

STANDARDS/MANUALS/ GUIDE LINES FOR SMALL HYDRO DEVELOPMENT

3.9

Electro-Mechanical–

Technical specifications for procurement of control, automation, protection and monitoring systems

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AHEC-IITR, “3.9 Electro-Mechanical – Technical specifications for procurement of control, automation, protection and monitoring systems”, standard/manual/guideline with support from Ministry of New and Renewable Energy, Roorkee, November 2012.

PREAMBLE

There are series of standards, guidelines and manuals on electrical, electromechanical aspects of moving machines and hydro power from Bureau of Indian Standards (BIS), Rural Electrification Corporation Ltd (REC), Central Electricity Authority (CEA), Central Board of Irrigation & Power (CBIP), International Electromechanical Commission (IEC), International Electrical and Electronics Engineers (IEEE), American Society of Mechanical Engineers (ASME) and others. Most of these have been developed keeping in view the large water resources/ hydropower projects. Use of the standards/guidelines/manuals is voluntary at the moment. Small scale hydropower projects are to be developed in a cost effective manner with quality and reliability. Therefore a need to develop and make available the standards and guidelines specifically developed for small scale projects was felt.

Alternate Hydro Energy Centre, Indian Institute of Technology, Roorkee initiated an exercise of developing series of standards/guidelines/manuals specifically for small scale hydropower projects with the sponsorship of Ministry of New and Renewable Energy, Government of India in 2006. The available relevant standards / guidelines / manuals were revisited to adapt suitably for small scale hydro projects. These have been prepared by the experts in respective fields. Wide consultations were held with all stake holders covering government agencies, government and private developers, equipment manufacturers, consultants, financial institutions, regulators and others through web, mail and meetings. After taking into consideration the comments received and discussions held with the lead experts, the series of standards/guidelines/manuals are prepared and presented in this publication.

The experts have drawn some text and figures from existing standards, manuals, publications and reports. Attempts have been made to give suitable reference and credit. However, the possibility of some omission due to oversight cannot be ruled out. These can be incorporated in our subsequent editions.

This series of standards / manuals / guidelines are the first edition. We request users to send their views / comments on the contents and utilization to enable us to review for further upgradation.

Standards/ Manuals/Guidelines series for Small Hydropower Development

General	
1.1	Small hydropower definitions and glossary of terms, list and scope of different Indian and international standards/guidelines/manuals
1.2 Part I	Planning of the projects on existing dams, Barrages, Weirs
1.2 Part II	Planning of the Projects on Canal falls and Lock Structures.
1.2 Part III	Planning of the Run-of-River Projects
1.3	Project hydrology and installed capacity
1.4	Reports preparation: reconnaissance, pre-feasibility, feasibility, detailed project report, as built report
1.5	Project cost estimation
1.6	Economic & Financial Analysis and Tariff Determination
1.7	Model Contract for Execution and Supplies of Civil and E&M Works
1.8	Project Management of Small Hydroelectric Projects
1.9	Environment Impact Assessment
1.10	Performance evaluation of Small Hydro Power plants
1.11	Renovation, modernization and uprating
1.12	Site Investigations
Civil works	
2.1	Layouts of SHP projects
2.2	Hydraulic design
2.3	Structural design
2.4	Maintenance of civil works (including hydro-mechanical)
2.5	Technical specifications for Hydro Mechanical Works
Electro Mechanical works	
3.1	Selection of Turbine and Governing System
3.2	Selection of Generators and Excitation Systems
3.3	Design of Switchyard and Selection of Equipment, Main SLD and Layout
3.4	Monitoring, control, protection and automation
3.5	Design of Auxiliary Systems and Selection of Equipments
3.6	Technical Specifications for Procurement of Generating Equipment
3.7	Technical Specifications for Procurement of Auxiliaries
3.8	Technical Specifications for Procurement and Installation of Switchyard Equipment
3.9	Technical specifications for procurement of control, automation, protection and monitoring systems
3.10	Power Evacuation and Inter connection with Grid
3.11	operation and maintenance of power plant
3.12	Erection Testing and Commissioning

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TECHNICAL SPECIFICATION FOR PROCUREMENT OF CONTROL, AUTOMATION, PROTECTION AND MONITORING SYSTEMS

1.0 GENERAL

1.1 Scope

This guide is intended to assist in preparation of technical specification for procurement of control, automation, protection and monitoring of main generating equipment viz. turbine, generator, transformer, associated auxiliaries, and switchyard equipment for small hydro stations up to 25 MW.

1.2 General

Selection of equipment for control, automation, protection and monitoring is detailed in separate guide.

This guide describes technical specifications for supply of control, automation, protection and monitoring systems for small hydro power plants selected as per guideline of the equipment selected.

1.3 References and Codes

R1	IEC 62053-2003	Electrical metering equipment
R2	IEC 61810-2008	Electro mechanical relays
R3	IEC 600 68 -1998	Environmental testing
R4	IEC 60255-21-1 -1988	Vibration
R5	IEC 60255-21-2-1988	National Electrical Code
R6	IEC 61000-4-2-2008	Static discharge test
R7	IEC 61000-4-3-2007	Dielectric test
R8	IEC 61000-4-4-2004	Transient fast burst test
R9	IEC 61000-4-5-2005	Surge protection
R10	IEC 61000-4-6-2007	Electromagnetic fields
R11	IEC 61000-4-11-2004	Voltage dips
R12	IEC 60255-22-1-2007	1MHz burst disturbance
R13	IEC 68-2-1 & 68-2-2 -1976	Temperature
R14	IEC 68-2-30-2005	Humidity
R15	IEC 68-2-6 -2007	Vibration of Unpackaged Products
R16	IEC 68-2-27 -2008	Shock of Unpackaged Products
R17	IEC 61000-4-3 -2006	Radiated Electromagnetic Immunity
R18	IEC 61000-4-5 -2005	Surge Transient Immunity
R19	IEC 61000-4-4 -2010	Electrical Fast Transient/Burst Immunity
R20	IEC 6 1000-4-6 -2008	Conducted Electromagnetic Immunity
R21	IEC 61116:1992	Electro mechanical guide for small hydroelectric installations

R22	IEEE Std 1249 – 1996	Guide for computer based control of hydroelectric plant automation
R23	IEEE Std 1020 – 2011	Guide for control of small hydro plant
R24	IEEE Std1010 – 2006	Guide for Control of Hydro Electric Power Plant
R25	IEEE 2519 -1999	Power Quality
R26	IEEE 60545:1976	Guide for commissioning operation and maintenance of Hydraulic Turbines
R27	IEEE 1046-1991	IEEE application guide for distributed digital control and monitoring for power plants
R28	IEEE C 37.101-2006	IEEE guide for generator ground protection
R29	IEEE C 50.12-2005	IEEE standard for salient pole 50 Hz and 60 Hz synchronous generator and generator / motors for hydraulic turbine application rated 5 MVA and above
R30	IEEE 421.4-2004	IEEE guide for preparation of excitation system specification
R31	IEEE C 37.101-2006	IEEE guide for generator ground protection
R32	IEEE C 50.12-2005	IEEE standard for salient pole 50 Hz and 60 Hz synchronous generator and generator / motors for hydraulic turbine application rated 5 MVA and above
R33	IEEE 421.4-2004	IEEE guide for preparation of excitation system specification
R34	IEEE 242:1996	IEEE recommended practice for protection and coordination of industrial and commercial power systems
R35	IEEE C 372-1987	IEEE standard electrical power systems device function numbers
R36	IEEE C 37.95 : 1974	(R1980) IEEE guide for protective relaying of utility
R37	IEEE C 37.102:1987	IEEE guide for generator protection
R38	CISPR11	Industrial, Scientific And Medical Equipment – Radio-Frequency Disturbance Characteristics – Limits And Methods Of Measurement
R39	ASTM D999-75	Vibration of Packaged products
R40	ASTM D775-80	Shock of Packaged products
R41	UL94V	Standard on Flammability and Resistance to Electrical Ignition
R42	AHEC,IITRoorkee-2002	Power Finance Corporation - Final Report 2002
R43	AHEC,IIT Roorkee -2005	Micro Hydro Quality Standards.

Abbreviations:

AHEC, IIT	:	Alternate Hydro Energy Centre, Indian Institute of Technology, Roorkee
ASTM	:	American Society for Testing and Materials
CISPR	:	Comité International Spécial des Perturbations Radioélectriques (CISPR; English: Special international committee on radio interference) – a group of IEC
IEC	:	International Electro-technical Commission

IEEE : Institute of Electrical and Electronics Engineers
UL : Underwriters Laboratories Inc, global independent safety science company,
USA

2.0 CONTROL, AUTOMATION, MONITORING AND PROTECTION OF PLANT OF PLANT EQUIPMENT

2.1 Control, Monitoring and Automation of Plant

2.1.1 Scope

Design, fabricate, assemble, test at manufacturer's works, supply, deliver, erect, test at site, commission and train owner's operating personnel for the Control, Protection and Monitoring Equipment and Systems for power generation at Hydro Power Plant .

2.1.2 Control systems

The control system shall primarily be computer based automation control system, programmable logic with back up hard wired manual control.

Supervisory Control and Data Acquisition (SCADA) system may be provided for SHP of capacity above 5 MW and below 5 MW where control room is not at generator floor or remote controlled SHP. However, provision for SCADA will be made for SHP below 5 MW for possible future provision.

Controls for Small hydro of 100 kW capacity or below will be as in accordance with AHEC Micro Hydro Quality Standards-2005.

2.1.2.1 General Requirements

- a) Power house will be designed for manual control from unit control switchboard and manual and automatic control from centralized control from panels located in the control room and shall be designed for operation by a single operator.
- b) Main single line diagram is shown in drawing to be attached by Purchaser. Metering and relaying as proposed is to be shown in the drawing. These would be tentative drawings. Final drawings will be prepared by Tenderer and approved by the Purchaser.
- c) Provision is to be made for manual and automatic control for unit starting, unit stopping and running control at the power house with provision for supervisory control and data acquisition
- d) Power house units operation and loading should to be suitable for isolated operation until grid operation is available. A fore bay with two minutes storage capacity is provided for power house operation.

- e) Dependable level sensor will be provided in the fore bay so that power generation is reduced/cut off in case of low level in fore bay.
- f) Necessary sensors and actuators for the turbine generator, transformers and other equipment have been specified along with the equipment. Any additional sensors or actuators required for the control and monitoring as detailed in this chapter shall be supplied.
- g) Open architecture system shall be followed.

Detailed layout of panels in machine hall and control room will be submitted by the Tenderer in the bid.

2.1.2.2 Control and Monitoring Equipment

2.1.2.2.1 Unit control board

The hard wired manual unit control switchboards (UCB), location shall be subject to approval by Purchaser and shall communicate with the unit and associated equipment and shall be designed to perform following functions.

- (a) Information receipt and monitoring
- (b) Start stop control sequencing
- (c) Annunciation of alarm conditions
- (d) Temperature information monitoring
- (e) Metering and instrumentation signals display
- (f) Event recording
- (g) Synchronising and connecting the unit to the system
- (h) Control of active/reactive power

2.1.2.2.2 Centralised control board

Centralized control system equipment located in the control room shall be interconnected to the unit control boards. Required control and monitoring of all functions of the hydro-electric power project shall be provided to the operator. The control console with conventional control devices and monitoring equipment in conjunction with a computer based data acquisition and control system (DACS), shall provide control and indication access to individual items of equipment to facilitate operation, supervision and control. Hard wired pushbutton switches shall provide for direct manual control of unit start-stop, breaker close (initiating automatic synchronizing), breaker trip, voltage raise-lower and gate limit raise-lower. Analog or digital panel meters and indicating lights shall continuously indicate the status of all main units, breakers, transformers, and lines. The DACS system display monitors and keyboards shall be available to operator control. The unit controls and instruments shall supplement or duplicate those on the unit control board, and provide the control room operator with the ability to transfer control of any selected unit or group of units to the unit control board in case of system trouble.

The control console may also provide project equipment control functions. Panels shall have 25% spare capacity of digital and analogue inputs/output.

2.1.2.2.3 Equipment Location

Arrangement of control and instrument switches and mimic bus should simulate the relative order of interconnections or physical order of the plant arrangement assisting the operator in forming a mental picture of connections. The top of the control console panel should be inclined to provide easier access to the control switches and to improve console visibility. Layouts of console visual display terminals (VDTs) shall be subject to approval.

2.1.2.2.4 Manual and Automatic Synchronising

Provision for synchronising manually and by a dedicated automatic synchronizer unit shall be made and details included in the bid.

2.1.2.2.5 Status Switchboard

The status switchboard shall contain graphic and visual indication, generator load recorders, station total megawatts (MW) and mega-vars(MVAR) recorders, and other required project data displays. The status switchboard should be located for easy observation from the control console. The status switchboard shall be a standard modular vertical rack enclosure joined together to form a freestanding, enclosed structure.

2.1.2.2.6 Annunciation and Alarm

2.1.2.2.6.1 Audio & Video Signals

Annunciation system shall be providing for both audible and visual signals in the event of trouble or abnormal conditions.

a) Audio Signals

Howler horns and intermittent gongs shall be used for audible signal devices. An intermittent gong shall be in the plant control room. Howler horns shall be used in the unit area and in areas where the background noise is high (e.g. in the turbine pit) or in areas remote from the unit (e.g. plant switchyard).

b) Visual Signals

Visual signals shall be provided by lighted lettered window panels of the annunciator. The annunciator panel indication shall be augmented by unit trouble lamps located in a readily visible position close to the unit. The plant sequence of event recorder (SER) shall be located in the control room. Separate annunciators for station service system and switchyard shall be located on associated control panels of the station service switchgear or on the switchyard control panels.

