**Section 6 - Employer’s Requirements**

**Table of Contents**

[1 Particualr Specification – I & C Works 7](#_Toc424029390)

[1.1 Foreword 7](#_Toc424029391)

[1.2 Scope of Works and Supply of Goods 7](#_Toc424029392)

[1.2.1 Diesel Generator Controls 7](#_Toc424029393)

[1.2.2 Electrical System Controls 7](#_Toc424029394)

[1.2.3 SCADA System 7](#_Toc424029395)

[1.2.4 Fire Alarm System 8](#_Toc424029396)

[1.2.5 Cabling 8](#_Toc424029397)

[1.2.6 I&C Spare Parts 8](#_Toc424029398)

[1.2.7 Training Program 8](#_Toc424029399)

[1.2.8 Foreign Training 8](#_Toc424029400)

[1.2.9 Miscellaneous 8](#_Toc424029401)

[1.3 General 9](#_Toc424029402)

[1.3.1 Control Location Criteria 9](#_Toc424029403)

[1.3.2 Design Rules 10](#_Toc424029404)

[1.3.3 SCADA System Vendors 11](#_Toc424029405)

[1.4 Field Instrumentation 11](#_Toc424029406)

[1.4.1 General 11](#_Toc424029407)

[1.4.2 Local Instrumentation 11](#_Toc424029408)

[1.4.3 Instrumentation for Protection 11](#_Toc424029409)

[1.5 Control of Electrical Systems 12](#_Toc424029410)

[1.5.1 General 12](#_Toc424029411)

[1.5.2 Design Requirements 12](#_Toc424029412)

[1.5.3 Mimic Displays 13](#_Toc424029413)

[1.6 Control and Supervisory System 15](#_Toc424029414)

[1.6.1 PLC 15](#_Toc424029415)

[1.6.2 SCADA System 16](#_Toc424029416)

[1.7 Local Controls 18](#_Toc424029417)

[1.7.1 General 18](#_Toc424029418)

[1.7.2 Local Control Panels 18](#_Toc424029419)

[1.8 Training Program 20](#_Toc424029420)

[1.8.1 Training at the nearest Vendor Training Centre 20](#_Toc424029421)

[1.8.2 Site training 20](#_Toc424029422)

[2 General Requirements – I & C Works 21](#_Toc424029423)

[2.1 Design Conditions 21](#_Toc424029424)

[2.2 General 21](#_Toc424029425)

[2.2.1 Requirements due to Environment 21](#_Toc424029426)

[2.2.2 Requirements due to Explosion Hazard 21](#_Toc424029427)

[2.2.3 Equipment Protection Class 21](#_Toc424029428)

[2.2.4 Standards 21](#_Toc424029429)

[2.2.5 Measuring Units 22](#_Toc424029430)

[2.2.6 Drawings and Documentation 23](#_Toc424029431)

[2.2.7 Miscellaneous 24](#_Toc424029432)

[2.2.8 Signal Listings 25](#_Toc424029433)

[2.3 Workshop and Site Tests 25](#_Toc424029434)

[2.3.1 Work’s Inspections and Workshop Tests 25](#_Toc424029435)

[2.3.2 Tests at Site 26](#_Toc424029436)

[2.4 Field Equipment 28](#_Toc424029437)

[2.4.1 General Design Requirements 28](#_Toc424029438)

[2.4.2 Installation of Instrumentation 30](#_Toc424029439)

[2.4.3 Instruments Valves 34](#_Toc424029440)

[2.4.4 Pressure Measurements 36](#_Toc424029441)

[2.4.5 Temperature Measurements 38](#_Toc424029442)

[2.4.6 Flow Measurements 40](#_Toc424029443)

[2.4.7 Level Measurements 42](#_Toc424029444)

[2.4.8 Water/Steam Analysers 44](#_Toc424029445)

[2.4.9 Vibration Measurements 45](#_Toc424029446)

[2.4.10 Miscellaneous Measurements and Controls 46](#_Toc424029447)

[2.4.11 Control Valves 46](#_Toc424029448)

[2.4.12 Control Actuators 47](#_Toc424029449)

[2.5 Supervisory Control and Data Acquisition System 51](#_Toc424029450)

[2.5.1 Operational Concept 51](#_Toc424029451)

[2.5.2 System Basic Design 51](#_Toc424029452)

[2.5.3 General Requirements 51](#_Toc424029453)

[2.5.4 PLCs 52](#_Toc424029454)

[2.5.5 Communication System 55](#_Toc424029455)

[2.5.6 Overall Functional Group Control Unit / Plant Control 56](#_Toc424029456)

[2.5.7 Operator Stations in Central Control Room, Local Control Room 56](#_Toc424029457)

[2.5.8 Diagnostic and Programming Station (Engineering Station) 62](#_Toc424029458)

[2.5.9 System Deviations 63](#_Toc424029459)

[2.5.10 Alarm System 64](#_Toc424029460)

[2.5.11 Protection System 65](#_Toc424029461)

[2.6 Conventional Instrumentation on the Local Panels / Boards 65](#_Toc424029462)

[2.6.1 General Design 65](#_Toc424029463)

[2.6.2 Local Panel Instruments 66](#_Toc424029464)

[2.7 Local Control Room 68](#_Toc424029465)

[2.7.1 Function 68](#_Toc424029466)

[2.7.2 Equipment 68](#_Toc424029467)

[2.8 Cabling and Wiring 68](#_Toc424029468)

[2.8.1 General Design 68](#_Toc424029469)

[2.8.2 Wiring in Cubicles, Desks and Panels 68](#_Toc424029470)

[2.8.3 Outgoing Cables 69](#_Toc424029471)

[2.8.4 Shielding and Grounding System 69](#_Toc424029472)

[2.9 Power Supply 69](#_Toc424029473)

[2.9.1 24 V DC Supply System 69](#_Toc424029474)

[2.9.2 AC Uninterrupted Power Supply System 70](#_Toc424029475)

[3 Annex 71](#_Toc424029476)

[3.1 Drawings 71](#_Toc424029477)

[3.1.1 Existing SCADA System Architecture 71](#_Toc424029478)

**ABBREVIATIONS**

|  |  |  |
| --- | --- | --- |
| AC | - | Alternating Current |
| ADB | - | Asian Development Bank |
| AFNOR | - | Association Francaise de Normalisation |
| ANSI | - | American National Standard Institute |
| ASA | - | American Standards Association |
| ASHRAE | - | American Society of Heating, Refrigerating and Air-conditioning Engineers |
| ASME | - | American Society of Mechanical Engineers |
| ASTM | - | American Society for Testing and Materials |
| ASTME | - | American Society of Tool and Manufacturing Engineers |
| AVR | - | Automatic Voltage Regulator |
| BS | - | British Standard |
| BSEN | - | British Standard Euro Norm |
| CB | - | Circuit Breaker |
| CCR | - | Central Control Room |
| CEE | - | Commission Internationale de Réglementation en vue de l’Approbation de l’Equipement Electrique |
| CFA | - | Consolidated Freight Association |
| CI | - | Cold Insulation |
| CIRIA | - | Construction Industry Research and Information Association, London UK |
| CT | - | Current Transformer |
| CWI | - | Chilled-Water Insulation |
| DCS | - | Distributed Control System |
| DGU | - | Diesel Generator Unit |
| DIN | - | Deutsches Institut für Normung |
| DO | - | Diesel Oil |
| ELS | - | Emergency Lighting System |
| EPA | - | Environmental Protection Agency |
| EUROVENT | - | Comité Européen des Constructeurs de Matériel Aéraulique |
| EU | - | European Union |
| GIS-SWG | - | Gas Insulated Switch Gear |
| GPS | - | Global Positioning System |
| GRP | - | Glass-fibre Reinforced Plastics |
| HI | - | Heat Insulation |
| HFO | - | Heavy Fuel Oil |
| HRC | - | High Recovery Fuse |
| HV | - | High Voltage (­ 36 kV) |
| HVAC | - | Heating, Ventilation & Air-Conditioning |
| IEC | - | International Electric Commission |
| IFO | - | Intermediate Fuel Oil |
| ISO | - | International Standardisation Organisation |
| ISRM | - | International Society for Rock Mechanics |
| I&C | - | Instrumentation and Control |
| KKS | - | :Kraftwerk Kennzeichnungs-System (= Designation System for Power Plants) |
| LCP | - | Local Control Panel |
| LCB | - | Local Control Boards |
| LLC | - | Logical Link Control |
| LV | - | Low Voltage (< 1 kV) |
| MCC | - | Motor Control Cubicle |
| MMI | - | Man Machine Interface |
| MV | - | Medium Voltage (­1 kV < 36 kV) |
| MVR | - | Manual Voltage Regulating |
| NB | - | Nominal Bore |
| NFPA | - | National Fire Protection Agency |
| NLS | - | Normal Lighting System |
| NLTC | - | No Load Tap Changer |
| OHL | - | Over Head Line |
| OLTC | - | On Load Tap Changer |
| OPC | - | Ordinary Portland Cement |
| PC | - | Performance Certificate |
| PGC | - | Potential Gradient Control |
| PLC | - | Programmable Logic Control |
| PPI | - | Personal Protection Insulation |
| PQR | - | Procedure Qualification Record |
| P&I | - | Piping and Instrumentation |
| SCADA | - | Supervisory control and data acquisition |
| SIS | - | Swedish Standard |
| SLD | - | Single Line Diagram |
| SLS | - | Security Lighting System |
| SPT | - | Standard Penetration Test |
| SRPC | - | Sulphate Resisting Portland Cement |
| SSD | - | Saturated and Surface Dry- Condition |
| SWG | - | Switch Gear |
| TOC | - | Taking Over Certificate |
| TRD | - | Technische Richtlinien für Dampferzeuger (= Technical Guidelines for  Steam boilers) |
| UPS | - | Uninterrupted Power Supply |
| UTM | - | Universal Transversal Mercator (Co-ordinate System) |
| VDE | - | Verband Deutscher Elektrotechniker e.V. |

# Particular Specification – I & C Works

## Foreword

The concept for the Fourth Power Development Project is for a power plant with ultimately three diesel generating units of approx. 8 MW each. However, only 2 diesel generating sets have now been installed under the original project and now the third engine is to be installed under ADB financing.

The present Employer’s Particular Requirements for I&C Works cover all Works and Supply of Goods financed under the ADB financing.

## Scope of Works and Supply of Goods

This specification covers all the electrical works to be carried out under this contract including design, supply, erection, testing and commissioning and any other required services to make the plant functional and complete in every respect. The required equipment, systems, materials, etc. are those necessary for the complete and proper execution of the contract on a turn-key basis contract and as generally shown in principle on Tender Drawings and/or stated in the General and Particular Technical Specifications.

The scope of the I&C Works shall include, but not be limited to, the following:

### Diesel Generator Controls

1. Single PLC based diesel engine control panels, complete with all necessary monitoring, supervision, and alarms, for installation in the Local Control Room (LCR)
2. Adding all the required auxiliary controls to the existing Common Control redundant H PLC (example fuel transfer to day tank from the Storage tank)
3. One (1) lot of interface panels as necessary to integrate the controls, indications, alarms, etc. of all equipment for the SCADA system, including the provision of all required cabling and wiring.
4. One (1) lot of field instruments for engines and auxiliaries

### Electrical System Controls

1. Single generator panels complete with automatic synchronizing equipment and synchro check relays for installation in the LCR. Related operation interface switches, synchroscope and indicators will be installed on the generator control panel under the electrical equipment scope of work
2. One (1) PLC based panel for remote control interface and data acquisition of new MV and LV electrical switchgear for installation in the LCR
3. One (1) lot of interface panels as necessary to integrate the controls, indications, alarms, etc. of all equipment for the SCADA system, including the provision of all required cabling and wiring.

### SCADA System

1. Interfacing the third generating set to the existing ICONICS (Genesis 9) system by adding the required pages to the redundant SCADA servers. If necessary adding or expanding the tag licenses where necessary. This addition work shall not occur in disruption of power to the customers. Main display should be changed from two engine sets to three engine sets, including all remote operation. Add new pages as necessary for the operation of the third engine and the whole power plant.
2. Single PROFIBUS fiber optic connections between the SCADA interface controller(s) and the new plant PLCs including redundant communication modules at all nodes. The SCADA vendor may alternatively propose an architecture without interface controller(s) where the PLCs are direct nodes of the SCADA LAN.

### Fire Alarm System

The existing fire alarm system needs additional sensor when the third engine is installed and where existing devices does not provide ample coverage. Coverage is also necessary in the basement are where there is risk of fire; like cable overheat or short circuit.

### Cabling

The following cabling shall be included as far as applicable:

1. One (1) lot DC and UPS power cables for I&C equipment
2. One (1) lot control cables for I&C digital, analogue and control signals
3. One (1) lot fiber optic cables for SCADA system
4. One (1) lot of different communication cables and SCADA LAN connections
5. One (1) lot of fire resistant control cables for fire alarm system

### I&C Spare Parts

1. Security spare parts. All items are to be priced individually
2. The scope of supply shall include complete sets of spare parts for all I&C equipment under the scope of the project that are adequate for at least 10,000 hrs operation. All items are to be priced individually.
3. Spare parts shall include one central processing module, one Industrial Ethernet module, DI module DO module, AI module, AO module, one touch display module and spare PC with display.

### Training Program

1. Training at the nearest vendor training centre
2. Site training on SCADA programming / fault finding – not applicable
3. Site training on PLC programming / fault finding

### Foreign Training

All living, accommodation, food, transport expenses of the trainees during the period of training/study tour including airfares, incidental expenses, medical expenses, medical insurances etc. shall be covered by the Bidder including pocket allowance of US$100/day/person.

### Miscellaneous

The scope of supply shall include any other item required to make the plant/ systems functional and complete in every respect. Such items shall be specified in detail with individual prices to be given for each item.

## General

The Contractor shall complete the scope of works with such items not specified, but found as evidently necessary with the Contractors proper design and/ or ensure a reliable and safe operation of the Plant. The I&C system shall cover all measurements / visualization of operation data, protection and control functions, in addition to the requirement of the present specification. If the Contractor proposes or supplies any additional plant/equipment, all corresponding instrumentation and control equipment shall be included in his scope, along with all necessary special tools and product specific configuring and diagnostic devices.

Specified instrumentation and control systems indicate only basic requirements, detailed design may be different. Only minimum instrumentation has been specified and should not be considered as a limiting factor. Any items not included hereunder but specified elsewhere shall also be included. Necessary space/ capacity for one further DGU unit and auxiliaries shall be reserved/ provided.

### Control Location Criteria

The Instrumentation and Control equipment shall be selected and designed in such a way that the specified functions can be fully performed locally from the Local Control Room (LCR) and remotely from the Central Control Room (CCR).

#### Local Control Room

Normal start, stop, and emergency operation of the DGU shall be possible from the LCR, including complete test and maintenance cycles. The LCR, in the power house, shall accommodate the local control panel of the diesel engine and generator.

For the local control of all systems installed under the present contract, an operator station terminal with 23 inch LCD monitor shall be installed in the LCR.

The engine and plant auxiliary systems consist mainly of the following:

1. Fuel oil (DO) transfer system (connection from existing fuel transfer system to third engine)
2. Fuel oil (DO) circulation and filtering system
3. HT and LT cooling water system including pre-heaters
4. Cooling water treatment and maintenance systems
5. Lube oil (LO) circulation and filtering systems
6. LO separators
7. Compressed air system for starting air, service air and control air ( connection from existing to third engine)
8. Sludge oil collection, transfer & treatment systems

These auxiliaries are equipped with independent local controls allowing local operation and forwarding all analogue measurements and status/alarm indications to the auxiliaries PLC panel in the LCR.

### Design Rules

The control of plant equipment and systems is realised by PLC based control panels located in the LCR at the new power house and a new SCADA system with equipment located in the LCR and the CCR.

All control sequence and protection logic of plant equipment as well as closed loop controls, in case required, shall be made in the PLC’s or other local controls connected to the PLCs. The SCADA system functions will include remote monitoring and control commands and management of plant assets but no control logic.

The graphic operation interface and control functions display shall be similar or better than the existing operation interface at the CCR in addition to the requirements of the present specification.

As stated in the scope of work, the required PLC based control panels are:

1. Engine control panel located in the LCR to perform all engine start and shutdown sequence logics.

The PLC shall be connected to remote I/O units at the location of the different auxiliaries.

The engines’ PLCs need not be redundant.

One panel shall be provided for each engine and shall include all conventional operator interface for local operation. Each engine’s auxiliaries required for the operation of the individual engine shall be integrated in the engine control panel.

1. Common auxiliaries control panel located in the LCR to perform all operation logic of plant common auxiliaries and to provide conventional operator interface for local operation.

The PLC shall be connected to remote I/O units at the location of auxiliary units. The common auxiliaries PLC shall be redundant (Already provided). If space in common auxiliary PLC is not enough contractor may propose alternative.

1. Electrical interface panel located in the LCR and connected to MV and LV switchgear, DC system, generator panel and synchronization / load sharing panel to acquire electrical data and relay remote commands from the SCADA system.

The electrical interface PLC shall be redundant.

The PLC shall preferably be connected through a serial interface with an intelligent protection and monitoring system installed in the switchgear.

An acceptable alternative solution is a design whereby the SCADA system controller will be a direct node of the SCADA LAN replacing the PLC in the local control and interface panels.

Some plant auxiliaries may have local hardwired logic with all status signals connected to the related PLC. Auxiliary equipment, as required, shall also have locally mounted operation interface connected to the related PLC.

The basic scope of work shall include data acquisition and control of the new generating unit and auxiliaries and associated plant electrical switchgear.

The SCADA server is already provide with the existing generating system. If necessary, the bidder shall upgrade RAM, Hard Disk, CPU of the server system for the proper function of the SCADA system with this additional generator unit.

The SCADA servers are already provided and shall be redundant.

### SCADA System Vendors

The SCADA system for this project shall be selected from and supplied, detail-engineered and commissioned by a reputed OEM SCADA Vendor. Systems integrated by the Contractor or by a system integrator subcontractor or from any other source shall not be acceptable. The Contractor, in his technical proposal, shall indicate his selection of the Vendor and the system.

## Field Instrumentation

### General

Field instrumentation shall be provided according to:

* Individual equipment, auxiliary package and electrical specifications
* Applicable standard practice

to fulfil the local supervisory tasks and the aims of the SCADA System as specified in any part of this Specification and to ensure the safe and reliable operation of the plant.

