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“जाने का अधिकार, जीने का अधिकार”
Mazdoor Kisan Shakti Sangathan
“The Right to Information, The Right to Live”

“पुराने को छोड़ नये के तरफ”
Jawaharlal Nehru
“Step Out From the Old to the New”

IS 15654 (2006): Supervisory control and data acquisition (SCADA) system for oil and gas pipeline [LIITD 10: Power System Control and Associated Communications]
Indian Standard

SUPERVISORY CONTROL AND DATA ACQUISITION (SCADA) SYSTEM FOR OIL AND GAS PIPELINE

ICS 33.200; 75.200
FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Power System Control and Associated Communications Sectional Committee had been approved by the Electronics and Information Technology Division Council.

This standard on SCADA system (Supervisory Control and Data Acquisition) provides guidelines for the performance analysis and application systems used for supervisory control and data acquisition for oil and gas pipelines covering natural gas, LPG, crude oil, multiproduct, etc, in attended or unattended stations like terminals, sectionalizing valve stations, compressor and pump stations. The system covered by this standard typically use servers, workstations, front end processors in the master stations and in Remote Terminal Units (RTUs)/Intelligent Electronic Devices (IEDs) at the remote stations. The SCADA provides facilities for incorporating monitoring and control functions in the system installed.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2: 1960 'Rules for the rounding off numerical values (revised)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.
1 SCOPE

1.1 This standard provides guidelines for the definition, specification, performance analysis, and application of systems used for supervisory control and data acquisition for oil and gas pipe lines, in attended or unattended stations like terminals, sectionalizing valve stations, including those associated with compressor stations/pump stations. Systems covered by this standard typically use servers, workstations, front end processor in the master station and RTU (Remote Terminal Unit), IEDs (Intelligent Electronic Devices) at the remote stations. Such a system provide facilities for incorporating monitoring and control functions, after the system is installed.

1.2 The oil and gas pipe line include pipelines for natural gas, LPG, crude oil, multiproduct, etc.

2 REFERENCES

The standards listed in Annex A are necessary adjuncts to this standard.

3 TERMINOLOGY

The definitions of various terms used in this standard shall be as given in IS 12746 (Part 1/Sec 3), IS 1885 (Part 50) and all sections of IS 1885 (Part 52).

4 FUNCTIONAL CHARACTERISTICS

The control and data acquisition equipment governed by this standard may be arranged in various configurations, and may perform some or all of the functions identified in this clause.

Typically, control and data acquisition equipment compose a system with at least one master station and one or more Remote Terminal Units/Intelligent Electronic Devices (RTUs/IEDs). Figure 1 illustrates the possible data and control flow between a master station and one or more RTUs/IEDs.

4.1 Typical Equipment Functional Diagrams

Functional diagrams of typical RTU and master station equipment and configurations are described below:

The links between the master station(s) and RTUs, and between the sub-master RTU and its slave RTUs, can be any suitable communication media but in case of a cross-country pipeline the same is recommended to be OFC (Optical Fibre Cable) based dedicated communication system. In case the OFC based dedicated system is not practical then lease line communication network or any other communication network such as satellite based communication, radio communication, etc, are recommended to be used for control functionality. However if only monitoring of data is envisaged at intervals (not in real time) and no real time control operation is to be performed in that case dial-up line can also be used. The communication protocol typically used requires a master station to initiate message transactions. In some cases the RTU can initiate the communication messages. For additional communications protocol information, see IEC 60870-5-101, IEC 60870-5-104 or DNP 3.0, etc.

The functional components of a master station are illustrated in Fig. 2. A dual server with hot standby master station is illustrated in Fig. 2, however, a single server master station may be adequate for some applications. In case of a cross-country pipeline it is recommended to go for dual master stations with emergency master station at some different location to cater to emergency like fire, etc. However, user may decide requirement of dual master station depending upon complexity and criticality of the pipeline network.

There may be different master stations (regional) collecting data from different pipeline network and a central master station which is updated with data from all the other regional master stations so that the entire data is available at a central place as illustrated in Fig. 3.

If the data is required to be viewed from different sites it is preferable to have WEB enabled system so that data can be viewed using intranet. The WEB enabled system should have the information security features like firewalls, intrusion detection system, etc. Also if the control functions need to be executed from different sites provision should be there for extending remote workstations. Separate history server may be used for historical data recording. Separate application server may be kept for running different pipeline applications. Auxiliary storage devices may be kept for routine backup of the system.

If required, a network time server (GPS) can be installed to synchronize entire network.
IS 15654:2006

**Fig. 1 Master/RTU Functional Data/Control Flow**

**Fig. 2 Master Station Functional Block Diagram**
The functional components of an RTU are illustrated in Fig. 4. Various interconnections of master station(s) and RTU(s) are illustrated in Annex B.

4.2 System Functional Characteristics

This clause provides guidance for helping both users and suppliers jointly define the functional capabilities that may be in a system.

Each generic function is described in terms of the minimum features or characteristics that shall be addressed to adequately define the function.

When the feature or characteristic is fixed by the design of the equipment, the burden of definition rests on the supplier (for example, number of inputs/outputs per card). However, variable features (for example, scaling resistors, switch settings, and software) shall be jointly defined by the user and the supplier.

4.2.1 Communication Management

The requirements to communicate between the master station(s) and the RTUs shall be well defined. See IEC 60870-5-101, IEC 60870-5-104 or DNP 3.0 for an example of the definition of a communication protocol.

The topics to be defined include:

- Message protocol;
- Number of channels;
- Channel considerations;
- Channel switching;
- Number of RTUs per channel and/or channels per RTU;
- Communication error reporting, failure criteria, and recovery;
- Channel quality monitoring (normal and backup);
- Channel diagnostic/test provisions;
- Equipment interfaces;
- Report-by-exception polling; and
- Point scan/RTU scan on demand.

4.2.2 Data Acquisition

The characteristics for each data type shall be defined. Ranges of data input, scale factors, rates, and accuracy shall be defined for the data types to be supported such as:

- Analog inputs,
- Status inputs — two state
  Status inputs — more than two state (more than two state status inputs are accomplished by using multiple two state status inputs),
- Status inputs — with memory,
- Accumulator pulse inputs,
- Sequence-of-events inputs, and
- BCD inputs-multi-bit.

The data acquisition capability for each data type shall be defined in terms of the following characteristics:

- Scan groups — Number of scan groups size of each group, points in each group.
- Scan cycle — Time to complete the acquisition of a scan group from all remotes on the
4.2.2.1 RTU data

The capacity (total inputs) and rate of acquisition (inputs per second) for field data interfaced to the RTU equipment shall be defined for all applicable data types (see 5.4).

The modularity (for example, minimum number of inputs per card) of each data type shall also be specified.

4.2.2.2 Master station data

The capacity (total inputs) and rate of acquisition (inputs per second) for local or RTU data interfaced to master station equipment shall be defined for all applicable data types (see 5.4).

4.2.3 Data Processing

Data processing capabilities shall be defined for each equipment item and all applicable data types. Systems with report-by-exception functions shall have the capability to report all data for initialization and periodic update purposes.

4.2.3.1 Analog data

Analog data is used to describe a physical quantity (that is, pressure, temperature, flow density, specific gravity, etc.) that normally varies in a continuous manner.

