PERFORMANCE TESTING OF SMALL HYDRO-POWER STATIONS IN INDIA

DR. H. K. VERMA
Professor of Electrical Engineering
Indian Institute of Technology Roorkee
Roorkee – 247667

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Why Performance Testing?

SHP POLICY OF GoI

GoI Provides financial assistance:

- To assist in constructing new SHP stations in the country
- To assist in making SHP projects commercially viable.
- To assist in making the country a leader in the manufacturing of SHP equipment through continuous R&D.
- To assist State Governments in renovation and modernization of old SHP stations
- To assist State Governments in completion of languishing SHP projects
- For development and up-gradation of Water Mills
- For Human Resource Development for small hydro-electric projects and water mills

CONCERNS OF GoI FOR NEW SHP PROJECTS

- Generation as designed and projected
- Generation efficiency
- Quality of equipment
  - Good performance
  - Long life
  - Low maintenance
- Quality of power
  - Minimum interruptions
  - Minimum fluctuations

FINANCIAL ASSISTANCE LINKED TO PERFORMANCE

1. Project should attain 80% of projected generation for at least 3 months in continuation.
2. Weighted average efficiency of units should be at least 75%
3. Overall performance should be good
4. Equipment should conform to Indian/ International standards

AND..

5. Tender document should contain adequate penalty and guarantee clauses
6. Bidding process should be transparent

TO THAT END…..

GoI has made

Performance Testing and Evaluation

of SHP stations

mandatory

for release of financial assistance

What is Performance Testing ?

BROAD OBJECTIVES OF PERFORMANCE TESTING

- To check and verify that all parts and systems in the power station are working fine and performing their assigned functions *correctly*.

- To test and verify that the generating units are operating *efficiently.*

SCOPE OF PERFORMANCE TESTING

- Inspection of all parts, systems, station auxiliaries.
- Functional checks on simpler devices / systems.
- Error checks on measuring instruments.
- Secondary injection tests on protective relays.
- Operational tests on control systems.
- Measurement of critical parameters.
- Measurement of maximum power output of units.
- Measurement of efficiency of generating units.
- Generating additional information (index test).

Tests are conducted subject to technical feasibility.

Test results are evaluated against specified values.

WATER CONDUCTOR SYSTEM

- **Overall inspection**
- **Measurements, if instruments are already installed :**
  - Different water levels/pressure heads
  - Gross head
  - Discharge

GENERATOR

- **Currents and Voltages**
  - Line currents
  - Terminal voltages
  - Power
  - Power factor

- **Temperature rise**
  - Temperature rise of stator
  - Temperature rise of rotor
  - Temperature rise of cooling medium

GENERATING UNITS

- **General health**
  - Temperature rise of windings
  - Temperature rise of bearings
  - Sound levels
  - Vibration levels

- **Performance measurement**
  - Maximum power output of the unit
  - Unit efficiency test
  - Load rejection test
  - Index test

Contd.

EFFICIENCY TEST

- **IEC-60041 makes efficiency test mandatory**
- **IEC-61116 makes it optional:**
  - If machine is small not justifying cost
  - If water flow greatly exceeds usable flow
  - If it is technically difficult to conduct the test
- As per IEC-62006:
  - Measurement Class A: Normal Test Program
  - Measurement Class B: Extended Test Program
  - Measurement Class C: Comprehensive Test Program
  - Efficiency test is required for Class C only
- **IEC-60041 specifies two methods:**
  - Discharge-head measurement method
  - Thermodynamic method

DISCHARGE-HEAD MEASUREMENT METHOD

- **Unit efficiency given by ratio of:**
  - Electrical power output of generator
  - Hydraulic power input to turbine

- **Requires measurement of 3 parameters:**
  - Discharge through turbine
  - Net head availed by turbine
  - Electrical power output of generator

DISCHARGE MEASUREMENT

IEC-60041 Specifies following methods:

- Propeller current meter method
- Ultrasonic transit-time flowmeter
- Pitot-tube method
- Pressure-time method
- Tracer method
- Weirs
- Differential pressure device
- Volumetric gauging method

Other method:

- Acoustic Doppler current profiler

DISCHARGE MEASUREMENT

Choice of the method affected by :

- Limitation imposed by the design of the plant
- Availability of provisions for measurement
- Cost of special equipment and its installation
- Limitation imposed by plant operating condition, for example draining of the system, constant load or discharge operation, etc.