### Local Instrumentation

Generally, the minimum requirements for local Instrumentation (when applicable) are:

1. Pressure gauges at each point of the system that needs pressure supervision for safe operation and/or fault finding
2. Pressure gauges at inlet/outlet of each pump
3. Pressure gauges at pressurized vessels, heat exchangers
4. Differential pressure devices with alarm contacts for filters
5. Thermometers at inlet/outlet of each heat exchanger
6. Thermometers at vessels containing hot liquids
7. Check valves & connections necessary for commissioning and tests
8. Thermometers at bearing oil outlets
9. Level gauges/measurements on heat exchangers with condense, on tanks, pits, etc.
10. All necessary standard instrumentation on package units as per good engineering practice that is required to monitor the package operation conditions.
11. All kW and KVar transducers to indicate maximum positive and negative value for an acceptable range to make decisions on overload or reverse real and reactive power for operators and engineers to see on SCADA screen or HMI displays.

### Instrumentation for Protection

In case those binary switches are used for protection, it is required, that for every mechanical equipment (pump, valve, etc.) and every criterion (protective shut-down, protective cut-in, etc.) a separate device shall be provided.

For important plant protection functions as well as for the protection of important assemblies and drives the corresponding analogue and binary variables have to be measured by three independent devices, whose signals have to be wired to safety certified module, in order to get a 2 out of 3 selection of field signals. For vital protection functions that safeguard against the loss of plant assets or are of personnel and environmental safety related, binary switches shall not be acceptable and only transmitters shall be used.

## Control of Electrical Systems

### General

This chapter includes the requirements for remote control of electrical systems. Automatic and remote control of electrical power plant and of individual electrical installations shall be performed as required and as basically described below through the SCADA system.

### Design Requirements

#### Control and Supervision

Remote control / supervision shall be performed via the plant SCADA system. All functions / indications / measurements / alarms, etc., available with the different systems shall be embraced into the above system as necessary for safe operation and supervision of the plant.

For local operation, the following devices shall be provided at the control panels of each unit as further detailed in the particular Specification for Electrical Works:

1. Generators

* Voltmeter with selector switch
* Phase current meters
* Co-ordinates indicator (vector meter) indicating:
  + active power vector
  + reactive power vector
* Winding temperature indication
* Synchronising instruments (V V, f f, synchroscope)
* Control and indication devices as required

1. Generator Feeder

* Voltmeter
* Phase current meters
* Power factor meter
* Active power meter
* Reactive power meter
* Control and indication devices as required

The above measuring devices and indications and controls are not limiting the scope. Any other measurement specified in the Particular Electrical Specification is deemed to be provided, as part of the I&C control scope of work, locally and/or remotely through the SCADA system.

#### Alarm Indication

Alarms for the individual systems as mentioned above shall be indicated in the SCADA system and may be grouped as indicated in the Particular Mechanical and Electrical Specification.

#### Event Recording and Fault Reports

All alarms and all trips of any equipment as well as all changes of status of main equipment shall be captured and recorded by the SCADA system. This shall include but shall not be limited to:

1. All individual alarms/ trips from generator and engines
2. All individual alarms/ trips from transformer protection
3. All individual alarms/ trips from MV protection systems
4. Group alarms / trip indication from the LV system. The individual alarm / trip information shall be indicated locally
5. Change of status of any generator breaker and of any MV circuit breaker as well as the incoming feeder breakers and bus sectionalizers of LV boards
6. Automatic fault reports at the trip of any generator or transformer to indicate a   
   trend snap shot of related analogue signals over a 20 minutes period of which 4 minutes prior trip and 16 minutes post trip
7. Automatic generation of SMS concerning important failures in the power plant to be sent automatically to a selected group of persons.

### Mimic Displays

Mimic displays are to be provided at the SCADA system operation stations and shall represent the applicable mechanical and electrical system configuration in accordance with the plant single line diagrams as provided by the Contractor on the basis of the approved drawings and the final plant layout. This shall include:

1. MV and LV AC SWG and other electrical equipment
2. DC systems
3. Diesel generator sets
4. Plant auxiliary systems and ancillaries.

The graphic operation interface and control functions display shall be similar or better than the existing operation interface in the CCR in addition to the requirements of the present specification.

The displays shall include all engine related data according to the engine, generator and electrical switchgear manufacturers’ recommendations and as specified in the Particular Mechanical and Electrical Specifications.

#### Synchronisation Systems

A separate, fully automatic synchronisation system as well as manual synchronisation devices shall be provided for each unit.

Normally, the MV generator breaker shall be synchronised by an automatic system, whereby synchronisation shall be actuated by soft key switches on the control room SCADA display stations. The key switch shall have three positions ‘test – off – automatic’. Synchronisation from the control room shall only be possible if a selector switch “local – remote” in the local control panel is in remote position.

Control shall also be possible from the local control panel (LCP). The local key switch shall have four positions ‘manual - test – off – automatic’.

In the automatic and test position of the synchronising key switch, the relevant synchronising instruments shall be connected to the measuring/ control circuits and all synchronising functions shall be controlled automatically.

In the manual position of the synchronising key switch on the LCP, both voltage systems shall be connected to the local synchronising instruments and then both systems shall be synchronised by manual actuation of the speed and voltage setting and of the circuit breaker control device via a synchro-check relay.

In the test position all automatic functions of the system shall be executed without the breaker closing command but the closing signal shall be indicated by an LED.

The following equipment shall be provided:

1. One (1) synchronising device with synchroscope, double voltmeter and double frequency meter at each LCP
2. One (1) synchro-check relay for manual synchronisation for each unit
3. One (1) electronic system for automatic connection of two voltage systems, with set point adjuster output for the generator voltage regulator and for the speed governor of the engine. Means shall be provided for adjustment of the circuit breaker closing time, the maximum admissible voltage and frequency difference and slip etc. for each unit, as required
4. Two (2) synchro-check relay for manual synchronisation of each of the new MV bus-bars with the corresponding existing MV bus-bar
5. All auxiliary devices such as push buttons, indication lamps, interposing transformers, relays, etc., as required

#### Automatic Load Sharing System

The Tenderer shall quote for a new load sharing system which shall be similar or compatible with the two existing MAN engines.

#### Metering

The following electrical meters shall be provided for the new system and arranged in the local panels and related SWG:

1. for each Diesel-generator unit MWh + MVArh
2. for each station service transformer MWh
3. for power export summation MWh + MVArh

The statistical data should at least comprise the following values with time & date and those specified elsewhere in this specification.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Actual Load  In kW & kVA | Noon Peak  9-16 | Evening Peak  18-03 | Minimum Peak | Maximum Peak | Absolute Minimum | Absolute Maximum |
| Daily | X | X |  | X |  |  |
| Weekly | X |  | X | X | X | X |
| Monthly | X |  | X | X | X | X |
| Yearly | X | X | X | X | X | X |

The statistical values for the absolute minimum load per day shall reflect only those days with normal network operation excluding days with load shedding or black-outs.

Generated energy in MWh and MVAh:

Generated energy for each gen-set, and sum of gen-sets: on daily, weekly, monthly and annual basis.

Internal consumption:

Sum of station auxiliary transformers on daily, weekly, monthly and annual basis. Exported energy:

Energy fed to the MV switchgear = generated energy - internal consumption.

## Control and Supervisory System

### PLC

The current PLCs are Siemens S7 400 main modules and S7 300 I/O modules. It is necessary to supply the same type or compatible devices. PLC programming is done via STEP 7 version 5.4 software from Siemens

In addition to the requirements of the General Technical Specification, the PLC’s functions shall include but not be limited to:

1. Signal acquisition, conditioning and processing
2. Open-loop control and interlocks
3. Closed-loop control
4. Related equipment protection
5. Alarm and status annunciation
6. Data communication
7. Data displaying and information presentation
8. System diagnostic

The PLCs shall be connected to the SCADA system through a fibre optical network.

The system shall be designed so as to allow an easy extension in case of subsequent modifications on the controls and the associated signal processing equipment.

All components shall provide a spare capacity for 30% of each type of signal, plus additional spares as follows:

* + 30% more for CPU load, communication modules and memory capacity
  + 20% more for racks.
  + Each type of rack shall allow the addition of a minimum of 20% of I/O modules, without needing a new rack. If necessary, additional racks shall be provided to comply with this requirement.

In any case, CPU load shall not exceed 60% of maximum capacity.

Each PLC processor shall be provided with battery backup to retain its memory for two (2) months.

Low battery level alarm shall be included as part of the diagnostic alarm.

The PLCs may have to perform process function such as PID control, integration, counting, etc., usually done via a DCS.

The PLCs shall be programmed and configured to meet the functional requirements at start­up.

The system shall be immediately and automatically available without human action. Watchdog Function shall be available. Logic functions, timing data and operating subroutines shall be loaded and tested into the PLCs at the VENDOR premises and shall be stored in non-volatile memory.

It shall be possible to configure the PLCs by means of easy-to-use language. The Contractor shall indicate the make and model of the selected PLC and shall specify which programming languages are available on the configuration software, and if it complies with the requirements of IEC 61131. PLCs shall be protected from unauthorized configuration modification by key-lock and/or password.

PLCs minimum performances shall be as follows:

* PLC execution time (input acquisition + program execution + output writing + communication): 0.5 sec maximum
* Analogue signal scan rate (signal used for safety loop): 50 ms
* Digital signal scan rate: 50 ms

The system shall be structured to reflect the redundancy provisions of the plant so that no single fault within the system will cause an operational disturbance or make a standby plant unavailable.

A single fault such as hardware failure, on-line swap of a module, short-circuit, wire break etc. shall neither cause the control equipment to fail nor to operate spuriously.

In case of any failure on the higher levels, operation on the lower levels shall be possible without an interruption of the plant process.

If, due to a failure, a plant component or a control function cannot respond as designed for, then that plant component or control function shall reach a safe condition.

In case of a hardware failure within the automatic controls, the corresponding control equipment shall be automatically switched-over to manual mode.

### SCADA System

In addition to the requirements of the General Technical Specification, the following functions and the following SCADA performance are emphasized:

#### Operation Stations

The major functions to be performed by the operation station shall be:

1. Manipulation of control loops including set point, mode, output, two position or multi position switches and selectors
2. Indication of analogue and digital control and non-control variables and controllers status
3. Overview displays
4. Group displays
5. Detail displays
6. Alarm displays
7. Trending and calculating hourly averages
8. Custom display (interactive schematics)
9. Customised program generation
10. System diagnostics and reporting
11. On-demand and automatic periodic reports print out
12. Alarms: on each display type, the incoming plant and system alarms shall be shown via a message
13. Alarm of plant and equipment shutdown conditions
14. Alarm and status information of all inhibited sensors (Start-up and maintenance inhibit)
15. Dedicated summary pages of all inhibits
16. Acknowledge and reset emergency shutdown alarms and trips
17. Discrepancy alarm command/position for safety valves isolators and breakers
18. Transmitter fault monitoring (bad value)
19. Fire alarm conditions
20. Acknowledge and reset fire alarms and shutdowns
21. System alarm of fire alarm equipment,
22. Transmitter fault monitoring (bad value)

#### Engineering Station

The SCADA Vendor shall provide all the software and hardware engineering tools necessary to build and to modify the configuration of operation stations, interface controller units as well as the network communication modules and the SCADA servers. The tools shall be clearly identified and supplied in sufficient quantity.

For the existing MAN Power Plant this is already provided with SCADA (graphic etc.) modifying tool so that engineers can bring small changes to system as required.

#### Special Displays & Reports

1. Historical trends

100% of the analogue and digital inputs and outputs shall be acquired for an historical trending, which maximum duration shall be advised by Vendor. All points can be long time historized. Sampling time basis can be tuned from 1s to 1 min. Averaging parameters shall be adjustable. About 25% of the points can be long term historized in the same period. Storage on hard disk shall be sized for 6 months. Historicals shall be transferable on CD Rom.

1. Alarm and event log

The SCADA system shall have the capabilities of storing information for 10,000 alarms & events with time resolution from 0.25 msec to 1 sec.

1. Custom displays

The quantities of graphic custom displays shall be estimated as 750. Together with process displays, are also quantified:

* Maintenance override commands
* Sensor failure report

1. System displays

System displays number shall be estimated by Vendor. They typically include :

* Systems and subsystems alarms and status
* bus alarms and status

1. Custom reports

Custom reports shall be shift and production reports. As a first estimate, SCADA Vendor shall implement 25 reports. On demand reports shall be available at any time, on operator request.

#### SCADA Performance

|  |  |
| --- | --- |
| Analogue signal scan rate (signal not used for control) | 0.5 sec maximum (0.25 sec for control) |
| Digital signal scan rate  (not used for operational interlock) | 0.5 sec maximum  (less than 0.25 sec for protection) |
| Time for an alarm/event from input change to report on alarm display | 1 sec |
| Data communication system rate on SCADA control bus | By Vendor. Shall allow specified  loop cycle time |
| Communication link data update time | 1 sec maximum |
| Graphic display build time  (time from pressing display call up key to complete display on screen) | 1.5 sec |
| Graphic display update time  (time from I/O scanning at I/O level, to data change on screen) | 1.5 sec |
| Trend display build time (4 variables, 48 hrs) | 5 sec maximum |

Frequency measurement scan rate, at the 11 kV switchgear bus, as an exception, shall be 100 msec. If the electrical interface PLC cannot satisfy this requirement, the Contractor shall provide a special hardware for this task to communicate directly with the SCADA system.

## Local Controls

### General

The Local Control Panels (LCPs) for the engine / generator units shall provide complete control and supervision of the respective unit with its associated auxiliary equipment.

The LCPs shall be installed with other unit control/ protection panels, as required, in the Local Control Room located in the new power house.

### Local Control Panels

#### Main Diesel Generating Sets

The local control panel of each gen-set shall have the following operation interfaces:

**Instruments:**

1. For mechanical equipment see Technical Specification Mechanical, Annex Alarms and Indications
2. Lube oil pressure
3. Lube oil temperature
4. Lube oil sump level
5. Jacket water temperature
6. Electronic tachometer with engine mounted magnetic pick-up
7. Manual / OFF / Auto switches for auxiliaries
8. Manual start / stop push buttons
9. Emergency stop
10. Running hour meter
11. Generator voltage meter with selector switch
12. Active power meter
13. Generator current meters
14. Power factor meter
15. Frequency meter
16. Excitation current and voltage meters
17. Generator temperature meters with selector switches
18. Synchronisation instruments.

**Fault annunciation:**

1. As a minimum for mechanical equipment those values which are given under 7.1.26 ANNEX 1 Alarms, the values considered necessary by the Contractor and the following:

|  |
| --- |
| Engine Start Failure |
| Hours Run Meter |
| Generator Temperature |
| Vibration |

1. For all alarm and protection of electrical equipment
2. Group alarm transmitted from CCR.

**Control devices/ signaling lamps:**

1. Local/ Remote selection
2. Diesel start/ stop
3. Excitation on/ off
4. De-excitation on/ off
5. Speed control
6. Voltage control
7. Synchronisation on
8. MV-generator breaker off
9. Emergency stop
10. Generator heating.

**Operation mode controls**

1. Start-up
2. Stand-by
3. On load
4. Shut-down
5. Diesel fuel
6. Operation from LCP
7. Operation from CCR
8. Alarm acknowledgement pushbutton
9. Horn acknowledgement pushbutton
10. Lamp test pushbutton, etc.

## Training Program

Sufficient training shall be provided in the premises of the manufacturers and at site to enable STELCO engineers and operators to perform the day to day operation and maintenance as well as qualified fault finding on the new system.

The Bidder shall propose to Employer for approval a comprehensive training program adapted to the specific requirements of the STELCO power plant in Malé and covering at least the following:

### Training at the nearest Vendor Training Centre

* PLC programming and PROFIBUS communication
* SCADA configuration, modification and networking

2 batches of 2 I&C engineers each, two weeks for each batch

### Site training

* Training in SCADA software programming / modification of SCADA system and fault finding strategies for the system implemented at STELCO
* Training in PLC software programming / modification of PLC system and fault finding
* strategies for the system implemented at STELCO
* Operation & maintenance of the fire detection & alarm system
* The training shall be performed, preferably, by trainers from original vendors for all STELCO I&C engineers for 1 week on PLC systems and 1 week on SCADA systems.

# General Requirements – I & C Works

## Design Conditions

## General

The instrumentation and control equipment being provided under this Contract according to the different Technical Specifications shall fulfil the requirements of this and any other relevant Specifications. The type and make of equipment shall be internationally proven in power plants.

The Contractor shall ensure the uniformity and standardisation of all instrumentation and control equipment of the whole Plant. Therefore the type and make of equipment shall also be approved by the Employer. The material of the equipment shall be suitable for the respective application and industrial service. The equipment lifetime shall be 25 years.

The instrumentation and control system shall be designed to reach the maximum grade of

* Safety
* Availability
* Reliability

according to the above priority order.

### Requirements due to Environment

All equipment shall be of vermin proof and tropical design and entirely suitable for use under the extreme prevailing site conditions as specified. Due to the aggressive environment, the corrosion protection and painting procedures as specified shall be strictly followed.

For indoor locations the additional temperature rise shall be considered.

### Requirements due to Explosion Hazard

Intrinsically safe I&C systems shall be used wherever applicable in the vicinity of boilers and fuel tanks. Intrinsically safe instruments, circuits and installations shall meet the requirements of IEC standards.

### Equipment Protection Class

For outdoor equipment the minimum protection class shall be IP65. That shall be applicable for all outdoor instruments, junction boxes and cabinets.

For cubicles, desks and panels installed in Equipment Room, Central Control Room or in Local Control Room, the requirements of the General Electrical Specifications shall be applied.

### Standards

#### General

The systems and equipment to be supplied by the Contractor shall be designed, manufactured, commissioned and tested in compliance with International Standards and Recommendations. Where such standards and recommendations do not exist, and unless otherwise laid down in this Specification, recognised National Standards accepted by the Employer may be used.

All materials and works shall be designed, manufactured, erected or installed and tested in conformity with the edition in force at the date of signing the Contract of the relevant Standards and Codes. Any specific requirement of the Specification shall, however, be binding.

#### Reference to Standards and Codes

Reference to Standards and Codes, where indicated either directly or as "relevant", is intended to provide a measure of performance, safety, shop and site testing, and methods of erection and/or installation which must be equaled or exceeded in order to be considered acceptable for use under the Specifications. If more than a single degree of quality of accuracy is permitted within the scope of a particular Code or Standard, the highest quality shall be applicable and the degree of accuracy commensurate with the intended function shall be selected but with the understanding in either case that the decision as to degree will be made exclusively by the Engineer. It is not intended, unless specifically otherwise noted, that Codes or Standards be employed to establish appearance, arrangement or overall dimensional limitations.

Abbreviations of the names of organisations responsible for developing Codes, Standards and references herein are listed and identified under the pertinent article.