The analog data processing options to be supported at both the master station and the RTU shall be defined. This is the responsibility of both the user and supplier. Particular attention shall be given to input data validity processing (for example, the validity of the data) and to the interface between the supervisory control function and the analog data processing function.

a) Data input scaling shall give adequate consideration to off-normal operation of the system (for example, pressure out of range).

b) Data change detection may be a function included as an alternative to processing every input on every scan. It is accomplished by testing to see if the new value for each input is within N digital counts (for example, dead band) of the last stored value for that input. The new value shall replace the last stored value only if the dead band was exceeded and then the input will be further processed as defined below.

When the data change detection function is included, the following characteristics shall be defined:

Location of processing, RTU or master station, or both.
4.2.3.2 Status data

Status data is used to describe a physical quantity (for example, device position) that has various possible combinations of discrete states. The information content of a digital signal is expressed by discrete states of the signal such as the presence or absence of a voltage, current, or a contact in the open or closed position.

The status data processing options to be supported at the master station and the RTU shall be defined. This is the responsibility of both the user and supplier. Particular attention shall be given to input data validity processing, and to the interface between the supervisory control function and the status data processing function:

a) Data change detection may be a function included as an alternative to processing every input on every scan. Data change detection is performed by testing to see if the current state is the same as the last stored state for that input. Changed data shall replace the last stored value and the point, or group of inputs, shall be routed to other functions such as data report-by-exception, alarm processing, or both. When the data change detection function is included, the following characteristics shall be defined:

1) Location of processing (RTU or master station),
2) Quantity of data reported when a single input changes,
3) Minimum signal duration to be considered a change, and
4) Security against loss of change data.

b) Data report-by-exception function is used to eliminate unnecessary communication of unchanged data from the RTU(s) to the master station. Its input is received from the change detection function. When the status data report-by-exception function is included, the following characteristics shall be defined:

1) Percent of status point changes per scan that result in the channel load associated with reporting all status points from the RTU.
2) Description of logic in the master station or RTU that can be used to select between using the status report-by-exception or the report all status data function when acquiring status data from each RTU.

4.2.3.3 Accumulator data

The following characteristics shall be defined when
pulse accumulation and/or accumulator data processing is included:

a) Input circuit (two or three terminal and how input circuit operates);
b) Sources of freeze command, if any (internal/external);
c) Ranges of values (RTU and master station);
d) Nominal and maximum counting rates;
e) Source of memory power;
f) Input voltage, if externally powered; and

g) Reset command (if any).

4.2.3.4 Sequence-of-events (SOE) data
The following characteristics shall be defined when SOE data acquisition capability is included:

a) Time resolution at RTUs;
b) Method of system time synchronization;
c) Time accuracy between any two RTUs;
d) Number of SOE inputs per RTU;
e) Size of buffers (number of SOE events that can be stored) per RTU;
f) Time (minimum/maximum) between successive change(s) of an input;
g) Method of indicating that SOE data is available at the RTU;
h) Data filter time constant and accuracy (for example, contact de-bounce);
j) Data time skew (introduced by de-bounce filters); and
k) Number of SOE events that can be transferred to the master station in one communications transaction.

4.2.3.5 Computed data
The following characteristics shall be defined when the capability of computing data (which are not directly measured) is included:

a) Location (RTU or master station);
b) Equations supported;
c) Resulting data types (numeric or logical, or both); and
d) Downstream functions (for example, limit checking).

4.2.3.6 Alarm data
The following characteristics shall be defined when the capability to process and report alarm conditions is included:

a) Conditions reported as alarms;
b) Methods of acknowledgment (single or groups);
c) Methods of highlighting alarms (for example, flash, tone, etc);
d) Information in alarm messages;
e) Hierarchy of alarms (priority level);
f) Size of alarm queue(s);
g) Queue management (for example, time ordered); and
h) Alarm limit(s).

4.2.3.7 Digital fault data
The RTU(s) and their microcomputers are sophisticated enough that they can monitor variations in data at such a rate as to be able to record data for pre-fault, fault, and post-fault analysis. The following characteristics shall be defined when the capability to process and report digital fault data is included:

a) Samples,
b) Number of data points per fault,
c) Maximum buffer size (total samples to be stored),
d) Sample triggers,
e) Number of faults to be reported and stored, and
f) Means of reporting digital fault data.

4.2.4 Supervisory Control Characteristics
When the capability to remotely control external devices and processes is provided, the characteristics of such a control capability shall be defined (see 5.4). Definition of characteristics common to all control interfaces shall include following and a time out alarm also in case control is not executed:

a) Control sequence description,
b) Type of checkback message (echo or re-encoded),
c) Security of control sequences,
d) Immediate operate controls,
e) Broadcast controls, and
f) Time out alarm.

4.2.4.1 Equipment control with relay interface
Control using a relay output shall be defined as follows:

a) Dwell time of relay contacts; and
b) Number of relays that can be simultaneously energized in each type of RTU processing actions (for example, logging and alarm suppression).

4.2.4.2 Equipment control with setpoint interface
Control using a setpoint output shall be defined as follows:
a) Resolution of setpoint value;
b) Duration of output value;
c) Processing actions (for example, limit check, equation, and alarms); and
d) Electrical interface.

4.2.4.3 Equipment/Process control with electronic interface

Control using an electronic interface shall be defined as follows:
a) Timing diagram of signals;
b) Interface communication protocol;
c) Processing actions associated with control; and
d) Physical interface.

4.2.5 Automatic Control Functions

When the capability to automatically control external devices provided the characteristics of such control capabilities shall be defined as follows:
a) Location of automatic control logic (RTU or master station);
b) Control equation(s);
c) Feedback value and accuracy, if closed loop;
d) Frequency of execution;
e) User alterable control parameters;
f) Associated logging or alarming; and
g) Method of altering control logic.

4.2.6 User Interface Characteristics

User interface functions shall be defined when the capability to support operating or maintenance personnel at the master station. The interface functions shall be defined in 4.2.6.1 to 4.2.6.4.

4.2.6.1 Control of equipment functions

When operator controllable functions are included the applicable characteristics shall be defined for the included functions, such as:
a) Control output options
   1) Enable/disable,
   2) Tagging (types and uses),
   3) Local/remote, and
   4) Open (off)/close (on).
b) Control of data acquisition
   1) Enable/disable scan (inputs or stations),
   2) Enable/disable processing,
   3) Manual entry of data,
   4) Change scan frequency by group, and
   5) Assign/re-assign data to a group.
c) Control of data processing
   1) Setting date and time,
   2) Setting input change limits,
   3) Defining formats,
   4) Defining conversion data,
   5) Defining operator override values, and
   6) Defining normal/abnormal status/data quality status.
d) Control of alarm processing
   1) Enable/disable individual alarms,
   2) Enter/edit alarm limit value(s),
   3) Enter/edit alarm dead band value(s),
   4) Enter/edit return-to-normal criteria,
   5) Enter/edit alarm assignment to area of responsibility,
   6) Enter/edit alarm priority,
   7) Acknowledge alarms (individual/page),
   8) Silence audible alarm,
   9) Inhibit alarms, and
   10) Override invalid alarms.
e) Control of function checks
   1) Enable/disable, and
   2) Change frequency.
f) Control of automatic control functions
   1) Enable/disable,
   2) Modify criteria,
   3) Add/delete control functions, and
   4) Reset to reference level or position.

