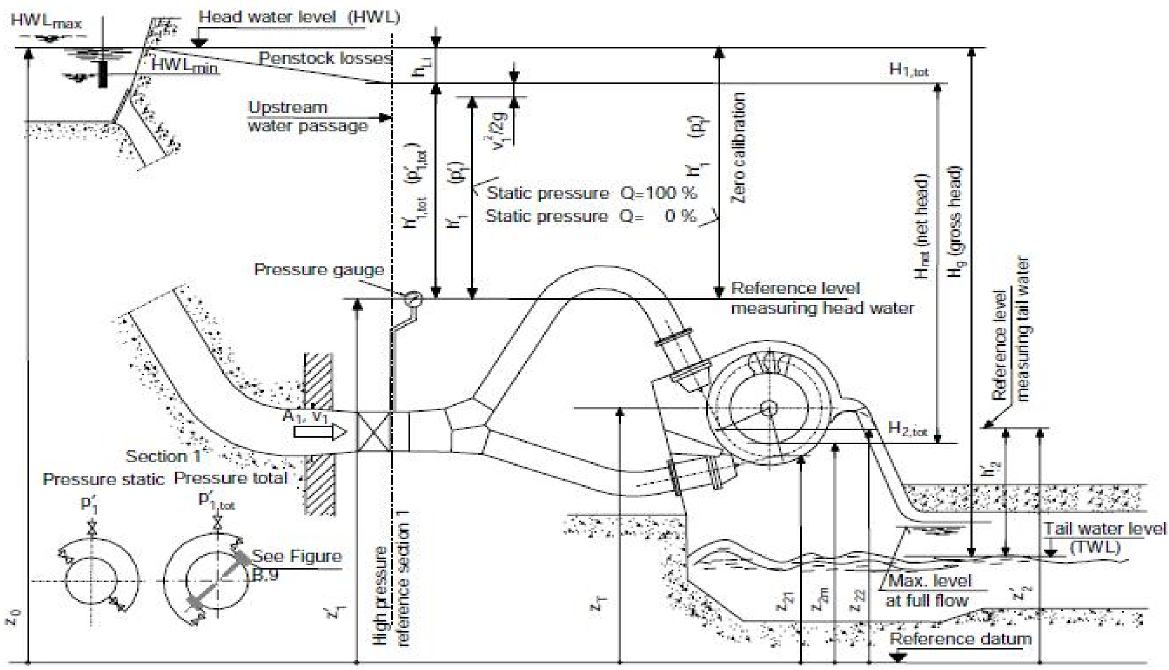

Figure B.11 – Pelton turbine with horizontal shaft

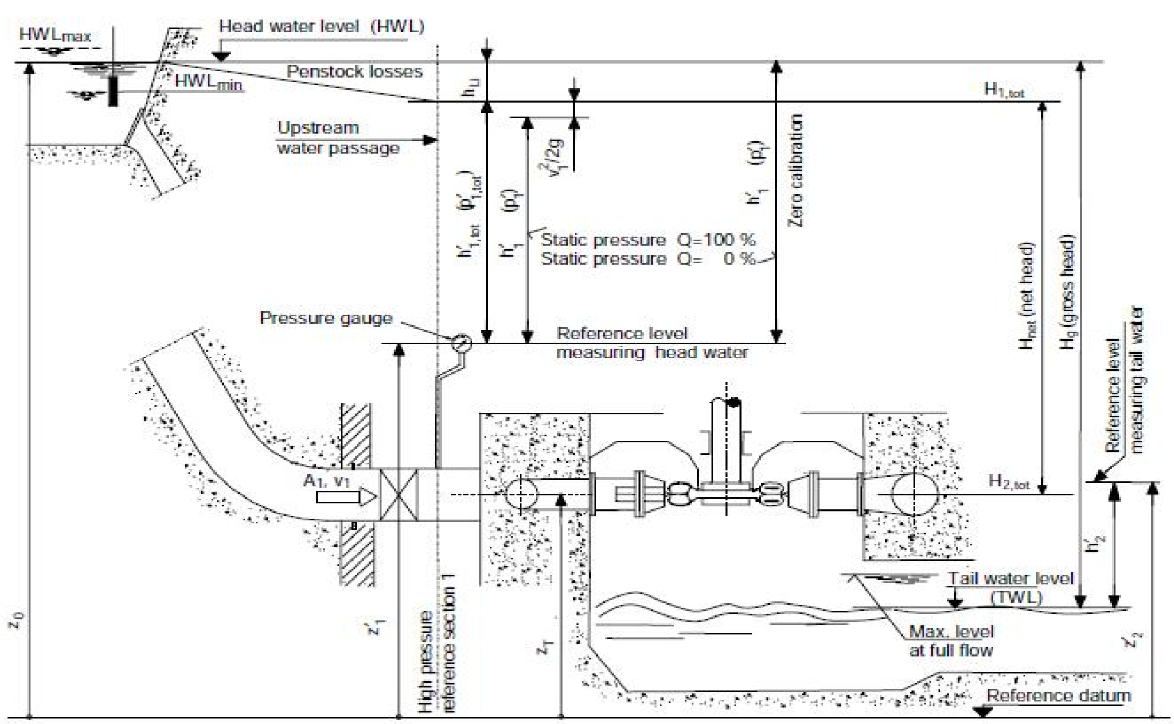

Figure B.12 – Pelton turbine with vertical shaft