#### Basic Standards

***International Standards and Recommendations***

ISO International Standardisation Organisation

IEC International Electrotechnical Commission

***National Standards***

ANSI American National Standards Institute

BSI British Standards Institution

DIN Deutsches Institut für Normung

***Recommendations***

IEEE Institute of Electrical and Electronic Engineers Inc.

VDE Verband Der Elektrotechnik Elektronik Informationstechnik

ASTM American Society for Testing and Materials

API American Petroleum Institute

For Standards and Regulations not covered by the publications of the above-mentioned standard organisations, other internationally recognised Standards may apply subject to the approval of the Employer.

### Measuring Units

The international SI-system of measures and weights shall exclusively be used for documents, correspondence, drawings, etc.

All instruments shall be calibrated and inscribed in this SI system. The major measuring units for the measured variables shall be as follows:

* Bar for pressure of steam, water, oil, compressed air and high pressure gas
* mbar for combustion air, flue gas and low pressure gas
* deg C (ºC) for temperatures
* mm or m for levels
* mS/m for conductivity
* rpm for rotating speeds
* % for positions
* Nm3/h for combustion air and gas flows
* T/h for steam, water and fuel flow
* % Vol for flue gas analyses
* mm or m/sec2 for eccentricity and vibrations
* mm for differential and absolute expansions
* Hz for frequency
* A, kA for current
* V, kV for voltage
* MW, kW for active power
* MVA, kVA for apparent power
* MVAr, kVAr for reactive power
* Wh, kWh for active energy
* VArh, kVArh for reactive energy

### Drawings and Documentation

All relevant documents shall be submitted by the Contractor to the Employer for approval. Those shall include, but not limited to:

1. Functional design documents
2. Selected Hardware and software specification
3. I&C signals list
4. I&C equipment list
5. Control room layout drawing
6. Instrument index
7. I & C Cable schedule
8. Hook-up drawings
9. Logic diagrams with functional description
10. Analogue Loop diagrams with functional description
11. P & I diagrams
12. Instrument data sheets
13. Detailed erection drawings where necessary
14. Interface points to other Lots
15. Layout drawings with I & C locations
16. Operational descriptions
17. Control narratives
18. Shop and site tests procedures
19. Other documents developed during detail engineering.

All symbols used on the drawings and layouts of diagrams and charts shall comply with applicable IEC Standards. All documents shall be also submitted electronically in PDF format.

### Miscellaneous

#### Space Heaters

Any major item of electrically connected I&C equipment either located outdoor or otherwise prone to suffer from internal condensation of moisture is to be fitted with electrical heating devices of such capacity as to raise the internal temperature slightly against the external ambient temperature. Such heating devices being of the "black heat emitting" type shall be controlled by hygrostat.

The ON/OFF status of heaters mounted in panels, boards, etc. is to be monitored by a white signal lamp.

#### Telephone Jacks

Panels, boards, cubicles, local motor control push button stations as well as major marshalling boxes are to receive telephone jacks suitable for external connection of plug-in type headphones.

The jacks are to be permanently interconnected via control cable spare cores to such an extent as to achieve a closed loop system each for common or unit services.

#### Air Filters

Wherever louvers for ventilation are foreseen, they shall be equipped with washable filters for specified protection classes IP4X or better.

#### Labels, Tags, Plates and Inscriptions

Every piece of Instrumentation and Control equipment is to receive sufficient labels, tags, plates, [etc. so](http://etc.so) as to allow correct operation, easy testing and efficient maintenance.

The tagging text shall follow the pattern:

**EQUIPMENT / SYSTEM – SIGNAL - VALUE**

The size/material of the labels shall be according to the General Electrical Specification and subject to Employer’s approval. The fixtures shall be of non-corrosive material. The fixation shall be done rigidly. Labels on chains or wires will not be accepted.

#### Locks, Keys and Key Cabinets

Every kind of hinged door in Electronic Room cubicles, local cubicles, control panels, etc., as well as withdrawable chassis shall be secured by means of a suitable lock. The general rules are stated in the Technical Electrical Specification.

#### Closing of Openings

The Contractor shall close all openings, penetrations and cut-outs for walls, floors and roofs, required for piping work, miscellaneous supports, cabling and bus ducts, etc., within his scope of supply. Special attention shall be paid to the proper sealing /closing of cable entries etc. The Contractor shall supply and install all the necessary materials for sealing work such as steel frames, sleeves, sealing material, flashing (flashing in cladding shall be from the same manufacturer as for cladding), masonry and finishing work. The sealing material shall meet the required fire protection class.

### Signal Listings

The database for signal listings, ready for data processing, shall contain as a minimum the following data:

* Serial number Instrument range from/to + unit
* Identification number Instrument span from/to + unit
* Function code (application), e.g. TZA Kind (range) of output signal
* Status, e.g. HH Signal code, e.g. xy51
* Denomination of medium, e.g. fuel oil Installation details:
* Location, e.g. common discharge line Type/size of tapping
* Location coordinates, acc. to layout drawings Sensor type
* Sensor type, e.g. transmitter, Tm Tapping arrangement
* Medium norm/max pressure Cable type and index no.
* Line nominal diameter Terminals nos.
* Process variable range + unit All set point data

And references to other documents, e.g. P & I Diagrams, Logic and loop diagrams, Wiring diagrams, Instrument data sheets, Circuit diagrams, etc.

Abbreviations or codes shall be uniform throughout the Plant.

The above comprehensive database shall be used to generate the different kinds of lists specified, e.g. List of Measurements, List of Set points, List of Alarms, etc. as well as for utilisation of the SCADA Vendor.

## Workshop and Site Tests

Every I&C system, subsystem or equipment provided under this Contract is to undergo workshop and site tests. The Contractor shall issue at the proper time a comprehensive test schedule describing kind and date of the intended test.

At his discretion, the Employer will participate in all or in a selected number of the specified tests. Hence the actual dates of said tests are to be announced in advance as required by the General Requirements.

Prior to commencement of site installation work, the Contractor shall deliver a site test organisation chart for his personnel as well as a list comprising all instruments and other facilities intended to be used for the site tests together with technical details of it.

### Work’s Inspections and Workshop Tests

#### General Remarks

The Employer and/or their authorised representatives are irrevocably entitled to visit the workshops of the Contractor or his Sub-Contractors at any time without prior announcement to inspect the works performed in connection with this project and to monitor the progress of work, scrutiny related documents such as suborders or work orders and to take photos as may be deemed adequate to the judgement of the said persons to document the actual state of work.

The Contractor shall issue a quality assurance program, indicating the kind and extent of inspections and tests to be carried out on plant components. The quality assurance program shall be based on the tests and inspections specified in the various parts of the Specification. These inspections and tests shall prove whether the equipment fulfils the requirements of the Contract in view of:

* Safety conditions, rules and regulations,
* Applied standards and regulations,
* Execution of workmanship,
* Conformity with the present state of modern technology.

The following procedure has to be adhered to with respect to test certificates:

Whenever inspections or tests are carried out all material certificates as well as all other intermediate test certificates, in accordance with the agreed test schedule, shall be made available to the Employer in legible copy for inspection and filing. Further the latest issue of the related drawings, indicating also the state of approval by the Engineer, shall be made available. The same applies to the final work's inspections or workshop tests when all test certificates have to be submitted to the Engineer.

A form sheet entitled "Test and Inspection Manual" has to be prepared showing all steps of the test procedure as well as the relating standards and codes. Test manuals have to be sent to the Engineer in due time before the tests are performed.

#### Visual Inspection, Test Instruments

The Engineer may from time to time make visual examinations and may check the plant equipment and the conditions under which it is manufactured or erected at the Contractor's or Sub-Contractor's premises to make sure that it complies with the relevant specifications and drawings.

Unless the calibration of test instruments is certified by recognised statutory institutes, they shall be calibrated at the premises and in the presence of the Employer or their authorised representatives. Test calibration certificates shall be submitted for each test instrument.

#### Test Runs and Functional Tests

Test runs and functional tests shall be carried out on individual equipment to prove the reliability and the correct functioning of the component and its compliance with the stipulations of the Contract. Rated operating conditions shall be simulated if possible; otherwise appropriate con-version factors shall be applied.

### Tests at Site

The equipment to be supplied under the Contract shall be tested at Site during erection, cold function (loop) checks and tests, pre-commissioning, commissioning and initial operation. These tests shall prove whether the equipment meets the requirements of the Contract and the safety conditions, whether it has been built and/or erected with satisfactory workmanship and whether the equipment is in conformity with the prevailing standards and regulations as well as with the present state of modern technology.

Where manufacture or finishing is done at Site, tests and inspections shall be conducted as a replacement for an appropriate workshop test. The preliminary check-out and test runs, the trial operation, the initial operation, the reliability test run and the performance tests shall be carried out by the Contractor's personnel in the presence of the Employer. All tests are to be accompanied by the test records signed by all parties. In case of tests involving also activity of other contractors all remarks and comments shall be placed in the test record signed by all participants.

Acceptance test readings shall be taken with calibrated instruments. Waiving of any tests shall not release the Contractor of his responsibility to fully meet the requirements of the Contract. Test record forms shall be submitted by the Contractor during the design phase for the Employer's approval.

#### Erection Checks/Tests

Erection checks/tests shall be announced and carried out after the electromechanical installation with all cables connected (mechanical completion). Erection checks/tests of major I&C installations (Equipment Room, Control Room, Computer Room, etc.) shall be done in one lot. Erection checks/tests of field instrumentation for mechanical/process equipment shall be done system wise (e.g. fuel oil system, exhaust boiler system).

The limits shall be marked on a reduce size P&I-diagram, submitted along with the application for test. Continuity and electrical rigidity / Megger tests for cables and hydrostatic / pneumatic testing of instrument lines are part of the erection tests.

After the erection checks/tests (ECT) were done for unit main components or for main auxiliaries, all test records shall be compiled by the Contractor and submitted to the Employer (one copy each) in a proper bound form with a covering sheet accompanied with the list of outstanding items/comments found during the erection checks/tests, showing also the intended completion date.

#### Pre-Commissioning Checks/Tests

Pre-commissioning tests shall be carried out to prove the completeness of the construction before releasing the Plant or a part thereof for the (hot) commissioning tests.

For the Instrumentation and Control items the pre-commissioning checks/tests (PCT) contain the so called cold commissioning tests, i.e. loop tests and calibration tests, setting of limit values, etc. After all tests were done for unit main components or for main auxiliaries, all test records shall be compiled by the Contractor and submitted to the Employer (one copy each) in a proper bound form with a covering sheet accompanied with the list of outstanding items/comments found during the pre-commissioning tests, showing also the intended completion date.

Pre-condition for safety clearance of any equipment is the existence of the signed ECT and PCT, further the completion of major outstanding items, as instructed by the Employer. Especially all outstanding items related to the protection system of the pertaining equipment are to be settled.

#### Commissioning Tests

The commissioning test of any equipment may start after the successful completion of all pertaining pre-commissioning tests and ends with the checking out of plant to ascertain its fitness for operation in live conditions.

After all relevant tests were done, the Contractor shall apply for and the Employer may agree to put into operation the relevant Plant.

#### Unit Optimisation

After the first synchronisation of a unit, the Contractor shall start with the optimisation of the plant, including the optimisation of the closed loop controls, the finalisation of the open loop controls, live tests of the machines protections, etc.

This task will be done under the solely responsibility of the Contractor, respecting, however, the agreed plant schedule.

After the unit optimisation was done, the Contractor shall confirm the successful completion and apply for the Initial Operation of the unit, demonstrating the results of the optimisation under extreme operational conditions as specified before releasing the unit for the Performance Test and Reliability Test Run, in line with the applied General Requirements.

## Field Equipment

The field mounted instrumentation and control equipment includes all devices such as local indicating devices, transmitters, switches, analysers, local controllers, etc. with all necessary cabling, wiring, local boxes/cubicles/panels, instrument piping and valves, instrument air supply, erection material, etc. up to the terminals ready to receive multi-core cabling to remote locations.

Items inherent to the process piping, such as valves with actuators, solenoids, orifices, sight glasses condensation vessels, equalising vessels, standing pipes, reference vessels etc. may also belong to the field mounted instrumentation and control equipment.

### General Design Requirements

All instrumentation shall be heavy-duty and of proven and reliable design with all materials of construction suitable for the intended application. The design shall facilitate an easy maintenance and repair of the components. Equipment with operating experience less than 5 years (as far as the basic type is concerned) and out-of-date models shall not be used.

The location of field instruments, cubicles, etc., shall be identical for the different units.

Open air installed parts shall be protected against sun radiation by means of adequate sun shade and shall be protected against high humidity and rainfalls. Movements (linkages, mechanisms, etc.), as applicable, for instruments shall be of stainless steel. Casing and bezel material of instruments shall withstand and resist the corrosive conditions at site. Scale plates and finishing are to be of such material that no peeling-off or decolourisation will take place with age. The material of those parts of the instrumentation and control equipment, which are exposed to the measured media, shall be compatible with the conditions of the respective media and with the piping material and shall be selected after Employer approval.

#### Local Cabinets

For transmitters, switches and local controllers closed protection boxes/cabinets with transparent glass windows are to be used outdoors. Location shall be as close as possible to the mechanical equipment. However, instrument grouping to the practicable extent shall be supplied. As far as possible bottom connections are to be used. Special care is to be taken to avoid water ingress into the cabinets by cable transitions/process piping and tubing entrances. No conduits shall be introduced to the cabinets but only cables with proper cable glands and sealing.

Piping, tubing, fittings and wiring shall be arranged so that any instrument or device may be removed or serviced without disturbing piping, tubing or wiring associated with other instruments.

Instrument brackets or accessories for surface or pipe mounting shall be supplied with each field mounted instrument e.g. pressure and temperature gauges.

#### Junction Boxes

Junction boxes shall be used to connect the field-mounted instruments to the multi-core cables laid to the relevant cubicles. All junction boxes shall be identified with nameplates. Junction boxes shall have 20 % spare terminals after final commissioning.

#### Measuring Equipment

The instruments shall quickly respond to any change of the measured variables. Measuring errors shall be as low as possible. Measuring ranges of local indicators, transmitters, etc. shall be selected in such a way that the rated value of the measuring variables appears at approx. 75 % of the span. The range and span shall be field and remotely adjustable as applicable.

For transmission of measuring signals (T/C or RTD's signal may be directly led to a receiving device) to remote locations, transmitters shall be used. The output signals of transmitters shall be a direct current of 4 - 20 mA and be linear, and over a wide range, independent of the burden in the output circuit.

The output of electronic instruments shall be short-circuit proof, which means that in case of short circuit the component is not damaged and there are no interactions to the inputs. All electric transducers shall have galvanic isolation.

All devices furnished with electric coil shall be capable of operating satisfactorily between 75% and 115 % rated voltage.

In case of ambient temperature effect on the accuracy, internal thermal compensation shall be provided to limit and minimise the effect of ambient temperature variation. The sensing elements shall be suitable for the temperature of the medium and pressure variation. The thermal drift of transmitters shall not exceed 0.04 %/ °C of the span or 0.055 %/ °C of the range.

All transmitters shall have an accuracy of ± 0.25 % or better. The manufacturer shall prove that his design ensures a good stability and eliminates any risk of drift.

For closed loop analogue control, for each measured variable two separate sensors, detectors, transmitters, etc. shall be used for control/alarm and for protection/trip functions with separate tapping arrangements shall be provided. Flow throttling elements like orifices, however, may not be doubled.

If a single transmitter cannot ensure the transmission of the parameter over the whole range with sufficient precision, two transmitters shall be used. Likewise, when too much different sets of working conditions are expected for one and same equipment, it would be necessary to provide two transmitters including additional indicator in order to ensure a good precision of measurements.

Measuring elements and chambers of transmitters, pressure switches, etc., shall be of stainless steel or better material. All mechanisms of regulation and setting shall be insensitive to vibrations and shocks.

The electronic apparatus shall be equipped to a high extent with automatic or manual checking devices for display of a wrong function. The terminal arrangement of the

transmitters shall include facilities to allow checking of the output signal without disturbing any permanent connections.

Transmitters shall be of the indicating type or equipped with separately mounted local indicator for output.

Contacts of level switches, pressure switches, flow switches, temperature switches, limit switches, etc., shall be of the snap-action type golden plated. The mechanical lifetime of the measuring element and the switching element shall be 10 million operating cycles.

The contacts shall be best suited for the control voltage applied (24 V DC if not otherwise specified) and be properly selected for the prevailing ambient /atmospheric conditions. Mercury contacts will not be accepted. Only double throw contacts shall be used. These contacts shall be equipped with the suitable resistors in order to provide connecting cable wire break/short-circuit detection (by the remote control and supervisory system). The connecting cables shall have sufficient core number for this purpose.

For protection signals, binary switches shall be used. For temperature the use of thermocouples with limit monitoring is allowed.

Devices for interlocking, protection and alarm systems shall be separate, i.e. contact devices and sensors serving commonly for interlocking or protection and at the same time for supervision and/or alarm purposes shall not be accepted.

All contact devices shall be of non-indicating type except the flow switches that are considered important like pump recirculation, etc., and differential contact pressure gauges for filters service. (In case the device has standard scale, this scale shall not be used for calibration purpose). Adjustments on the switches shall be provided for calibration purposes. Adjustments shall have protective covers.

If not otherwise specified, the accuracy of the contact devices shall be 2 % or better.

The residual differential display (hysteresis) of contacts shall be in a range of 3-5 % of the full-scale range. However, it can be different, depending on specific requirements.

All external screws, bolts and nuts shall be of stainless steel.

### Installation of Instrumentation

#### General Requirements

Each device shall be mounted and piped so that removal and replacement may be accomplished without interruption of service of adjacent devices. Piping and tubing shall not run across the face or rear of any device in a way that will prevent the opening of covers or obstruct access to leads, terminals, or instruments for servicing.

All instruments shall be installed in such a manner as to protect all equipment from moisture, excessive temperature and variation, and to provide easy access to the instruments for repair, calibration, removal, and remounting. Where necessary vibration/ shockproof equipment of appropriate grade shall be applied. Local mounting of instruments on pump bases, foundations, etc. where equipments are liable to experience shocks and vibrations shall not be accepted.

Instrument piping shall be routed to allow easy removal of valves, tube bundles, motors, etc. Piping which must pass through such an area shall be isolable and removable. An allowance for thermal lagging on process piping shall be included when locating and routing instruments and tubing.

Where possible, process connection shall be located so as to provide accessibility to valves, pots, manifolds, etc., for servicing.

All instrument blows down lines shall be routed to exhaust at a safe place of disposal. Blow down exhausts shall not exhaust onto equipment or in areas, which will create an unsafe condition.

Hot lines, of surface temperature above 60 ºC, shall be covered with appropriate screens or insulation, if required for personnel protection.