4.2.6.2 Display functions

The applicable characteristics shall be defined when the following formats are included:
a) Generation of display formats
   1) Format definition capabilities,
   2) Use of colours,
   3) Use of special features (flash, reverse video, etc),
   4) Control level of detail (declutter),
   5) Display call-up time, and
   6) Use of features (pan, zoom, windowing, etc).
b) Standard formats
   1) Index formats,
   2) System formats,
   3) Communication channel format,
   4) Summary of inhibited alarms,
   5) Input point profile formats,
6) Alarm summary,
7) Tag summary,
8) Abnormal summary,
9) Override summary, and
10) Station notes format.

c) Control of cursor
1) Cursor operation,
2) Selection of formats,
3) Response time,
4) Update cycle (from database),
5) Paging of multi-page formats, and
6) Selection of declutter (zoom) levels.

4.2.6.3 Digital and analog display functions
When such display devices are supported the applicable characteristics shall be defined as follows:

a) Digital displays
1) Numeric range with decimal, and
2) Update frequency.

b) Analog displays
1) Ranges, and
2) Update frequency.

4.2.6.4 Hard copy functions
When support of hard copy devices is required such as loggers, video copiers, etc, the applicable characteristics shall be defined as follows:

a) Device assignments
1) Initial,
2) Automatic re-assignment, and
3) Manual re-assignment.

b) Generation of log formats
1) On-line/batch capabilities,
2) Symbols supported, and
3) Spooling capabilities.

c) Demand logs
1) Standard/Customised formats, and
2) Time for response.

d) Logged activities
1) Alarms;
2) Standard events (for example, user and device actions);
3) System events (for example, equipment failover and communication failure); and
4) Output from diagnostic routines.

e) Device performance
1) Print speed (characters/second),
2) Print quality (dots/inch), and
3) Colour requirements.

4.2.7 Sub-master RTU
An RTU can act as a master station with respect to other slave RTU(s) and Intelligent Electronic Device(s) [IED(s)]. The master station functions allocated to such sub-master RTU shall be defined using the applicable preceding subclauses. This is the responsibility of both the user and supplier. The user shall define the applicable characteristics as follows:

a) Database,
b) Communication protocol,
c) Point configuration,
d) Scan interval,
e) Downloading characteristics, and
f) Other characteristics defined in this standard that may be applicable.

4.2.8 Backup and Failover
It is common practice today to failover a system by switching peripherals or the total computer subsystem in order to recover from a peripheral or computer failure. In a distributed computer implementation, functions may be re-allocated to recover from a hardware failure. The applicable characteristics shall be defined when both primary and backup facilities are provided as follows:

a) Database backup
1) Data residency (bulk or main memory),
2) Frequency of backup (by data type), and
3) Other uses of backup facilities.

b) Database update
1) Data residency (bulk or main memory),
2) Frequency of update (by data type), and
3) Other uses of update facilities.

c) Failure monitoring
1) Method of failure detection,
2) Response time for detection, and
3) Effect on a programme or task in progress when fail over occurs.

d) Failover
1) Method of failover,
2) Time required for failover,
3) User interface response following failover,
4) User actions following failover, and
5) Effect on a programme or task in progress when failover occurs.

4.2.9 Historical Data
The appropriate characteristics shall be define when the capability for historical data archiving and retrieval is included as follows:

1) Data residency (bulk or main memory),
2) Frequency of backup (by data type), and
3) Other uses of backup facilities.
a) Data quantities,
b) Data intervals,
c) Number of data intervals,
d) Method of file management,
e) Method of data archiving,
f) Method of data retrieval, and
g) Data usage (for example, displays, reports, applications, etc).

4.2.10 Local Networks

Local area networks may be used to provide data exchange capability between the different functions at a site (for example, IEDs, RTUs, etc). When the capability of a local area network is included, the characteristics of such communication capability shall be defined as follows:

a) Bit rate,
b) Electrical interface (for example, 10/100 BaseT, RS-232, RS-485, etc),
c) Equipment to be interconnected,
d) Transfer rate (bytes per second),
e) Protocols (for example, Ethernet, TCP/IP, etc),
f) Redundancy, and
g) Reliability (for example, sectionalizing for isolating failures).

4.2.11 Third Party Interface

The system should be compliant with user defined open interface like ODBC (Open Data Base Connect), etc for the integration of third party software/hardware.

5 INTERFACES

The control and data acquisition equipment shall have interfaces as described in this clause. The interfaces described consist of those illustrated in Fig. 5.

5.1 Mechanical

5.1.1 Enclosures

Equipment enclosures shall be suitable for the proposed environment. Enclosures should therefore conform to the relevant IP Classification tests as per IS 13947 (Part 1).

5.1.2 Electromagnetic Compatibility (EMC) and Special Requirements

The location of access doors, enclosure mounting requirements, temperature/ventilation requirements, terminal-block type and location, cable entry locations, and special cabling and connector requirements should be specified for individual applications.

Electromagnetic Interference (EMI) and Radio Frequency Interference (RFI) characteristics of enclosures should be determined in conformance with IEC 60870-2-1 (1995) for minimum level 2 requirements.

5.2 Grounding

Control and data acquisition equipment shall not ground a floating power source. Care shall be exercised to ensure ground compatibility when grounded power sources are used. The code of practice for earthing may be referred as given in IS 3043 and IEEE Green Book Standard 142:1991.

FIG. 5 MANUAL AND SUPERVISORY CONTROL EQUIPMENT INTERFACE BLOCK DIAGRAM
5.2.1 Safety or Equipment Ground

The safety or equipment ground protects personnel from injuries caused by live or hot conductors coming in contact with the equipment cabinet or enclosure. The ground conductor shall be bundled with the power conductors, but be insulated from the power conductors and from other equipment and conduit. The ground conductor is usually terminated in the cabinet enclosure, and grounded only at the same point that the electrical service or UPS neutral is grounded. All cabinets and/or enclosures comprising any control or data acquisition equipment shall be grounded together by means of a ground cable or strap.

Any buildings or allied structures for keeping all cabinets and/or enclosures comprising any control or data acquisition equipment shall be protected from lightening and code of practice for protection against lightening may be referred as given in IS 2309.

Additionally, metal decking or other electrical paths should be grounded only at the same point that the electrical service or UPS is grounded. Safety or equipment grounds shall be established in accordance with SP 30.

5.2.2 Signal or Instrumentation Circuit Ground

The signal or instrumentation circuit ground shall be connected to an external ground at a single point so that ground loop conditions are minimized. The shielded wire, drain wire, and/or ground wire of input/output cables shall be terminated at one ground point in each cabinet. These ground points shall be connected together and connected to the facility ground. Caution shall be used to prevent inadvertent ground paths from devices such as convenience outlets, conduit, structural metal, test equipment, and external interfaces.

A special caution on filtering is worth noting. If the noise is shunted to the signal ground, then it becomes another source of signal reference corruption. Sometimes separate power, noise, digital, and analog ground buses are necessary. However, the NEC requirement for a single point safety grounding source shall always be met. A very important design rule is to keep all signal reference voltages, at all frequencies of operation, as close to zero as possible (that is, at zero voltage signal reference).

5.2.3 Electrical Ground

The station power source shall be grounded in accordance with the NEC.

5.3 Electrical Power

The electric power interfaces to control and data acquisition equipment shall meet the following requirements:

a) The alternating current source defined below may originate directly from the station source or from a regulating/uninterruptible power supply.

b) Equipment operating on direct current shall not sustain damage if the input voltage declines below the lower limit specified or is reversed in polarity.