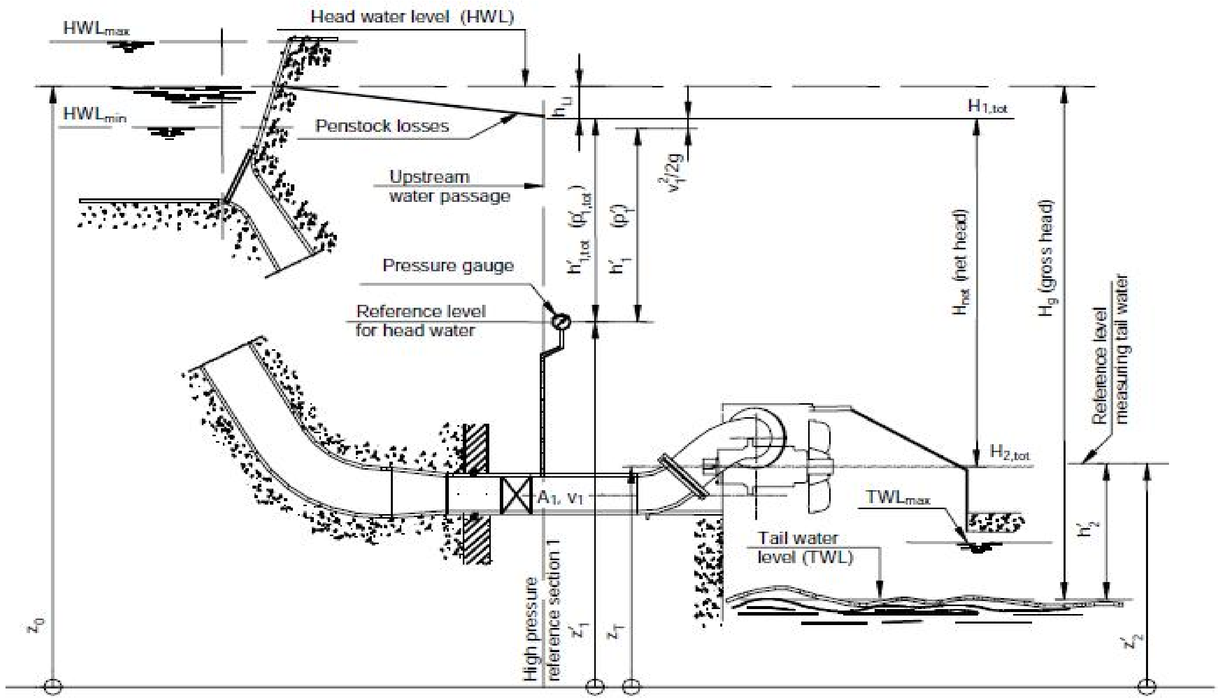

Figure B.13 – Turgo turbine with horizontal shaft

APPENDIX B: CHECKLIST OF TESTING AND COMMISSIONING

COMMISSIONING CLEARANCE FORM

PROJECT :   Date:
DEVELOPER :   Ref :
SCOPE :