HEAD MEASUREMENT

IEC-60041 Specifies following methods:

- Propeller current meter method
- Ultrasonic transit-time flowmeter
- Pitot-tube method
- Pressure-time method
- Tracer method
- Weirs
- Differential pressure device
- Volumetric gauging method

Other method:

- Acoustic Doppler current profiler

TURBINE
INDEX TEST

- **It needs relative (indexed) discharge measurement**
- **Methods as per IEC-60041:**
  - Taps on spiral case (Winter-Kennedy Method)
  - Suitably located taps in tubular turbines
  - Taps on a taper section of penstock
  - Suitably located taps on a bend
  - Single-path ultrasonic transit-time flow meter
  - Single current meter
  - Measurement of needle stroke on pelton turbine

TURBINE
INDEX TEST

- Purpose as per IEC-60041
  - *Variation in unit efficiency with load*
  - *Variation in unit efficiency with gate/ valve opening*
  - *Relationship between runner blade angle and guide vane opening for maximum efficiency*
- Index test can generate additional information useful in operating the plant
- IEC-61116 is silent on Index Test
- Test is conducted as far as possible

MEASURING INSTRUMENTS

- Error checks
  - All electrical panel meters
  - All digital multi-function meters
  - Error checked at single operating point
- Functional checks
  - Gate / blade / needle position indicators
  - Speed indicators
  - Temperature indicators
  - Temperature scanners

INSTRUMENT TRANSFORMERS
(Current and Voltage Transformers)

- Ratio Test, if necessary

- Test can be conducted:
  - Either on-line
  - Or off-line

PROTECTION GEAR

- Secondary Injection Tests on Protective Relays
  - O/C, E/F and REF relays
  - Voltage-controlled O/C relays
  - O/V and U/V relays
  - Negative sequence relays
  - Directional Power relays
  - Differential relays
  - Field failure relays
  - Other measuring relays
- Measurement Tests on Management Relays
- Functional Checks on
  - Tripping / master relays
  - Auxiliary/ simple relays
  - Circuit breakers
  - Fault annunciators

CONTROL PANELS AND DESKS

Inspection and Functional checks on

- Control / selector switches
- Indicating lamps
- Hooters / buzzers / bells
- Panel light
- Panel light switch
- Space heater
- Thermostat of space heater
- MCCBs / MCBs /contactors
- Other functionally important devices

REGULATION & CONTROL SYSTEMS

- Functional checks on
  - Speed regulation
  - Field regulation
  - Manual synchronization
  - Automatic synchronization
  - Manual Start / stop sequences
  - Automatic Start / stop sequences
  - Emergency stop sequence
  - Transformer tap-changer control
  - AVR relay of tap-changer
- Functioning of governor
- Functioning AVR

GOVERNOR

- All-functions of the governor
- Governor sensitivity test
- Governing stability test
- Load rejection or overspeed test
- Oil temperature test
- Pressure tank capacity test

EXCITATION CONTROL SYSTEM AND A.V.R.

- All functions of AVR
- Excitation control stability test
- Excitation system ceiling voltage
- Excitation system response ratio
- Excitation system response time

IEEE-421A

POWER TRANSFORMERS
(Power and Station Transformers)

- Temperature rise test, if necessary
  - Temperature rise of tank
  - Temperature rise of conservator

- Transformer ratio test, if necessary

STATION AUXILIARIES

Inspection of

- Station AC supply
- Station DC supply
- Emergency power supply
- Oil pumping units
- Cooling systems
- Vacuum pumps
- Air compressors
- Drainage system
- Dewatering system
- Earthing system(s)
- Equipment handling crane and hoists
- Other auxiliaries, if any

How is Performance Testing carried out?

PERFORMANCE TESTING PROCEDURE

PREPARATORY STEPS

I. Obtain power station data and generation data

II. Make advance visit to station, if required

III. Plan inspection, checks and tests

VII. Make provisions for testing, if not available, through owner, like

- Pressure taps and manifold for pressure at turbine inlet
- Mounting structure for current meters
- Guide rail for ADCP
- Platforms for ultrasonic level sensors

V. Recheck / recalibrate test instruments

PERFORMANCE TESTING PROCEDURE

STEPS AT SITE

A – Inspection

B – Functional checks

C – Tests and measurements

PERFORMANCE TESTING PROCEDURE

INSPECTION

- General inspection
- Inspection of civil and hydraulic works
- Inspection of equipment in power house
- Inspection of equipment in outdoor switchyard

PERFORMANCE TESTING PROCEDURE

FUNCTIONAL CHECKS

- Functional checks on control panels
- Functional checks on master / trip/ auxiliary / other simple relays
- Functional checks on annuciators
- Functional checks on circuit breakers
- Functional checks on regulating/ control devices / systems