2.1.2.2.6.2 Annunciation systems

The annunciation system shall be designed for station DC voltage system. All remote contacts used for trouble annunciation shall be electrically independent of contacts used for other purposes so annunciator circuits are separated from other DC circuits. Auxiliary relays shall be provided where electrically independent contacts cannot otherwise be obtained. The annunciator equipment should use solid-state logic units, lighted window or LED type, designed and tested for surge withstanding capability in accordance with ANSI C37.90.1-2002, and manufactured in accordance with ANSI/ISA S18.1-1992.

The switchboard and annunciator operational sequence should be a manual or automatic reset sequence as listed in Table 1.

Automatic reset should be employed for the SCADA system backup. For SCADA system the design reset features of the annunciator shall be coordinated to ensure proper operation.

The unit control board shall be provided with annunciator alarm points for unit emergency shutdown, generator differential lockout, generator incomplete start, generator bus ground, generator over speed, generator over current, generator breaker low pressure, unit control power loss, PT fuse failure or under voltage, and low forebay level water.

Table 1: Switchboard Annunciator Operational Sequence

Field Contact	Control Pushbutton or Switch	Alarm Lights	Horn	Auxiliary or Repeater Contacts
Normal	--	Off	Off	Off
Abnormal	--	Flashing	On	On
Abnormal	Acknowledge or silence	On	Off	On
Normal	Reset	Off	Off	Off
Normal	Test	On	Off	Off

The unit control board shall be provided with an additional annunciator for the generator step-up transformer and unit auxiliary equipment alarms, these alarm points shall be transformer differential, transformer lockout trip, transformer overheat, transformer trouble, switchgear trip, and trouble.

The switchboard shall be provided with auxiliary or repeater contacts to drive control room console remote annunciator word indicating lights.

A control console window-indicating light annunciator shall be common to all units. One unit at a time can be selected by use of the appropriate unit trouble status lighted pushbutton. Visual indication shall be provided when the unit switchboard annunciator is activated. The console window indicating lights shall be generally grouped by switchboard annunciator points and provide essential trouble status to the operator. Unit troubles shall be categorized by

shutdown differential, over current, cooling water, bearing oil, unit trouble, breaker air, control power etc.

2.1.2.2.6.3 Trouble Annunciator Points

Alarm signals transmitted to the unit control board annunciator from turbine generator, excitation system, generator terminal cabinet generator breaker, step up transformers shall be provided.

2.1.2.2.7 Equipment racks

Equipment racks shall be provided for mounting line relays, automatic synchronising equipment, common and outside annunciator chassis, auxiliary relays, communication equipment, and transfer trip equipment. The equipment racks should be standard, modular, vertical rack enclosures.

2.1.2.2.8 Cabinet Construction

Generator switchyard panels and doors shall be 3mm thick (14 gauge) smooth select steel with angle or channel to approx. 6 mm radius: panels and doors shall be mounted on sils and supplied as ready for powerhouse installation. All switchboards shall be mounted and wired in the factory.

2.1.2.2.9 Equipment Arrangement

The arrangement of equipment on the control switchgear, switchboard, or control console should be carefully planned to achieve simplicity of design and to replicate unit control placements familiar to the intended operating staff. Simplicity of design shall be a definite aid to operation and shall tend to reduce operating errors; therefore, the relative position of devices should be logical and uniform. Switchboard and control console design should be patterned to attain to degree of standardization in the arrangement of indicating instruments and basic control switches. Control switches shall be equipped with distinctive handles generally as shown in table 2. Each item of equipment should be located by consideration of its functions, its relation to other items of equipment and by its use by the operator.

Location and layout of unit control switchboard and control room layout shall be subject to approval by Purchaser.

2.1.2.2.10 Indication System

The control panel shall incorporate the visual indication such as Breaker on, Breaker off, Breaker Trip, MIV (main inlet valve) open, MIV close, D.C on, D.C. off etc.

2.1.3 Computer based Control System

2.1.3.1 Functional Capabilities

Functional capabilities required are generally as below:

- i. Computer based automation system shall permit operation of power plant, switchyard, Main Inlet valves etc. from a single control point in centralised control room.
- ii. Local control shall be provided by the side of equipment located at the generator floor level. The local unit computer shall be part of the equipment.
- iii. Automatic unit start/stop control sequencing shall be part of computer based automation. Automation system shall include capability to provide diagnostic information so as to isolate the problem and get the unit on line as fast as possible.
- iv. Auto synchronising shall be computer based. There is no objection to provide synchronising function as internal to the automation system. Check synchronising relay shall be provided for security.
- v. The computer system shall optimise individual unit turbine operation to enhance unit operation in respect of following:
 - a) Efficiency maximization - gate position, flow, unit kW output, unit reactive power output.
 - b) Minimization unit vibration or rough running zone - gate position, unit vibration.
 - c) Minimization of cavitation: Gate position, flow, Hydraulic head, turbine manufacturers cavitation curve.
 - d) Black start control - this may be including starting emergency generator.
 - e) Centralised Control – Individual units, switchyard, station service control, plant voltage/Var control, water and power optimization; Forebay level control.
- vi. For large units and offsite group control plants.
 - a. Data acquisition capabilities
 - b. Alarm processing and diagnostics
 - c. Report generation
 - d. Maintenance and management interface
 - e. Data archival and retrieval
 - f. Data access
 - g. Operator simulation training (for offsite control and large plant)

Table 2: Plant Control and Instrument Switch Types

Switch function	Contact Type	No. of Positions	Handle Type	Nameplate Marking	Escutcheon or Dial marking				Ind. Lights
					Pos-1	Pos-2	Pos-3	Pos-4	
Exciter AC voltage control	A	3	BPG	AC volt adjust	Lower	-	Raise		
Excitation breaker control	A	3	BPG	Exc. Bkr.	Trip	-	Close		G,R.
Exciter DC voltage adjust	A	3	BPG	DC volt adjust	Lower	-	Raise		R,A,A,G
Generator breaker control	A	3	BPG	Gen PCB	Trip	-	Close		G,R
Generator start/stop control	A	3	BPG	Unit start-stop	Stop	-	Start		G,R
Emergency shutdown (main unit)	A	-	RPG	Emerg. shutdown	Pull	AND	Turn		-
Governor gate limit control	A	3	BO	Gate limit	Raise	-	Lower		-
Governor speed level control	A	3	BO	Speed adj	Raise	-	Lower		-
Synchronizing (main units)	B	2	RBO	Synch	Off	ON			-
Synchronizing (switchyard)	B	3	RBO	Synch	Run	OFF	Inc		-
Governor oil pump motor control	A	3	BPG	Transf oil pumps	Stop	-	Run		G,R
Ammeter switch	B	4	BK	Gen AM	A	B	C	Off	G,R
Voltmeter switch	B	4	BK	Gem VM	Off	A-B	B-C	C-A	
Volt regulator transfer switch	B	3	BPG	Volt reg	Off	Main	Reg		W,R

*Type A-Momentary spring return to neutral

Type B-Maintained

BPG –Black pistol grip

RPG- Red pistol grip

BO- Black oval

RBO- Removable black oval

BK- Black knurled

To suit each application

2.1.3.2 Control and Monitoring of Plant Equipment

2.1.3.2.1 Control and Status Data

Control and status data to be transmitted from various equipment to Unit Control Board and from Unit Control Board to the equipment etc is detailed below. This is tentative and may be increased or decreased as required with Purchaser's approval.

Information and control signals will be needed between the control board and each of the following:

- (i) Canal/Fore bay/ Surge Tank water level
- (ii) Turbine
- (iii) Turbine speed governor
- (iv) Generator
- (v) Generator excitation system
- (vi) Unit transformer
- (vii) Circuit breaker and switches
- (viii) Intake gate/MIV and draft gate

Additionally, control signal shall also be from Auxiliary equipment, Fire Protection, Auxiliary AC Power Supply, DC Power supply, Service Water, Service Air shall be provided as per IEEE – 1010.

These equipment blocks represent auxiliary service equipment needed for the proper operation of the generating plant. abnormal conditions of this equipment will be alarmed.

Abbreviations used subsequently are:

- | | |
|---|---|
| C | = Control |
| P | = Protection Trip |
| A | = Annunciation/Event Recording |
| T | = Temperature Monitoring |
| I | = Indication analog, digital, status lamps) |

2.1.3.2.1.1 Control and Status Data Transmitted from Turbine to Unit Control Switchboard

- i) Turbine guide bearing temperature- Provision for mounting two sensors in bearing shell.
T, A, P, I
- ii) Turbine guide bearing oil temperature **T, A, P, I**
- iii) Turbine guide bearing oil level high **A**
- iv) Turbine guide bearing oil level low **A**
- v) Wicket gate shear pin failure **A**
- vi) Bearing cooling water low flow **A**
- vii) Turbine pit water high level **A, C**
- viii) Turbine shaft air maintenance seal applied **A, P**

- ix) Water pressure in Intake **P, I**
- x) Draft tube water pressure-vacuum **A**
- xi) Wicket Gate Servomotor Position **C**
- xii) Runner Blade Servomotor Position **C**

2.1.3.2.1.2 Control and Status Data Transmitted from Unit Control Switchboard to Turbine

Turbine lubes oil system start/stop- Enable turbine lubrication prior to unit run. **C**

Brake “ON” /“OFF” - Starting interlock **C**

2.1.3.2.1.3 Operating Power, Air and Water from Service Equipment to Turbine

- i) DC Power supply for control and protection devices
- ii) Power supply for turbine pit water pump
- iii) Air supply for shaft maintenance seal.
- iv) Water supply for bearing oil coolers and turbines seals
- v) Power supply for Lubricating oil system for bearing

2.1.3.2.1.4 Control and Status Data Transmitted from Governor to Unit Control Switchboard

- i) Speed indication- **I**
- ii) Over-speed(mechanically actuated) **C, P**
- iii) Over-speed(electrically actuated) **C, P**
- iv) Synchronous speed **C, P**
- v) Under speed switches **C, P**
- vi) Speed signal failure **A, C, P**
- vii) Wicket gate position indication **C, I**
- viii) Wicket gate position switches **C, P, I**
- ix) Governor Oil Pressure Unit – oil level switches in Pressure Vessel **A, P**
- x) Governor Oil Pressure Unit -pressure switches on Pressure Vessel **A, P**
- xi) Governor Oil Pressure Unit – sump tank oil temperature high **A**
- xii) Governor Oil Pressure Unit – standby pump operation **A**
- xiii) Governor power supply failure **A, C, P**
- xiv) Wicket gate automatic lock applied/released **C, I**
- xv) Wicket gate automatic lock failure **A**
- xvi) Manual control indication **I**
- xvii) Pilot valve strainer obstruction **A**
- xviii) Fire detection system operation/trouble **A, P**
- xvi) Governor balance indication **I**

2.1.3.2.1.5 Control and Status Data Transmitted from Unit Control Switchboard to Governor

- i) Speed reference raise /lower commands **C**
- ii) Power reference raise /lower commands **C**
- iii) Gate limit raise/lower commands **C**
- iv) On-off command to start/stop solenoid 65SS or gate limiter motor **C, P**
- v) On/off command to partial shutdown (speed-no-load) solenoid **C, P**
- vi) Generator voltage and current **C**
- vii) Unit on-line **C**
- vii) Unit brakes on/off command **C**
- viii) Level difference between headwater and tail water **C**

2.1.3.2.1.6 Operating Power, Air and Water from Service Equipment to Governor

- i) Power supply for DC control
- ii) Power supply for Oil Pressure Unit pumps
- iii) Alternate supply for governor power supplies
- iv) Air supply for generator air brakes (if provided)
- v) Air supply for OPU (if provided)

2.1.3.2.1.7 Control and status data Transmitted from Generator to unit control board

- i) Stator winding temperature- Temperature detectors (typically 12) embedded in stator winding accordance with ANSI C50. 10-1977 (1). Two hottest RTDs connected to thermal overload relay 49G **T, A, P**
- ii) Stator Core **T, A, P**
- iii) Thrust bearing temperature **T,A,P**
- iv) Guide bearing temperature **T, A, P**
- v) Bearing oil temperature **T, A, P**
- vi) Air cooler outlet air temperature. **T,A,**
- vii) Air cooler inlet air temperature. **T,A,**
- viii) Generator field temperature **T, A, P**
- ix) Bearing oil level high **A**
- x) Bearing oil level low **A**
- xi) Bearing water contamination detector **A**
- xii) Thrust bearing high pressure oil system start interlock/failure alarm. **C, A, I**
- xiii) Temperature detectors for fire protection system **P, C, A**
- xiv) Fire extinguishing system operation **P, A**
- xv) Air brake position indication **C,I** (if provided)
- xvi) Neutral end and terminal end current transformers **P, I**
- xv) Cooling water valve position **C, I**
- xvi) Cooling water flow low **A, P**

2.1.3.2.1.8 Control and status data Transmitted from Generator to unit control board

- i) Thrust bearing high pressure oil pump start/ stop command. **C**
- ii) Generator cooling water system start/ stop command. **C**
- iii) Fire extinguishing system operates command. **C, P**
- iv) Air louver operate command **C, P**
- v) Generator lube oil system start/stop command. **C**

2.1.3.2.1.9 Operating Power, Air and Water from Service Equipment to Generator

- i) Power supply for thrust bearing high-pressure oil pump.
- ii) Power supply for DC control circuits.
- iii) Air supply for brakes and rotor jacking system (if provided)
- iv) Water supply for fire extinguishing system
- v) Power supply for generator housing space heaters.
- vi) Water supply for generator air coolers and bearing oil coolers.
- viii) Air supply for operating discharge and inlet air louvers
- ix) Power supply for CO₂ fire extinguishing system.
- x) Power supply for generator lube oil system.