NO	Description	Completed by	Verification by

No	Name and Company	Signature	Date

Checklist for Intake		
Project		Date:
Description		Ref:

i- Confirm weir details are as per the design and specification requirement. ☐

ii- Confirm the following at the sluice gate as per the design and specification requirement ☐
- Water level at safe level
- Size
- Gate guide
- Gear type/screw or bewel
- Material
- Type/brand

iii- Confirm wing wall details as per the design and specification requirement ☐
- Level
- Concrete wall
- Embedded to soil

iv- Confirm the following on the river bank at sediment basin as per design and specification requirement ☐
- Gabion mattress
- Rock fill
- Grass/river bank protection

v- For river crossing purpose, confirm the following is availabe (if necessary) ☐
- Boat
- Bridge
- Grass/river bank protection

vi- Sedimentation behind weir ☐

Comments:

Checklist for Settling Basin		
Project		Date:
Description		Ref:

i- Confirm trash rack details are as per the design and specification requirement. ☐

i- Confirm fine screen details are as per the design and specification requirement. ☐

iii- Check the sediments and particles in the setling basin ☐
- Type of particles
- Particle thickness

iv- Confirm flushing valve details are as per the design and specification requirement. ☐

v- Confirm pipe sluice gate details are as design and specification requirement. ☐

vi- Check there is no leakage on the settling basin wall and the concrete finishes is according to specification. ☐

vii- Confirm fencing and gate as per design and specification ☐

viii- Confirm steel railing as per design and specification requirement ☐

Comments:

Checklist for Pipeline		
Project		Date:
Description		Ref:

- i- Air Valve and Scour Valve ☐
- ii- Pipe Support ☐
- iii- Anchor Block ☐
- iv-Pipe crossing culvert ☐
- v- Pressure Relief Valve (PRV)/ Plunger Valve ☐
- vi- Slope protection ☐
- vii- Access road and drainage ☐
- viii- Pipe conditions; protection and marking ☐
- ix- Pipe bridge ☐

Comments:

Checklist for Building - Power House and Sub-station		
Project		Date:
Description		Ref:

i- Inspect and confirm structural and related portion (frame, tailrace, floor,wall,windows, doors, truss and roof) are per design and specification ☐

ii. Inspect and confirm that slope, road and drainage are as per design and specification ☐

iii. Inspect and confirm that the crane works where applicable, are as per design and specification ☐

iv. Inspect and confirm that the building services (plumbing, sanitation, lighting, fire-alarm system and air conditioning) ☐

Comments:

Checklist for Prior filling Waterway		
Project		Date:
Description		Ref:

Prior to filling the Waterway/Pipeline

i- Inspection of all turbine waterway and removal of all foreign or loose ☐

ii-Calibration of scales for wicket-gate opening or needles and deflectors ☐

iii- Operation of all pressure oil unit, Hydraulic valves ☐

iv. Operations of governor, automatic and manual starting and stopping devices and signalling devices. ☐

v. Protective devices i.e alarms and relay ☐

vi. Times of opening and closing of gates and valves ☐

vii. Bearing and seal clearances. ☐

viii. Operation of leakage and drainage pumps ☐

ix. Oil, grease and water supply to all bearings requiring lubrication and cooling. ☐

x. Operation of braking system of the unit ☐

xii. Proper fastening of all screw and nuts. ☐

xiii. Blades of moveable-blade turbines set at rest position ☐

Comments:

Checklist for After filling Waterway		
Project		Date:
Description		Ref:

After filling the Waterway/Pipeline

i- Fill slowly via bypass or small opening ☐

ii- Tailwater gate or valve opened. ☐

iii- Checks for leaks ☐

iv. Check pressure and open inlet valve ☐

v. Check pressure relief valve, if any ☐

vi. Check operational on needles for impluse turbines, if any with deflector diverting ☐

Comments:

Checklist for No-load Test		
Project		Date:
Description		Ref:

No load Test

i- Bearing temperature are satisfactory	☐
ii-Check for no covers and support deformation	☐
iii- Noise or vibration in turbine and generator	☐
iv. Water supply for bearing lubrication or cooling	☐
v. Checks on condition for oil pressure and other pumps	☐
vi. Bearing oil leaks shall be eliminated	☐
vii. Action on braking system satisfactory	☐
viii. Governing system functionality	☐
ix. Overspeed protection devices.	☐

Comments:

Checklist for Load Test		
Project		Date:
Description		Ref:

Load Test

i- Generator sycnhronized parellel with Grid ☐

ii-All necessary precaution to ensure rated values of penstock and turbine stresses not exceed. ☐

iii- Check accuracy output of the unit to values by vendors ☐

iv. Check vibration and cavitation; if any ☐

v. Governor functionality ☐

vi. Check momentary pressure and speed variations ☐

vii. Adjust closing time of gates and valves accordingly. ☐

viii. Permit hydraulic and electrical protection equipment testing ☐

ix. Increase by steps i.e 25%, 50%, 75% and 100% ☐

x. Two rejection for each step; by governor control and emergency shutdown via stop solenoid. ☐

Comments:

Checklist for Power Generator		
Project		Date:
Description		Ref:

i- Visual inspection on generator	☐
ii- Loop test rotating excitation system.	☐
iii- DC winding resistance on stator, rotor and excitation.	☐
iv- Pressure test on stator and field breaker/leads.	☐
v- Stator phase rotation	☐
vi- Stator open circuit saturation and short circuit saturation	☐
vii- Heaters functionality checks.	☐
viii- Overspeed, load rejection and bearing tests.	☐

Comments:

Checklist for Excitation Panel		
Project		Date:
Description		Ref:

i- Visual Inspection on the excitation panel ☐

ii- Pressure test on field breakers/leads ☐

iii- Circuitry check on field breaker/leads and controls ☐

iv- Check DC winding resistance on rotating dc shunt exiter, 3-phase ac/dc exciter and excitation transformer. ☐

v- Check insulation resistance on rotating dc shunt exiter, 3-phase ac/dc exciter and excitation transformer. ☐

vi- Functionality check ☐

Comments:

Checklist for Excitation Panel		
Project		Date:
Description		Ref:

- i- Visual Inspection on the excitation panel ☐
- ii- Pressure test on field breakers/leads ☐
- iii- Circuitry check on field breaker/leads and controls ☐
- iv- Check DC winding resistance on rotating dc shunt exiter, 3-phase ac/dc exciter and excitation transformer. ☐
- v- Check insulation resistance on rotating dc shunt exiter, 3-phase ac/dc exciter and excitation transformer. ☐
- vi- Functionality check ☐

Comments:

Checklist for Flow Meter System		
Project		Date:
Description		Ref:

i- Visual Inspection and functionality checks ☐

ii- Control cable insulation resistance ☐

iii- Continuity checks on contrl cable ☐

iv- Circuitry check on flow, alarm, inputs and transmitter. ☐

v- Calibration of flow devices ☐

vi- Check for all the terminations were done correctly / properly ☐

Comments:

Checklist for Governer PLC Panel		
Project		Date:
Description		Ref:

i- Visual Inspection of governor PLC panel ☐

ii- Calibration of servos, switches, controller and sensors. ☐

iii- Check emergency shutdown system ☐

iv- Check governor controller during load rejection. ☐

v- Check DC polarity of signals, annunciator and controls. ☐

vi- Check for electromagnetic or radio frequency interference. ☐

vii- Check for servomotor timing. ☐

viii- Functionality check ☐

Comments:

Checklist for Oil Pressure Unit		
Project		Date:
Description		Ref:

i- Visual inspection on the oil pressure unit ☐

ii- Piping, valves, pumps and strainers pressure testing. ☐

iii- Leak test on nitrogen containers. ☐

iv- Insulation resistance on motors and cables. ☐

v- Continuity checks on cables. ☐

vi- Calibration on switches, instruments, gauges and relays. ☐

vii- Check and Record motor start and running current ☐

viii- Functionality check ☐

Comments:

Checklist for LVAC		
Project		Date:
Description		Ref:

i- Visual Inspection as per approved drawing ☐

ii- Test AC configuration is as per the single line diagram provided ☐

iii- Perform DC insulation resistance test for the LVAC ☐

iv- Test all indication meters and lights of the LVAC ☐

v- Test all relays where applicable ☐

vi-Test AC distribution circuit and ensure the labelling is in order ☐

vii- Test any interlock provided on the LVAC ☐

ix- Test that the AC sources are not paralleled at the distribution side ☐

x- Test on transducer if available. ☐

xi- To ensure all outgoing feeders for charger, transformer supplies are distributed on different section of AC busbar ☐

xii- Earthing correctly installed ☐

Comments:

Checklist for DC System - DC Charger		
Project		Date:
Description		Ref:

- i- Visual Inspection as per approved drawing ☐
- ii- Charger detail available ☐
- iii- Charger settings available ☐
- iv- Test Boost Interlocking scheme ☐
- v- Float and Boost voltage setting ☐
- vi- Low and High Voltage alarm setting ☐
- vii- Boost charging current ☐
- viii- A/C fail condition ☐
- ix- Charger fail condition ☐
- x- Low electrolyte level alarm ☐
- xi- DC earth fault ☐
- xii- Transducer (if available) ☐

Comments:

Checklist for DC System - Battery and Distribution Board		
Project		Date:
Description		Ref:

- i- Visual Inspection as per approved drawing ☐
- ii- Battery detail available ☐
- iii- Charge and discharge test for all battery cells including spares - Discharge test shall be carried out for a minimum duration of 8 hours ☐
- iv- Voltage measurement for each cell shall be taken hourly during discharge test. ☐
- v- Check all battery cell, isolation fuse, distribution board, MCB are labeled clearly. ☐
- vi- Check that the distribution board is configured as per sld and confirm labeling of all distribution MCB's are in order by test. ☐
- vii- Test battery bank isolation system ☐
- viii- Open circuit voltage of the battery when it is fully charged shall be measured and recorded. ☐
- ix- Terminal connection tightness check ☐

Comments:

Checklist for Current Transformer		
Project		Date:
Description		Ref:

i- Confirm CT details are as per the design and specification requirement. ☐

ii- Check nameplate installed and contents are complete. ☐

iii- Physical check on the CT for any damage or defect. ☐

iv- Confirm the primary positioning of the CT - P1 and P2 according to the schematic drawing. ☐

v- Check and confirm the ratio selection (for multi ratio), neutral grounding and shorting link at the switchgear panel / CRP. ☐

vi- DC Insulation Resistance Test ☐
- Between primary and earth (5kV)
- Between secondary and earth (1kV)
- Between primary and secondary (5kV)

vii- Polarity Test ☐

viii- Magnetisation Test ☐

ix- Ratio Test ☐

ix- Measurements of the CT Resistances ☐

Comments:

Checklist for Voltage Transformer		
Project		Date:
Description		Ref:

i- Confirm VT details are as per the design and specification requirement. ☐

ii- Check nameplate installed and contents are complete. ☐

iii- Physical check on the VT for any damage or defect. ☐

iv- Confirm the primary positioning according to the schematic drawing ☐

v- Check and confirm the ratio selection (for multi ratio), neutral grounding and star point at the switchgear panel / CRP. ☐

vi- DC Insulation Test ☐
- Between primary and earth (5kV)
- Between secondary and earth (1kV)
- Between primary and secondary (5kV)

vii- Polarity Test for all windings ☐

viii- Polarity Test ☐

ix- Ratio Test ☐

Comments:

<table>
<tr><th colspan="3">Checklist for Secondary Injection of Relays</th></tr>
<tr><td>Project</td><td></td><td>Date:</td></tr>
<tr><td>Description</td><td></td><td>Ref:</td></tr>
<tr><td colspan="3">i- Confirm relay details are as per the design and specification requirement. ☐

ii- Calibration of indicating meters and transducers shall be done over its complete range ☐
iii- Relay setting available ☐

iv- All Protection Relays Tested by Energy Commission Certified Tester and Test Results submitted ☐</td></tr>
<tr><td colspan="3">Comments:</td></tr>
</table>