PERFORMANCE TESTING PROCEDURE

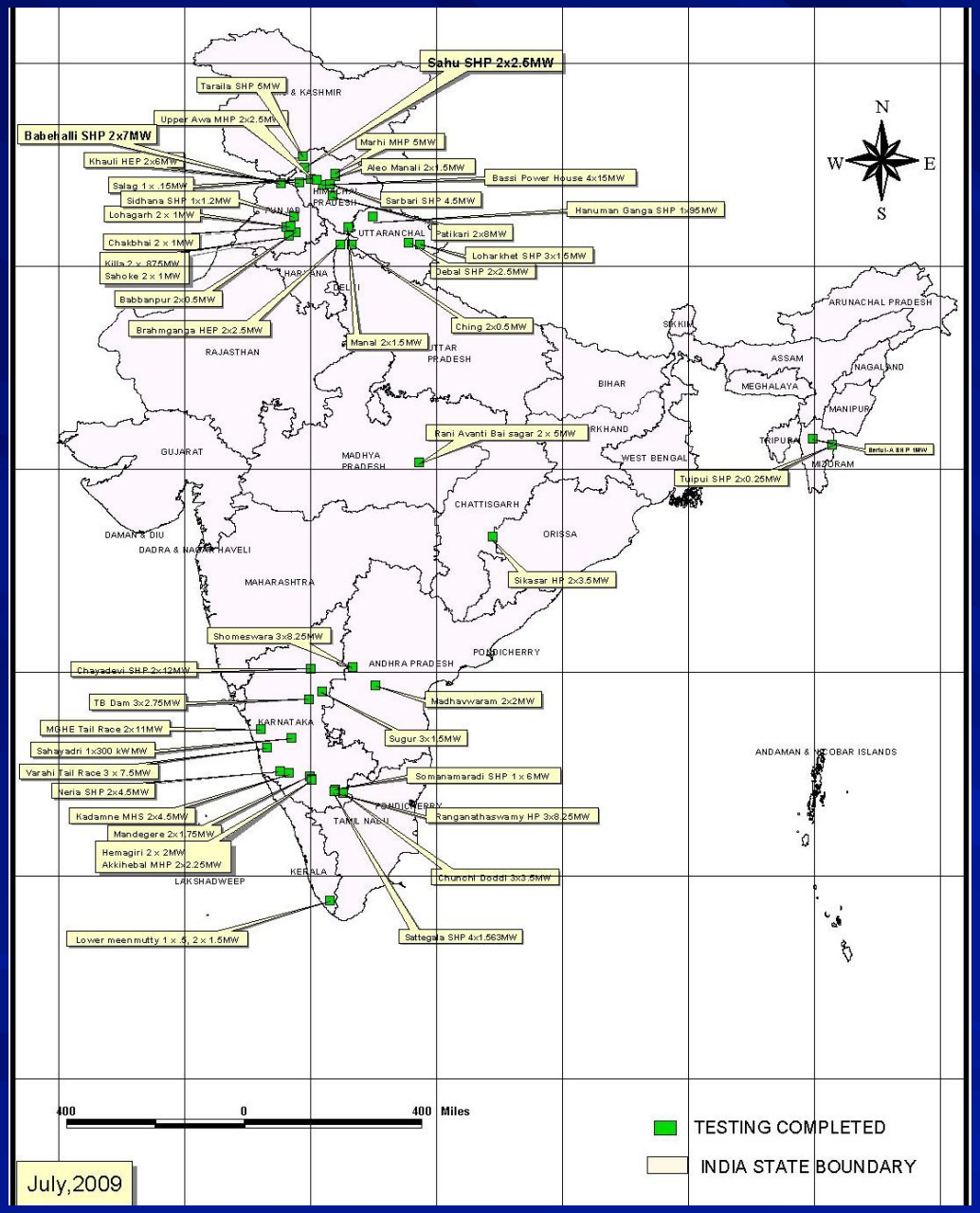
TESTS AND MEASUREMENTS

- Error test on measuring instruments
- Secondary injection tests on protective relays
- Vibration measurements
- Sound-level measurements
- Load-rejection test
- Maximum-power output test
- Unit efficiency test
- Index test

Capacity and Experience of IIT Roorkee

CAPACITY

- Test Team of IIT Roorkee comprises faculty / scientists from:
  - AHEC
  - Electrical Engg. Deptt.
  - Mechanical & Ind. Engg. Deptt.
  - Civil Engg. Deptt.
- Test Team is fully equipped with :
  - Test Instruments
  - Data Acquisition Systems
  - Wireless communication equipment
  - Data-analysis software