2.1.3.2.1.10 Control and Status Data Transmitted from Generator Terminal Equipment to Unit Control Switchboard

- i) Current signal for relaying and metering
- ii) Voltage signal for relaying and metering
- iii) Current indication **I**
- iv) Frequency indication **I**
- v) Voltage indication **I**
- vi) Metering **I,A**
- vii) Voltage signal for automatic voltage regulator (AVR) **C**
- viii) Governor speed sensing **C**
- ix) Power transducer **C**

2.1.3.2.1.11 Control and Status Data Transmitted from Unit Control Switchboard to Generator Terminal Equipment

- i) Fire extinguishing system command- Deluge valve operation upon differential and high temperature detection **C, P**

2.1.3.2.1.12 Operating Power, Air and Water from Service Equipment to Generator Terminal Equipment

- i) Power supply from DC control circuits- For uninterruptible systems such as fire protection
- ii) Power supply for forced air bus duct circulation system
- iii) Carbon- di- oxide supply for fire extinguishing system and forced air cooling

2.1.3.2.1.13 Control and Status Data Transmitted to and from the Cooling System and Unit Control System

Conventional Cooling System

- i) Fan failure **A.P.**
- ii) Cooling water low flow **A**
- iii) Strainer differential pressure **A**

2.1.3.2.1.14 Control and Status Data Transmitted from excitation system to unit control switchboard

- i) Exciter transformer o/c protection **P**
- ii) Field overload **I**
- iii) Field current indication **I**
- iv) Field voltage indication **I**
- v) Field ground detection **P or A**
- vi) Failure of preferred field flashing source **A**
- vii) Field breaker position **C, I**
- viii) Field flashing contactor position **I**
- ix) Exciter start sequence incomplete **P, A**
- x) Pole slip protection **P**
- xi) Cooling fan failure –Stage I **A**
- xii) Cooling fan failure –Stage 2 **P**
- xiii) DC power supply failure **P or A**
- xiv) Exciter transformer over temperature –Stage I **A**
- xv) Exciter transformer temperature –Stage 2 **P**
- xvi) Rectifier transformer temperature-stage I **A**
- xvii) Rectifier failure –Stage 2 **P**
- xviii) Heat exchanger failure **A**
- xiv) Exciter transformer temperature indication **I**
- xv) Manual voltage adjuster with 70V End-of travel indication **I**
- xvi) Auto voltage adjuster with position 90 V End-of –travel indication **I**
- xvii) 70V preset position-Interlock in start sequence **C**
- xviii) 90V preset position-Interlock in start sequence **C**
- xix) Station service A.C test supply switch position **I**
- xx) Indication mismatch between auto and manual **I**
- xxi) Voltage regulator output **I**
- xxii) Voltage set point

2.1.3.2.1.15 Control and Status Data transmitted from unit control Switchboard to excitation

- i) Field tripping from generator **P**
- ii) Field breaker tripping from manual control and unit shutdown sequence logic **C**
- iii) Field breaker closing from manual control and unit start sequence logic **C**

- iv) Exciter de-excite -Close contact to initiate field flashing at 95% speed during auto start or under manual control **C**
- v) Exciter de-excite - Open contact to initiate phase back below 95% speed, unit separated form System **C**
- vi) Voltage transformer - Transfer exciter from auto voltage control to manual control **C**
- vii) Close contact transfer exciter to manual voltage regulator control **C**
- viii) Close contact to transfer exciter to auto voltage regulator control **C**
- ix) Run 70V to preset position preparation for unit starting **C**
- x) Run 90V to preset position preparation for unit starting **C**
- xi) Raise manual voltage adjuster **C**
- xii) Lower auto voltage adjuster **C**
- xiii) Raise auto voltage adjuster **C**
- xiv) Lower auto voltage adjuster **C**
- xv) Generator CB Auxiliary switch **C**
- xvi) Analog signal representing wicket gate position **C**

2.1.3.2.1.16 Operating Power from Service Equipment to Excitation system

- i) Station service as test supply
- ii) Battery-fed field flashing
- iii) Station service field flashing source

2.1.3.2.1.17 Control and Status Data Transmitted from Generator Transformer to Unit Control Switchboard

- i) Current signal for relaying and metering **A, P, I**
- ii) Gas accumulation detection **A**
- iii) Gas pressure device **A, P**
- iv) Main tank sudden pressure relief device **A, P**
- v) Main tank over pressure switch- Trip generator breaker **A, P**
- vi) Transformer winding temperature thermal device in each separate winding - Temperature detectors embedded in each separate winding for first stage temperature control. RTD are in each winding because of the possibility of unbalanced loading. **A, T, P**
- vii) Top oil temperature indicator **A, T**
- viii) Conservator tank oil level indicator **A**

2.1.3.2.1.18 Control and Status Data transmitted from Unit Control Switchboard to Transformer

Fire extinguishing system command- Actuated upon differential relay operation or sudden pressure relief device. Fire detection sensors shut off the transformer fan and pumps **C, P**

2.1.3.2.1.19 Operating Power and Water from Service Equipment to transformer

- i) Power supply for DC control circuits
- ii) Power supply for fans, pumps, ac control circuits

- iii) Water supply for fire extinguishing system
- iv) Water supply for cooling

2.1.3.2.1.20 Signals Transmitted from Plant Equipment to Generator Breaker

- i) Unit control -Normal shutdown **C**
- ii) Breaker control switch, trip/close **C**
- iii) Generator overspeed **P**
- iv) Synchronizing equipment **C**
- v) Wicket gate position switch **C**
- vi) Generator bearing temperature **P**
- vii) Turbine bearing temperature **P**
- viii) Breaker test switch **C**
- ix) Step-up transformer over temperature **P**
- x) Step-up transformer sudden pressure rise **P**
- xii) Too low oil level/ pressure in **P**
- xiii) Turbine bearing oil level low **P**
- xiv) Generator winding temperature **P**
- xv) Unit synchronizing selector switch **C**

2.1.3.2.1.21 Signals Transmitted from generator Breaker to Unit Control Switchboard

- i) Breaker open-close **C, I**
- ii) Generator breaker loss of DC control power **A**
- iii) Generator breaker pole failure **P, A**
- iv) Breaker air pressure switch **C**
- v) Generator breaker low air pressure **P, A**

2.1.3.2.1.22 Intake Gate/MIV and Draft Gate

Controls for automatic operation of the Intake gate shall as per table-3:

Table 3: Controls for Automatic Operation of the Intake Gate

1	Unit Control Board	<ul style="list-style-type: none"> • Raise/lower control switch • Indicating lights for fully open/fully • Position indication showing actual position of the gate
2	Local	<ul style="list-style-type: none"> • Raise/lower control switch • Mechanical device showing gate position
3	Annunciation	<ul style="list-style-type: none"> • Failure of gate to open or close in response to an automatic signal • Failure of gate to maintain partial closure position during sluice operation • Hydraulic system trouble

2.1.3.2.1.23 Canal/ Fore bay/ Surge tank Water Level Signal for Governor Control

- (i) Breaker open-close **C, I, P**
- (ii) Generator breaker loss of dc control power **C, I**

2.1.4 System Architecture, Communication and Databases

Open architecture system shall be followed in accordance with IEEE-1249-1996. Interface or operating standards for the following shall be intimated and should comply with ISO/IEC 12119-1994/IEEE 802.3-2008.

Hardware interconnectivity

Time stamping of data,

Communications

Operating system

User Interface

Data base

- a. Each of these elements should be capable of being replaced by or communicate with system elements provided by other vendors.
- b. The scope of the bidder is not limited to the parts & components explicitly identified here in and shall have to provide any and all parts/components needed to meet the functional requirements laid down herein or are necessary for satisfactory operation of the plant.

2.1.5 Control Sequencing

2.1.5.1 Start/Stop Sequencing

Control shall be divided into four parts.

- i. Pre start checks
- ii. Auxiliaries start
- iii. Unit run and load
- iv. Unit shut down

Logic representation of pre start check, Auxiliary start and unit run sequence in generator mode is shown in drawing (to be attached by Purchaser).

2.5.2 Unit Shut Down

Three types of unit shut down – normal, controlled action and emergency are proposed. The logic diagrams for these are tentatively shown in drawings (to be attached by Purchaser).

In partial shutdown the unit is brought to speed no load and not shut down.

2.1.6 Centralised Control

Centralised controls are proposed to be located in the control room. The centralised control shall be computer based system. Following major control and monitoring functions shall be provided from the centralised controls.

- i. Unit run
- ii. Unit stop
- iii. Emergency shut down
- iv. Speed level control
- v. Load level control
- vi. Voltage/var control
- vii. Load/var control
- viii. Monitoring of status information i.e.
 - a) Readiness for automatic start
 - b) Automatic start sequence initiated
 - c) Unit ON or OFF joint or automatic control
 - d) Unit ON, OFF offsite control
 - e) Unit circuit breaker open or closed
 - f) Inlet valve open or close
 - g) Mode of operation
- ix. Monitoring of Analog Measurement

This may include.

 - a) Unit and plant real and reactive powers
 - b) Unit voltage and current
 - c) Frequency
 - d) PF
 - e) Turbine wicket gate position
 - f) Head water and tail water levels
 - g) Various temperature readings
 - h) Gate limit positions
- x. Alarms and annunciation of faults, relay operation and plant troubles e.g. station service, fire etc.

2.1.7 SCADA System

2.1.7.1 Control Data Networks

Local area networks (LANs) should be configured to IEEE 802.3 -2008(Ethernet) standard.

Commercially available software should be used as far as possible.

2.1.7.2 Human-Machine Interface (HMI)

The operator's station of the station controller (SCADA system) shall have an elaborate and friendly man-machine interface. A 48 mm(19") or larger monitor shall be provided for the display. Provision shall be made for connecting a second colour monitor in parallel. The screen displays shall be suitably designed to provide information in most appropriate forms such as text, tables, curves, bar charts, dynamic mimic diagrams, graphic symbols, all in colour. An event printer shall be connected to PC of the SCADA system. Events shall be printed out spontaneously as they arrive. Provision shall be made to connect and use another printer simultaneously. Touch control screen, voice and other advanced modes of HMI are desired and shall be preferred. The entire customization of software for HMI and report generation shall be carried out to the satisfaction of the purchaser. A windows based operating system shall be used.

2.1.7.3 Hardware

Input/output system should have following capabilities.

- i. Portability and the exchange of I/O cards from one I/O location to another. This can reduce spare parts requirements.
- ii. Availability of I/O cards to be replaced under power. This avoids the need to shutdown an entire I/O location to change one card.
- iii. Sequence-of-Events (SOE) time tagging at the I/O locations; accuracy and resolution.
- iv. Availability of I/O signal types and levels that support the field device signals to be used.
- v. Support of redundant field devices, capability for redundant I/O from field device to the database and operator interface.
- vi. I/O diagnostics available at the card, e.g., card failure indicating LEDs, or through software in the system.

2.1.7.4 Grounding

Each equipment rack in which automation system components are located shall be separately connected to the powerhouse ground mat by a large gauge wire.

Shielded cables shall be used for analog signals between the transducers and the automation system. Each shield shall be tied to the signal common potential at the transducer end of the cable. If there are terminations or junction boxes between the transducers and automation system, each shield circuit shall be maintained as a separate continuous circuit through such junction or termination boxes.

2.1.7.5 Static Control

Equipment shall be immune to static problems in the normal operating configuration. Anti-static carpet and proper grounding for all devices that an operator may contact shall be provided.

2.1.8 Parameters to be monitored from SCADA

The SCADA system shall be complete with all primary sensors, cables, analyzers/transmitters, monitors, system hardware/ software and peripherals etc. to monitor/ control the parameters for control, protection, annunciation, event recording etc and including the following:

- a) Generator stator and rotor winding temperatures.
- b) Lube oil temperature
- c) Radio frequency interference
- d) Acoustic levels
- e) Vibrations
- f) Flow measurement.
- g) Turbine efficiency.
- h) Cavitation of turbine blades
- i) Turbine blade tip clearance
- j) Governor control monitoring of turbine speed.
- k) Generator terminal voltage, current, kW, kVAR, kVA, kWH, Frequency, power factor, field voltage and field current.
- l) Annunciation for violation of permissible limits of the above parameters.
- m) Turbine bearing temperature.
- n) Guide bearing temperature.
- o) Guide bearing oil level.
- p) Guide vane bearing oil temperature.
- q) Generator bearing temperature.
- r) Generator winding temperature.
- s) Turbine speed.
- t) Generator speed.
- u) Governor oil pumps, oil pressure indicator and low pressure switch.
- v) Cooling water pumps, suction and discharge pressure switch/ gauge.
- w) Inlet pressure gauge at inlet of turbine.
- x) Vacuum gauge for draft tube pressure.
- y) Level indicator for level in the fore bay.
- z) Flow meter for measurement of flow.
- zi) Annunciation

Bidder shall provide suggestions relating to measurement points and sensors. If in his opinion, an enhancement in condition monitoring capability can be attained by use of additional sensors these should be provided and details to be indicated in the bid.