Checklist for Switchgear - 1		
Project		Date:
Description		Ref:

1) Physical Check/Inspection

i- Detail labeling on panel front, rear and CB truck. ☐

ii- Earthing switch connected to earth grid ☐

iii- Busbar shutter operation and VCB truck alignment and racking in/out ☐

iv- Cable entry e.g. proper clamping and sealed ☐

v- Dust and Vermin proof i.e. all holes shall be covered externally and internally, including the earth switch-operation rod (rubber lining for door and boot for the earth-operating rod to be installed. ☐

vi- Tightness of connections using correct torque ☐

vii- Earthing connection ☐

viii- Wire and cable connections ☐

ix- Cable entrance to control cubicle shall be from botttom, sealed and water proof ☐

x- Heaters and lamps in working order ☐

xi- Ensure recommended thermostat temperature setting label is available inside the control cubicle. ☐

xii- Locking facilities ☐

Comments:

Checklist for Switchgear - 2		
Project		Date:
Description		Ref:

Electrical Test

i- Power Frequency Withstand test (AC pressure test).	☐
ii- CB Timing Test	☐
iii- Insulation resistance of the busbar before and after AC pressure test.	☐
iv- Vacuum Check on vacuum bottle	☐
v- Contact resistance measurement on breaker	☐
vi- Complete circuit loop resistance measurement	☐
vii- Operational test	☐
viii- Interlock test	☐
ix- SF6 gas leak (for SF6 Insulated Switchgear)	☐
x- Moisture Content (for SF6 Insulated Switchgear)	☐
xi- SF6 purity (for SF6 Insulated Switchgear)	☐
xii- Density Measurement (for SF6 Insulated Switchgear)	☐

Comments:

Checklist for Transformer		
Project		Date:
Description		Ref:

1) Physical Check/Inspection

i- Detail labeling of the Transformer i.e. TF make, type, vector group, capacity, imp., ratio, serial no., rated voltage, DOB and S/C rating ☐

ii- Check for any corrosion, damage or defect,. ☐

iii- Labelling ☐

iv- Earth connections ☐

v- Pressure relief device ☐

vi- Buchholz relay for main and OLTC tank ☐

vii- Breathers (properly inspect for leaks, silica gel, etc.) ☐

viii- Valves in operational positionals. ☐

ix- Correct oil levels in main tank & OLTC conservator, oil pocket, cable box and bushing. ☐

x- Missing Component ☐

xi- Ensure all terminal blocks, oil level gauges and other accessories including marshalling kiosks are fully sealed/moisture & vermin proof ☐

xii- Correct positioning of the cooler/radiator with respect to the ventilating system. ☐

xiii- Transformer Oil Sample result from recommended laboratory test ☐

Comments:

Checklist for Transformer-2		
Project		Date:
Description		Ref:

2) Electrical tests

i- Insulation resistance	☐
ii- Polarization Index	☐
iii- Turns Ratio	☐
iv- Vector Group	☐
v- Impedance Voltage	☐
vi- Zero Sequence Impedance	☐
vii- Winding Resistance (DC)	☐
viii- Excitation Current	☐
ix - Calibration of oil and winding temperature indicators.	☐
x- Winding Power Factor	☐
xi- Oil Leak Test	☐
xii- Functional test/check	☐
xiii- Transformer Insulating Oil Test	☐
xiiii- Correct Operation of pumps and fans if installed	☐

Comments:

Checklist for Auxillary Transformer-1		
Project		Date:
Description		Ref:

1) Physical Check/Inspection

i- Detail labeling of the Transformer i.e. TF make, type, vector group, capacity, imp., ratio, serial no., rated voltage, DOB and S/C rating	☐
ii- Check for any corrosion, damage or defect,.	☐
iii- Labelling	☐
iv- Earth connections	☐
v- Pressure relief device	☐
vi- Buchholz relay for main and OLTC tank	☐
vii- Breathers (properly inspect for leaks, silica gel, etc.)	☐
viii- Valves in operational positionals.	☐
ix- Correct oil levels in main tank & OLTC conservator, oil pocket, cable box and bushing.	☐
x- Missing Component	☐
xi- Ensure all terminal blocks, oil level gauges and other accessories including marshalling kiosks are fully sealed/moisture & vermin proof	☐
xii- Transformer Oil Sample result from recommended laboratory test	☐