Indicating instruments shall be located/ sized so that their dials are easily readable from their applicable operating levels.

Field instruments that are stand-mounted shall be mounted at least 900 mm above grade or operating level to bottom of blind instruments, or 1200 mm to the bottom of indicating instruments.

Sensing instruments and their associated valve manifolds are preferred to be located as follows, relative to the process connection, in order to avoid gas pockets in a fluid-sensing line or liquid pockets in a gas or vapour sensing line:

Medium Preferred Instrument Elevation Manifold Mounting

* Fluid Below line Above instrument
* Slurry Below instruments line with purge Above or below instrument   
  instruments or above line without purge
* Steam > 1.4 bar Below line Above instrument
* Steam < 1.4 bar Below line Above instrument
* Gas Below line Above instrument

#### Installation of Impulse Lines

Lines shall be neatly installed, straight vertically and horizontally. Lines shall be installed so that it is free from contact with sharp corners, which could wear or cause damage to the pipes. Lines shall not be supported from structures or piping subject of vibration. Lines shall be supported and run in areas where it will not be subject to mechanical damage. Lines shall be run with sufficient clearance from all steel and concrete surfaces. In no case shall it be run in direct contact with painted or unpainted concrete surfaces.

Full lengths of lines with as few unions or fittings as possible shall be utilised to the maximum extent practicable. The minimum-bending radius for lines shall be three times the outside diameter of the pipe.

Bends in lines shall be made by industry standard tools. Tools used for bending shall be of the mandrel type, of good quality, and shall not damage the pipes by nicking or flattening. The Contractor shall determine the exact sensing line routing to result in an installation consistent with generally accepted instrumentation procedures and good engineering practice.

Process sensing impulse lines (pipes) shall be of 12 mm or 14 mm O.D. stainless steel. Sampling line for analysers shall be of 8-10 mm I.D. size. Connection of stainless steel lines to process line isolation valves shall typically be made by socket-weld adapters.

The run of pipes containing liquids shall be arranged such that their slope allows entrained air or gas bubbles to rise to vent points, and liquids or solid deposits to fall to settling chambers or blow down points. In pipe runs where obstructions have to be avoided the pipes may be run in a series of slopes providing that gas vents are fitted at high points as settling chambers shall be arranged in positions suitable for ease of operation.

Primary sensing lines at local panels and racks shall be as short as possible and neatly arranged with easy access to blow down connections and instrument valves or manifolds. Primary lines between the instrument valve or manifold and the instrument shall be arranged properly not to apply strain to the instruments when connections are made.

Instrument valves or manifolds shall be rigidly attached to the local panel or rack framing so as not to strain the lines when operating valves.

Valve drain connections and drop or dirt chambers shall be installed at low points of impulse lines. All high points in liquid and steam service sensing lines shall have a valves vent connection. However, generally no high points shall be allowed.

If a sensing line has a liquid purge, the line shall be arranged so that the purge flow is up. If a gas purge flow is into a process liquid, the purge flow shall be down.

The discharge of bleed connections shall be piped to a safe disposal point if opening the bleed may create a hazard. The outlet of the valve on an atmospheric bleed shall not be plugged or capped to avoid potentially hazardous pressure build-up on the downstream of the valve.

A pair of head-type sensing lines shall be run together, to the maximum extend practical, to keep both lines at the same temperature.

All process shutoff valves shall be provided with tag number on nameplate by the Contractor providing the valve.

Sufficient piping flexibility shall be provided for each installation to accommodate process connection primary point motion and thermal growth of the piping itself during hot blow down and during normal operation. The requirements for slope shall not be violated by the configuration.

All lines runs shall be grouped together and run in common trays wherever possible. All lines runs shall be appropriately supported throughout their entire run.

Whether specifically specified or not, the Contractor shall furnish anchor bolts, mounting brackets and straps, air sets, tubing trap supports, tube and piping supports, hangers, wire

connectors and any other miscellaneous hardware or material required to properly install and place in service the furnished equipment. Material for line clamps, bolting, line raceways, and other supports shall be compatible with material used for lines.

#### Instrument Air Supply and Signal Lines

Routing of branch headers shall not interfere with process piping, electrical cable trays, or equipment and shall not obstruct walkways or stairways.

Main and branch airlines shall incorporate low point moisture traps. All instrument air piping shall be sloped so drainage toward drip legs or moisture traps will be facilitated.

Each header or main line shall be provided with outlets as close as possible to the point of application. Outlets shall always be taken from the top of the pipe to minimise condensed moisture carry-over.

Air supply branch material shall be 12 mm O.D. stainless steel pipe. Individual instrument signal lines shall be 6 mm O.D. copper tubing or stainless steel.

A shutoff valve shall be installed at each takeoff from the branch header for air supply lines to the equipment requiring instrument air.

All copper tubing shall be protected with an external plastic sheet. Air filter/reducing stations (regulators) shall be equipped with pressure gauges for output pressure.

#### Instrument Lines Support

Brackets and means of support of instrument pipes for instrument process sensing lines, instrument air supply and signal lines shall be furnished and installed by the Contractor. All supports shall be secured in place by expansion anchors in concrete or by welding to structural members of the plant. Welding of supports to structural members is to be reviewed by Employer before installation.

Expansion bends shall be provided as necessary to allow for movement (including thermal) of supporting structures.

Lines shall be supported with guides wherever practical. The guides shall be large enough to allow the tubing to fit loosely and not be misaligned. Guide tube ends shall be reamed to ensure no sharp edges exist which could damage the tubing. U-bolts or loosened clamps shall not be used as guides. Guides used to support copper pipes shall be cut from brass pipe.

Rod-type hangers, which allow free lateral movement, may be used where conditions so require. When two or more lines are supported by a single hanger, each line shall be guided so that it can move endwise independently of the others.

Lines subjected to severe vibrations shall be supported as required to minimise damage from vibration.

Lines and supports shall be arranged this way that harmful stresses be not applied to the instrument.

Line supports shall be designed and installed so that pipes will not be crimped or damaged.

Line Support Span Requirements:

***Tube OD mm Tube Material Max Unsupported Span mm***

10 Stainless Steel 1200

12 Stainless Steel 1500

14 Stainless Steel 2500

10 Copper 1000

12 Copper 1200

6 Copper Use continuous support.

#### Lines Connections

The Contractor shall provide all the test, purge, vent, and drain connections as required.

As far as practicable, bends rather than tube or pipe fittings shall be used to change direction of a run of pipe. Pipe on the process side of condensate or seal pots shall be bent as required.

Flare less or threaded connections or seal welds over threaded or flare less fittings may not be used where weld connections are required. A weld fitting may replace a threaded or flare less fitting, except where removal for test, calibration, or maintenance may be required.

Impulse line connectors, which cannot be inspected and tightened in service, must be the weld type.

Lines that must be connected to vibrating equipment shall be fabricated to provide flexible connections. These vibration loops shall not form gas pockets and liquid traps.

Elbow fittings are to be used only where the pipes cannot be installed by bending. Compression fitting shall be installed in accordance with the manufacturer's recommended procedure.

When connections are made, the pieces being connoted or joined shall be clean and free of residue, borings, and foreign materials, which may plug and instrument or make it inoperable. Lines shall be blown free of foreign matter before connections are made.

### Instruments Valves

#### General

All valves shall be of approved manufacture, design and material of non-corrosive type. Blow down valves shall be provided on all steam and water applications.

All primary isolating valves and valves used for protection purposes shall be capable of being locked in the "OPEN" or "SHUT" position. Fittings associated with locking of valves shall be securely attached to the valve body. Padlocks for locking the valves shall be supplied if necessary by safety reasons.

Primary isolating valves and blow down valves shall have clearly marked on the face of the hand wheel, the direction of rotation to close the valve together with the word "CLOSE" or "SHUT".

Instrument isolating valves, vent/test valves and valves on instrument valve manifolds are preferred with the hand wheel direction for closing to be clockwise. Where this is not possible the direction to close shall be clearly marked on the hand wheel together with the word "CLOSE" or "SHUT."

Where spindle extensions are provided they shall be independent of the valve body and provided with separate support and thrust gear.

#### Primary Isolating Valves

The primary isolating valve shall be located at the tapping point and be of the parallel slide or globe type and capable of being subjected to the temperature of the main line.

Double isolating valve shall be provided for rated pressure above 25 bar.

Where the primary isolating valve at the tapping point cannot be made easily accessible, a further isolating valve shall be provided adjacent to the measuring device so that double isolation is achieved when disconnecting the device without closing the primary isolating valve at the tapping point.

#### Instrument Isolating Valve

The instrument isolating valves shall be located on the connecting pipe at the measuring device end of the line. These valves shall be as near to the instrument as is practicable and shall be of the needle type. Instrument isolating valves shall be rated to at least 100 ºC and the pressure of the main process line. The valve may form part of a valve manifold or be an individual valve.

#### Venting and Test Valves

Vent and Test valves may form part of an instrument valve manifold together with the instrument isolating valve.

In all applications vent/test valves shall be located as close to the instrument as possible such that the maximum amount of entrained air can be vented from the pipe work and a minimum pipe work volume is achieved for testing.

#### Equalising Valves

Equalising valves shall be provided for all differential pressure measuring devices. With the exception of those services, which use seal pots without partitions, the equalising valve shall be positioned as close to the measuring device as possible and may form part of an instrument valve manifold.

#### Blow down Connections

Blow down pipe work and valves shall be provided in the connecting lines to all transmitters used on water, steam and compressed air services.

The valves shall be capable of being subjected to the pressure and temperature of the main line. The blow down pipe work connection shall be made at a point as close to the device as practicable and preferably at the lowest point in the system.

#### Cabling and Wiring

All power and control cables for the instrumentation and control systems shall form a safe and reliable network. Special care has to be taken to the selection of fire retarding cables.

Power cables shall be separated from signal cables i.e. it is not allowed to use one cable for power supply and signals.

Low level analogue type individual instrumentation cabling/wiring shall be 2 or 4 cores, twisted and shielded.

Appropriate segregation and spacing shall be maintained between power cables, signaling cables and low level instrumentation cables along cable trays and within the cubicles. Generally, power and instrumentation cables shall be laid in separate cable trays.

The multicore cables shall have 20 % spare cores after final commissioning. For general cabling requirements refer to the Electrical Specification.

#### Cleaning and Protection

After complete installation of each piece of equipment, the Contractor shall clean and touch­up each piece of equipment with paint as required. During construction, instruments and cubicles/cabinets shall be protected at all times from wetting, dirt, and physical damage.

When connections are made, the pieces being connected or joined shall be free of residue, borings, and foreign materials, which may plug an instrument or make it inoperable.

Tubing shall be blown free of foreign matter before connections are made. Tubing and instruments connection shall be capped during storage.

After installation, but before it is placed in service, the Contractor shall protect equipment from damage or contamination. All work shall be done in an orderly, workmanlike manner and shall present a neat appearance when completed.

#### Instrumentation Testing

The Contractor shall perform operational (cold function) tests to ensure that the instrument is in working condition. All testing equipment shall be in good working order, properly maintained and calibrated.

Instruments shall be isolated during pressure testing of the piping and tubing to prevent damage. In the case of measurement and control systems involving electronic or pneumatic transmission, a simulated input signal shall be applied and varied over the full range. Each device shall be calibrated and checked for correct operation. Static head shall be

considered, if any. The Contractor shall be responsible for proper protection of the instruments and devices that may be damaged by any of the required tests.

Loop checks of electronic instrument circuits shall be performed to ensure that wiring is correctly terminated, shielding is properly grounded, and that the complete circuit operates correctly. Particular attention shall be paid for intrinsically safe equipment cabling and wiring, checking and testing.

All instruments shall be elaborated to verify that the output or visual indication is correct in the range span of the instrument. Span checks shall be at 0, 25, 50, 75, and 100 % of range. Operational adjustments (zero, offset, suppression, etc.) shall be included in the Contractor's data/ documentation.

After installation, process-sensing lines shall be hydro tested to the same pressure as the process lines to which they are attached. Instruments shall not be hydrostatically tested.

After installation, instrument air piping shall be pneumatically tested in accordance with the appropriate standards.

Appropriate documents shall be issued after tests completion.

Instruments, in the systems activated during start-up operations (steam blows, line flushing etc.) shall be recalibrated 90 days after the system has been first activated or just prior to commercial operation of the unit, or whichever comes first.

### Pressure Measurements

#### General Design Requirements

Pressure measuring instruments shall have linear scales. Over ranging the measured pressure shall not affect the pressure instrument or its calibration.

Pressure instruments for viscous liquids or fluids with suspended solids shall be filled systems with appropriate diaphragm seals. Pressure devices on pulsating services shall be equipped with pulsation dampers.

#### Pressure Transmitters

Pressure gauges with position transmitter devices will not be accepted as pressure transmitters.

Pressure transmitters for fuel oil and fuel gas shall be explosion-proof / intrinsically safe.

#### Pressure Gauges

The error for pressure gauges shall be limited to ± 1.0 % of the span range (FSD).

Pressure gauges shall be 160 or 100 mm in diameter (e.g. 160 mm for important measurements and higher elevation - 100 mm for aggregates with high amount of local measurements - however uniform size for a given area shall be used). Stainless steel case white dials and black lettering are required. Scale graduation shall be in "bar".

The gauges shall be shock and vibration-proof. Pressure gauges shall be filled with glycerine or other adequate liquids, when necessary. High pressure gauges shall be supplied with a relief device (rubber plug at rear side) for safety in case of leaks.

Pressure gauges mechanism shall allow a fine micrometric adjustment (zero and span) without removing the pointer from the spindle.

#### Pressure Switches

The error for pressure switches shall be limited to ± 1.5 % of the span range (FSD). The set point shall be adjustable between 5 and 100 % of full span.

Use of contact manometer shall be limited to lube oil and some auxiliary equipment in package units subject to the approval of Employer.

#### Differential Pressure Gauges and Switches

All prescriptions for pressure gauges and pressure switches shall be applied to differential pressure gauges and switches. Differential pressure gauges with contacts for filters service will be accepted.

The high and low-pressure connections of differential pressure instruments shall be marked accordingly.

#### Installation Requirements

Pressure instruments in condensable vapour and liquid service shall be mounted below the process line connection so that the impulse lines slope down to the instrument.

Instruments mounted above the line, in steam or vapour service shall have a siphon or equivalent wet-leg to keep the instrument cool. The siphon shall be close to the instrument. A wet-leg shall have a filling connection at the top. Loop seal design shall be incorporated at source taps for all pressure transmitters and gauges in steam service.

For gas measurements pressure instruments shall be arranged above the tapping point. If this arrangement is impossible condensate traps and blow-down valves shall be installed.

In case of flowing substances, the measuring point shall be selected in regions of undisturbed flow according to the requirements of Standards and Codes.

Pressure gauges over 10 bar or for steam as well as pressure transmitters and pressure switches shall not be directly mounted on the pressure tapping point. They shall be mounted apart from the tapping point and grouped if practicable in gauge panels, instrument cabinets, etc.

All gauges, transmitters and pressure switches shall be readily accessible for supervision and maintenance. The design and arrangement of tapping point, piping and valves shall be according to the relevant standards. Each pressure switch and transmitter for absolute or differential pressure shall be equipped with an instrument isolating valve, drain valve and with a test connection with isolating valve and plug. Each pressure gauge shall be equipped with isolating instrument valve and test connection with plug.

Globe valves in horizontal sloping lines to be installed with their stems horizontal, if possible.

Horizontal runs of pipe between vessel connections and seal or condensate pots shall be of minimum length and shall be level or slope toward the vessel.

Pulsation dampers, when required, shall be installed in the instrument line, downstream of the instrument block valve.

Instruments supplied with diaphragm seals shall be installed in accordance with the manufacturer's instructions.

Pressure gauges on the discharge of pumps, or those used for operation of valves or equipment, shall be oriented so that they can be seen from the operating position.

Pressure test points must be accessible. If the root valve is not accessible, tubing and an instrument valve shall be installed at a convenient location. When pressure and temperature or sampling connections occur together, the pressure connection shall be upstream of the temperature or sampling connection.

### Temperature Measurements

#### Thermocouples and Resistance Thermometers

All temperature measurements except the local temperature measurement and other specified exceptions shall be measured by means of thermocouples (T/C) or resistance thermometers (RTD).

Resistance thermometers and thermocouples shall be equipped with waterproof connection heads. These thermometers shall be arranged in such a way that the connection heads do not become warmer than 80 °C and that the measuring inserts are easily exchangeable. The temperature sensors shall be selected in such a way that only a small number of different spare inserts is required.

Resistance thermometers shall generally be of type Pt 100 and shall not be applied for measuring values above 250 °C. For resistance thermometers 4 wire circuits shall be applied.

Depending on the operating temperature the following thermocouples shall be used:

* NiCr-Ni for temperature up to 950 °C
* Pt Rh-Pt for temperature higher than 950 °C

The sensing elements shall be insulated from the cladding. The completed measuring devices (elements with protective wells) shall have a fast transient response for temperature changes. Thermocouples and RTD shall be mounted inside pockets so that fluids does not come out when these are removed or replaced. The thermo-wells shall be of stainless steel and of adequate length to ensure sufficient penetration into the fluid to give a precise measurement. The elements shall fit into wells as described above ensuring a good heat transfer from the well to the element e.g. by an appropriate liquid or material.

For measuring air and flue gas temperatures of the higher range and within highly corrosive atmosphere sensing elements of increased accuracy have to be provided. The protective wells shall be selected to enable maximum life endurance.

Resistance thermometers and thermocouples for control purposes shall be separated from element used for supervision purposes. The error shall be within ± 1.5 ºC maximum in the range up to 400 degree C and ± 0.7 % in the temperature range above 400 ºC.

The cold compensation shall be done by the remote control system itself using conventional type junction boxes with internal temperature measuring element. The construction of the thermocouples compensation leads shall be as follows:

* Core insulation: Teflon
* Metal shielding: tinned copper wires
* Main insulation: Teflon
* Each pair of wires shall be twisted.

Generally, inserts with two thermocouples/resistance thermometers shall be provided so that one of them is available for spare. Thermocouples and resistance thermometers for bearings or motor windings must withstand, without damage, vibrations of frequencies from 10 to 2000 Hz. For bearings the protecting sleeve may be of the type fitted with springs that press the sleeve to the hot surface in order to maintain a good thermal contact.

#### Local Thermometers

Local thermometers for temperatures above 120 ºC or which cannot be installed directly on the pipe or apparatus shall be of the mercury expansion or gas expansion, dial-type. The bulbs shall be of stainless steel and of adequate length to ensure sufficient penetration into the fluid to give a precise measurement. The bulbs shall fit into wells as described above ensuring a good heat transfer from the well to the bulb, e.g. by an appropriate liquid or material. Thermometers shall not be installed in locations which are prone to strong vibrations.