2.1.9 Automation of Control System

Master relay type control system is proposed.

- i. Report Generation. This may meter logs and reports of plant activities printed out on printers. A disturbance file to store selected real time values and a history file for subsequence generation of hourly, daily, weekly and monthly reports.

- ii. Trending. Video trending and chart recorders shall be provided.
- iii. Sequence of Events Recording: i.e. Recording and co-relating event information, prior, to during and after disturbance to plant operation.

2.1.9.1 Control System Hardware

Redundant computer based system shall be provided and shall consist of consoles equipment with VDU's (Video Display unit) and operator control hardware (keyboard, Right pen etc.) which provide operator indication and control of all plant activities.

2.1.9.2 Shut down Hardware

The controller should have a conventional relay logic shutdown circuit. This circuit should include start and stop relays for controlling the turbine. The start relay circuitry should provide for auto and manual control capability. A controller fail relay should drop out the start relay when the auto relay is on. All shutdown hardware should be powered by the station battery. The stop relay should drop the start relay whenever a contact input which is strapped for shutdown on a digital input module is closed.

2.1.9.3 Digital Status and Alarm Inputs

The controller should be capable of connecting to at least 60 contact type inputs representing digital status and alarms. All contact inputs should be sensed through optical couplers with an isolation voltage of at least 1500 Volts. The controller should accept station battery voltage level inputs. Controller input modules should be strappable for 24, 110 Volt station batteries. Controller digital input modules should also have straps to allow any contact input to cause a hardware shutdown directly to the stop relay.

2.1.9.4 DC Analog Inputs

The controller should accept 0-1ma, 0-5V, 4-20ma or 1-5V DC analog signals. The controller should be able to measure DC analog signals with as much as 5 volts common mode signal with differential inputs. The controller should provide ground straps that can be inserted on the negative lead of any input signal that should be grounded at the controller. The controller should also provide selective terminating resistors for 1ma and 20ma signals. The DC analog signals should be converted to digital signals using at minimum 12 bit analog to digital converter in the controller with all conversion errors considered the controller should maintain an accuracy of 0.1% or better of full scale and a resolution of 1 part or less in 2000. All DC analog inputs should be protected from transient spikes and voltages with circuitry that meets the IEEE surge withstand test.

2.1.9.5 AC current inputs

The controller should connect directly to current transformers. The controller should accurately measure all current inputs from 0-6.25 amps. It should withstand 10 amps continuously and 50 amps for 1 second. The controller should be able to measure magnitude of

the current with a true RMS to DC converter and its phase shift with respect voltage. The current measuring accuracy should be to .1% and the phase shift accuracy should be to .1 degree. The controller should induce a burden of less than 0.5VA on each current transformer it connects to.

2.1.9.6 AC voltage inputs

The controller should connect directly to the potential transformers. The controller should accurately measure voltage inputs from 80 to 150 VAC. It should withstand up to 200 VAC continuously. The controller should be able to measure the magnitude of the voltage with a true RMS to DC converter and measure the phase shift of the voltage with respect to current. The voltage measuring accuracy should be to 1% and the phase shift accuracy should be to 1 degree. The controller should induce a burden of less than 1 VA in each potential transformer that it connects to.

2.1.10 Control Outputs

The controller should provide control relays to operate the circuit breaker, voltage regulator, and other equipment. The contacts should be DPDT rated 125 VDC at 0.5 A. Two contacts should be available from the DPDT relay and either should be strappable as normally closed or normally open. An optional high-powered relay should be available that provides one normally open contact rate 150 VDC at 10A. Each relay should have an LED indicator mounted on a manual control panel to indicate the status of the relay, on or off. Next to the indicating LED should be a switch to operate the relay manually. Each switch/LED should be clearly marked as to its function.

2.1.10.1 RTD inputs

The controller should have provisions to connect directly to RTDs. RTD readings should be corrected for nonlinearity and readings should be accurate to + 0.25°C. The temperature range should be 0-160°C. The controller must have a 10, 100 and 120 ohms 8 input RTD module. The correct linearizing curve should be selected by configuring. The controller should be capable of reading temperatures from eight RTDs. If eight RTDs are not required, any of the RTD inputs should be able to be used as a 4-20 mA analog input. Each of the eight inputs should be assigned three alarm set points; two high alarm set points and one low alarm set point.

2.1.10.2 Analog outputs

The controller should output 4-20ma signals for calculated signals such as KW, KVARs, power factor, frequency, voltage, and current. The signals should be isolated outputs with 1000 common mode voltage capability. The accuracy of these outputs should be better than .25%.

2.1.10.3 Alarm outputs (option)

The controller should be capable of outputting contacts for alarms that it generates internally. The contact rating for these alarms should be 1 Amp. at 120 VDC.

All digital inputs should be capable of meeting the surge withstand capability in accordance with ANSI/IEEE C37.90.

2.1.10.4 Electrical transducers

The controller should connect directly to current transformers (CTs) and potential transformers (PTs). The controller should be capable of deriving the generator voltage (line to line and line to neutral), generator amps, generator WATTS, generator VARS, generator Power factor, generator kVA, generator frequency and bus frequency from the CTs and PTs: The controller should be configurable for open delta (line to line) or star (line to neutral) connected CTs and PTs.

2.1.11 Supervisory Controller

Standard Desktop Redundant Computer/Mini computer should be used as Supervisory Controller and should at minimum have following configuration:

Intel dual core Processor 2000 MHz (or more recent) / Desktop Mini computer with support for running windows 2007.

- 1 GB second level cache
- 2GB SDRAM
- 160 GB HDD
- DVD read / write
- Graphic controller
- 21" Digital Colour Monitor
- Keyboard, Mouse and speakers

2.1.11.1 Speed Sensor

A speed sensor to be mounted on generator unit shaft giving output as 4 to 20 mA/0-5 V DC is to be provided.

2.1.11.2 Wicket gate position transducer

It should comprise of LVDT mounted on hydraulic cylinder for actuating wicket gate. It should convert linear movement of cylinder into 4-20 mA signal. 4 mA should correspond to 0% and 20 mA to 100% stroke of the servomotor.

2.1.11.3 Upstream water level transducer

Two level sensors, one float operated and other non-floated should be provided for level controlled operation of the machine. The level controller should be redundant to each other. One level transducer may consist of a diaphragm type sensor and internal signal conditioning system and should be able to provide standard output such as 4 to 20 mA/0-10 V DC.

2.1.11.4 Speed switches

Speed switches should be provided for application of brake, overspeed tripping and creep at 30%, 112% and 5% of the rated speed respectively.

2.1.12 Shielding and Grounding

Suitability of the computer system for operation in the harsh power plant environment should be certified. Surge protection, grounding and shielding provided should be elaborated in the bid.

2.2 Protection System

All hydro turbines generators, auxiliary system and switchyard equipment shall be provided protection system against all mechanical, electrical, hydraulic and thermal damage that may occur as a result of abnormal condition in the plant or in the grid to which the plant is connected.

2.2.1 Mechanical Protection

Plant mechanical equipment troubles for generators and turbines e.g. excessive vibration, bearing problems, over speed, insufficient water flow, shear pins failure etc. and hydraulic oil level, low accumulator pressure and electrical/ electronic or hydraulic malfunctioning within the governing or gate positioning system and water passage equipment malfunctioning e.g. failure of head gates or inlet valve, head gates, trash rack blockage and water level control functioning will be assigned to plant control system which will provide signal for monitoring, alarm and protection.

2.2.2 Electrical Protection

Multifunction digital protection relays should be provided with limited additional back up static relays for the following.

- (i) Hydro Generator
- (ii) Generator transformer
- (iii) Line protection

Multifunction numerical relays shall have following provision.

- (i) Self monitoring / diagnostics capability of operating status on continuing basis and to alarm when to function.
- (ii) Self calibration by software programming.
- (iii) Programmable set point by software programming
- (iv) Event recording facility should be provided for line relays of 66 kV and above
- (v) Communication facilities to SCADA as per IEC protocol

Common tripping relays for similar function should be provided with lock out facilities. All these relays shall have potential free contacts for trip and alarm purpose and externally hand reset type of flag indicators and housed in draw out type of cases with tropical furnish.

CTs for all the unit protection and metering shall be provided. The secondary current of CTs located in switchyard may be 1 amp. Because of long leads so as ensure efficient and accurate operation of their protective schemes. CTs proposed should be specifically approved by Purchaser.

2.2.3 Protection for Generating

The following protection may be provided by using integrated numerical generator protection relay on generator, generator transformers and feeders, back up electromagnetic relays with instrument transformers may be provided as mentioned below:

2.2.3.1 Generator

- (i) Generator differential protection (87G)
- (ii) Negative phase sequence (46) (phase Unbalance)
- (iii) Generator reverse power protection (32)
- (iv) Voltage restrained over current protection (51V)
- (v) Stator earth fault protection (64G)
- (vi) Loss of excitation protection (40)
- (vii) Over speed (electrical & mechanical) protection (12G)
- (viii) Rotor earth fault protection (64R)
- (ix) Over voltage protection (59)
- (x) Fuse failure protection (97 on PTS)
- (xi) Under voltage (27)
- (xii) Check synchronizing

Following additional back up electromagnetic relays from different set of CTs and PTs be also provided.

- (i) Voltage restraint over current relay
- (ii) Stator earth fault

Following Mechanical Protections are proposed:

- (i) Embedded Temperature detector (PT-100) in stator core and in bearing for indication, alarm, recording and shut down of the unit.
- (ii) Governor oil pressure low.
- (iii) Over speed mechanical for normal and emergency shutdown.

2.2.3.2 Generator Transformer

- (i) Generator transformer differential protection (87 GT)

- (ii) Over current and earth fault protection with high set Inst. Element (50/51,64)
- (iii) Stand by earth fault protection (64GT) on 33 kV side.
- (iv) T/ F Winding Temperature High Alarm/ Trip (49T)
- (v) T/ F Oil Temperature High Alarm/ Trip (38T)
- (vi) Buchholtz relay

Following additional back up electromagnetic relays from different set of CTs and PTs be also provided.

Over current earth fault

2.2.3.3 33/66 kV Line Protection

- (i) Phase comparison/distance relays for 66 kV and above
- (ii) Digital Directional over current and earth fault relay with high set unit (50/51,64).
- (iii) Under voltage (27)
- (iv) Over voltage (59)
- (v) Over/ under frequency (81)
- (vi) Reverse Power Relay
- (vii) Check Synchronizing

Back up electromagnetic, Directional over current and earth fault relay with high set unit

2.2.3.4 Bus Zone Protection

Differential Bus Zone Protection with check features are proposed.

2.2.3.5 Station Transformer Protection

- (i) Fuse set on 33 kV side.
- (ii) Digital over current and earth fault relay with high set unit

2.2.4 Brief Description of Protective Relays

2.2.4.1 Generator Protection

i. Generator Differential Protection (87G)

The generator primary protection is proposed by high impedance type of circulating current relays having proper setting range. The relays will be of high speed type and shall be immune to A.C. transients. Necessary provision shall be made in the relay to ensure that the relays do not operate for faults external to the protected zone. The relays shall not mal-operate due to harmonics in spill current produced by through faults or due to saturation on one set of current transformers during an external fault. Provision shall also be made for alarm /indication in case of current transformer secondary circuit fault.

The relay operation actuates lockout relay for complete shutdown of the unit including release of CO₂

ii. Generator ground fault protection (64G)

The generator neutral will be earthed through the primary winding of a distribution transformer of proper capacity and ratio. The secondary will be loaded by a suitable resistor rated for 60 seconds. A suitable voltage relay with continuous coil rating with proper setting is proposed to be provided. The relay shall be insensitive to voltage at third harmonic frequencies.

The relay operation actuates lockout relay for complete shutdown of the unit.

iii. Neutral Grounding Transformer and Loading Resistor

Neutral Grounding Transformer and Loading Resistor are as per table 4.

Table 4: Neutral Grounding Transformer and Loading Resistor

Neutral Grounding Transformer		
a.	Type	Dry type, Natural air cooled, single phase.
b.	Connection	Between generator neutral and ground
Loading Resistor		
a.	Construction	Non-ageing, corrosion resistant, punched stainless steel grid elements provided with necessary installations, and temperature rise not exceeding 300 deg. C.
b.	Housing	Enclosure with IP:22 degree of protection. However, transformer and resistor can be housed in same container with metallic partition.

iv. Generator over-voltage protection (59)

A set of single phase relays is proposed with suitable time delay setting so that operation of relay under transient conditions is avoided. The relay setting range is proposed from 110% to 150%. The relays shall be immune to frequency variation. Provision of instantaneous tripping element at some suitable setting is also proposed.

The relay is set to operate lockout relay for partial shutdown to speed no load position.

v. Negative phase sequence current protection (46)

A two stage protection complete with filter network is proposed for this purpose. The first stage with a lower suitable range shall be instantaneous and shall be arranged to give alarm and annunciation and the second stage with higher range will energise a timer which shall

perform the various tripping functions in two stages at different time settings. The current transformer for this protection is proposed to be located on the generator line side.