Comments:

Checklist for Auxillary Transformer-2		
Project		Date:
Description		Ref:

2) Electrical tests

i- Insulation resistance ☐

ii- Polarization Index ☐

iii- Turns Ratio ☐

iv- Vector Group ☐

v- Impedance Voltage ☐

vi- Winding Power Factor ☐

vii- Oil Leak Test ☐

viii- Functional test/check ☐

ix- Transformer Insulating Oil Test ☐

Comments:

Checklist for XLPE Power Cable (33kV and Below)-1		
Project		Date:
Description		Ref:

1) Physical Check/Inspection

i- Check cable route and joint markers. ☐

ii- Check link box ☐

iii- Check of cable tagging i.e jointers' ID ☐

iv- Verify the labelling of the phases, circuit and feeder name ☐

v- Verify the use of sand bedding ☐

vi- Check for all the terminations were done correctly / properly ☐

vii- Check for sufficient creepage distances for terminations. ☐

viii- No oil leak at the cable box ☐

ix- No physical damage/stratch marks at the outer jacket ☐

x- Verify the use of cable slabs (concrete reinforcement) ☐

xi- Bending radius shall not exceed manufacturer's specified value. ☐

xii- Check for the trenches area and cable ducting e.g PVC, HDPE ☐

Comments:

Checklist for XLPE Power Cable (33kV and Below)-2		
Project		Date:
Description		Ref:

2) Electrical tests

i- Cable Insulation resistance test ☐

ii- Sheath insulation test ☐

iii- AC Voltage Test ☐

☐

☐

☐

☐

☐

☐

Comments:

Checklist for Multicore Cable Termination Chect and Test		
Project		Date:
Description		Ref:

i- The multicore cables are numbered at both ends.	☐
ii- The multicore cable core size used as per size requirement	☐
iii- The multicore cable colour used accordingly	☐
iv - The multicore cable screen/armour is grounded.	☐
v- All spare cores are numbered.	☐
vi- The terminal block numbering and isolated type.	☐
vii- No jointing along the multicore cable.	☐
viii- The termination is neat, proper and tight.	☐
ix- Correct size of cable glands and lugs are used.	☐
x- Separate multicore cable used for AC/DC	☐
xi- Insulation resistance at 1kV DC. (During test, terminal block to be isolated)	☐
xii- Continuity Check	☐
xiii- Cable Core schedule available and updated	☐

Comments:

APPENDIX C: SEDA TEST FORMS

1.0 HYDROSTATIC PRESSURE AND LEAKAGE TEST REPORT

HYDROSTATIC TEST TABLE

Project :
Date :
Location :
Prepared By :

A. WORKS INFO	
Contractor	
Type of pipeline	
Size of pipe (ID)	Ø mm
Pipe material	
Pipe length (L)	meter
Test preparation	

B. PRESSURE TEST		
Initial Specified Pressure (Pi)	Bar	
Final Pressure after 10 minutes (Pf)	Bar	
Result	PASS	FAIL
Leakage test shall not continue if any drop in pressure		

C. LEAKAGE TEST	
Initial Pressure (Pi)	Bar
Final Pressure (Approx. 24 hours) (Pf)	Bar
Total make-up water	Liters
Test Duration	Hours

D. LEAKAGE TEST RESULT (24 HOURS)					
Date	Time	Pressure Bar	Water Added (liters)	Observations	Remarks
PASS			FAIL		

E. CALCULATIONS	
TEST DATA	
1. Finish Initial Diameter (ID) 2. Length of Pipe Testing (L) 3. Location	Meter Meter From CH to CH
TEST PRESSURE	
1. Specified Pressure Test 2. Specified Leakage Test Pressure	Bar – 10 minutes Bar – 24 hours
ALLOWABLE LEAKAGES	
1. Maximum Allowable Leakage : $= 0.34 \times \text{ID (cm)} \times \text{L (km)} \times \frac{\text{H (hr)}}{24\text{hr}} \times \text{Pi(Bar)}$ = liters Total make-up water = liter	
REMARKS	