The design shall allow a free swiveling of dial in order to obtain the best reading. The casing shall be weather-proof and dust tight and of stainless steel. The dials shall be 100 or 160 mm in diameter (see item Pressure Gauges) and bear a black graduation in degrees centigrade on white background.

Mechanism shall allow a fine micrometric zero adjustment without removing the pointer from the spindle. Local thermometers shall have an accuracy of ± 1.5 % of the span range (FAD) or better and shall be insensitive to ambient temperature variations, shocks and vibrations.

Thermometers for temperatures up to 120 ºC which can be installed directly on pipes or apparatus shall be preferably straight thermometers like Sitka type. Angular thermometers of the Sitka type are not allowed. Thermometers shall be installed preferably on horizontal surfaces or such that the thermometer is vertical, e.g. on pipe bends. In case thermometers have to be installed on vertical surfaces they may be installed as longer straight thermometers in a well which is placed in approx. 30 to 35 ° angle from the vertical line.

#### Temperature Switches

Temperature switches shall be of the liquid/gas expansion type. The error for the switches shall be limited to ± 1.5 % of the span range (FAD).

#### Installation Requirements

Elements for steam service shall be located so that they are never submerged in condensate. Elements for liquid service shall be located so that they are always submerged. Elements for air and gas service shall be located so that they sense the average temperature.

Capillary-type temperature instruments shall have their capillary supported and protected similar to instrument tubing. Excess length of capillary shall be limited and neatly coiled and provided with permanent protection to prevent damage. Static head shall be considered according to manufacturer's prescriptions.

The Contractor shall install temperature indicators in their original thermo-wells after the wells are in place in the process piping. The temperature indicators shall be oriented so that they are visible from operating positions when they are used for operating purposes.

Temperature elements installed in piping shall be located to be accessible for servicing, calibration, or replacement, and shall not be located where vibration or shock is expected. Adequate space shall be provided for the removal of thermocouples, resistance temperature detectors (RTD's), thermal bulbs, or indicators from their protecting wells. Temperature elements shall not be installed in the allotted straight run of pipe upstream or downstream of a flow element.

All wells of local thermometers, resistance thermometers and thermocouples for steam, condensate, feed water, circulating water, service water and fuel oil, shall, as far as possible be of the weld-in-type.

Wells of thermometers and temperature sensors of the screw-in and plug-in type shall be restricted to such measuring points where welding is not suitable, e.g. at cast-iron parts. However, these wells shall be properly secured against inadvertent removal. Shop-welded thermometer wells shall be covered by screwed plugs for protection during transportation and erection. For test measuring points, thermometer wells with screwed plugs of same design shall be installed. The wells shall be designed in order to achieve fast speed response.

All thermo-wells shall be of the stainless steel material. For high temperature CrMo44 or similar shall be used, adapted to the pipe material. Gastight ceramic inside tubes shall be provided in addition to the outside protective tube for temperatures higher than 650 ºC.

### Flow Measurements

#### Primary Elements

Concentric orifice plates shall be used as the standard metering method. (Full details of orifice calculations shall be provided).

The throats of flow metering orifices shall be properly protected against erosion by means of satellite lining. Standard orifices according to ISO 5167 shall be used except for the following measurements:

* The flow in flue gas and air ducts to be measured with ultrasonic flow meters and venturi tubes respectively.
* The flow of seawater shall be measured by magnetic flow meters.
* Fuel oil flow will be measured with positive displacement meters.
* In case the flowing medium has a flow velocity higher than 2.5 m/s venture tubes with protected lining shall be used.
* In case of Reynolds numbers below 100 000, double tapered orifices shall be provided.
* Steam, fuel gas, air flow measurements at measuring point with variable temperature and pressure, shall be provided with automatic correction of flow signals.

#### Transmitters

For orifice measurements, differential pressure transmitters shall be used. The different pressure transmitters shall withstand maximum process pressure with one side at atmospheric pressure. The root extraction of the measurements shall be effected within circuitry located in control panel. The error for differential pressure produced across the orifice shall be limited to ± 1.0 % of the measuring range in the flow range from 10 % to 100 %.

Positive displacement meters will equipped with pulse transducers or vibration type mass meters. The error for these transmitters shall be limited to ± 0.3% of the top measuring range.

For open channel flow measurement (e.g. Ventura channels or V-notch weirs) ultrasonic non-contact flow transmitters shall be used.

#### Indicators

Local flow indicators may be of differential pressure type, propeller type, lever type or floating body type. U-tube manometers and mercury filled instruments shall not be permitted. The accuracy for the indicators shall be ± 2 % of the top measuring range.

Sight flow gauges shall be of the through vision type, with a glass window at each side of the flowing stream.

#### Switches

The flow switches employed shall be of any one of the following types subject to Employer approval.

#### Differential Type Flow Switches

Important flows like pump recirculation, air flow, etc. shall employ differential pressure actuating flow switches of approved calibre (qualities and standards) having very high accuracy and repeatability, suitable for easy switch adjustments between 20 % and 80 % of the flow scale.

The switch and instrument settings shall not get altered and/or the switch shall not malfunction under excessive or severe vibrations or shocks. The choice of the equipment

and its constituent parts shall match with the process characteristics. The maintenance, setting or replacement of important parts like diaphragm, bellows and switches shall be easily possible.

Also flow lines of 50 mm nominal pipe size or more shall employ differential pressure type flow switches (if any). Accuracy required ± 2 % of the full scale.

#### Float Type Flow Meters Equipped with Magnet Operated Switches

Flow switches of lesser importance or where less accuracy is permissible like cooling water flow may employ rota-metric flow meters with magnet operated switches, which can give reliable and satisfactory performance, subject to Employer’s approval.

Line size limitation: less than 50 mm nominal pipe sizes only. Accuracy: better than ± 5 % of full scale flow range.

#### Baffle Type Flow Switches

Baffle type flow switches having facility to adjust for different flows (if possible) but of proven quality having good accuracy and repeatability shall be employed in services like lube oil flows to pump bearings provided the line size is less than 50 mm nominal pipe size. The flow switch shall not get affected in case there is a reverse flow. Accuracy: better than ± 5 % of the full scale flow range.

By-pass lines shall be provided for both baffle and rotametric magnet actuated type flow switches. Baffle type switches shall not be used where failure of baffle can cause equipment damage. The direction of flow shall be indicated on the switch casing.

#### Installation Requirements

Differential pressure instruments on liquid or steam service shall be located below the lowest process connection so that the sensing lines slope down to the instrument.

Differential pressure instruments on air, gas, or vacuum service shall be installed above the highest process connection so that the sensing lines slope up to the instrument.

If a water or steam flow instrument is located above the primary element, air vents must be installed at the highest point in the sensing line to the instrument.

Differential pressure sensing lines shall be checked to make sure that they are connected to the correct sides, high pressure and low pressure, of the instrument. Wherever possible, bends shall be used instead of fittings for differential sensing leads.

In case of flow measurements for fluids with pressures of 25 bar and higher double shut-off tapping valves shall be installed.

Installation of orifice plates shall be as follows:

* A drain hole shall be at the bottom of the element for steam, air, or gas installations.
* A vent hole shall be at the top of the element for liquid installations.
* Orifice plates shall be installed so that the stamped side of the tab/name plate faces the upstream section of pipe and that the beveled edge of the orifice hole is on the outlet or downstream side.
* If gaskets are required, the gaskets shall be installed on each side of the orifice plate. However, the gasket must not extend inside the pipe.

Condensate pots are not required for a sensing element that has negligible dynamic displacement; e.g., a force-balance flow transmitter. If displacement is not negligible, and if the process fluid is steam, other condensable fluid, water hotter than 120 °C, or other fluid that may flash, then condensate pots shall be used. The pot shall have a volume not less than three times the displaced volume. Condensate pots on the high and low-pressure lines shall be at the same elevation and as high or higher than the highest process connection. For process fluids hotter than 120 °C, the pipe from a process connection to a condensate pot shall be insulated.

The differential pressure sensing lines associated with the high and low-pressure ports of an instrument shall have an equalising manifold with bleed valves.

### Level Measurements

#### Level Transmitters

The remote measurements for the liquid level shall be done generally by means of differential pressure transmitters. Impulse lines dilatation compensation, appropriate reference columns etc. shall be provided when necessary.

For drum level remote measurement pressure compensation for full operating range of drum pressure shall be provided.

For corrosive or dirty liquids preferably capacitive measurement or ultrasonic non-contact devices shall be provided. The capacitive sensor has to be selected according to the measured fluid analysis and shall consist of non-corrosive material. For ultrasonic devices temperature compensation is required.

For capacitive level transmitters the error limits shall not exceed 1.5 % of FSD and for ultrasonic ± 0.5 % of FSD.

For special cases level measurements with bubble tube may be accepted, subject to the Employer’s approval.

#### Level Indicators

Local level indicators of tanks shall be of the magnetic type and shall be equipped with a scale of sufficient length according to the height of the tank. For local measurement at pressurised vessels (e.g. drum) the bicolour water indicator type shall be used. For clear readability electric illumination has to be installed.

#### Level Switches

The external cylinder (positive displacement) float chamber type shall be used unless otherwise specified. The level switches with float chamber shall be provided with isolating and drain valves.

Connections shall be by flanges.

The float shall be calibrated according to the depth of liquids and specific weights. Floats as well as collecting rods and mechanisms shall be made of stainless steel. These mechanisms will include an adjustment of the working point and must be insensitive to effects of vibrations and shocks.

Floats shall be suited for the maximum test pressure and temperature of the system.

#### Installations Requirements

The lower level connection on a vessel shall be located on the side of the vessel in lieu of locating the connection vertically downward from the bottom of the vessel. This is to minimise entrapment of solids in the level sensing lines.

A stilling well shall be used in all cases, where displacement or float-type elements are located inside a vessel, to reduce the turbulence, except for rotary-type floats. A well may be required to protect a bubble tube against excessive turbulence. Stilling wells and bubble tubes shall be firmly supported. Headroom shall be provided to permit withdrawing them if they are removable.

Differential-type level instruments shall be located at an elevation lower than the vessel connections, unless a gas purge is used, so that the impulse lines slope down to the instrument.

External-chamber level instruments shall be installed with process piping. The root valves and shutoff/isolating valves for these instruments shall be gate type.

When gauge glasses and level instruments are installed on the same standpipe, the gauge glass shall be oriented so that it can be used in calibrating the associated level instruments. Gauge glasses used in conjunction with level instruments shall cover a range in excess of that covered by the instrument.

Gauge glasses and other instruments shall be visible from walkways, whenever possible.

So far as practicable, level devices shall be placed away from areas of turbulence and shall not interfere with other vessel parts or instruments, such as thermo-wells or sample nozzles, which may be required.

If the operational conditions require, filling line for the water leg shall be provided from the make up or condensate line. The filling line shall have a shutoff valve, needle valve and local indicating flow meter on the instrument side.

### Water/Steam Analysers

Each analyser shall have a self-contained readout meter. The outputs from the analysers shall be 4-20 mA DC. The special requirements are as follows:

#### Dissolved Oxygen Analysers

The analyser shall continuously monitor the dissolved oxygen in the process stream.

The analyser shall be the amperometric or galvanic cell type. The analyser shall have at least two switch-selected ranges. One range shall be 0 to 50; the other shall be the manufacturer's standard. Both ranges shall be available as a remote output.

* Response time: 1 min
* Accuracy: ± 1 % of full scale range
* Sensitivity: 0. 1 ppb
* Temperature: Compensation up to 55 °C.

#### PH-Analysers

The sensing element system shall provide continuous operation for six months or longer under normal operating conditions.

The sensor output shall be automatically compensated for process temperature variations within the design range. The base temperature shall be 25 °C.

* Accuracy shall be ± 1.0 % of the full scale deflection −Temperature compensation:

#### Conductive Instruments

Conductivity elements shall be either flow-type or immersion type as determined by the Contractor to be best suitable for the service, AC - bridge design.

* Accuracy: ± 1.5 % of the span
* Temperature compensation: up to 80 °C.

#### Silica, Hydrazine, H2 Purity and Turbidity Measurements

Method of measurement, accuracy response time, etc. shall be of the best suitable industrial type, which is available and shall be subject to the separate approval of the Employer.

#### Installation Requirements

The installation of the analysis instruments together with their sample systems shall be in strict conformance with the manufacturer's recommendations for the installation.

All analysis instruments shall be grouped and supplied in shop-assembled sample cabinets/racks containing the required sample conditioning equipment and interconnecting pipes, valve tubing, wiring etc.

The analysis and sampling systems shall be capable of satisfactory continuous operation without attention other than routine maintenance (e.g. weekly checks).

Sample lines shall be of socket-welded construction and shall be routed separately from pneumatic signal lines and process instrument sensing lines. Sample line routing shall be as short as possible. Traps and dead legs shall be avoided to the maximum extent possible. Sample line tubing shall be bent using proper bending tools. Elbows shall not be used. Sample lines shall be stainless steel tubing.

If no cooling media are available on the spot, chillers units or compact coolers with electrical supply shall be provided by the Contractor, if necessary.

Conductivity electrodes, pH-electrodes, may be built directly into the pipes if the medium pressure is below 10 bar, and if the sensors are separable for regular maintenance without disturbing the process/ operation. In all other cases sampling devices with measuring chambers of stainless steel shall be provided.

The sampling points and associated probe positions shall be located so that representative samples may be obtained under all conditions. Liquid and steam sample connections (sample probes) shall be located after a 3-pipe diameter minimum runs of straight process pipe. The connections shall not be installed within 3-pipe diameters of elbows or tees. A sample line return shall be installed at a minimum of 1200 mm downstream from its isokinetic probe. Each automatic analysis sampling point shall be provided with a manual sampling point. The manual sampling facility stations shall be so located as to permit samples to be easily taken. Manual sampling shall not interrupt automatic sampling. All sampling lines shall be run to a common sampling rack in the analyser room on which shall be fitted all the analysis and associated equipment.

Manual sampling points shall be provided at points agreed with the Employer e.g. for monitoring suspended solids at economiser inlet.

Each measurement is to have a corresponding indicator either as an integral part of the analyser or mounted adjacent to the analyser. If an analyser can be damaged in the event of inadequate cooling of the sample, a protective system must be provided to ensure that the sample is not allowed to reach the analyser. Upon the operation of the above protective facility an alarm shall be installed in the Central Control Room.

Each sampling system shall be provided with a suitable drainage system and in the case of manual sampling points, a tray shall be provided to receive a sampling flask. Where capillary sampling is employed, e.g. for suspended solids sampling it shall be to the approval of the Engineer. In addition to any valves for instrument test and isolation purposes, two isolating valves shall be provided between the tapping point and the cooler. A needle valve shall be inserted in the sample line to control flow.

Adequate pressure relief facilities shall be supplied for each sampling system to the approval of the Engineer. Where a cooler is required, inlet and outlet isolating valves shall be supplied for the cooling water together with a flow regulator and flow indicator.

Whenever required for a useful analysis measurement, the installed sampling device shall include a cat ion-anion exchanger and/or other required accessories. The specific type of samples conductivity (specific/cat ion) measurement shall be finalised during the detail design stage.

### Vibration Measurements

Under steady state conditions and at all loads the vibration shall not exceed the limits stated in regulations VDI 2056 or ISO 8528-9 or other equivalent code or standard, subject to the Employer's approval. The Contractor shall indicate what vibration sensors are provided by the engine Vendor.

The measurement devices have to be supplied by an experienced manufacturer and shall provide sensing for the relative and absolute vibrations at each bearing selected. The sensors for both types of measuring shall be mounted in an adequate position to the bearing at an angle of 45 °C to the vertical.

#### Shaft Vibration (Relative Measurements)

Sensors of the non-contacting type (inductive, eddy current) are prescribed and temperature compensation is required. Two sensors on each bearing have to be connected to two-channel amplifiers. For each supervised bearing the vibration has to be indicated locally and remote and single alarms have to be initiated in case of excessive vibration values. Sensors shall be oil proof and designed for an ambient temperature of 100 °C and measuring range 0¬ 150 mm.

#### Bearing Vibration (Absolute Measurement)

For the bearing vibration a seismic (moving coil) sensing device shall be preferred. Sensors shall be designed for an ambient temperature 70 °C and measuring range 0 -150 mm.

Two sensors on each bearing mounted near the position of the shaft sensing devices have to be connected to a pair of independent amplifiers each. The output signal of one amplifier has to be indicated locally and remote and single alarms for excessive vibration have to be initiated.

### Miscellaneous Measurements and Controls

#### Position Transmitters

Position transmitters of the potentiometer type will not be accepted for any automatic control purpose. Inductive position transmitters or similar types are acceptable. Characteristics of the position transmitters shall be linear with a linearity deviation of not more than 1 %. The reproducibility shall be better than 0.3 %.

#### Local Controllers

For simple control functions that are not essential for the operation of the plant and that need no interference by the operator during start-up, shutdown and operation, locally mounted controllers can be used. These automatic Controllers shall be of uniform type and shall be of simple and reliable design.

They shall have an indication of controlled variable and a set point adjuster for 0 to 100 % of full-scale range. The accuracy of set point adjuster shall be 1.5 % of full-scale range or better.

The local controllers shall be insensitive to vibration and shall be mounted in separate cabinets near of the equipment they are serving.

In case the local controllers are including the measuring systems for pressure, temperature or level, the appropriate specification shall apply to the measuring systems including tapping point, piping and valves.

### Control Valves

#### Design Requirements

Minimum body size shall be 25 mm with reduced trim as required. Valve sizing shall be based on handling of the maximum design flow at 70 % to 85 % of the valve capacity.

In case of the high maximum to minimum process flow ratio, double valve split range arrangement shall be used. All Valve operators shall be sized to shutoff against at least 110 % of the maximum shut-off pressure differential.

The stroke/throughput characteristic shall, depend on the purpose, either be linear or logarithmic. The valve stem shall be well guided, and the valves shall operate without excessive vibration and noise (max. 87 dB (A) at 1 m distance). They shall achieve a stable fluid control over the entire flow range.

All control valves (except for high temperatures) gland packing shall be self-lubricating Teflon type. Isolating and bypass valves adequate for full flow shall be provided for control valves in lines of 450 mm diameter or less.

Control valves for pressures over 25 bar shall have preferably the following features:

* Single seat.
* Angle shape with medium flow in losing direction.
* Valve body of forged steel.
* Welding connections shall be applied for steam in any cases and for other media only in case of nominal pressure equal or higher than 64 bar.
* Pressure sealing bonnet.