5.3.1 Master Station

Master station equipment shall be capable of operating without error or damage with one or more of the following source voltage ranges:

a) 230 V ac single phase or three phase ±10 percent at 50 Hz ±3 percent,

b) 21 to 29 V dc (24 V dc nominal),

c) 42 to 58 V dc (48 V dc nominal).

5.3.2 Remote Station

Remote station equipment shall be capable of operating without error or damage with one or more of the following source voltage ranges:

a) 230 V ac single phase ±0 percent at 50 Hz ±3 percent,

b) 21 to 29 V dc (24 V dc nominal),

c) 42 to 58 V dc (48 V dc nominal), and

d) 10 to 16 V dc (12 V dc nominal).

5.3.3 Power Quality

Station power shall be of such quality (free from noise, spikes, etc) to be suitable for use as a source to electronic equipment. The user and supplier shall both be responsible for conditioning (as required) the electric power for use by SCADA equipment. The one end of ac power supply to master station for SCADA system should be grounded with isolating transformer.

5.3.4 Internal Noise

The control and data acquisition equipment internally generated electrical noise, from 1 000 to 10 000 Hz, appearing on the power source terminals shall be less than 1.5 percent (peak to peak) of the external power source voltage. This is measured into an external power source impedance of 0.1 to minimum.

5.4 Data and Control Interfaces

Data and control interfaces consist of electrical interconnections between control and data acquisition equipment and the device being monitored and controlled. Two types of signal paths are defined as follows:
a) Data paths — Inputs to data acquisition or supervisory control equipment, and

b) Control paths — Outputs from data acquisition or supervisory control equipment.

For each input (data) or output (control) path, various signal characteristics shall be defined to specify the interfaces between equipment.

Data and control signal cabling, which are external to control and data acquisition equipment, are not specified.

5.5 Communication

5.5.1 Master Station/RTU Links

Communication interfaces consist of functional, mechanical, and electrical interconnections between control and data acquisition equipment and the communication apparatus. Any specific application requires one of the two following types of general signal interfaces.

Signal interfaces between the control and data acquisition equipment and the data communication equipment (for example, a data modem) occur whenever the data communication equipment is not packaged as an integral part of the control and data acquisition equipment, as illustrated in Fig. 6.

Signal interfaces between the control and data acquisition equipment and a communication channel are illustrated in Fig. 7.

Subsequent clause define specific signal characteristics for these mentioned interfaces. However, one of the characteristics is common to both types of interfaces and shall be measured regardless of the configuration utilized. This characteristics is:

Channel bit error rate is measured between data communication equipment and control and data acquisition equipment. Due to the variety of channel and modem qualities available and in use, an average value of 1 bit error in 10⁶ bit is recommended for design and analysis purposes.

5.5.2 Sub-master/Slave RTU Links

The sub-master/slave RTU links shall consist of at least one communication link to a master station as well as at least one additional link to slave RTUs, or a link to a distributed RTU module of the same RTU, or a link to an Intelligent Electronic Device (IED).

5.5.2.1 Sub-master RTUs

The communications link(s) to the master station(s) is identical to that described in 5.5.1.

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Fig. 6 Signal Interfaces Between Control and Data Acquisition Equipment and Data Communication Equipment

<table>
<thead>
<tr>
<th>CONTROL AND DATA ACQUISITION EQUIPMENT (1)</th>
<th>DATA COMMUNICATION EQUIPMENT (2) (data modem)</th>
<th>COMMUNICATION CHANNEL (3)</th>
</tr>
</thead>
</table>

NOTES
1 This equipment is called data terminal equipment (DTE) in the standards referenced.
2 This equipment is commonly called a data modem, but called data communication equipment (DCE) in referenced standards.
3 Channel includes microwave, radio, cable, fiber optic types, etc.

Fig. 7 Signal Interfaces Between Control and Data Acquisition Equipment and Communication Channel

<table>
<thead>
<tr>
<th>CONTROL AND DATA ACQUISITION EQUIPMENT (1)</th>
<th>COMMUNICATION CHANNEL (2)</th>
</tr>
</thead>
</table>

NOTES
1 Data modem is packaged as an integral part of this equipment.
2 Channel includes microwave, radio, cable, fiber optic types, etc.
5.5.2.2 Remote terminal units

The communication links to slave RTUs is similar to that described in 5.5.1, except that the role of the master station is assumed by the sub-master RTU.

5.5.2.3 IEDs

The interface described in 5.5.1 is typical. These interfaces vary among IED suppliers and therefore coordination and specific definitions may be required when interfacing with IEDs. Further, the user is cautioned that the master station RTU protocol may not support the acquisition of data from, and the control of, the IEDs.

5.6 User Interface (UI)

The user interface is defined as the user contact with the control and data acquisition equipment.

The user interface for operation concerns standards and recommendations for information displays, control capabilities, colours, and user interaction with the equipment and is given below.

5.6.1 Information Displays

Characters used by printers, loggers, and illuminated displays shall have unique codes so that their display may be electrically initiated. The alphanumeric characters and their corresponding codes as defined in IS 10315 shall be used to represent alphanumeric data at the user interface. A set of graphic symbols shall be part of the system. The capability to create additional graphic symbol and graphics by the user is to be provided.

5.6.2 Control Capabilities

The capabilities provided for operator inputs at the user interface are defined as the control capabilities. The control capabilities may include a combination of the following:

a) Keys and switches (alphanumeric or function, or both);
b) Cursor (mouse, trackball, joy stick, or key controlled);
c) Light pen;
d) Poke points (defined monitor displayed control selection fields); and
e) Pull down or pop up menus.

The user's input to the UI equipment shall be recognized and acknowledged (valid or invalid) to the operator within 0.5 s. The UI equipment shall confirm control actions using the reencoded checkback message from the RTU within 2 s.

When labelled function push buttons are included in control and data acquisition equipment, the labels shall be legible from a distance of approximately 1 m in the user specified environment. When lighted push buttons are included, the significance of the state of the light (on, off, blinking) shall be clearly defined and shall be consistent throughout the system.

Control push buttons (for example raise, lower, trip, open, and close) shall be within convenient viewing distance of the information display that will be used during the control operation.

5.6.3 Colour Codes

The standard meanings for colours (for example, monitor displays, status lights) used at the UI to highlight the condition of device monitored and controlled through control and data acquisition equipment shall be defined by users.

The significance of colours shall be consistent throughout the system.

The color status of a device under operator control shall only change to its new state (may include attributes such as colour and shape change, flashing, etc) after the status of the device has changed.

5.6.4 Interactive Dialogue

The activity at the UI during operational use of control and data acquisition equipment shall be clearly described and shall be consistent throughout the system.

5.6.5 Alarms

When alarm conditions detected by control and data acquisition equipment are first interfaced to the user, both an audible (voice, tone, or bell) and visual (flashing light or symbol) annunciation shall be presented. It shall be possible to silence the audible alarm without affecting the visual annunciation. The visual indication of each alarm condition shall remain as long as the alarm condition exists.

5.6.6 Dialogue During Control

The selection of a point for a user control action shall result in a visual feedback at the user interface. This positive feedback to the user shall signify that the control and data acquisition equipment is ready to accept a control action. The results of the control action (check-before-operate or direct operate) shall be displayed only after a status change has been received from the RTU equipment.