Owner	Consultant	SEDA Representative
Name : Designation : Date :	Name : Designation : Date :	Name : Designation : Date :

2.0 LOAD REJECTION TEST REPORT

LOAD REJECTION TEST

Project :
Date :
Location :
Prepared By :

A. WORKS INFO	
Contractor	
Type of MIV	
Size of MIV inlet	Ø mm
MIV Pressure Rating	bar
Pipe Pressure Rating	bar
Max Allowable Pressure Rise	bar
Rated Speed	rpm
Maximum Allowable Speed Rise	rpm

G. LOAD REJECTION TEST TABLE

No	Parameter	Percentage of Loads			
		25%	50%	75%	100%
1	Start Time				
2	Stop Time				
3	Head Water Level (HWL) in Meters				
4	Tail Water Level (TWL) in Meters				
5	Gross Head Available in Meters				
6	Net Head Available in Meters				
7	Load in kW				
8	Rated RPM				
9	Maximum RPM during test				
10	Speed Rise percentage (%)				

11	Penstock Pressure (bar)				
12	Maximum Pressure Rise (bar)				
13	Pressure Rise percentage (%)				
14	Nozzle/Guide Vane Opening (%)				
15	Nozzle/Guide Vane Closing (sec)				
16	Deflector Closing (sec)				
17	Main Inlet Valve Opening (%)				
18	Main Inlet Valve Closing (sec)				
19	Stator Voltage (kV)				
20	Max Stator Voltage (kV) during test				
PASS		FAIL			

REMARKS

Owner	Consultant	SEDA Representative
Name : Designation : Date :	Name : Designation : Date :	Name : Designation : Date :

3.0 ACCEPTANCE TEST REPORT

ACCEPTANCE TEST

Project :
Date :
Location :
Prepared By :

A. WORKS INFO

Acceptance tests shall be conducted to meet the functional guarantees specified for Turbine and Generator. The tests shall be conducted as per IEC-62006 – Hydraulic machines – Acceptance tests of small hydroelectric installation. The measurement so made will be the basis for the assessment of values guaranteed.

Please enclose the method, measurements and result with this form.

I. ACCEPTANCE TEST	
PASS	FAIL

REMARKS

Owner	Consultant	SEDA Representative
Name : Designation : Date :	Name : Designation : Date :	Name : Designation : Date :

4.0 RELIABILITY RUN

7 DAYS RELIABILITY RUN

Project :
Date :
Location :
Prepared By :

A. WORKS INFO

A reliability run must be carried out in respect of a renewable energy installation utilising small hydropower technology as its renewable resource over 7 continuous days where the installation experiences no more than 3 forced outages as stipulated in SEDA requirement.

SEDA requires the machines to be running a minimum of 80% of the 168 hours (7 days) which is 134 hours and 20 minutes at 50% of the rated installed capacity.

Please enclose the 7 days data log with this form.

K. ACCEPTANCE TEST	
PASS	FAIL

REMARKS

Owner	Consultant	SEDA Representative
Name : Designation : Date :	Name : Designation : Date :	Name : Designation : Date :

SMALL HYDRO RELIABILTY RUN SHEET

GENERATOR PARAMETER LOG R E P O R T

DATE	PHASE TO PHASE VOLTAGE (V)			PHASE TO PHASE CURRENT (A)			PF	KW	FREQ (Hz)	MWH	KVAR	KVA	RPM	STATOR WINDING TEMPERATURE (°C)						GEN TEMP (°C)		TURBINE BRG TEMP (°C)		GRID VOLTAGE (V)		
TIME	RY	YB	BR	R	Y	B								R1-RTD 1	R2-RTD 2	Y1-RTD 3	Y2-RTD 4	B1-RTD 5	B2-RTD 6	DE RTD 7	NDE RTD 8	DE RTD 9	NDE RTD 10	RY	YB	BR
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PREPARED BY			
CHECKED BY			