Further requirements:

* All control valves for steam and boiling water shall have stilted seats and plugs.
* Valve stem, seat and plug for water shall be of stainless steel.
* Flow directional arrow on the valve body shall be provided.
* Design and manufacturer are subject to Employer approval. 6.3.3.14.2 Installation Requirements

The Contractor shall route in a neat and effective manner and connect control signal and supply tubing or piping associated with all pneumatically operated control valves. All necessary hardware required to complete the control air installation shall be supplied by the Contractor.

Control valves requiring remote mounted volume tanks shall have the tanks mounted as close to the valves as practical. Solenoid pilot valves shall be mounted on the valve. Control valve air supply and signal sensing lines shall be suitably supported in channel and routed such that water or condensation will not collect at the control valve; i.e. slope tubing up to valve. All auxiliary devices shall be installed so that they are accessible and visible to plant operators. Installation of tubing at the valve shall be such that the tubing will not be damaged by vibration or thermal shock and will not interfere with maintenance of the valve.

Pressure test measuring points with isolating valves and lugs shall be provided before and after each control valve.

### Control Actuators

#### General Requirements

For control and on/off valves/dampers electric motor or solenoid actuators shall be used. In special cases, pneumatic actuators may be used; however, the use of such actuators shall be subject to Employer’s approval.

Valve actuators shall be directly mounted on the valves, as far as possible.

Modulating valves and dampers actuators shall be designed to preclude the possibility of their snapping closed when operating near the fully closed position. The damper actuators shall be of the base-mounted type, provided with output shaft and mounted lever with suitable ball joints. Direct shaft-mounted actuators shall be avoided.

The valve actuators with linear output motion shall be supplied with standard flange to be fitted on the valve yoke. The output shaft shall have metric thread suitable to match the coupling provided by the valve manufacturer.

Areas of the actuator subject to full thrust or torque, e.g. mounting base, thrust pads of power gear train, end stops and bearings shall be designed to withstand the maximum over-force / over-thrust which can be generated by the actuator, e.g. if it drives against the valve seat or the end stops with full motor speed at rated voltage without being switched off. This is to avoid any damage of the actuators in the event that the limit switches fail to operate and has to be proven by a type test for each actuator size.

Each control valve/damper actuator shall include an inductive position, transmitter with 4 - 20 mA output signal. This transmitter shall be protected from mechanical damage by a friction clutch. Enclosures with position transmitters and limit switches shall be provided with space heaters to maintain the temperature inside above dew point. Special care shall be paid to the problem of quick opening or closing.

Available power supply sources are specified in the Specification. If the actuator power supply is different from above specified one the Contractor shall deliver suitable transformers/ converters, etc. for such application.

A hand wheel shall be provided for manual operation. The hand wheel shall preferably not rotate during motor operation, however, shall the hand wheel rotate it shall be smooth without protrusions or spokes and not exceed 150 mm diameter. If power to the motor is interrupted it shall not prevent hand wheel operation. On completion of a hand wheel

operation the unit shall automatically reset to motor operation, or reset when the motor is energised and shall remain in motor operation until hand wheel operation is again selected. Movement from motor operation to hand wheel operation shall be accomplished by a positive declutching knob, or lever, which will disengage the motor and motor gearing mechanically but not electrically.

For actuators utilising non-self-locking ratios and/or recirculating ball nuts, it shall be possible to drive back through the power train. For these units a continuous hand wheel engagement by a superimposed gearing can be used, which does not declutch the motor during hand wheel operation. For these units the hand wheel has to be equipped with devices, which automatically lock the hand wheel when the operator releases it. The counter-torque at the hand wheel shall not exceed 200 N. Hand wheel diameter shall not exceed 500 mm. Hand wheel rotation shall be clockwise for the closing associated valve or damper.

#### Electric Motor Actuators

Actuators shall be built up as a compact unit containing the following components:

* Electric Servomotor
* Reduction gear base-mounted with lever output for damper actuation, and flange
* mounted with linear output for valve actuation
* Mechanism for hand wheel operation
* Feedback unit with position transmitter
* Torque switch mechanism (if required)
* Limit switch mechanism.

Torque switches shall be provided for all not stall-proof actuators.

**Motors**

The requirements for motors are defined in the Electrical Specifications.

**Continuous Control**

The motor shall be controlled continuously and generate a variable output torque to balance the counter torque/force of the final control element to move and to keep it into the desired position. The maximum torque in stalled condition shall be not higher than twice the rated torque. For this mode motors with stall-proof characteristics shall only be used. The motors shall be capable for direct reversing operation at full speed.

**Step Control**

The motor shall be controlled stepwise and braked electrically after each step.

The motor shall have a minimum duty rating to S4/S5 duties - 1200 starts/hour at 25 percent duty cycle according to International Standards. The shortest step the motor follows shall be no longer than 200 ms including start up, running and braking. The motors shall be capable of reversing operation. If a time delay between two mutual steps is necessary it shall not exceed 100 ms.

For a required positioning time of less than 30 seconds, an actuator for step control will not be accepted. Mechanical or electromechanical brakes can be fitted to the servomotor if they are not used under normal operation to slow down the motor after each step.

**Gearing and Gearboxes**

The actuator with servomotor shall have a self-locking characteristic in order to maintain its last position in case of switching off the motor or power failure against 120 % counter force/torque. If the motor is not fitted with a brake for these purposes a gearing with a self-locking characteristic may be used. In order to avoid any influence caused by the gear backlash on the positioning behaviour during reversal a non-self locking gearing with high efficiency controlled in a force balancing mode will be preferred.

If a self-locking gearing and/or a control in stepping mode will be used, the backlash shall not exceed an amount, which can be overcome by a control step of 300 ms during reversal in idle mode.

All power gearing and rotary thrust conversion shall be oil or flow grease lubricated with an approved lubricant, which is suitable for at least four years' operation under the given ambient conditions.

All units shall be designed to permit mounting in any position without detrimental effect to the lubricant system or actuator operation. Proper seals have to be used to prevent leakage of lubricant into the feedback and limit switch compartments, terminal box and motor. Provisions for change of breather, filling and drain holes are required to suit all mounting positions of the actuators.

The number of motor revolutions necessary to overcome the backlash for reversal operation has to be stated in the actuator data sheet and will be subject to a 100 % routine test. The power gearing shall consist of spur, helical and/or worm and wheel gears. Spur, helical and worm gears shall be made from heat-treated steel and/or have hardened parts at the matching areas. Worm wheels shall be made from a copper-based alloy. Gearing made of other materials such as lignostone and resophil and worm wheels of cast iron are not acceptable.

Any gears, forming part of the power gear train of the actuator being fixed to shafts, shall be fitted with keys of splines. Other fixing methods are subject to Employer approval. Ball or roller bearing shall be used throughout. The gearbox output shaft for damper actuators must, in all cases be supported by two bearings. Arrangements utilising one bearing of the driven device to support the output shaft are not acceptable. The output shaft of the linear actuators has to be protected against torsion. The rotary thrust conversion has to be supported by roller bearings capable of withstanding the max. Over force which may be generated by the actuator.

**Mechanical Stops**

All actuators are to be equipped with mechanical stops adjustable to the used travel range in order to prevent the actuator and the associated equipment from travelling past its normal range in the event that the limit switches fail to operate. For actuators with stall-proof motors these end stops shall be used for normal travel limitation. The mechanical stops are to be adequately rated to avoid any damage to the plant and to limit the generated over force/torque to the final control element to an admissible level.

All linear actuators are to be supplied with internal spring packs or have provision for externally fitted spring packs as optional equipment to absorb the kinetic energy of the unit to limit the corresponding over force in combination with the mechanical stops in the actuator to an admissible value. The spring packs are also to compensate the temperature expansion of valves and valve stem due to changes in operating temperature. For damper actuators, for these purposes, the spring behaviour of the intermediate linkage will be used.

If the actuator design especially the servomotor, requires a switching off in the end positions, the actuators shall be equipped with a torque switch mechanism. The torque switch shall function to avoid inadmissible overheating of motor and over torque/force of actuator under stalled condition.

Actuators with stall-proof motors not requiring torque switching-off are preferred. If the actuator with above mentioned cut-off switches is proposed then a minimum of two switches, one for the closing direction and one for the opening direction shall be provided. The torque switches shall have changeover contacts with a switching time of not more than 10 ms and an expected mechanical life of not less than 10 million switching cycles. The torque switches are to be individually adjustable by means of screwdriver or spanner on an indexed or calibrated scale within the limit switch enclosure. The minimum range of adjustment is to be 50 to 120 % of the rated actuator torque.

Actuators requiring partial or complete disassembly of the actuator mechanism to obtain the range adjustment of torque switches are not acceptable. The design of the gear box/torque switch assembly shall be such that, once a torque switch has been operated, its status shall be maintained and can only be reset by operating the actuator in the opposite direction.

Provisions shall be made that the max. Over torque/force at the actuator output in case of torque switch response does not exceed values higher than twice of the adjusted point.

If the actuator design requires a switching off in the end positions, the actuator shall be equipped with a travel limit switch mechanism. Actuators with stall-proof motors using adjustable mechanical end-stops are preferred.

If the actuator with above mentioned cut-off switches is proposed then a minimum of two switches, one for the closed position and one for the opened position shall be provided. The switches must be adjustable for a minimum accuracy of 0.5 % of travel. Manual over travel of the closed or open position shall not displace the set points or damage the mechanism.

#### Solenoid Actuators

Pilot solenoid valves shall be fed with 24 V DC directly from the remote control cubicle. Solenoid valves of a higher power rating may be fed from uninterruptible AC source.

The solenoid valves shall be of standard weather - and waterproof type. The insulation of the coils shall be of class "H".

The solenoid valves shall have a manual testing facility with a tool or special key for testing purposes and normal status indication to avoid misuse/mis-operation. All solenoid valves shall be designed for continuous operation. The protection class shall be IP 54 or better.

#### Pneumatic Actuators

Pneumatic actuators (if accepted by Employer) shall be spring-diaphragm type. The diaphragm material will not deteriorate in the operating conditions due to ageing. Actuators shall be sized for reliable operation within 0.2 to 1.0 bar pressure range.

Positioners shall be adapted to the actuator for which they are used. The positioner shall include an adjustment for variation of valve opening (e.g. for split range), a bypass system, an action inverter and a system to vary actuator speed. The accuracy shall be 1 % and the sensitivity 0.5 % of range. Pneumatic positioners shall be provided with individual air supply. Air pressure of input (0.2 - 1.0 bar), output signals and instrument air supply pressure shall be indicated. The connecting tubing between converter and positioner shall include expansion-bends to absorb vibrations.

For electronic controllers working on pneumatic actuators separate E/P converters shall be installed. They shall be of the dynamically balanced force balance type, robust, vibration and noise resistant, weather and dustproof. The accuracy shall be 0.5 % of span range with temperature compensation, if necessary.

Converters shall be mounted in cabinets close but apart from the actuator they serve. Each converter shall be provided with an individual air supply. Output and supply pressure shall be indicated.

## Supervisory Control and Data Acquisition System

### Operational Concept

The design of the SCADA system shall allow supervision and highest hierarchical level coordinated control of the power generation units along with the control and supervision of the plant common auxiliaries including electrical system from the central control room. The detailed operational concept is specified in the Particular Technical Specifications.

### System Basic Design

The system for measuring, analogue and logic controls/interlocks and supervision shall be a programmable self-diagnostic digital process control system based on the latest generation of microprocessors and proven in power plants in the last 3 years as far as the system family is concerned.

The independent protection system shall be compatible with the SCADA system in order to allow a good signal exchange between the two systems.

The SCADA system shall comprise different PLC panels to be installed at different locations in the equipment room, the electrical switch gear room and the local control room at the new power house, system panels including interface controllers and SCADA servers to be installed in central control room or the next door communication room and the operator stations to be installed in the central control room.

The system shall include the following main functions:

* Data acquisition with time tagging
* Signal conditioning
* Open loop controls
* Step sequence controls
* Function group controls
* Data communication.

With the following main components:

* PLCs and remote I/Os
* Communication and interface controllers
* SCADA servers
* Operation stations
* Printers and fault reporter
* Power supply modules.

One system engineering workstation shall be provided for system programming / configuration, system failure detection, troubleshooting, editing of back-up documentation, etc.

### General Requirements

The system shall contain standard equipment of a proven SCADA system from a well known Vendor selected from the SCADA Vendors list given in the Particular Technical I&C Specification.

The configuration of functions shall be possible by software modifications without changing hardware components.

As far as the system and the components are concerned internal safe design shall be applied. It means that no failure of system elements, on-line change of cards/modules or external influences (short-circuits, wire break, noises, etc.) will cause erroneous operation or deterioration on any hardware or software system. The circuitries shall be protected against interactions between cards and systems (e.g. galvanic isolation of inputs/outputs by optical coupling devices). For control and protection circuits fail-safe design shall be applied. All failures, anomalies and missing functions shall be automatically detected by the system itself and alarm shall be given to the diagnostic station in clear text, showing the exact origin and the kind of failure. This auto diagnostic system is required for every card, module, peripheral, etc. belonging to the system. The failure to be annunciated also at the concerned equipment (e.g. LED-S on the front plate of equipment, for easy identification) and announced in the control room e.g. by group alarms. The system shall automatically recognise the type of card inserted and proceed with automatically booting/reprogramming without manual interaction. In case of not suitable card type alarm shall be given.

The following data are required for the system:

* Better than 3 ms resolution time for alarms and events
* For signals with the same time tag the sequence shall be correct
* 0.2 - 0.5 s cycle-time or better for closed loop controls, when applicable
* Interrupt for open loop controls
* 1 s to get a synoptic (mimic diagram) on the display upon operator's request (also
* dynamic refreshing)
* 1 s to get an alarm on the display,
* 1 s to get the confirmations on the display upon operator's command from the keyboard/display/mimic.

Important measured analogue values of the plant shall be scanned periodically. The period shall be:

* 100 ms or better for frequency
* 1 s for flow, pressure, other electrical values, flue gas analysis
* 10 s for temperature, analytical parameters.

All controllers processing and communication modules shall be redundant. The power supply of the system shall be redundant from safe AC system (UPS). The internal power supply unit of the cubicles shall also be redundant.

### PLCs

#### Remote I/O Modules

Distinct input modules will serve as interface between the local control PLCs and the measuring / sensing instruments and will accomplish necessary signal conditioning as far as practicable.

#### Analogue Inputs (through serial communication to the PLCs)

The following requirements to be applied:

* High insensibility against noises and other disturbance signals (e.g. walkie-talkies) Intrinsically safe input circuits, where required
* High insensibility against over-voltages (IEC 255-4 class II)
* High accuracy of conversion (resolution min. 10 bits without prefix signal, accuracy 0.5 % or better)
* Working range – 50 % to 150 % of the adjusted measuring range
* Supervision of signals verification against limiting values (e.g. – 5 % and 115 % of the adjusted range. (In case of invalid signal it will be marked in the message in order to be identified by the receiver-module e.g. control module)
* For multi-channel measurements the transmitter’s outputs shall continuously be supervised so that if these deviate by approx. 5 % from each other, the related controller shall automatically be switched over to manual. This limit may be changed by the Contractor according his practice or special process requirements. Before this limit reached, pre-alarm shall be given.
* Linearization of thermocouple and resistance thermometer signals
* Reference-correction facilities for thermocouples
* Connection of 4 wire-measuring devices (e.g. RDT's)
* Limit switching with four (4) limits for each analogue signal. The limit setting will be done via bus system remotely. For each limit value the hysteresis shall be adjustable separately. In case of invalid analogue signal the digital limit signals shall be put to zero.
* Supply of transmitters via galvanic isolation and supervised fusing, each transmitter circuit
* Analogue output signal 4 to 20 mA or 0 to 10 V or 2 to 10 V (if necessary)
* Remote setting for all parameters via bus system.

#### Digital Inputs (through serial communication to the PLCs)

The following requirements to be applied:

* High insensibility against noises and other disturbance signals (e.g. walkie-talkies) Intrinsically safe input circuits where required
* High insensibility against over-voltages (IEC 255-4 class II)
* Supply of external contacts voltage with 24V DC generated by the system itself
* Contact chattering protection/damping
* Input circuit supervision (short-circuit, wire-break contact faults). In case of invalid
* signals it will be marked in the message in order to be identified in the receiver module
* (e.g. control module).
* Signal status indications by LED's on the front
* Supervised fusing for input circuits
* Binary input cards if necessary for counting purposes.

#### PLC Processing modules (as required)

The modules shall include all necessary functions, such as:

* Open loop controls
* Closed loop controls
* Step/sequence controls
* Function group controls
* Bus supervision
* Memory checking
* Watch dog functions
* Supervision of peripheral devices, if necessary.

#### Remote Logic Control (as applicable)

The controls shall include all necessary functions, such as:

* Through serial communication for
  + On/off control of motor/solenoids or open/close control of valves
  + Status signalisation and fault signalisation of the controlled element and from the switchgear like discrepancy of on/off contacts, SWG-fault, SWG in "test" position and remote control "off" (selector switch in "local" or in "off" position).
* Generation of signalisation for interlocking and protection status
* All functions necessary for reliable operation, e.g.
  + First priority for trip signals with operator’s acknowledgement
  + Priority for close/off command signals against open/on commands
  + Supervision of running time (servomotors, valve actuators)
  + Continuous supervision of feed back signal contacts.

A faulty processing module shall not send active signals to the switchgear.

#### Functional Group Controls (as applicable)

The function shall include the starting/stopping procedure and the normal service of the group, the sequence control with the necessary interlocking of steps taking into consideration the process conditions.

The sequence control will be started, stopped either by operator's manual commands or by the master control. The operator shall be able to initiate manually each individual step of the sequence in the "on line" or "stand by" mode. The running down of the sequence shall be displayed in the control room for the operator. The change over to the next step shall be indicated at the end of the previous step. Any fault during the program, missing criteria/failures on the drive level, in the electrical or electronic circuits shall be announced to the operator without delay.

When operating times are exceeded, the programme shall be stopped, all commands at the step must be inhibited, and the programme step and not fulfilled criteria shall be alarmed and indicated selectively.

Manual intervention shall be possible at any stage of operation, and the sequence control shall be able to continue at the correct point of the programme in the correct mode when returning to automatic control.

For sub-groups with sets of two 100 % drives, one on duty, the other on standby, or e.g. 3 x 50 % drives with one or two on duty and one on standby, the sub-group control shall act as a switch-over device ensuring that the continuity of the service is maintained by automatically switching over to the reserve drive in case of failure of the running drive. It shall be possible to activate the sub-group either from the functional group control or by manual intervention. In a sub-group of this type, it shall be possible to select each drive for auto-start from sub-group control or manual start only. It shall also be possible to select the order of operation of the drives selected for auto-start. This order may be designated priority of the different drives.