SHP STATIONS TESTED

Jammu & Kashmir	(01)
Himachal Pradesh	(35)
Punjab	(14)
Uttarakhand	(05)
West Bengal	(01)
Orissa	(01)
Mizoram	(03)
Chhattisgarh	(02)
Madhya Pradesh	(01)
Maharashtra	(03)
Gujarat	(03)
Andhra Pradesh	(02)
Karnataka	(25)
Kerala	(03)
Total	**(99)**

SHP STATIONS TESTED

- **Total number of SHP Stations tested till Dec 2011: 99**
- **State-wise Distribution**

1. Jammu & Kashmir (01)
2. Himachal Pradesh (35)
3. Punjab (14)
4. Uttarakhand (05)
5. West Bengal (01)
6. Orissa (01)
7. Mizoram (03)
8. Chhattisgarh (02)
9. Madhya Pradesh (01)
10. Maharashtra (03)
11. Gujarat (03)
12. Andhra Pradesh (02)
13. Karnataka (25)
14. Kerala (03)

EXPERIENCE (1)

- **Types of Power Stations tested**
  - Run-of-river (65)
  - Canal-fall based (25)
  - Dam-toe-based (09)

- **Water Heads**
  - High head
  - Medium head
  - Low head
  - Ultra-low head
  - Highest head: 601m
  - Lowest head: 1.86 m

EXPERIENCE (2)

- **Station Capacities**
  - Min : 150 kW
  - Max : 25 MW
- **Unit Sizes**
  - Min : 150 kW
  - Max : 8.25 MW

EXPERIENCE (3)

- **Turbines**
  - Pelton turbine
  - Full Kaplan turbine
  - Half Kaplan turbine
  - Francis turbine
- **Generators**
  - Synchronous
  - Induction
- **Excitation Systems**
  - Static
  - Brushless
  - Brush type rotating exciter

EXPERIENCE (4)

- **Controls**
  - Digital electronic governor
  - PLC based governor
  - Analog electronic AVR
  - Digital electronic AVR
  - SCADA
- **Transformer Tap Changers**
  - Off load
  - On load

EXPERIENCE (5)

- **Relays**
  - Electromechanical relays
  - Analog static relays
  - Digital relays
  - Management relays

- **Meters**
  - Analog panel meters
  - Digital panel meters
  - Digital multi-function meters

INSTITUTIONS ASSOCIATED WITH IIT ROORKEE

- Jadavpur University, West Bengal
- NIT Bhopal, Madhya Pradesh
- NIT Jalandhar, Punjab

STANDARDS ON TURBINE

1. IEC Standard 60041, “Field Acceptance Tests to Determine the Hydraulic Performance of Turbines, Storage Pumps and Pump Turbines”, 1991.

2. IEC Standard 61116, “Electromechanical Equipment Guide for Small Hydroelectric Installations”, 1992.

3. IEC 62006, “Hydraulic Machines - Acceptance Tests of Small Hydroelectric Installations”, 2010

STANDARDS ON GENERATOR

1. IEC- 34-1 (1983), "Rotating Electrical Machines" Part-1: Rating and Performance"
2. IEC- 34-2 (1972), "Rotating Electrical Machines" – Part-2: "Methods for Determining Losses and Efficiency of Rotating Electrical Machinery from Tests"
3. IS- 4722 (2001), "Rotating Electrical Machines – Specification"
4. IS- 12824 (1989, Reaffirmed 1999), "Types of Duty and Classes of Rating Assigned to Rotating Electrical Machines"

STANDARDS ON GOVERNOR

1. ANSI/IEEE Standard 125 “IEEE Recommended Practice for Preparation of Equipment Specifications of Speed Governing of Hydraulic Turbines Intended to Drive Electric Generators”, 1988.
2. IEC Standard 308, “International Code for Testing of Speed of Governing Systems for Hydraulic Turbines”, 1970.
3. IEC Standard 61116, “Electromechanical Equipment Guide for Small Hydroelectric Installations”, 1992.
4. ASME Power Test Code Number 29, Speed Governing Systems for Hydraulic Turbine-Generator Units”, 1965.

STANDARDS ON EXC. SYSTEM

1. IEEE Standard 421, “Criteria and Definitions for Excitation Systems for Synchronous Machines”, 1972.
2. IEEE Standard 421A, “IEEE Guide for Identification, Testing and Evaluation of the Dynamic Performance of Excitation Systems”, 1978.
3. IEC Standard 61116, “Electromechanical Equipment Guide for Small Hydroelectric Installations”, 1992.