The relay is set to operate the lockout relay for partial shutdown to speed no load position.

vi. Voltage restraint over current protection (51V)

This backup protection for the generator operates for over current which are accompanied by dip in voltage so that false tripping due to through faults are avoided. The relay is set to trip lockout relay for partial shutdown to speed no load position.

vii. Reverse power relay (32)

This relay is proposed because of grid connection. The relay is proposed to be set to trip lockout relay to speed no load position.

viii. Check Synchronising relay (25)

Check synchronising relay is provided to ensure the closing of the circuit breakers on synchronising at a phase angle not greater than about 7 degrees so as to prevent damage to circuit breaker especially in case of auto synchronising.

ix. Potential transformer fuse failure protection (60)

Suitable voltage balance relays are proposed to monitor the fuse failure of 3 sets of potential transformers and to block the relays (50/51 V or 40) or other devices that may operate incorrectly on the voltage due to fuse failure of potential transformers. The relay is set to give an alarm only.

x. Mechanical Protections

Following mechanical protections are proposed for the generator:

- a. Resistance temperature detectors in stator core (12 no.) and in the bearings for indication, alarm and recording. RTD's are to be provided by Generator Suppliers.
- b. Turbine and generator bearing, metal and oil temperatures – alarm/shutdown.
- c. Governor oil pressure low to block starting and low-low for emergency tripping.
- d. Over speed for normal and emergency shutdown depending upon its extent.
- e. Signal to canal regulating gates to avoid channel overtopping due to emergency shutdown of unit.
- f. Contractor will co-ordinate with Generator and Turbine supplier for mechanical protection.

2.2.4.2 Exciter Protection

i. Generator field failure protection (40)

An offset mho type of relay having its circular characteristics adjustable both in offset and diameter, along the X-axis of the R-X plane, is proposed for this purpose.

The protection shall consist of two stages. The first stage with a lower range shall be arranged to give alarm and annunciation. The second stage with a higher range shall carry out the tripping.

ii. Generator rotor earth-fault protection (64 F)

Direct current injection type of protection is proposed for this purpose. The relay will be suitable for the field system voltage and be capable of detecting deterioration of insulation level below about 0.2 Mega-ohms. 110 Alternating current potential transformer auxiliary supply will be available but the relay will have its own internal rectifiers etc. to drive the D.C. injection supply. Failure of A.C. auxiliary supply will not totally incapacitate the protection. The tripping of the relay is set to open the excitation breaker and bring the unit to speed no load.

iii. Over current relay (51 EX)

This over current instantaneous relay in the excitation circuit before the excitation transformer will cater to rectifier transformer faults and other excitation system faults. This relay is set to trip excitation circuit breaker and bring the unit to speed no load.

iv. Over excitation relay (OER) in the DC circuit and excitation relay (31) in the field flashing circuit are other relays proposed in the excitation system.

2.2.4.3 Station Service System Protection

i. Over Current Protection (51)

Suitable relays are proposed to be provided for unit auxiliary transformers over load protections. The relay will operate from the three current transformers on the Low Voltage side of the transformer and will be arranged to trip the Low Voltage breaker

An instantaneous time over current relay is proposed from the CT's on the 11 kV side of the auxiliary transformer. This relay at a higher setting will cater to transformer faults and the tripping of the relay is set to bring the unit to speed no load

ii. Phase sequence relay (47)

This relay on the station service system trips the LV circuit breaker so as to prevent operation of the three phase motors in the reverse direction (

iii. Under voltage relay (27)

These relays have been provided to trip the LV circuit breaker

2.2.4.4 Generator Transformer Protection

i. Over current/earth fault protection (50/51, 64)

Instantaneous and IDMT over current relays along with earth fault relays shall be provided for protections of power transformer. This protection shall be provided through 33 kV current transformers.

ii. Generator Transformer Differential Protection (87 GT)

A sensitive percentage biased differential relay is proposed to be provided for each step up transformer protection with proper operating and bias setting. It shall have harmonic restraint feature to prevent its mal-operation due to magnetising in-rush surges encountered in normal power system operation. Provision shall also be made for alarm/indication in case of current transformer secondary circuits faults.

The C.T.'s on 11 kV side are proposed be located in the Generator neutral side and on --- -- kV side in the switchyard. The auxiliary/interposing current transformers as required for the protection shall also be provided.

The relay is set to operate lockout relay for shutdown as shown in Drawing No. -----.

iii. Standby earth fault protection (64 T)

For this protection Inverse Definite Minimum Time Lag type relay having suitable setting range and operating time is proposed. The relay shall be energized by zero sequence current supplied to it through current transformer in the power transformer neutral. This relay is proposed to trip the unit circuit breaker and bring the unit to speed no load. The relay will be coordinated with line earth fault protection.

- iv. Buchholz gas pressure relay** for first stage alarm and second stage trip.
- v. Transformer oil level and temperature**
- vi. Winding temperature**

2.2.4.5 Bus Bar Protection

Bus zone Differential Protection (87 B₁, and 87 B₂) (if provided)

A high speed, high impedance type bus-bar differential protections proposed to be provided for each bus zone. The scheme shall have separate and independent check and supervision features incorporated in it.

Necessary separate C.T. cores shall be provided at the incoming and outgoing circuits for check features. The main zonal relay and check relay scheme will have their contacts connected in series in the trip circuit.

The protection will be capable of detecting all type of faults on the bus-bar. The sensitivity of protection shall be such that it does not operate for faults on the C.T. secondary wiring of the most heavily loaded circuit. C.T.'s on one side of the bus coupler/section breaker are proposed and inter-locked overcurrent relay will be provided.

The supervision relay will be capable of detecting open: Cross or broken C.T. secondaries and pilots by employing sensitive alarm relay, which shall be connected across the bus wires of each protected zone. It shall be capable of taking the protection of the effected zone out of service by shorting the appropriate bus-wires.

'No volt' relays to indicate failure of D.C. alarm and trip supply to the bus-bar protection scheme is also proposed to be provided.

High speed tripping relays shall be provided to trip the connected circuit breakers connected to the faulty bus bar.

2.2.4.6 Feeder Protection

Protective relay design for line is important because of high fault power from grid substations. Main protection proposed are as follows:

- i) Static over current and earth fault relay with high set unit shall be provided(50/51, 64)
- ii) Over/under frequency relay (81)
- iii) Over voltage (59)
- iv) Under voltage (27)

The protection requirement with respect to characteristics operating principle, tripping schedule and type of relays shall be discussed during detailed engineering stage, and Bidder shall provide the same to the satisfaction of the Purchaser.

2.2.4.7 Instrument Transformer & Surge Protection Equipment

2.2.4.7.1 Potential Transformers

The potential transformers to be used for metering & protection circuits shall be epoxy cast resin, class 'F' insulation dry type units. The potential transformers shall be protected on primary and secondary side by current limiting fuses. The potential transformers shall conform to the latest Indian standard. IS-3156.

2.2.4.7.2 Current Transformers

The current transformers should be suitable for metering & protection circuits shall be epoxy cast resin, class 'F' insulation dry type units. The current transformer will be wound primary or bar primary as the case may be. The current transformers shall confirm to the latest Indian standard. IS-2705.

2.4.4.7.3 Surge Arrestors

The L.T surge arrestors shall be provided in the control panel. The L.T. surge arrestors shall confirm to the latest Indian standard.

2.2.4.7.4 CTs / VTs and Generator Surge Protection Equipment

All current and voltage transformers required for protection system of the unit shall be provided and shall have adequate VA burdens, knee point voltage, instrument safety factor and characteristics suitable for the application, and shall be subject to approval of the Purchaser.

CTs/VTs used for different applications shall have following accuracy class:

a)	Differential protection CTs	Class PS
b)	Protection CTs other than differential protection	Class 5P10
c)	Generator AVR/metering CTS for generator circuit	Class 0.2
d)	Metering CTs for 415 V switchgear	Class 0.2
e)	CTs for performance testing and low forward power Relay	Class 0.2
f)	Core balance CTs	Class PS
g)	Protection VTs	Class 3P
h)	VTs for generator metering, AVR synchronisation	Class 0.2
i)	VTs for performance testing and low forward power relay	Class 0.2

CTs and PTs are tentatively shown in the specifications drawing. Tenderer will work out detailed characteristics for approval by purchaser.

2.3 Tests

2.3.1 Factory Tests for Unit Control Switchboards

1. Review front and rear elevations versus the final approved drawings. Check each item of equipment for proper location and verify the instrument/catalog number is correct per the specification.
2. Review the interior of the UCS in the same manner as the elevations. In addition, verify the lighting is adequate and grounding connections are provided.
3. Check anchor channels and cable entrances. Confirm they are in accordance with the drawings.
4. Review test certificate or witness the insulation resistance test of all wiring, current transformers, and potential transformers.

5. Check approximately 5 to 10 percent of the internal cabling. Verify that the following items conform to the drawings :
 - a. Cable numbers;
 - b. Terminal block designations;
 - c. Terminal designations on individual components such as control switches and lockout relay;
 - d. Raceway layouts; and
 - e. Equipment identification nameplates.
6. Activate all protective relays. Confirm that the appropriate lockout relay is energized and the correct annunciation and/or printout occur.
7. Confirm that settings of all protective relays are in accordance with approved documents.
8. Check all annunciation points.
9. Check factory calibration of all devices possible, including electronic speed relays, current and potential transformers, and vibration monitors.
10. PLC checks:
 - a. Check the I/O racks for type and number of analog and digital I/O cards;
 - b. Check for future expansion capabilities on the I/O racks;
 - c. Check for surge protection provided on the I/O rack and I/O cards;
 - d. Identify grounding connections for the PLC and the I/O rack; determine whether chassis and logic grounds are the same or separate (this will affect the type and quantity of external surge protection required);
 - e. Review the PLC ladder diagram viewed on the video display terminal versus the final approved PLC software coding documentation; and
 - f. Verify that modem connections are provided and functional.
11. Perform the function checks listed below with the final approved schematics, PLC software coding, and control block logic diagrams in front of you. All premissives and interlocks should be provided by using the “dummy” toggle switchboard to provide these inputs.
 - a. Manual start/stop sequence (does not apply to redundant PLC control schemes);
 - b. Auto start/stop sequence;
 - c. Manual emergency stop sequence;
 - d. Automatic emergency stop sequence (usually performed by activating one of the lockout relays while in the “normal running” mode);
 - e. Change position of all control switches as follows (typically done while in the normal running mode);
 - i. Local control to remote control
 - ii. Remote control to local control
 - iii. Manual control to automatic control
 - iv. Headwater level control “OFF” to “ON”

- v. Headwater level control “ON” to “OFF”
 - vi. Excitation manual control to excitation automatic control
 - vii. Excitation automatic control to excitation manual control;
- f. Verify the performance of the automatic synchronizing circuit and the manual sync-check relay (if provided).

2.3.2 Field Tests for Unit Control Switchboards

1. Verify tags on all factory-calibrated instrumentation devices.
2. Check all external interconnection wiring against the approved power house/equipment drawings, verifying the following items :
 - a. Cable numbers and type;
 - b. Terminal block designations; and
 - c. Raceway layouts
3. Perform point-to-point continuity and megger tests on all external cabling.
4. Calibrate all remaining instrumentation devices.
5. “Bench test” all protective relays to ensure proper settings.
6. Perform functional checks tests on all unit and station auxiliary equipment controlled from the UCS to verify proper operation.
7. Perform functional checks on unit start/stop sequences, duplicating the factory sequences. These checks should be performed first with the associated power circuits de-energized, and then with both power and control circuits energized.
8. Methodically document steps 1 through 7 to ensure that no cables, instrumentation devices, protective relays, or control systems have been overlooked.
9. Water-up the unit and perform all start/stop sequences.

2.3.3 Tests for SCADA System for Large and Group Control Plants

2.3.3.1 Additional Factory and Field Tests for Distributed Control Systems

1. Point-by-point database check.
2. Database linkage to graphical displays.
3. Response times during normal loading and high activity loading scenarios for:
 - a. Graphical display updates;
 - b. Control sequence implementation;
 - c. Alarm processing and logging; and
 - d. Sequence of events recording
4. Communications connectivity/protocols.
5. Man-machine interface (MMI) user capabilities.
6. Application software functionality.

2.4 Completeness

All such systems/equipment/components/works which are necessary for the completeness of the system but not mentioned explicitly shall also be a part of the scope of the contractor. The control room shall be dust-free and air-conditioned as described elsewhere.

2.5 Training Plan

The training plan should include the following information on individual courses:

- a) Outline;
- b) Duration and scheduling;
- c) Location (e.g., user site, manufacturer's site)
- d) Qualification of instructor;
- e) Objectives;
- f) Prerequisites;
- g) Content;
- h) Training material (handouts);
- i) Audiovisual aids;
- j) Special equipment, tools, etc;
- k) Ratio of hours of classroom to hours of hands-on laboratory experience.

2.6 Data/ Document to be Furnished by the Bidder

Documentation should be provided that adequately describes the system such that the design can be verified. Documentation should also be provided such that it can be used to support installation, testing, system activation, hardware operations and maintenance, and software maintenance and development.

Design documentation should include follows:

- a) Operator interface:
 - 1) Keyboard layout and operation;
 - 2) CRT format;
 - 3) Cursor control philosophy;
 - 4) Display call-up philosophy;
 - 5) User of color, flashing, inverted video, etc.;
 - 6) Display building
- b) Functional documentation and Drawings:
 - 1) Outline drawings, including dimensions and arrangements;
 - 2) System block diagrams showing nomenclature, equipment types, model numbers and input/output provisions;

- 3) Input/output lists with ranges, labels, and other related specific information.

2.6.1 System Support Documentation and Drawings

Documentation should be furnished that will allow the user to fully support the equipment throughout its life. In addition to the requirements described in 8.0 the following items shall be furnished to meet this requirement.