#### Analogue Controls (as applicable)

The analogue controls shall have the following features:

* Communication with the system for:
  + Open/close and hand/auto control signals
  + Set point up/down signals
  + Status and fault signalisation of the controlled element
  + Signalisation of protection status
* First priority for protection criteria of the controlled drive (e.g. trip of valve actuator, motor
* by torque switches)
* All functions necessary for reliable operation e.g. bump less transfer from automatic to manual operation in case of any failure in the automatic mode. Any fault in the automatic control shall switch the controller to manual. In this case the operation and information system shall guide the operator via overview - and group display to the detail display of the faulty element. Normally, the final control element will be blocked in actual position when control failure occurs. Some other cases may be required by the process and have to be worked out during design stage. List of fail safe positions shall be submitted to the Employer for approval.
* Priority for stop/close command signals against start/open signals
* Pulse or continuous (modulating) control as required
* Continuous supervision of controller output signal and actual position signal to issue discrepancy signal in case of deviation.

#### Power Supply Modules

According to the prevailing manufacturer’s standards.

#### Communication and Interface Modules

The PLCs shall have dual PROFIBUS interface modules.

#### Diagnostic and Programming

Each PLC has to provide full range of auto diagnostic and programming functions. The PLC itself shall be able to communicate with the engineering workstation in the central control room for diagnostic and programming functions. It shall be also possible to connect a notebook PC to the PLC locally for diagnostic and programming functions that shall include:

* Access to all signals and storage automation of the station
* Auto diagnostic features for all internal modules and external equipment connected with the hardwired station
* Signalisation of failures and disturbances with easy interpretation of the kind and origin of the failure to minimise the time of disturbance and non-availability.
* Facilities for:
  + - Indication of system configuration and structures
    - Indication of signals and parameters
    - Simulation of signals
    - Modification of the system as far as the configuration and parameters are concerned, without interruption of the operation (on line modifications).

### Communication System

The communication between local PLCs and the system shall be made through dual PROFIBUS bus system. The SCADA Vendor, however, may propose an architecture where the PLCs are direct nodes of the SCADA LAN.

The bus communication media shall be fibre optic cables. The transmission shall be designed as dual channel and event oriented transmission.

The main characteristics of the remote bus systems shall be as follows:

* High reliability of communication realised by double bus (redundant) system. The two systems work together continuously in order to avoid any interruption, with automatic change over to the backup channel. The data transmission has to be checked permanently on line by a diagnosis system. By this principle all PROFIBUS modules shall be double to form the complete system.
* Insensibility against external disturbances (noises, electromagnetic fields, walkie-talkies, etc.)
* Continuous detection and indication of failures/ errors for each bus with detailed diagnostic possibility (bus control)
* Synchronising with the connected stations/systems.

The structure of the bus system shall not restrict the allocation of any incoming signal to any controller or part of the process information and operation system.

The detailed design of the operator interface and functions are described in the Technical Specifications.

### Overall Functional Group Control Unit / Plant Control

The highest automation level will be realised by the unit / plant PLCs. All necessary functions for the coordinated control shall be included with the required function control groups. The detailed design is described in the Technical Specifications. However, the following general conceptual tasks shall be done automatically by the control system.

#### Start-up

* Selection of the function groups and analogue control loops depending on the conditions of the unit
* Establishing of starts and stops signals for the individual function groups and analogue control loops
* Supervision of the development of the process characteristics and of the correct function of the individual function groups and analogue control loops. Information for the operator about the progress of the start up period, need of additional control actions and alarms.

#### Operation

* Automatic loading of the plant with due consideration of the plant components
* Plant management.

### Operator Stations in Central Control Room, Local Control Room

The task of those stations is the central and local supervision of the units, the control of the common process and electrical auxiliaries, further the overall block control of the plant.

#### Clock Synchronization

The on-line application of the system requires synchronisation of the whole digital system internally. Clock synchronization shall be realized through GPS.

#### Storage of Data

The data storage capacity shall handle all background information necessary for process monitoring, printed log representations, fault report trends and plant historian, etc. The necessary storage capacity shall be proposed by the Contractor subject to Employer’s approval.

#### Operator Station Functions

All functions necessary for central supervision and manual remote control of the units / plant shall be available at the operator stations. Each of the stations (LCD monitors) shall allow a free selection of displays on each monitor. The failure of one monitor or keyboard with its interface shall not cause blocking of other monitors / keyboards.

#### Plant Monitoring

Analogue and binary process values, analogue and binary control loops shall be displayed in a standardised form and in a systematised hierarchy, consisting of plant overview display, area overview displays, group displays, and loop displays, with the appropriate instantaneous values being integrated in the displays.

The final number of displays will be decided during detail design and needs the approval of Employer. A dedicated area on the top of the display shall show the exact time and date, the designation of the power plant and the unit concerned.

Remote control shall be possible for all remotely operated elements of the plant, if the operation is not limited to the local panels.

Functions, not admitted to the operator shall be disabled by key selector switch or shall be restricted by software on system engineer’s workstation only.

#### Graphic Displays

The hierarchical layout of the standard and user graphic displays shall be identical in a way that selection of either one of the displays on the same level shall be easily possible.

Getting started with the general plant outline with main synoptic overview(s) the following graphics shall be monitored with the relevant analogue and binary real time data:

* Display of one synoptic overview
* Display of one main area
* Display of one synoptic group with all primary elements belonging to it −Detailed display synoptic of all primary elements of the above group.

Each graphic shall display the current value and status of all measured data associated with the graphic. The alarmed values shall appear in flashing, the status indication of display elements like motor on/off, valve open/close can be done by colour coding. Each analogue value shall be numbered with its proper accuracy and floating point showing also the engineering units. All display components shall be provided with identification codes according to the agreed Plant Identification System.

Provisions shall be made to display the following for primary elements:

* Operating field for remote control operation
* Clear text concerning designation of alarms
* Indication of on/off, open/close criteria, etc.
* Clear text concerning designation of primary element
* Bar chart display, curves, etc. for analogue measurements and controls
* Reference to the specific logic diagram, graphics, curves, etc.
* For single-loop binary controls, the monitor display must include the drives with their
* interlocks and protective logic, with non-fulfilled binary control conditions also being
* marked.

The selection for single binary loops, sub-group and function-group binary controls and for the entire analogue control and control level on the monitors shall correspond to the hierarchy of the control system. The steps required for selecting an operating field shall be kept to a minimum.

#### Curves, Bar charts, Lists and Diagrams

Any analogue variable measured or calculated may be assigned for a curve display giving a clear picture of its trend as a function of the time interval selected. The normal time selectable shall be defined from 1 minute up to 1 hour in not less than 5 steps with a minimum resolution of 1 sec for analogue values (except for frequency trend associated with fault reports where resolution of 100 msec is required). The curves are continuously shifted to the left, while actual updated values appear on the right-hand side.

One curve representation shall contain no more than 6 parameters in system of coordinates. The number of parameters is selectable. The possibility shall be given to show additionally binary limits within the curve as well as the curve related actual values display with numbers and clear text on the same display. Analogue prints shall be plotted with high resolution and dedicated colours.

Besides the above curve representation, long-term curves can be generated (up to 31 days) with sample rates 5-60 seconds and may be assigned for a limited number of analogue data.

The curve representation shall have the following features:

* Colour filling technique for absolute values (area below the plotted curve). For comparison between two curves, one of each may be defined as a constant and displayed as a limit value. Positive and negative deviations can be marked with different colours.
* Reading of amplitude, moving the cursor bar along the curve and getting an alphanumeric display of the selected y-value on the screen.
* Manual rescaling facility of the y-axis, on line.

Bar charts shall be provided for selected kinds of data (controlled analogue values). Up to 10 bar charts may be represented on one bar chart display. The length of the bar represents the actual value of the analogue signal allowing quick comparison with other measurements

of the same group. Limit values will be indicated flashing. Simultaneously displayed numerical values with engineering units and clear text will provide exact reading of the monitored data. Maximum values (range), engineering units and scale (percentage up to 100 % in 5 % steps) shall also be displayed. Diagrams of operational characteristics shall be provided for dedicated applications.

For all types of curves, diagrams and bar charts, the representation of items, values, etc. shall be done with proper identifications code and clear text within each display. Altogether at least 600 curves, bar charts and diagrams shall be offered by the system. The actually displayed graphs shall be decided during design stage and will be subject to Employer’s approval.

On operator's request display of disturbance and status messages shall be monitored. It shall be possible to distinguish between messages by origin and importance and to display them on the monitor sorted according to these criteria.

#### Alarms and Sequence of Event Listing

All alarms and sequence of events shall be listed up on a dedicated station. Nevertheless the operator may call up the listing on any station.

The listing-up shall be done in chronological sequence showing

* The precise date and time with the required resolution (specified in other item)
* Plant identification code
* Clear text/denomination of alarms and events
* Status message (open, close, off, high, low)
* The actual value in case of high/low alarms derived from analogue values.

Altogether a minimum of 20 alarms shall be displayed on the screen. In case when more alarms are coming, only the not yet acknowledged alarms shall be retained on the first page. The acknowledged still existing-alarms shall be shifted to the so-called secondary pages. In case of first page overflow the not yet acknowledged alarms shall be shifted to the so-called new pages. The new pages and the secondary pages can be recalled by operator at any time. If any new alarm appears while monitoring a new page or a secondary page, flashing signal on the screen shall warn the operator to return to the first page.

Dedicated keys shall serve the operator for alarm handling such as buzzer signal acknowledgement, alarm acknowledgement, alarm clearing and page flipping. Differentiation between alarms and events shall be done by colour coding (alarms: red colour). Eventually further colour for distinction of alarms according to the degree of urgency or type of alarms may be required.

All flashing / blinking functions of alarm messages shall be according to applicable standards specified for the conventional alarm system. First out alarms shall be marked clearly and need special acknowledgement.

Grouping of alarms shall be done in two different ways:

* All alarms of the concerned unit
* All alarms of certain groups of a unit (e.g. on operator's request) for important plant functions.

#### Special Tasks

The plant monitoring/control system shall support the operator with proper monitoring when executing special tasks. By this task the operator may enter the schedules, follow-up logic sequences and monitor the closed loops for certain groups.

Before starting, the operator may ask for the initial criteria and shall get:

* A summarised list of operating instructions
* A checklist of criteria to be fulfilled. Missing criteria and not fulfilled steps shall be pointed out allowing the operator to carry out the necessary steps to fulfil all criteria required for starting.

During the sequence the operator shall get all necessary information from sequence synoptic, such as

* Logical steps
* Time exceeded
* Missing criteria list
* Executed steps of the sequence
* Not yet executed steps of the sequence
* End of sequence.

Some further display features shall be made available according to the manufacturer's standards (e.g. allocation of printers to different tasks, selection of contacts for trend logs selected by cursor from the monitored analogue status report). These functions shall be included in the contractual scope of supply if helpful or important to the operator.

#### Printer Logs

For plant follow-up and on-line / off-line analysis different kinds of printed protocols shall be available. The following kinds of protocols shall be printed.

* Sequence of event and alarm protocols shall contain all alarms and selected events associated with one or more units or with a part of the plant (including manual commands of operators) in chronological order, giving the following data:
* Exact time (with the specified resolution)
* Identification code
* Denomination of item in clear text
* Attribute (high, low, open, close, etc.)
* The actual value in case of alarms derived from analogue values
* The printout is in red for off normal and black for return to normal. The printing will be done spontaneously without interaction of the operator when alarms/events appear. On operator's request printing of alarm summary protocols shall be possible, to printout all plant items being currently in alarm. All points not yet acknowledged shall be printed in red.
* Pre and Post fault report for "post mortem" analysis shall be edited for selected plant

items/groups. The printout will be initiated by a trip of the equipment. The report shall contain all important analogue values and binary events/alarms, which may have contributed to the trip 6 minutes before as well as 14 minutes after the trip.

* If the trip signals cannot be identified indisputably by the time stamp of the signal

they are to be generated by the so-called "first out" logic.

* The fault report will be printed out automatically after 20 minutes after the trip occurs. Or on request from an overflow buffer memory, containing the last 10 numbers of trips. The trip signal shall be marked on the listing and shall also be mentioned in the heading along with the identification of the fault report of the component.
* Periodic plant data protocol
  + At the end of each hour, or on demand, a protocol of the main plant values (analogue inputs and integrated values) and the calculated efficiency of the units running shall be printed out.
  + At the beginning of each protocol the time and the system-status check shall be printed.
  + Time shall be printed in red if a power failure has occurred which has not been acknowledged. The necessary performance calculations shall be done by the system. The system status check shall indicate any error that has developed in the input item.
  + All points that are currently in alarm during a periodic log shall be printed in red. All values shall be printed as 4 digit values with suitable column heading multipliers such as 0.1, 1.0, 10 etc. Pulse integrations shall be logged as 4 digit values, resetting the pulse integration after a scheduled log.
  + When on demand periodic log is initiated, the current value of the pulse integration is logged but not reset.
* Balance of energy protocol
  + At the end of each day and month, or on demand, a protocol of the integrated energy export and mass flows (fuel oil, fresh water, sea water, etc.) shall be printed out. −Maintenance protocol print-out
  + At the end of each day and month, or on demand, a protocol of the main components that have reached or will soon reach the limit of a prefixed maintenance period shall be printed out.
  + Capacity of the program: Operating time of all plant equipment shall be integrated with an accuracy of plus/minus 10 sec max. Operating time that can be counted (service hours count) shall be 99999 hours.
* Performance calculation protocols
* Upon operators' request, different performance calculation protocols of the unit and pertaining major equipment or subsystems shall be available. The performance calculations package shall be proposed by the Contractor and shall include the efficiency and heat rate calculation of the unit and the main cycle(s).
* It shall be possible to store the plant generated / delivered load and the auxiliary consumption for a period of one (1) year with the following data:

(a) Daily integrated values

(b) Daily maximum values

(c) Daily minimum values

(d) Daily average values. −Binary status report

* Status of all digital inputs and commands for the whole unit or for prefixed groups. To be printed out on demand, with the plant identification code numbers.
* Analogue status report
* Status of all analogue inputs and commands for the whole unit or for prefixed groups. To be printed out on demand, with the plant identification code numbers.
* Scan remove (off-scan) protocol
* On demand, this protocol gives the list of all measuring points disturbed, simulated or removed from the scanning.
* Trend log print out
* On operator's demand, analogue trend log shall be provided and printed out. The operator will select on his own discretion up to six (6) analogue variables and enter the trend interval (1 to 240 minutes).
* The scanning of the selected points will be done with system scanning and the values shall be stored on disk files. After preset time has elapsed or on demand the values will be transferred to the printer with a sample frequency depending on the trend interval. The possibility shall be given to edit the curve.
* Plant Status Protocols
* On request, the printout of the following plant status protocols shall be possible.

(a) List of all analogue control loops in manual mode

(b) List of all function groups and standby logics in manual mode

(c) Status list of all main plant items, like power generating units, seawater pumps, fuel oil pumps, etc. with indication of the operational equipment. The same shall also appear on the screen on operator’s request.

* All the protocols concerning hardware and software of the SCADA system itself will be edited at the system engineer’s workplace (e.g. system status and failure reports, protocols of system interventions.).

#### Editing of Protocols

Each printed paper shall bear the following information at the top of the sheet:

* Date and time
* Designation of the Employer
* Designation of the power plant
* Designation of the unit (or auxiliary equipment)
* Name of the protocol concerned.

In case of protocols on more than one page the heading with process identification (e.g. plant identification code numbers and engineering unit for analogue trend logs) shall also be repeated on every page. The clear text description of the signals shall be clear and easily interpretable without using additional documents.

#### Hardware Specification (Peripherals)

#### **Monitors**

The monitor for plant operator stations shall high resolution 23 inch LCD. The resolution required is 1280 x 1024 pixels or better. The screen illumination shall be enough to give a good readability under the existing lighting conditions in the control room. The dimension and kind of character and symbols shall be selected in such a way that the operator sitting on his chair can easily differentiate between them. The monitor shall be equipped with all necessary control (adjusting) elements accessible on the front plate. For monitors integrated into the desk special care shall be given for the easy replacement. The connection of cables shall be done by cable connectors. High reliability and long life monitors shall be used. The MTBF value of monitor shall be acceptably high.

#### **Keyboard and Pointing Device**

The functional keyboards for plant operator stations shall be adapted to the individual operator tasks and to the monitor functions. They shall contain all keys necessary for the plant operation arranged in an ergonomically, self-teaching manner. Multifunctional keys shall be provided with automatic display for the modified functions. Freely programmable keys (minimum 6) shall be available for special user applications.

For user manipulations on higher levels (e.g. operator hierarchical levels 2 and 3) such as

* Level 1: plant supervision only (selection of monitored pictures)
* Level 2: Level 1 plus plant control functions (e.g. valve open/ closed commands)
* Level 3: Level 2 plus limited configuration functions if available for plant operator (e.g. scan remove).

Key selection or use of password is required. High quality pointing device shall be provided along with the keyboard.

**Printers**

Low-noise A3 / A4 laser printers shall be used. The printers shall have high reliability (MTBF in switched-on position not less than 5000 hours, in printing not less than 1500 hours) with max. ambient temperature of 40 ºC or better. The printers shall be provided with proper auto diagnostic facilities and with failure annunciation. "No paper" alarm shall be given in time on the equipment itself by LED lamp and buzzer and also linked to the alarm system.

### Diagnostic and Programming Station (Engineering Station)

The task of this station is the maintenance and the modification of system configuration (system engineer's tasks).

#### Diagnostic Function

The main tasks of the diagnostic function shall be as follows:

* Monitoring and protocolling in clear text of all events and faults of the digital system and
* of the peripherals (like supply failure of transmitters, switches, failure of printers.
* monitors, etc.) including the protection system, if compatible
* Indication of the exact time when event/failure occurs
* Indication of each parameter and signal of the system on demand
* The information "failure" will show in detail all measures and strategies to be taken
* Indication of each parameter and signal of the system on demand
* Simulation possibility of each and every input signal.

All operator interventions in the system like simulation, scan remove, etc. shall be considered as events and protocolled with exact time and operator's assignment. Possibility shall be given to print out all operator interventions for a certain time interval and all interventions of a certain operator for a given interval or to clear all interventions (e.g. simulations) of an operator for a given interval.

#### Programming Function

The programming function shall contain all necessary functions programming / configuration, modifications/ reconfiguration and for the documentation of these tasks:

* Monitoring/protocolling the system structure/ configuration
* Indication/protocolling each system signal and parameter
* The possibility to elaborate or to modify the structure of the system (configuration/

reconfiguration)

* The possibility to introduce new parameters or to modify existing ones
* Documentation of the actual system configuration, in tabular and graphic form, cross

reference lists, signal lists, etc.