6 ENVIRONMENTAL CONDITIONS

This clause contains a definition of the environment in which control and data acquisition equipment is required to operate.
There are unusual conditions that, where they exist, shall receive special consideration. Such conditions shall be brought to the attention of those responsible for the application, manufacture, and operation of the equipment. Devices for use in such cases may require special construction or protection. The user should specify those special physical requirements that apply to specific locations. Examples are:

a) Damaging fumes or vapours, excessive or abrasive dust, explosive mixtures of dust or gases, steam, salt spray, excessive moisture, or dripping water;
b) Abnormal vibration, shocks, or tilting;
c) Radiant or conducted heat sources;
d) Special transportation or storage conditions;
e) Unusual space limitations;
f) Unusual power limitations;
g) Unusual communication limitations;
h) Unusual operating duty, frequency of operation, difficulty in maintenance;
i) Altitude of the operating locations in excess of 1 000 m;
j) Abnormal electromagnetic interference; and
k) Abnormal exposure to ultraviolet light.

6.1 Environment

6.1.1 Ambient Temperature and Humidity Conditions

Ambient temperature and humidity are defined as the conditions of the air surrounding the enclosure of the equipment (or the equipment itself, if it uses open rack construction) even if this enclosure is contained in another enclosure or room.

For temperature and humidity parameters by operating location, see Table 1. This table is a guideline to establish five equipment classification groups. Equipment designated to be in a specific group shall meet all conditions set forth in that group.

Equipment subjected to temperature and humidity variations outside of the first four group classifications listed in Table 1 will require special consideration. Methods to resolve these problems include the following:

a) Low temperature — A thermostatically controlled heater strip should be used in the cabinet enclosure or use wide temperature range equipment.
b) High temperature — A sun shield, some other cooling method, or wide temperature range equipment should be used.
c) High humidity — Heater strips or special shelters should be used.
d) Low humidity — A humidifier should be used to maintain acceptable humidity levels.
e) Temperature restrictions — If it is necessary to use heating/cooling equipment to meet the parameters set forth in Table 1, the equipment should be so marked by a warning sign and a warning statement in the associated documentation.

6.1.2 Dust, Chemical Gas and Moisture

Suppliers shall be made aware of the presence of atmospheric pollutants so that special provisions for protection can be made where necessary.

<table>
<thead>
<tr>
<th>Sl No.</th>
<th>Equipment Group</th>
<th>Typical Location of the Equipment</th>
<th>Humidity Operating Range (percent Relative Humidity)</th>
<th>Temperature Operating Range °C</th>
<th>Allowable Rate of Change of Temperature °C/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
<td>(6)</td>
</tr>
<tr>
<td>i)</td>
<td>(1)(a)</td>
<td>In a building with air-conditioned areas</td>
<td>40-60</td>
<td>+20 to +23</td>
<td>5</td>
</tr>
<tr>
<td>ii)</td>
<td>(1)(b)</td>
<td>In a building with air-conditioned areas</td>
<td>30-70</td>
<td>+15 to +30</td>
<td>10</td>
</tr>
<tr>
<td>iii)</td>
<td>(2)</td>
<td>In a building with heating or cooling but without full air-conditioning</td>
<td>10-90 without condensation</td>
<td>+5 to +40</td>
<td>10</td>
</tr>
<tr>
<td>iv)</td>
<td>(3)</td>
<td>In a building or other sheltered area without special environmental control</td>
<td>10-95 without condensation</td>
<td>0 to +55</td>
<td>20</td>
</tr>
<tr>
<td>v)</td>
<td>(4)</td>
<td>Outdoors or location with wide temperature variations</td>
<td>10-95 without condensation</td>
<td>-25 to +60</td>
<td>20</td>
</tr>
<tr>
<td>vi)</td>
<td>(5)</td>
<td>Extremes outside the above (see 6.1.1)</td>
<td>User to specify</td>
<td>User to specify</td>
<td>User to specify (see 6.1.1)</td>
</tr>
</tbody>
</table>

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In groups (1), (2), and (3) of Table 1, all equipment cabinets that are vented shall have dust filters. In groups (3) and (4), equipment that is exposed to moisture, corrosive and explosive gases, or other unusual environmental conditions shall have a special enclosure. Available types of enclosures for various conditions are specified in IS 13947 (Part 1).

Consideration should be given to possible contamination inside the enclosure during storage and transit, and also when the enclosure is opened for maintenance or repairs.

6.1.3 Altitude
The equipment shall be suitable for operation at altitudes up to at least 1 000 m.

6.1.4 Ultraviolet (UV) Light Exposure
Suppliers shall be made aware of the expected level of exposure to ultraviolet radiation attributable to sunlight where equipment is to be installed outdoors. Equipment cabinets, paint finishes, and jacket material of any exposed cabling shall be sufficiently treated to resist damage or degradation due to UV exposure. The user shall supply information pertaining to altitude above mean sea level and the anticipated average daily hours of direct exposure to sunlight.

6.2 Lightning and Switching Surge Protection
The purpose of this subclause is to describe design criteria and recommend practices that will minimize the adverse consequences of exposure to lightning discharges and switching surges. Effective protection can only be accomplished through a combination of adequate design and proper installation and should be in conformance with IEC 60870-2-1 for minimum level 2 requirements.

6.2.1 Design Criteria
The basic design goal for achieving protection from lightning and switching surges shall be that of keeping any abnormal voltage or current, or both, out of the equipment cabinets.

6.2.1.1 Voltage surges
Voltage surges can enter the cabinet and cause damage. Equipment failures resulting from such damage should be fail-safe. Logic designs should be such as to minimize the possibility of false or improper operation of field devices. Partial failures that do not disable the equipment but can reduce or eliminate security features, such as error checking in communication circuits, shall be detected and cause the blocking of control outputs to prevent false operations of field devices.

6.2.2 Installation Criteria
The basic installation goal for achieving protection from lightning and switching surges shall be to minimize the exposure of all connecting wires and cables.

6.2.2.1 Power, signal and communication circuits
Power, signal, and communication circuits provide a path through which lightning and switching surges enter equipment. Circuits totally within a protected building can generally be installed without regard to these external effects. These circuits may still be subjected to transients generated by the operation of solenoids and control relays. Circuits that are connected to, or are part of, circuits not within a protected building should be installed in a manner that will minimize exposure.

6.2.2.2 Installation constraints
When installation constraints result in a high degree of exposure to lightning or switching surges, supplementary protection such as spark gaps or surge limiters should be considered.

6.3 Electromagnetic Interference (EMI) and Electromagnetic Compatibility (EMC)
Manufacturers shall design and test their equipment to ensure that EMI limits are not exceeded, and users shall design and test locations (environments) to ensure that EMC limits are not exceeded and should be in conformance with IEC 60870-2-1 for minimum level 2 requirements.

Computer and microcomputer-based equipment are expected to perform their intended functions in substations even when exposed to transient electromagnetic interference. The user should be aware of EMI in control rooms/substations, metering stations, etc and either specify the EMI level for guaranteeing proper operation or accept the risk of misoperation in the presence of EMI.

6.3.1 EMI Limits
Control and data acquisition equipment shall not generate radiated emissions in excess of (1 V/m)/MHz as measured 1 m from the enclosure. Manufacturers shall mechanically and electrically design equipments for emission limits by employing attenuation techniques such as isolation, shielding, grounding, gasketing, filtering, and bonding.