- a) Hardware drawings :
 - 1) External connection diagrams showing the details of all wires connected to user's equipment;
 - 2) Power and environmental requirements for each equipment item;
 - 3) Site preparation procedures, including: equipment grounding, cable routing, equipment handling, mechanical assembly, etc.;
 - 4) Spare parts list.
- b) Software documentation:
 - 1) Hierarchical list of software, including revision level;
 - 2) Program design standards;
 - 3) Configuration control methodology;
 - 4) Program requirements specifications;
 - 5) Program descriptions;
 - 6) Program interface control;
 - 7) Acceptance test procedures and test reports;
 - 8) Annotated source code program assembled listings;
 - 9) Maintenance, reference and user's manuals.
- c) Operations and maintenance data:
 - 1) Operations data, including specific operating instructions, functional description of operating parts, and special precautions.
 - 2) Maintenance data, including instructions for dismantling, assembling, repairing, adjusting, and trouble-shooting all mechanical and electrical equipment; parts catalogues, elementary and connecting diagrams; control and interlock system diagrams; and a list of special tools required. Instructions for dismantling, assembling, repairing, testing, and adjusting should include recommended clearances, voltages, amperages, trouble-shooting procedures for printed circuit cards and any other items needed for maintenance of the equipment. The trouble-shooting procedures should include step-by-step diagnostic procedures for each function performed.

Electrical data should include waveforms, component identification photographs, test points, and parts lists.

2.7 Spare Parts & Tools

The contractor shall ensure supply of the spares for all the offered equipment/components (at least one module of every type) for use for 5 years and any special tools and plants, spanners etc. required for site assembly, erection, testing, commissioning, operation & maintenance of the equipment.

3.0 TECHNICAL SPECIFICATIONS FOR SHP OF CAPACITY UP TO 100 kW

3.1 General

Power generation control & protection equipment as per Micro Hydro Standards issued by AHEC are given below in table 5.

Table 5: Power Generation Equipment Special Requirement

	Description	Category (Installed Capacity in kW)		
		Category A (Upto 10 kW)	Category B (Above 10 kW and upto 50 kW)	Category C (Above 50 kW and upto 100 kW)
Turbine	Types	<ul style="list-style-type: none"> • Cross Flow • Pump as turbine • Pelton • Turgo • Axial Flow • Turbine • Any other turbine meeting the technical requirement 	<ul style="list-style-type: none"> • Cross Flow • Pelton • Turgo Impulse • Axial Flow Turbine • Francis • Pump as Turbine • Any other turbine meeting the technical requirement 	<ul style="list-style-type: none"> • Cross Flow • Pelton • Turgo Impulse • Axial Flow Turbine • Francis • Any other turbine meeting the technical requirement
	Rated Output at rated head (at Generator output)	Upto 10 kW	(Above 10 kW and upto 50 kW) as specified	(Above 50 kW and upto 100 kW) as specified
	Bid evaluation – equalization for shortfall in overall weighted average efficiency	NIL	Each 3% for every 1 percent difference by which rated average efficiency (computed) is lower than the highest weighted average efficiency	Each 3% by which rated average efficiency (computed) is lower than the highest weighted average efficiency

	Description	Category (Installed Capacity in kW)		
		Category A (Upto 10 kW)	Category B (Above 10kW and upto 50 kW)	Category C (Above 50 kW and upto 100 kW)
Generator	Types	Synchronous/ Induction - Single Phase/3 phase	Synchronous/ Induction 3 Phase	Synchronous 3 Phase
	Terminal Voltage, frequency	240 V, 1 –phase, 50 Hz	415 V 3 phase, 50 Hz	415 V, 3 phase, 50 Hz
	Make and Runaway withstand	Standard / Special generators designed to withstand against continuous runaway condition.		
	Insulation and Temperature Rise	Class F/H insulation and Class B Temperature rise		
Overall Efficiency	Minimum required Weighted Average Efficiency of the turbine Generator set ($\eta_{T Av}$) $0.50 \times \eta_{T100} + 0.50 \eta_{T50}$	45%	50%	60%
Control and Switchgear and Metering	Controller (Preferable/Micro processor based)	(ELC) Electronics load controller or IGC Induction Generation Controller	(ELC) Electronic Load Controller (preferred) or IGC Induction Generator Controller	(ELC) Electronic Load Controller or Flow Control Governor
	Ballast Load of Electronic Load Controller	Air heater	Water Heater	Water heater
	Inertia and Flywheel	Adequate flywheel should be provided for isolated operation.		
	Switchgear / Earth Fault Protection	MCB/MCCB for O.C. Protection Provide Earth Leakage Circuit Breaker (ELCB)/Residual current operated circuit breaker		
	Monitoring & Protection	Current, voltage, frequency	<ul style="list-style-type: none"> • Current, voltage, frequency • Stator temperature • Over current (stator) • Maximum & minimum voltage • Reverse Power • Over/under frequency • Bearing temperature 	
	Metering	As required.		

Notes:

1. For efficiency of turbine, the performance curves of similar turbines manufactured by the bidder (tested by independent institution) will be provided.

2. Generator will conform to IS:4722 -2001 and single-phase induction generators to IS:996- 1979.
3. Electric load controllers shall be type tested by an independent institution for adequacy, for performance, surge protection, waveform deviation, electromagnetic interference, emissions of radio noise and in successful operation in 2 power plants for 2 years.
4. Micro hydro for power generation category B & C should have the following provisions:-
 - (i) Parallel operation in local grids whenever available.
 - (ii) Parallel operation with main grid whenever extended.
5. Micro hydropower generating station category B & C having more than 1 unit shall have following additional provisions:-
 - (i) Parallel operation between units at the station
 - (ii) The Governor/Load Controller, AVR should have adequate provision for adjusting the Speed Droop and Voltage Droop for facilitating the Parallel Operation of the Units.

3.2 Governor Functions

Shunt load Governors can be designed to perform following jobs in a micro hydro-electric installation.

- i. Stable speed control for all inflows
- ii. Management of surplus energy for useful purpose.
- iii. Prevent overloading of a hydro-electric plant in case of reduction in stream inflow. Shedding load at peak demand periods or during low water.
- iv. Control and protection functions as described in a subsequent paragraph.

3.3 Architectural View and Hardware Details of the Digital Load Controller

The system is controlled by an 8 bit microprocessor running a real time operation system. The processor is interfaced to a Digital Input Output device giving a total of up to 24 digital Input/Outputs.

A L.E.D. / LCD display is interfaced through the input/output device. The input output device and clock timer controls the dummy load (five step loads and one variable load) through a Triacs module.

The step and variable load indications are shown through LEDs.

3.4 Detailed Specification

1.	Processor Type	:	8 bit
2.	EPROM	:	8 K
3.	RAM	:	8 K
4.	Digital Input/Output Lines	:	24
5.	Display	:	Frequency (LED or LCD)
6.	Power Supply	:	Built in from 230 V

- | | | | |
|-----|-----------------|---|--|
| 7. | Frequency input | : | From 230 V single phase |
| 8. | Output | : | 3 Phase or single phase |
| 9. | Protection | : | Over frequency, over voltage,
under voltage, overcurrent etc. |
| 10. | Control | : | Start/Stop/Emergency shutdown. |

3.5 Triacs

The triacs load (variable internal load) can typically change from zero load (or vice versa) in 3 cycle (50 milliseconds) for normal frequency changes. Step load can be switched on directly by triacs (single phase) or by energising coil or Power Contractors. Operating Time of Contractors is 25 milliseconds and electrical life is of 1 million operation.

3.6 Stability

Provision of adjustable dead band and Dash pot time equivalent are necessary to ensure stability due to change of water inertia and load characteristics. Dashpot time is the adjustable time between two successive changes.

3.7 Parallel Operation

The units with shunt load governor can be operated in parallel amongst themselves and with grid using manual speed control (Phase control by Triac).

4.0 TECHNICAL SPECIFICATION FOR SHP OF CAPACITY ABOVE 100 kW TO 5000 kW

4.1 Control Equipment and Data Acquisition

The control equipment shall comprise following:

a. Generating Units Control

- i. Local manual control of generating units and auxiliaries, water passage equipment from hard wired control panels located in the control room.
- ii. Manual/automatic control of generating units from control panels located in the control room as well as near the respective units by PLC based unit controllers

b. Switchyard Control

- i. Manual control from hard wired control panels located in the control room.
- ii. Automatic control from the control room.

c. Data Acquisition

The PLCs will acquire data from generating units, transformers, 33 kV switchgear, auxiliaries, transducers/sensors, CTs and VTs, etc. as necessary for their optimal operation. Wherever signals are weak or there is strong noise due to EMI or RI etc, shielded cables shall be used to carry signals/data.

Notes:

- i. The control equipment offered should have been in successful operation for 2 years in at least 2 power stations. Certificates to this effect from the users shall be submitted by the bidder.
- ii. The UPS required for the PLCs system and the batteries needed for the UPS for 1hour backup shall also be supplied by the contractor.
- iii. Calculation for kVA rating of the UPS and battery specifications shall be submitted by the bidder for purchaser's consideration.

4.2 Synchronization

Manual synchronization shall be provided in addition to computer-based auto-synchronization with an appropriate change-over switch on the control panel.

4.3 Alarm and Annunciation

Window annunciation shall be provided on the control panels in the control room as well as those near the generating units and the same shall be complete with audio and video alarm system. The system shall be designed to have low DC power consumption.

4.4 Metering

- i. All panel meters shall be digital with at least 2 cm digit size, at least three-and-a-half digit LED display and accuracy class of 1.0.
- ii. Energy metering shall be provided on the 11/33 kV and generators with microprocessor based trivector meters of an accuracy class of 0.2 or better.
- iii. Electronic energy meters of accuracy class of 1.0 or better will be provided for metering at the station transformer.

4.5 Protection Relays

- i. Each generator, generator transformer and outgoing lines shall be provided with multifunction digital relay incorporating all protection functions, measurements and fault data logging features.
- ii. Generators, generator transformers and line protection shall have limited additional protection using static (analog) relays.
- iii. Digital relays shall be provided for the protection of feeder and station transformer.

4.6 Temperature Scanners

Temperature scanners and recorder shall be provided for stator windings, bearing temperatures and transformers including cables from temperature sensors. The scanners shall have two alarm settings for high temperature for each point adjustable over the entire range. There shall be one scanner for each generating unit along with generator transformer. Each scanner shall have at least 32 channels.

4.7 Functional Requirements of Control Systems

4.7.1 Automation System

4.7.1.1 Control Options

Computer-based automation systems shall permit operation of the power plant and switchyard from each of the three control points, namely local and remote. Local manual control shall also be provided in the equipment as a backup.

4.7.1.2 Unit Controllers

Local control will be provided by equipment located near the generating unit as well as in the control room. For each generating unit, there will be an independent PLC based unit controller. Back up manual control shall be provided for each unit. Suitable remote terminal units (RTUs) shall be provided in the switchyard and at station auxiliaries to enable control of the switchyard equipment and station services.

Each PLC will have a dual power unit. The main power unit will work on 24 Volts D.C. and the hot-standby power unit will take power from a UPS at 240 Volts A.C.

4.7.2 Unit Control

4.7.2.1 Control Functions

The unit controllers will control the generating units individually and shall perform following functions:

- i. Governor control
- ii. Excitation control
- iii. Sequence control
- iv. Alarm and annunciation
- v. Synchronization
- vi. Input from transducers & sensors
- vii. Output to actuators
- viii. Communication
- ix. Active power control
- x. Reactive power control

4.7.2.2 Auto Start/Stop

The equipment controlled and monitored during the start/stop sequence will include the following:

- a. Main inlet valve;
- b. Governor hydraulic oil system;
- c. Guide Vane operating mechanism;
- d. Cooling water system;
- e. Excitation equipment;
- f. Unit speed;
- g. Protective relaying status;
- h. Unit alarms;
- i. Unit breaker status;

4.7.2.3 Diagnostic Information

Automation system shall have capability to provide diagnostic information in the event something fails to operate during the start sequence/running.

The protective relays and devices of generator and turbine are proposed to be grouped into four categories subject to modification by purchaser in consultation with contractor / equipment supplier.

4.7.2.4 Control Scheme of Turbine

(a) Controlled action shut

Controlled action shutdown will be initiated by any of the following conditions.

- Generator thrust bearing pads temperature very high
- Generator guide bearing pads temperature very high
- Turbine guide bearing pads temperature very high
- Governor OPU oil level low stage-II
- Governor OPU oil pressure low stage-II

The controlled action shut down system will not cause immediate tripping of the generator and field breaker but smoothly transfer load and initiate tripping of generator transformer breaker & field breaker only when entire load is transferred.

Trip Alarm in control room and VCB will operate.

(b) Emergency Shut down

Emergency shutdown will be initiated by any of the following conditions.

- a. Speed 115% and deflector apparatus not moved to closing
- b. Guide vane fail to close in preset time

- c. Unit over speed (electrical)>140%
- d. Unit over speed (mechanical)>150%
- e. Stop push button on unit control board is pressed.
- f. Stop push button on control panel in control room is pressed.

Emergency shutdown system will perform following functions:

Trip 3.3 kV main generator transformer breaker

- a. Stop turbine by governor action
- b. Trip generator field circuit breaker
- c. Operate trip alarm in control room/UCB/
- d. Energizes emergency solenoid valve in governor cubicle to stop the turbine by bypassing governor.
- e. Close main inlet valve

(c) Immediate Action Shut down

Immediate action shut down will be initiated by any of the following conditions:

- a) Generator differential protection operates
- b) Generator stator earth fault protection operates
- c) Generator field failure protection operates
- d) Generator transformer stand by earth fault protection operates
- e) Over current in stator
- f) Over current instantaneous protection in the excitation circuit (if provided)

The immediate action shut down will perform following function.