* Set-up of calculation programs
* Set-up of background system for monitoring and protocolling and modifications
* Graphic editing programs.

Reconfiguration or an expansion of the SCADA System has to be done without any interference or redesign to already operating stations. Protocolling of operator interventions shall be handled as specified for the diagnostic station.

**Graphic Editor for Display Mimics**

The editing of mimic graphics shall be done easily, without requiring special knowledge in computer programming. Special software tool packages shall help the operator in his task. A symbol library with a minimum of 128 pre-programmed symbols and with the possibility of further 128 user-defined extensions shall be provided. New symbols can be created at any time or existing symbols can be modified and entered as new symbols. Up to 64 macro-pictures consisting of more individual symbols can be stored and re-used on further pictures. For better orientation dotted background shall be provided. Creation of new symbols shall be done on an appropriate drawing pad with increased size, showing, however, also the original size on the screen.

Edition of graphics shall be possible using only the cursor and a limited number of multifunctional keys. Entering plant identification codes and windows for alphanumeric process data needs only use of alphanumeric keys.

**Software**

The software of the control, supervisory and data acquisition system shall fulfil all functional requirements and special tasks requested by the application of a decentralised operating and centralised supervision/control system of the power plant.

The necessary software for configuration/ reconfiguration/ system development shall not require special computer programming knowledge and shall correspond to the level of an experienced process instrumentation and control engineer. For programming assignment lists and / or graphic methods shall be used. All necessary algorithms shall already be included as firmware.

For the off-line created programs syntax validity and plausibility check with testing possibility under process conditions shall be done before being finally loaded.

All modifications will be first documented and then executed. Possibility of graphic on-line back-up documentation will be preferred.

Besides standard software all necessary application software packages shall be delivered under the scope of the Contract (e.g. calculations, plant management, statistics, special software tools, documentation, etc.).

User licenses for all system and application / SCADA software registered on the name of the Employer that need no annual fees and that permit free upgrades for at least 6 (six) users shall be granted to the Employer along with the system for the operator / engineering stations. The Contractor shall also provide licenses for two lap tops in case a lap top tapped to the SCADA LAN nodes and / or to any of the PLCs needs licenses.

### System Deviations

The Contractor shall provide all hardware and software items for all tasks and functions specified for the SCADA system in any part of the Specification without any extra cost to the Employer.

This shall especially be considered in cases, when the SCADA Vendors’ hardware or software configuration is deviating from the specification. In such cases additional equipment or programs e.g. fault analyser, plant management system, historian server, program for

efficiency and performance calculations... etc. shall be provided by the Contractor within the contractual scope of work to comply with the specification at no cost to the Employer.

### Alarm System

The alarm systems shall contain all alarms for a safe and reliable operation of the plant. Alarms shall be given when important plant values exceed their limits or when abnormal operating conditions occur in the plant.

Alarms shall be initiated by means of:

* Position or limit switches
* Pressure-, temperature-, level or flow switches
* Protection relays
* Fuses and miniature circuit-breakers
* Auxiliary contacts of switchgears, breakers, etc.
* Electronic limit value monitors.
* or generated by the programmed digital system itself as far as internal failures (system alarms) are concerned.

All fuses, circuit breaker, protection relay, miniature circuit breakers, etc., shall be included in the alarm system so that any and each protection relay trip will be annunciated. These alarms shall be combined to a group alarm per cubicle or switchboard. The group alarms shall be connected in such a way that identification of an announced fault within the respective group is easy.

Tripping of motors, motor-operated valves, circuit breakers etc. shall be annunciated with flashing lights via the indicating lamp of the control station (monitor or desk control station). Acknowledgement of this flashing light shall be effected by operating the relevant control pushbutton or control discrepancy switch. Apart from the flashing light of the indicating lamp, such trips shall also be announced on the alarm system. The determination of the individual alarms shall be prepared by the Contractor and will be subject to approval by the Employer.

All alarm messages with time designation will be transmitted via the bus system (highway bus) of the remote control and supervisory system. The selection of signals shall be possible by simple programming without cable modifications.

Alarm annunciation in the central control room shall be done in two separate ways:

* Annunciation by the operator consoles. An accumulation of alarms, e.g. 100 alarms in one second, must not cause any loss of alarms.
* Annunciation on conventional luminous alarm windows on the panels and desk horizontal part. Preferably, all conventional alarms shall be group-alarms of the process, the electrical and the digital system.

In case of alarm, a horn shall sound, the alarm window is flashing and the alarm will be displayed on the alarm monitor. The acoustic horn signal can be cancelled by horn-off acknowledgement pushbutton.

Coming and going alarm signals both for monitor and conventional alarm annunciation system will be announced by flashing lights. The frequency of flashing is higher for coming, lower for going alarms and synchronised for all kinds of alarm annunciations in the same room. By acknowledgement the higher frequency flashing of coming alarms will change to steady light, the lower frequency flashing of going alarms will vanish.

The alarm acknowledgement pushbutton (different from horn acknowledgement) shall be done separately for monitor (on the keyboard) and for the conventional part. Special pushbutton for alarm-lamps testing shall be provided. The alarm signalisation system shall follow the requirements of the standard DIN 19235.

**Alarms on Local Panels**

The alarm system on local panels can be conventional type. In all cases the signals to the remote central alarm system shall be given by potential free (SPDT) contacts for both individual and group alarms. The acoustic signal will be automatically cancelled after 60 seconds.

### Protection System

The main components of the unit shall be interlocked and provided with protection system so that they are protected properly against mal operations and any other fault occurrences, and so that safety is maintained through all operation phases.

The protection equipment shall be of failsafe design and be equipped with on-line automatic test facility.

Any system failure has to be announced as alarm in the central control room. Internal failures of the system shall cause neither the activation of the protection (active failure) nor the blocking of active protection signals issued by the process (passive failure).

Pre warning alarms shall be initiated as far as possible before the protection system trips in order to enable the operators to take precautions. Tripping of a protection system as well as the sources of protection action shall be indicated and recorded as an alarm. Unless otherwise required for special purposes, protection shall remain in the tripped position until the operator resets manually.

The system shall be a programmable digital system, compatible to the SCADA system and preferably a safety PLC of the same make as the control PLCs. The redundancy of the field equipment shall be 2 of 3 or higher, when required (2 out of 4 e.g. drum level). The input cards for these values shall be installed in different cubicles or, if not possible in different racks of the same cubicle with separate power supply. In case when error was detected at the field sensor, the system shall automatically change to 1 out of 2 selection.

The criteria and control commands (process inputs/outputs) shall be hardwired connections; only the transmission of information to other systems will be done by the highway bus system.

The redundancy of the electronic system shall be at least of two channel design. Each channel shall be supplied from different power source. Internal on-line self-checking routines shall be used on both channels. Failed cards/modules have to be announced selectively, and be changeable in on-line mode.

For protection purposes normally closed (NC) contacts and de-energise to trip philosophy shall only be used. The protection system has to fulfil the requirements of the standards DIN 57116 and VDE 0116.

## Conventional Instrumentation on the Local Panels / Boards

### General Design

The same specification shall be applied to the instruments installed in any part of the plant.

The indicators, recorders etc. shall get standard current signals (4 - 20 mA DC) from the analogue output modules (O/A) with the following characteristics:

* High precision of conversion (total accuracy 0.3 % or better)
* Auto-checking of output signal validity
* Linear output signal in a wide range of burden caused by cabling and the instruments

connected (min. 500 Ohm)

* Short circuit and open circuit proof output
* Galvanic separation of each output
* Max. 8 outputs per module used
* Manual check possibility of each output on the card front
* Remote adjustment of all parameters by the digital system.

### Local Panel Instruments

#### Recorders

Recorders shall be of the paperless type with dust proof housing. Recorders with circular charts will not be accepted.

#### Indicators

Indicators shall be of the digital indication type suitable for 4-20 mA input. The accuracy shall be 0.5 %. Repeatability shall be 0.2 % of the range.

For the panel big size digital indicators for e.g. steam or hot water temperature, flow, frequency, unit power output, etc. with 1.0 % accuracy is required.

Indicators for mosaic type panels shall be provided with plug/sockets and shall be removable from the front side.

Sizes of Indicators, Recorders, etc.

The indicating instruments and recorders shall have the following or similar sizes:

* Indicators on local control cubicles: 144 x 72 mm and / or 96 x 48 mm
* Synchronising instruments, generator load diagram Indicator: 144 x 144 mm
* Recorders (line and 6-point): 144 x 144 mm
* Recorders (12-point): 288 x 288 mm
* Indicators on MV switchgear, LV, main distributions, etc.: 96 x 96 mm
* Indications on motor control centres, etc.: 48 x 48 mm
* Mosaic type panels/ boards/ desks: According to the system standard

The control switches, adjusters, etc., on the panels shall harmonise with the above mentioned indicator sizes.

#### Signalisation

Signal lamps with LED’s shall be preferred. The change of LED’s or bulbs shall be easy, without using soldering iron (socket connections).

For mosaic installation the signaling lamps/LEDs shall be installed in mosaic tiles of appropriate size (24 x 48 mm). The windows shall bear proper inscriptions, easily exchangeable, with a minimum of 20 characters. Supply of lamps shall be done from the electronic system. For all lights special "lamp test" pushbutton shall be provided.

#### General On/Off Control Stations

All control stations shall be of pushbutton type of high reliability and long life. For mosaic installation 24 x 48 mm elements shall be used. Each module shall bear exchangeable labels for inscription (min. 20 characters). The connection shall be plug/socket allowing removing the unit from the front side.

#### Analogue Control Stations

The station allows the back-up manual remote control and the supervision of analogue control loops with the following elements:

* Hand/auto, set point increase/decrease, output increase/ decrease pushbuttons
* Hand/auto and failure signaling.

For each analogue remote control station position indicator of the controlled equipment with indication of the control deviation/set point shall be provided.

#### Single Equipment Control Station

The station allows the back-up remote control/supervision of drives and switchgear with the following elements:

* On/off pushbutton for motors/switchgear or open/close pushbutton for motor-operated valves
* Signaling of on/off or open/close status and failures
* Stop pushbutton and signal light for inching operation if necessary.

Position indicator (0 to 100 %) for valves with intermediate position shall also be installed. Flashing signal will display the discordance between actual position and control demand. The signaling system shall follow the requirements of DIN 19235 standard (or equivalent).

#### Sequence Control Stations

The control displays allows the remote control/supervision of tertian level group controls with the following elements:

For sequence control

* Pushbuttons for hand/auto selection and for sequence start/stop −Signalisation of the above functions and failures.

For master controllers

* Pushbuttons for hand/auto, output increase/decrease and set point increase/decrease
* Signalisation of hand/auto, failure, etc.

#### Electrical Measuring Instruments

All indicating instruments shall be of flush mounted design, dust and moisture proof. Ammeters and voltmeters for AC shall be provided with a moving iron mechanism of at least 1.5 accuracy classes, for connection to the secondary side of instrument transformers. Measuring instruments for DC shall have a moving coil mechanism of the same accuracy. Wattmeter’s shall have an electrodynamic measuring mechanism or alternatively a moving coil mechanism if fed by transmitters. Wattmeter’s shall be suitable for unbalanced load.

Indicating instruments shall be provided with a wide range linear scale.

All indicating instruments shall generally withstand without a damage a continuous overload of 20 % referred to the rated output value of the corresponding instrument transformer. Moreover, ammeters shall not be damaged by the passage of fault-currents within the rating and prospective fault duration time of the associated switchgear through the primaries of the corresponding instrument transformers.

If more than one measured value is indicated on the same instrument, a measuring point selector switch shall be provided next to the instrument and shall be engraved with a legend specifying each selected measuring point.

Ammeters provided for indication of motor currents shall be provided with suppressed overload scales of 2 times full scale.

Energy meters shall have an error of maximal 1 %. The casings shall be dust and moisture proof and shall fit into the switchboard in such a way as to permit reading without opening the corresponding front door. They shall be suitable for unbalanced load. Their counter shall comprise 5 digits before and 1 digit after the decimal point.

The Generator Load Diagram Indicator shall indicate the actual value on a screen in such a way that the two variables (MW and MVAR) are indicated as illuminated lines (horizontal and vertical). The intersection of these lines means the actual point of load. The screen shall be provided with coordinates as a transparent grid and shall show the generator load diagram and power factors (-0.5 to +0.5 in 0.1 steps). The set point coordinates, set point area and the inadmissible areas shall be shown in different colours.

Operation hours counter shall have 5 digits before and 1 digit after the decimal point.

## Local Control Room

### Function

The plant instrumentation shall be selected and designed in such a way that all specified functions can be easily performed by the operator from the Local Control Rom.

The instruments to be surveyed and actuated in the local control room shall be arranged on control panels and control desks in a logical and clear manner. The anthropotechnical aspects should be obeyed.

### Equipment

The design and construction of control panels and desks shall comply with the relevant Specifications, in particular the General Electrical Specifications. Mosaic tile sizes shall be standardized, whereby 48 x 48 mm are preferred.

Desks shall have an inclined vertical part in addition to the slightly inclined horizontal desk console. The vertical part shall bear the required displays along with unit alarm annunciation windows and indicators.

The horizontal part shall be reserved for integrated keyboards, push buttons, writing pad, communication services, etc. and for all manual operating devices following a simplified mosaic type mimic diagram.

Panels in the local control room shall be totally closed type, preferably with access doors from the rear side with mimic diagram for station and unit auxiliaries.

## Cabling and Wiring

### General Design

All power and control cables for the instrumentation and control systems shall form a safe and reliable system. The General Requirements for Electrical Equipment and other relevant specifications shall be applied.

Power supply cables of the instruments shall be separated from signal cables, i.e. it shall be forbidden to use one cable for power supply and signals.

Screened instrument cables shall be used to transfer analogue and binary signals. In an electromagnetically noisy environment double screened (screen for each pair and common metal screen) instrumentation cables shall be used for all analogue signals. The analogue and binary signals from sensors, switches and transmitters are transferred by individual signal cables to junction boxes.

Cabling between electronic cubicles and the switchgear, the control room and the field junction boxes shall be made by screened instrument trunk cables. Trunk cables shall have 20 % spare wires after final commissioning.

### Wiring in Cubicles, Desks and Panels

The wiring inside of cubicles, desks and panels shall be made in the manufacturer's factory. Disconnectable connections shall preferably be done by plug-in connector blocks, individual connections by spring loaded FASTON type connections. Use of screwed terminals should be avoided.

Fix installed wires and cables shall be connected e.g. by thermipoint or wire wrap technology, without using soldering. For coaxial and flat cables for bus systems appropriate reliable special connections may be provided. In case of fibre optic cables all connections shall be factory made.

Direct cabling of cards is not allowed. Plug-in cards shall be used, preferably the 19" rack system. All wiring/interconnections between card sockets will be done on the backside of the cubicles, freely accessible for maintenance.

### Outgoing Cables

The cable connections between cubicles in the equipment room and switchgear or field will be realised by conventional type multicore cables (see specification of cables in the electrical Part). Whenever required, shielded cables shall be provided.

Cable entries in the Electronic Room shall be done from the bottom of the cubicles. Proper fire restrictive closing of cubicle bottom according to the relevant prescriptions shall be realised.

### Shielding and Grounding System

Design and method of grounding and the treatment of the common reference and the cable screens shall be unified for all control systems and DC supply systems throughout the plant.

In order to avoid double earthing of cable shields by earth fault or by erroneous connection a systematic shielding network with easy checking possibility shall be realised.

The grounding of all cable shields shall be done systematically in the Electronic Room in the relevant cubicles on an isolated bar with disconnectable connections.

All isolated shielding bars of the individual cubicles shall be connected to a central earthing bar situated in the Equipment Room easily accessible for maintenance. This central bar will be earthed individually apart from the electrical earthing of equipment (electrical shock protection). By this way successive cubicle by cubicle and point by point checking of shielding earth faults can be performed periodically.

## Power Supply

### 24 V DC Supply System

The supply for the I&C equipment shall be provided from 24 V DC supply from battery or from UPS. Each power supply distribution bus for DC shall get two in feeds from separate batteries. From this power supply cubicles each electronic cubicle shall get two separate feeders provided with isolating diodes.

Every measuring loop (transmitter and auxiliary circuits) shall be fused separately. The closed analogue control loops shall be individually fused. Each loop shall have separate fusing for both the automatic and the manual control part if system allows. Thus the manual control shall remain workable if the automatic control fails, and vice versa.

For fusing miniature circuit breakers with auxiliary contacts for alarm shall be provided. The alarm shall be indicated by an alarm lamp in each cubicle and by a group alarm for each type of cubicle in each room. Miniature circuit breakers with two sets of auxiliary contacts: one for automatic protection, and the other one for intentional switch-off shall be provided and selectively alarmed.

All the miniature circuit breakers and the power distribution as far as not integrated in electronic cubicles shall be assembled in auxiliary power supply cubicles, installed in the equipment room, the electrical room or the control room. For each distribution bus voltage supervision with alarm in the control room shall be provided.

Great care shall be given to the general design of the power supply of the instrumentation interconnecting network. The main concern shall be to minimise the risk of failure, and in case of abnormal condition, to minimise the damage and to facilitate the detection of the failure.

Basically grounded system is required. In case of ungrounded system as manufacturer standard, isolation monitoring system shall be provided measuring the total resistance of the circuit with respect to the ground. In addition, a ground detection system shall be provided in order to locate the ground failure. Isolation monitoring as well as failure location detection shall be automatically performed continuously during plant operation without interfering with the control signals.

A loss of analogue drive controller’s power supply is probably the most important failure. Even with a provision of a back-up power it is necessary that automatically all the final control elements fall into safe condition, and the control loops transfer automatically to manual mode with necessary annunciation. Moreover, on a system power failure the system shall transfer to manual. On a resumption of power the system shall not return back to automatic.

### AC Uninterrupted Power Supply System

The AC UPS system shall secure the power supply e.g. for the following equipment:

* SCADA equipment
* Recorders and printers
* Generation units local panels PLCs with AC power supply, necessitating continuous, safe supply
* Central control equipment with 230V power supply.

The DC/ AC inverters are defined in the Electrical Specifications.

# Annex

## Drawings

The bidder required to provide all drawings in softcopy format including AutoCAD Drawings.

**The list of drawings:**

|  |  |  |
| --- | --- | --- |
| **Item** | **Title** | **Drawing Number** |
| 1 | Existing SCADA System Architecture | 0030.0.G.CM.001 |

### Existing SCADA System Architecture

Single Line Diagram Drawing No.: 0030.0.G.EV.001