6.3.2 EMC Limits
Control and data acquisition equipment shall be capable of operating in radiated fields as specified by the user. Information available to date indicates that
the average field strength may run in the order of (1 V/m)/MHz. The specified value of (1 V/M)/MHz refers to broadband radiated fields due to station environment, resulting from such things as corona and switching transients. This requirement is not intended to cover narrowband radiated field sources such as electronic test equipment or portable radio transmitters (walkie-talkies). Where such equipment may be used, the field strength is properly expressed as volts per meter at a specified frequency, and different EMC limits may be required.

7 CHARACTERISTICS

This clause defines and discusses general characteristics that are required of the control and data acquisition equipment. These characteristics include reliability, maintainability, availability, security, expandability, and changeability.

7.1 Reliability

Mathematically, reliability is the probability that a unit or system will perform its intended function under specified conditions during a specified period of time. For complex equipment, failures will occur on the average at a constant rate throughout the useful life of the equipment. This allows the manufacturer to characterize equipment reliability with a simple figure of merit called mean-time-between-failure (MTBF).

The exceptions to this constant failure rate are higher, decreasing failure rate, early in the equipment's life, called 'infant mortality', and a higher, increasing failure rate, that signals the onset of 'end-of-life'. These phenomena give a typical plot of failure rate versus time, a shape known as a 'bathtub curve'.

The failure modes of equipment, and the effects of these failures shall be formally analyzed by the supplier. The results of these failure modes and effect analysis (FMEA) shall be available for review upon request.

Failure distribution versus time data for equipment while in the possession of the supplier, and for those field units for which data are available from the users, shall be documented and available upon request.

7.2 Maintainability

Control and data acquisition equipment shall be maintainable on-site by trained personnel according to the maintenance strategy specified by the user. Requirements for training, documentation, spares, etc, shall take the user's organization and geography into account.

The most common repair strategy is for the supplier to train the user's personnel to identify and replace failed modules on-site from the user's stock of spare modules. These may then be either returned to the supplier for repair or repaired to the component level at the user's maintenance facility. If on-site service by the supplier is necessary, it is most likely to be required for failures of complex computer equipment.

The supplier shall, upon request, be required to provide as part of the system proposal, a list of test equipment and quantities of spare parts calculated to be necessary to meet the specified availability and maintainability requirements. In establishing the quantities of spare parts, the supplier shall consider the time required to return a failed component (field and/or factory service) to a serviceable condition.

The maintainability of equipment is reflected in a figure of merit called mean-time-to-repair (MTTR). The MTTR values used in the supplier's availability computations shall be based to the maximum extent possible upon maintenance experience.

MTTR is the sum of administrative, transport, and repair time. Administrative time is the time interval between detection of a failure and a call for service. Transport time is the time interval between the call for service and on-site arrival of a technician and the necessary replacement parts. Repair time is the time required by a trained technician, having the replacement parts and the recommended test equipment on-site, to restore nominal operation of the failed equipment.

Unless otherwise specified by the user, the following values shall be used in availability calculations:

Administrative time 0.0 h
Transport time 0.5 h

7.3 Availability

Availability is defined in the following as the ratio of uptime to total time (uptime + downtime):

\[ A = \frac{\text{uptime}}{\text{uptime} + \text{downtime}} \]

and is normally expressed as a percent (of total time).

Downtime normally includes corrective and preventive maintenance. When system expansion activities compromise the user's ability to operate device via the system, this may also be included in downtime.

Typical availabilities achievable by non-redundant commercial grade equipment range from 99.99 percent, for simple devices, to approximately 97 percent for complex, computer-based sub-systems. Proper use of redundant configurations with automatic fail over can provide an overall availability of primary system functions of 99.9 percent.

The availability level required, and the planned maintenance strategy, shall be specified by the user,
requiring suppliers to provide supporting predicted availability calculations in their proposals.

An availability test of from 30 to 90 days is often specified prior to acceptance of a system. Operating and maintenance records shall be kept and used to prove the predicted, and to support the achieved availability computations (see 9.6).

For design analysis, and to determine the prediction of availability for sub-assemblies and units, the following equation utilizing MTBF and MTTR shall be used:

\[ A_p = \frac{MTBF}{MTBF + MTTR} \]

where \( A_p \) is predicted availability.

Equations for modeling complex designs shall be formulated by the supplier. Use of the equations associated with parallel redundant components (or subsystems) are valid under the following conditions:

a) Failure of parallel elements are independent. Component failures do not propagate failures of other components.

b) Sufficient repair turnaround and standby replacement parts are available to handle multiple simultaneous failures.

The impact of the outage of each system element or function on the availability of the total system shall be mutually agreed upon between the user and the supplier.

Availability test results shall be calculated separately for major system components (for example, Server system versus RTUs). Since these components may have a varying impact on the usefulness of the system as a whole, different definitions of downtime are applicable.

Major component downtime shall be defined to reflect the proportional significance of the equipment that is down. For example, downtime for the data acquisition system could be defined as the sum of the downtime for all RTUs divided by the total number of RTUs. At the master station, downtime should not include malfunctions in peripheral devices that do not detract from the functional capabilities of the master station as a whole (for example, printers and tape units).

7.4 System Security

System security (of operation) is defined as the ability to recognize an inappropriate or undesirable operation or condition in such a fashion that causes an appropriate alarm, a non-operation, or both.

Security of operation considerations are divided into the following three areas:

a) Operating practice and procedures,
b) Communication security, and
c) Hardware and software design.

7.4.1 Operations Security Features

Security features comprising operating practice and procedures include the use of function and operating checks (manual and/or automatic). Function and operating checks may include:

a) Analog reference points (0 and 90 percent),
b) Control function check (loop-back),
c) Scan function check (loop-back),
d) Poll function check,
e) Logging function check,
f) Queue overflow alarms,
g) Diagnostic aids,
h) Calibration checks,
i) Logging of all operator actions, including whether the equipment completed the requested action,
j) Tagging of out-of-service control points at the user interface, and
m) Use of an RTU local/remote switch, with feedback to a status point, to disable all control actuators while an RTU is being serviced.

Equipment designed for remote control of valve shall use both a select-before-execute user interface (UI) sequence and a checkback-before-operate communication sequence for control operations.

The UI sequence shall provide visual feedback of the selection to the user, so the user can verify that the system has interpreted the selection correctly before executing the control function.

The communication sequence checkback message shall be derived from the RTU's point selection hardware, and not be just a simple echoing of the received select message. This allows the master station to verify not only that the communication was error free, but also that the RTU's I/O hardware and software acted correctly in interpreting the selection.

In order to provide maximum security against random channel noise being interpreted as a select/execute sequence at an RTU, the following safeguards should be incorporated:

a) The communications protocol shall have a very effective redundancy check code (this is necessary, but not sufficient, security);
b) There shall be a relatively short timeout between the select and operate steps;
c) The next master station message following the select shall be the execute;
d) The complete point identification shall be contained in the select, checkback, and execute messages, which shall be fully compared before the control operation is executed;

e) If any of the above checks fail, the control sequence shall be re-set immediately, and a new select message shall be required to restart it; and

f) Both the master station and RTU shall enforce the above rules.

The communication checkback sequence may be performed either concurrently with the control selection sequence at the UI, or after the selection sequence has been completed. When performed concurrently, the selection of a point for control shall cause the select message to be transmitted to the RTU. Upon successful receipt, the RTU shall arm itself for control, generate the checkback message, and transmit it back to the master station. A valid checkback message shall result in visual selection feedback to the user, who can then choose to either execute or cancel the control function.