- Trip generator transformer breaker
- Trip field breaker
- Initiates controlled action shut down.
- Stop turbine by governor action.
- Trip annunciation in control room/UCB.

(d) Electrical shut down

Electrical shutdown system will be initiated by any of the following conditions.

- Over current in the excitation circuit (if provided)
- Generator back up protection operates
- Generator over voltage protection operates.

- Excitation failure protection operates.
- Reverse power protection operates.
- Generator T/F IDMT over current, over current instantaneous & earth fault protection operates.

Electrical shut down system will perform following functions:

- (i) Trip generator transformer breaker
- (ii) Trip field breaker
- (iii) Governor brings the unit to spin at no load.

4.7.2.5 Synchronization

Automation system shall be capable of auto synchronising. A synchronising check relay will be provided.

4.7.2.6 Turbine Operation Optimization

Optimization of energy generation will be ensured by monitoring water level of the forebay. For this purpose signals shall be taken from the level transducers on forebay.

4.7.3 Protection

Protection relay panels for the generating units and 3.3/33 kV generator transformers shall use microprocessor based (digital) and static (analog) relays as described in Generator Protection. The 33 kV feeder shall be protected with microprocessor based digital relay as described in 33 kV line protection herein after. Protective relays for other equipment shall be digital type.

4.7.4 Metering

The metering equipment (Meters, CTs and VTs) will meet the requirements shown in relevant drawing to be enclosed by the Purchaser.

4.7.5 D.C. Supply

The D.C. power at 24/110 V for all controls, circuit breakers, relays and meters etc. shall be obtained from one set of station battery. The battery bank shall have 300 AH capacity tentatively and shall be float and boost charged from separate rectifier units. Tentative details of charging arrangements and distribution are shown in drawing to be enclosed by the Purchaser. Further details are given in subsequent paras. Calculations for the capacity of batteries shall be submitted by the bidder for the consideration of the purchaser.

4.8 Protection and Metering Details

4.8.1 Protection and Metering Scheme

Requirements of metering and protection/scheme and the function performed by various relays are explained in following tentative drawings (to be enclosed by Purchaser):

- i. Main Single Line Diagram
- ii. Metering and relaying Single Line Diagram
- iii. Station service system single line diagram
- iv. Interconnection with Grid Single Line

All the protective relays will be housed in the control room of the Power Plant. The tentative locations of C.T.s and P.T.s housed in GT and NG cubicle for the protection and metering. Alternative arrangements may be proposed by the bidder.

The final drawings for the protection & metering shall be submitted by the contractor and will be subject to the approval by the Purchaser.

4.8.2 CTs / VTs

All current and voltage transformers required for protection system of the unit shall have adequate VA burdens, knee point voltage, saturation factor and characteristics suitable for the application, and shall be subject to approval of the Purchaser.

4.8.3 Special Features of Proposed Protection System

1. The protection system shall be built on latest technology and the bidder has to guarantee for supply of spares for at least 10 years. Moreover, the bidder should have full range of manufacture of the system offered.
2. Wide setting ranges with fine setting steps for each protection shall be available.
3. The offered system shall have proven record of satisfactory performance for at least 2 years and in two power stations. Necessary certificates to this effect shall be a part of the offer.
4. The protective relays shall preferably be housed in draw out type of cases with tropical finish.
5. Common tripping relays (each for similar functions) will be provided with lockout facilities. All these relays shall have potential free contacts for trip and alarm purposes and externally hand reset type of flag indicators

4.8.4 Generator and Transformer Protection

Multifunction numerical protection relay and limited analogue protective relays in accordance with guidelines for selection of equipment for control & protection shall be provided as outlined in Para 2 of section II.

5.0 TECHNICAL SPECIFICATION FOR SHP OF CAPACITY ABOVE 5 MW TO 25 MW

5.1 Control and Monitoring System

5.1.1 Scope

5.1.1.1 Manual (hard wire) unit Control, Metering and Protection panels.

- (i) Local manual mode by hard wired control board located in machine hall floor/control room for manual/automatic control of the unit. The digital governor electrical control will be adjacent to the generator switchboard separate from the actuator cabinet.
- (ii) Hard wired manual/automatic control for 66 kV and 33 kV feeders control, metering and protection panels located in control room (in case switchyard is far away than this may be provided in the switchyard control room and with a remote terminal unit (RTU) for control from centralized control room).
- (iii) Hard wired control of unit & station auxiliaries in the control room.
- (iv) Hard wired control of Penstock, intake valves, level sensors for tailrace and head water etc. in control room.

5.1.1.2 Centralised control, Supervisory Control and Data Acquisition System

- (i) Manual/Automatic Mode (Centralised control room). A PLC – based system communicating with a proprietary protocol on fiber optic medium.
- (ii) Supervisory-Manual Mode (Centralised control room). Provided through separate RTU hardware to gather generating information.
- (iii) Supervisory Automatic Mode (Centralised control room). Provided by a Computer-based SCADA system communicating directly to the local PLC network from the centralised control room.

5.1.1.3 Manual and Automatic Synchronising Equipment

5.1.1.4 Status Switchboards

5.1.1.5 Annunciation and Alarm System

5.1.1.6 Programme and training console

5.1.2 Control and Monitoring System

5.1.2.1 General Considerations

Generally considerations involved in providing control and monitoring systems for the power plant and the switchyard are given in Para 2.1.2.1 . Further specific considerations are as follows:

- a) Main Single Line Diagram is shown in drawing (to be enclosed by Purchaser); Metering and Relaying as proposed is shown in drawings(to be enclosed by Purchaser);
- b) The power house is proposed to be controlled by supervisory control from centralized control room of powerhouse.
- c) Dependable digital controls for system control with conventional manual control as backup are proposed.
- d) Power house units operation and loading is controlled based on fore bay/surge tank level
- e) Emergency conditions (power house unit tripping etc.) will be taken care of by operating regulating Bypass Gates. For this purpose suitable provisions will be made in the control.
- f) The generators are proposed to be provided with static excitation system.
- g) Generator transformers of suitable rating are proposed to step up the generated power to voltage suiting Power Evacuation system.
- h) A single sectionalised bus is proposed for reliability.

The control system will be designed in accordance with IEC – 62270 & ANS/IEEE – 1010-2006 and will be subject to approval by Purchaser.

5.1.3 Manual Control, Metering and Protection System

5.1.3.1 Scope of Supply and Design Criteria

Design, manufacture, testing, commissioning of manual control, metering and protection system which includes Electrical protection by conventional relay; manual control and metering of the Power House.

5.1.3.2 Standards

All materials and equipments shall comply in every respect with the requirements of the latest edition of the relevant Indian, I.E.C. Standards or any other recognized International standards, except in so far as modified by this specification. Where standards offered are other than the Indian /IEC, copies of the relevant portion of standard specification in English language must be attached.

5.1.3.3 Design Criteria

The control will have provision for start, stop, manual synchronizing and emergency stop. Sequencing will be as follows (tentative Drawings to be enclosed by Purchaser).

- (i) Start Sequence for synchronous generator
- (ii) Synchronization
- (iii) Controlled action shut down
- (v) Emergency Shut down
- (vi) Immediate Action Shut down

(vii) Electrical shut down

Final drawings will be submitted for approval of Purchaser by the Contractor

5.1.3.4 Protection and Metering Scheme

Requirements of metering and protection/scheme and the function performed by various relays are explained in following tentative drawings (to be enclosed by Purchaser).

- (i). Single Line Diagram Main
- (ii). Metering and Relaying Single Line Diagram
- (iii). Unit tripping and annunciation block diagram
- (iv). Interconnection with grid (single line diagram)

Common tripping relays for similar functions have been provided with lock-out facilities. All these relays shall have potential free contacts for trip and alarm purposes and externally hand reset type of flag indicators. They should preferable be housed in draw out type of cases with tropical finish.

All the protective equipment will be housed in the Power Plant main control room. The details of C.T.'s for all the unit protection and metering are as per Drawings to be provided.

The drawings for the proposed system will be subject to approval by the Purchaser.

5.1.3.5 Protective Relays

(Refer Para 2.2)

5.1.3.6 Metering System

Meters as shown in Schematic drawing (to be enclosed by Purchaser) shall be provided on unit control boards. These are summarised below:

5.1.3.6.1 Generator (Unit Control Board)

- (i). 3 ammeters (each phase)
- (ii). Power factor
- (iii). kW meter
- (iv). kVAR
- (v). Voltmeter with voltmeter switch
- (vi). Temperature scanner

5.1.3.6.2 Auxiliary Transformer

- i. kWh meter
- ii. Ammeters (3 No.)

5.1.3.6.3 Bus Coupler Panel

No Metering is required on this panel.

5.1.3.6.4 Feeder Panel

- i. Voltmeter with voltmeter with selector switch
- ii. 3 Ammeters (each phase).
- iii. kWh import / export meter.

5.1.3.7 Annunciation

Conventional 16 window annunciator for each generator turbine faults; 12 windows each for feeder faults and Bus Coupler is proposed for important faults. Schedule for these windows may be proposed for approval by purchaser. All other annunciation will be on SCADA system.

5.1.3.8 Recorder

All recording will be done on SCADA disk.

5.1.3.9 CTs/VTs and Generator Surge Protection Equipment

(Refer Para 2.2)

11 kV Current Transformers

- 1 11 kV Current Transformers of appropriate rating
 - (a) Generator neutral side – Three core
 - Core 1 PS class for differential protection relay 87G.
 - Core 2 5P10 class for General protection relay i.e. 32,40,46,51V.
 - Core 3 PS Class for Differential Protection relay of Generator Transformer 87GT with three Nos. interposing CTs
 - (b) Generator Line side – Two core -6 Nos.
 - Core 1 Class 0.5 for AVR.
 - Core 2 Class 0.2 for metering.
- 2 11 kV CT ratio 600/5A in 11 kV cubicle
Single core PS class for Differential Protection of Generator 87G relay.
- 3 11 kV CT 11kV cubicle
(Ratio to be decided after capacity of Exciter Transformer decided)
Single core 5P10 class for over current protection of Exciter Transformer circuit 51EX relay.
- 4 11 kV CT for unit auxiliary in 11 kV cubicle
Single core 5P10 class for over current protection of Unit Aux. T/F 50/51 relay.

5.1.3.10 Control Panel Layout

Layout of Control panel is shown in drawings to be enclosed by Purchaser. Details of control panels are as follows

5.1.3.10.1 Generator transformer control and relay panels

Floor mounted, sheet steel simplex type control and relay panels with the following equipment mounted on them shall be supplied for Generator Transformer control and protection. Details of control panel are given in table-6

Table 6: Generator Transformer Control Panels

S. No.	Nomenclature	Quantity	Description
1.	-	-	Mimic diagram of bus –bars and connections.
2.	BI	1 set	Semphore indicators for isolators.
3.	CB	1 set	Semphore indicators for circuit breakers.
4.	AG	3 Nos.	Dial type A.C. ammeters for measuring generator current in Amperes range 0-800A
5.	VG	1No.	Dial type A.C. voltmeter for measuring generator voltage in kV range 0-15 kV
6.	VS	1No.	Voltmeter selector switch.
7.	PF	1No	Polyphase indicating power factor meter range – 0.5 to 0 to +0.5
8.	KW	1 No.	Polyphase indicating kW meter of range 0 to 15000 kW
9.	KVAR	1No.	Polyphase indicating KVAR meter of range 0-6000 kVAR
10.	FM	1 No.	Frequency meter 0-75 Hz
11.	AF	1 No.	Field current meter 0-200 A
12.	VF	1 No.	Field voltage meter 0-300 V
13.	SI	1 No.	Speed indicator 0-1000 rpm
14.	SL	1No	Gate limit indicator
15.	SW	1 no.	Remote/ local selector switch
16.	A/M	1 No.	Auto/manual selector switch
17.	S ₁	1No.	C.B. control switch with indicating lamps including healthy trip supply indication.
18.	S ₂	1 set	Bus Isolator control switch with indicating lamps
19.	S ₄	1No.	Gate limiter control switch (Raise/lower)
20.	S ₅	1 No.	Speed level control switch (Raise/lower).
21.	SS	1No.	Synchronising switch with locking key
22.	T	1 No.	Temp. indicator with selector switch
23.	86 G	1 No.	High speed tripping relay
24.	30 X(EPB)	1No	Emergency stop switch with cover
25.	30 Y	1N.	Stop reset push Button
26.	KWH	1 No.	Energy meter with test block
		1 Set	Annunciation block with 16 windows complete with alarm cancellation lamps reset and lamp test push buttons .25% windows should be spare.

Relay Panels

Multi function digital relays are to be provided. Additional static relays will also be provided.