This type of operation requires a longer select/execute timeout at the RTU, and will either violate the execute-next rule, or will stop scanning on that channel until the user responds with an execution or cancellation.

When the UI sequence and communication sequence are performed sequentially, the selection of a point for control should cause the master station to display a visual indication of that selection for verification.

In this type of operation, the user’s verification of selection does not come from the RTU, but all other security features may be fully implemented.

The user may then execute the control function. Status and data scanning should then be interrupted, and a select message sent to the RTU.

The RTU shall then arm the control function and return a checkback message. The checkback message shall be checked by the master station, and an execute message sent automatically to the RTU. If this execute message is received as valid, the RTU shall execute the command and return an acknowledgment that the function has been performed.

7.4.2 Communication Message Security

Communication security features include:

a) The design goal that an error in a message shall not result in a critical failure of the system.

b) Alarming the failure of an RTU to respond to a message within a specified number of automatic retries.

c) Ensuring that communication channel error control, in concert with the communication protocol and line discipline, reduce the probability of acceptance of messages received with error rate to less than $10^{-12}$ when the channel bit error rate is $10^{-6}$.

d) Verification of the proper operation of communication channels on a regular basis.

e) Counting, and periodically logging, communication errors on a per-channel basis.

f) Ensuring that no two RTUs with the same address share the same party line or switched communication channel.

g) Ensuring that each RTU communication channel(s) supports only one communication protocol.

7.4.3 Hardware/Software Security Features

Security features comprising hardware and software design include the following:

a) Power supply protection — over current, over/under voltage,

b) Automatic initialization and restart,

c) Equipment self-check with alarm,

d) Watchdog timer(s) with alarm,

e) Automatic failover with alarm,

f) Fail-safe operation, and

g) Non-volatile station address retention in RTUs.

7.5 Expandability

Expandability is the ease with which new RTU, new points and/or functions, or both, can be added to the system, and the amount of downtime required.

Expansion point types are defined as spare point, wired point, and space-only. Spare point equipment is equipment that is not being utilized but is fully wired and equipped. Wired point is the capacity for which all common equipment, wiring, and space are provided, but no plug-in point hardware is provided. Space-only point is the capacity for which cabinet-space-only is provided for future addition of equipment and wiring.

Expandability limitations may include, but are not restricted to, the following:

a) Available physical space;

b) Power supply capacity;

c) Heat dissipation;

d) Processor throughput and number of processors;

e) Memory capacity of all types;

f) Point limits of hardware, software, or protocol;
g) Bus length, loading, and traffic;

h) Limitations on routines, addresses, labels, or buffers; and

j) Unacceptable extension of scan times by increased data (given bit rate and protocol efficiency).

7.6 Changeability

Changeability is defined as the ease with which system, RTU, and point data base parameters may be changed at both the master station and RTU. Parameters that shall be easy to change include the following:

   a) Operating parameters, and
   b) Configuration and setup parameters.

The supplier’s documentation (see 10.3.2) shall contain the step-by-step process as given in 7.6.1 to 7.6.3.

7.6.1 Operating Parameters

Operating parameters must be easily changed by the system user. They include, but are not limited to the following:

   a) RTU on/off-scan,
   b) Point on/off scan,
   c) Point tags on/off,
   d) Manually entered values,
   e) Point alarm limits,
   f) Point deadband values, and
   g) IED parameters.

7.6.2 Configuration and Setup Parameters

Configuration and setup parameters must be easily changed by an authorized system engineer, but shall be protected against being changed by the users. They include the following:

   a) Configuration password,
   b) Major/minor alarm conditions and actions,
   c) User-definable calculations,
   d) Definition of a new RTU,
   e) Communication port and/or station address assignments of RTUs,
   f) Addition and/or rearrangement of an RTU’s points,
   g) Correspondence of status points to control points,
   h) Point and state descriptions, for presentation to the system user,
   j) Point scaling factors, for conversion of data to engineering units, and
   k) Output relay dwell times.

7.6.3 Changeability Limitations

Changeability limitations may result from, but are not limited to the following:

   a) Inability to make master station and RTU data base changes on-line from the master station,
   b) Storage of parameters in memory (for example ROM) that is not modifiable in-circuit,
   c) Restrictions caused by data base structure,
   d) Hardware/software compatibility,
   e) Hardware limitations,
   f) Software operating system limitations, and
   g) Restrictions caused by use of IEDs.

7.7 Spare Capacity

Spare capacity is defined as the additional capacity that can be added to the master station.

7.7.1 Main Memory

A requirement of no less than 50 percent unused main memory initially will allow enough expansion for new functions, enhancement of existing functions, and growth of the power system and the equipment that needs to be monitored. Computer documentation shall also be consulted to determine how much main memory capacity can be expanded over and above the capacity initially installed. As a minimum, it shall be possible to double the initial capacity with the addition of memory modules.

7.7.2 Auxiliary Memory

A requirement of no less than 50 percent spare disk capacity initially will allow for moderate expansion. Computer documentation shall also be consulted to determine how much disk capacity can be expanded over and above the capacity initially installed. As a minimum, it shall be possible to double the initial capacity with the addition of disk units.

8 MARKING

The control and data acquisition equipment and major sub-assemblies shall be suitably marked as necessary for safety and identification.

8.1 Identification

Each type of equipment shall be identified so that it can be easily correlated with the documentation. The means of identification shall be uniform throughout the system, and it may include colour coding, labelling, and part number. The identification mark shall be permanently affixed to the part that it identifies. Consideration shall be given to using bar code labels to identify the equipment and sub-assemblies.
8.2 Nameplates

Each separate unit of the system shall be furnished with nameplates bearing relevant information.

Nameplates shall be legible at a distance of approximately 1 m.

8.3 Warning

Warning signs or safety instructions shall be applied where there is a need for general instructions relative to safety measures (for example, supply circuit).

9 TESTS AND INSPECTIONS

The purpose of this clause is to describe the tests and inspections recommended to ensure that control and data acquisition equipment will perform reliably and correctly according to the user's technical specifications. Users shall specify all tests to be performed. Test requirements shall cover, as a minimum, all critical portions of the specification, especially functional and design requirements. Tests shall be required to be conducted by user and supplier. Test results and all deviations from test plans shall be required to be documented.

9.1 Stages of Tests and Inspection

The test and inspection process requires that various functions of the equipment be tested or verified during one or more stages in the production and installation cycle of the equipment. These stages and appropriate tests are illustrated in Table 2.

Across the top of the table are shown the four major classes of tests and inspections, being interface, environmental, functional, and performance. The three stages of testing and inspections, being certified design, factory and field, are shown along the left-hand edge of the table. The specific tests and inspections in each class are listed in the body of the table, below the class heading. Tests listed without notation are recommended for all applications at the stage they can be most economically performed.

Tests marked with an asterisk are optional and are performed only when specified by the user. Certified design tests on equipment can be accepted at the user's discretion.

9.1.1 Certified Design Tests

These are tests performed by the supplier on specimens of a generic type of production model equipment to establish conformance with its design standard. The conditions and results of these tests shall be fully documented and certified.

9.1.2 Factory Tests and Inspections

This stage includes the inspection and approval of interface drawings prior to fabrication of the equipment and all functional tests and inspections performed on the actual equipment to be supplied to the user prior to the shipment of that equipment from the supplier's facilities. The factory tests shall be a highly structured procedure designed to demonstrate, as completely as possible, that the equipment will perform correctly and reliably in its intended application. Factory tests may also include tests to verify some or all of the results of the certified design tests.