Details of relay panels are given in table-7

Table 7: Generator Transformer Relay Panel

S. No.	Nomenclature	Quantity	Description
1	87 G	1 Set	Tripple pole generator differential protection relay including auxiliary relay etc.
2	50/51T	1 No.	Overcurrent Earth fault relay for Generator transformer.
3	51 V	1 No.	Backup protection relay (over current voltage restraint.
4	64 G	1No.	Generator ground protection relay.
5	64T	1No.	Transformer ground protection relay
6	59	1No	Over voltage relay
7	25	1 No.	Check synchronising relay(on synchronizing panel)
8	32	1 No,	Reverse power relay
9	46	1No.	Negative phase sequence relay
10	40	1 No.	Field failure relay
11	87 GT	3 Set.	Generator Transformer differential protection relay including auxiliary relay etc.
12	64 F	1No.	Rotor earth fault relay
13	12 G	1No.	Over speed relay (electrical)
14	27	1No.	Under voltage relay
15	47	1No.	Phase sequence voltage relay
16	84	1No.	Generator trip relay
17			Auxiliary and locking relays

5.1.3.10.2 Feeders control and relay panels

Floor mounted, sheet steel simplex type control and relay panels with the following equipment mounted on them shall be supplied for control and protection of feeders. Details of feeder control panels are given in table-8

Table 8: Details of feeder Control Panels

S. No.	Nomenclature	Quantity	Description
1.	-	-	Mimic diagram of bus –bars and connections.
2.	BI	1 set	Semaphore indicator for Bus isolators.
3.	LI	1No.	Semaphore indicator for line insulator
4.	CB	1 set	Semaphore indicators for circuit breakers.
5.	A	3 Nos.	Dial type A.C. ammeters for measuring feeder current in Amperes range 0-200A
6.	V	1No.	Dial type A.C. voltmeter for measuring voltage in kV range 0 to-----kV
7.	VS	1No.	Voltmeter selector switch.
8.	KW	1 No.	Polyphase indicating kW meter of range 0 to -----kW
9.	KVAR	1No.	Polyphase indicating KVAR meter of range 0 to----- kVAR
10.	S ₁	1No.	C.B. control switch with indicating lamps including healthy trip supply indication.
11.	S ₂	1 set	Bus Isolator control switch with indicating lamps
12.	S ₃	1set	Line Isolator control switch with indicating lamps
13.	SS	1No.	Synchronising switch with locking key
14.	86 G	1 No.	High speed tripping relay
15.	KWH	1 No.	Export/ Import Energy meter with test block
16.	Annunciation	1 Set	Annunciation block with 16 windows complete with alarm cancellation lamps reset and lamp test push buttons with provision of 25% extra windows

Details of feeder relay panels are given in table-9.

Table 9: Details of feeder Relay Panels (Digital relays)

S. No.	Nomenclature	Quantity	Description
1.	50/51, 64	1 set	Static over current and earth fault relay with high set unit
2.	27	1set	Under voltage relay
3.	59	1set	Over voltage
4.	81H/L	1 set	High / Low frequency relay
5.			Auxiliary relays as per actual requirement. Other protections relays as decided by feeder protection designer .

5.1.3.10.3 Bus Coupler control and relay panel

Floor mounted, sheet steel simplex type control and relay panels with the following equipment mounted there on shall be supplied for Bus Coupler control and protection. Details of bus coupler control panels are given in table-10

Table 10: Bus Coupler Control Panel

S. No.	Nomenclature	Quantity	Description
1.	-	-	Mimic diagram of bus –bars and connections.
2.	BI	2 sets	Semaphore indicators for isolators.
3.	CB	1 set	Semaphore indicator for circuit breaker.
4.	AB	3 Nos.	Dial type A.C. ammeters for measuring current in Amperes range 0-500A
5.	S ₁	1No.	C.B. control switch with indicating lamps including healthy trip supply indication.
6.	S ₂ A/B	2 sets	Bus Isolator control switch with indicating lamps
7.	86 G	1 No.	High speed tripping relay
8.		1 Set	Annunciation block with 16 windows complete with alarm cancellation lamps reset and lamp test push buttons

Details of bus coupler relay panels are given in table-11

Table 11: Bus Coupler Relay Panel

S. No.	Nomenclature	Quantity	Description
1.	87 B1/B2	2 Sets	Triple pole Bus Bar differential protection relay including check and auxiliary relays etc.
2.	51	1 No.	Interlocked over current relay
3.			Other Auxiliary relays as per requirement

5.1.3.10.4 Synchronizing Panel

Sheet steel swinging panel mounted on the side of the switchboard complete with internal wiring connections equipped as synchronizing panel with the following equipment mounted there on. Details of synchronizing panels are given in table-12

Table 12: Details of Synchronizing Panels

Quantity	Description
2 Nos.	Dial type A.C. voltmeter of suitable range for measuring voltage in kV.
2 Nos.	Dial type frequency meters of suitable range.
1No.	Synchro-scope.
1No.	Synchronizing lamps control switch (ON/OFF)
2Nos	Synchronizing lamps.
1 No.	Synchronization selector switch (Auto / Manual).
1 No	Synchronising check in relay

5.1.3.11 Test Blocks

Test blocks shall be provided on switchboards where test facilities are required but are not provided by use of draw out type meters or relays. The test blocks shall be of the back connected semi-flush mounted switchboard type with removable covers. All test blocks shall be provided with suitable circuit identification. The cases shall be dust tight. Test blocks shall be rated not less than 250V at 10 amps and shall be capable of withstanding a di-electric test of 1500 V, 50c/s for one minute. All test blocks shall be arranged to isolate completely the instruments or relays from the instrument transformers and other external circuits so that no other device will be affected and provide means for testing either from an external source of energy or from the instrument transformers by means of multiple test plugs. The test blocks and plugs shall be arranged so that the C.T. secondary circuits cannot be open circuited in any position, while the test plugs are being inserted removed.

5.2 Supervisory Control and Data Acquisition (SCADA) System

5.2.1 Scope of Supply and Design Criteria

Design, manufacture, testing, commissioning of the Supervisory Control and Data Acquisition (SCADA) system which includes all equipments required for measurement, control, metering protection data logging data recording, annunciation and sequence of event recorder, main computer, display unit with keyboard.

The SCADA system required should provide monitoring of parameters and control in grid mode and isolated mode operation of the Power station centralized control room. This SCADA system should have following features:

- a. Reliable safe control of the unit with very high availability
- b. Automatic startup, on-load control and shutdown of the units by the control system
- c. Control of auxiliary equipment
- d. Remote monitoring of all plant status and alarm information
- e. Remote normal startup, on-load control and shutdown of units by operators.

SCADA system should have following controllers

- a. Unit Controller.
- b. Common Plant Controller/Supervisory Controller at Power House control room

The SCADA system where it is proposed to be set up in this specification shall be designed for safe, reliable, efficient and easy operation of Hydro Turbine Generator and its associated auxiliaries and transmission lines.

The SCADA system shall consist of a redundant microprocessor based computer system, a dedicated sequence of events recording system, a health/condition monitoring and analysis

system, system cabinets, local panels, sensors, local instruments, erection hardwares, interposing relays etc.

The SCADA to be supplied shall be of proven design; operation in at least six power house for more than 5 years and will be subject to approval by purchaser and will consist of following.

- (a) Main microprocessor based computer system.
- (b) Modem and Communication system
- (c) Data logger/sequence of events recorder.
- (d) 21" colour graphic monitors with key boards
- (e) System console
- (f) Inkjet dot matrix printer-2 nos.
- (g) Complete field instruments like transmitter/transducers, sensors, interposing relays, erection hardwares all interconnecting cables etc.
- (h) Bidder shall supply all necessary software required for the SCADA system including operating system, compiler, application software etc.
- (i) The transducers required for the measurement of electrical parameters. The output of transducers will be 4-20 mA.

The SCADA system shall be capable of performing the following functions in real time.

- a) Acquire data from primary sensors.
- b) Process and retain data for each primary sensor.
- c) Perform detailed thermal and vibration analysis.
- d) Report machine performance in tabular and graphical format.
- e) Trending of turbine and generator efficiencies
- f) Sequence of event logging.
- g) Supervisory control of auxiliaries, governing system, excitation system, circuit breakers, including synchronising.
- h) Display software including system monitoring alarm processing and display of data, fault, and status of devices.
- i) Application software including state estimation, bad data detection, and on line power flow.
- j) Data logging and report generation.
- k) Report alarms.
- l) Predict need for shut down and maintenance of equipment.
- m) Software shall be such that the monitoring system will take care of the transient parameters during system run-up and shut down.
- n) Software shall be modular and upgradable.
- o) The SCADA software shall run in co-ordination with existing/proposed SCADA software for gate control operation. It can received data of Gate positions etc. from it and send generation etc. data to it.

5.2.2 Response Time

Fast response time of computer system is required. Bidder will intimate following:

- (a) Time duration required to update a graphical display from the instant a field contact changes state.
- (b) Time duration from the instant a control is activated at the operator station until the command is implemented at the field device.
- (c) Overall time duration to process and lag an alarm once it is received at the computer.

Methodology by which these “times” were verified must be given.

Acceptable time shall be verified at the factory acceptance test.

5.2.3 Plant Operation Philosophy

The normal, start-up, shut down and emergency operations of the hydro turbine generator, auxiliaries and feeders shall be performed in three different ways as follows:

- (i) PLC based governor control panel for unit and plant control
- (ii) Remote Control from Power House control room
- (iii) Manual control panel

The Control Engineer shall be able to perform the following operations from the CRT through keyboards.

- a) Call up mimic, alarm, data display.
- b) Call up control display to carry out control operations for hydro turbine generators and its associated auxiliaries and main & electrical power supply systems controlled from CRT/key board.
- c) Demand, logs, report including performance calculation reports, summaries, trends and plots for hydro-turbine generator and its auxiliaries and main & auxiliary electrical power supply system.
- d) The control engineer shall be able to set up all pre-start check of devices from the CRT/keyboard for unit starting such as :
 - 1) The wicket gate control
 - 2) The control of generator brakes
 - 3) Power supply to the governor
 - 4) Load/frequency device selection on speed setting mode.
 - 5) The selection of speed droop equal zero.
 - 6) The blades at fully open position etc.
- e) The control engineer shall be able to set the interlocks to start the unit from the CRT/key board and once the start command is given following sequence shall take place through the SCADA system.

- 1) Level control shall be put off.
 - 2) The governor pump shall start.
 - 3) When the oil pressure is established in the governor circuit, blades shall set at the starting position.
 - 4) Release generator brakes.
 - 5) After having ensured that the bakes are released and blades are in starting position command shall be given to open the wicket gates.
 - 6) With opening of wicket gate unit speed shall rise.
 - 7) At 90% unit speed, generator shall be excited, wicket gate shall be stopped and its position maintained by energizing governor relays speed adjustment, blades/movements shall be achieved.
 - 8) When unit frequency and phase voltage is matched to that of existing power system, unit circuit breaker shall be closed.
 - 9) After unit breaker is connected to the system, governor parameters shall be set to automatic mode.
- f) The control engineer shall be able to shut down the unit during normal condition in the following sequence. .
- 1) Level control on governor shall put off
 - 2) Blades shall close
 - 3) When blades are closed, wicket gate shall be allowed to close.
 - 4) When no output power is sensed unit breaker shall be tripped.
 - 5) After unit breaker is open, blades shall open again.
 - 6) When downstream gate is closed and unit speed is 30%, brakes, shall be applied.
- g) The control engineer shall also be able to trip the unit during emergency condition with the following sequence. .
- 1) Unit breaker shall be tripped.
 - 2) Wicket gate shall be closed.
 - 3) Other sequence of operation as per the normal shut down.

5.2.4 Unit Controller

Redundant microprocessor based/PLC based governor system control should be interfaced with SCADA powerful enough to perform all the required functions mentioned above. It should have capability to implement closed loop PID function for governing. The scan time of the complete sequence for each process should be less than 100 msec. It should have lock to prevent unauthorised modification and be capable of detecting hardware and software failures. It may also have digital relays for over current, over-voltage and differential generator protection. It should have following hardware features. It should have a console and keyboard to program the controller as well as communicate with Supervisory controller. Unit controller should support remote management and remote programming for supervisory controller.

5.2.5 Programming & Training Console

The Console should permit software development and operator training while providing backup hardware for use where the manual operator interface is out of service. Interlocking should be provided to permit only one console to be in control at a time.

5.2.6 Printers

2 nos. Printers must be provided with supervisory and unit controllers.

5.2.7 CCTV cameras

The plant control system should include recording system of selected parameters i.e. Generator temperature etc.

5.3 Communication Link

5.3.1 Scope

Design, supply, delivery, Site, erection, communication and training of personnel for communication links between the power house and off-site control (if provided)and communication and between power house and grid substation (interlinking points) for voice communication.

5.3.1.1 Code Standards

ANSI/IEEE 1010 – 2006
Relevant National / International Standards

The contractor shall furnish detailed design and calculation for approval by purchaser.

5.3.1.2 Regulatory Requirement

Govt. regulatory requirement and sanctions for the communication system shall be obtained by Contractor. Necessary assistance will be provided by Purchaser.

5.3.2 Dedicated Communication by Fiber Optic System Cable

Dedicated communication system for SCADA, voice communication from power house to offsite control (if provided) shall be by Fiber optic cable.

5.3.2.1 Fiber optic cable

A fiber-optic cable system consisting of a terminal with multiplexing equipment, and a transmitter and receiver coupled to fiber-optic light conductors that are routed to the other terminal, which also has a receiver, transmitter, and multiplexing equipment shall be provided.

Because the transmission medium is nonmetallic, it offers the advantage of electrical isolation between terminals and immunity from electromagnetic interference.

5.3.2.2 Repeaters

Repeaters if needed shall be provided. Necessary equipment at sending and receiving and for interfacing remote supervisory controller with SCADA. Centralized SCADA system to remote supervisory control shall be provided by the dedicated Fiber optic cable. The design will be subject to approval by purchaser and will confirm to latest relevant standard.