9.1.3 Field Tests and Inspections

Field tests and inspections are performed on the equipment after it has been shipped from the supplier's facilities. These include pre-installation inspections and

Table 2 Test Stages and Classes of Tests

(Clause 9.1)

<table>
<thead>
<tr>
<th>SI No.</th>
<th>Test Stages</th>
<th>Interface Tests and Inspections</th>
<th>Environmental Tests and Inspections</th>
<th>Functional Tests and Inspections</th>
<th>Performance Tests and Inspections</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) i)</td>
<td>Certified design tests</td>
<td>Power input*</td>
<td>Temperature</td>
<td>Humidity*</td>
<td>I/O point checkout</td>
</tr>
<tr>
<td>(2) ii)</td>
<td>Factory tests and inspections</td>
<td>Mechanical power source*</td>
<td>Temperature*</td>
<td>Humidity*</td>
<td>Communications</td>
</tr>
<tr>
<td>(3) iii)</td>
<td>Field tests and inspections</td>
<td>Dust*</td>
<td>Special functions</td>
<td>Special functions</td>
<td>User interface</td>
</tr>
<tr>
<td>(4)</td>
<td></td>
<td></td>
<td>Special functions</td>
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<td>(5)</td>
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<td>(6)</td>
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</tbody>
</table>

* Optional tests performed only when specified by the user.
tests to ensure the equipment has not been damaged during shipment and post-installation tests to verify the equipment performs its functions reliably and correctly.

9.2 Interface Tests and Inspections

These tests are designed to demonstrate that the various mechanical and electrical interfaces to the equipment are in accordance with applicable portions of 5, together with other applicable parameters called out in the user's specifications. For the most part, these interface parameters can either be demonstrated during factory tests or accepted on the basis of certified design tests.

9.2.1 Mechanical

Mechanical characteristics (for example materials, workmanship, dimensions, fabrication techniques, and finishes) shall be verified through visual inspections and comparisons with applicable drawings.

9.2.2 Electrical

These tests include all those to be performed on electrical interfaces to the equipment, with the exception of those related to the functional performance of the equipment.

9.2.2.1 Power source

The equipment shall be tested to demonstrate the proper operation of the equipment throughout the range of specified power source parameters.

9.3 Environmental Tests

These tests are designed to demonstrate that the equipment will perform correctly and reliably while exposed to the applicable environmental parameters described in 6, together with other applicable parameters called out in the user's specifications. The results of certified design tests are usually sufficient to demonstrate that the equipment will operate reliably and correctly within a specified environment. The user may require the supplier to perform factory tests on the equipment to demonstrate that it will indeed perform correctly under the specified environmental conditions. Equipment in environmental tests should be operating with realistic inputs and outputs.

The environmental parameters and testing requirements specified by the user should be limited to the worst case conditions that can be realistically anticipated in the location where the equipment will ultimately be installed. Refer IS 9000 series or IEC 60068 series for various environmental tests.

9.3.1 Physical

The equipment shall be tested to verify that it operates correctly in the following physical environments described in 9.3.1.1 to 9.3.1.3.

9.3.1.1 Temperature

To test the equipment within the specified temperature range (see 6.1.1), it shall be placed in an environmental test chamber where it can be operated for a specified period at both the low and high ends of the range, and cycled between them. Calibration and accuracy checks shall be made throughout the range.

9.3.1.2 Humidity

Humidity tests (without condensation) shall be performed in conjunction with the temperature test (see 9.3.1.1). Humidity test data shall include the humidity ranges tested at each temperature.

9.3.1.3 Dust

Testing shall consist of inspection to determine whether or not the equipment is properly sealed to prevent intrusion of dust.

9.4 Functional Tests

Functional tests shall be designed to ensure that the equipment performs its functions reliably and correctly. They are performed during the factory, or field test stages, or both. Preliminary testing should be performed by the supplier before verification by the user. For many applications and types of equipment, successful factory tests will be a sufficient basis for acceptance of the system by the user. For more complex applications or systems, additional tests in the field may be required to fully verify correct and reliable performance.

The following functional tests should be carried out:

a) Interface of RTUs with IEDs;
b) Database and alarms validation;
c) Remote workstation testing;
d) Checking of various reports, archiving and trending functions;
e) Clock synchronization between the nodes of master station and RTUs; and
f) Security/Password testing.

9.4.1 I/O Equipment Checkout

All I/O equipment to be supplied shall be tested during factory tests to demonstrate that it performs its functions correctly, accurately, and reliably. These tests shall be performed with equipment that simulates the actual equipment to be monitored or controlled.

9.4.2 Communication

The communication tests shall demonstrate proper
operation of all aspects of the equipment's communication capability, including modems, security checking, and message protocols. The data modems or signalling equipment shall be exercised to verify that they operate correctly and reliably on the type of channel for which they are designed. The tests shall be conducted under conditions that duplicate as closely as possible the specifications for the channel including simulated channel noise, communication failures, and recovery. Provisions shall be made to log communication outages and update communication statistic displays where these features are provided.

The communication tests shall exercise all message protocols and formats to which the equipment is designed to respond. The tests shall also demonstrate that any error detection or correction capabilities function properly and that the equipment does not respond to erroneous commands.

9.4.3 User Interface (UI)

Comprehensive user interface tests shall be performed to verify the correct functional operation of all user interface hardware and software. All indications and displays shall be verified to ensure that they correlate with the correct I/O equipment, and all user controls shall be checked to ensure that they result in only the correct sequence of operations.

9.4.4 Special Functions

When the equipment supplied is to perform functions tailored expressly to the user's application (for example closed loop control), these functions shall be checked during the appropriate test stage. It is often necessary to perform these tests in the field, after the equipment has been adjusted to the parameters of the installation.

9.5 System Performance Tests

The performance of all critical parameters of the equipment (for example communication, peripherals, user interfaces, I/O processing, and CPU) shall be measured under various loading conditions or scenarios. System performance shall be measured as early in a project as possible to identify any system weaknesses. This will allow the user and supplier an opportunity to resolve problems in a timely manner.

The loading scenarios shall simulate the following:

a) Normal activity — initial system.

b) Heavy activity (disturbance loading defined by user) — initial system.

c) Normal activity — fully expanded system.

d) Heavy activity (disturbance loading defined by user) — fully expanded system.

e) Communications failures or high noise conditions such as high noise on an entire microwave system.

Loading conditions should be determined by analyzing worst case conditions experienced by the user and the worst possible condition likely to happen in the future over the life of the system. Table 3 is provided as a guide.

The measurements for performance assume that all functions of the system have been individually verified by functional tests and that the total system is ready to be evaluated.

If actual system inputs are not available, they shall be simulated with special hardware or software. For a meaningful test, these inputs shall include the following:

a) Simulated RTU inputs (alarm contacts, analog inputs, status input, etc).

b) Simulated message data structures from the RTUs into the master station communication interfaces.

c) Simulated data links to other computers, specifying the amount, type and frequency of data to be transferred.

d) Simulated user interfaces such as wall mimic.

e) Other simulated inputs.

Table 3 System Performance Tests

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<thead>
<tr>
<th>SI No.</th>
<th>Input Activity Cycle</th>
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<tbody>
<tr>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>i)</td>
<td>Normal Activity</td>
</tr>
<tr>
<td></td>
<td>Each user</td>
</tr>
<tr>
<td></td>
<td>Status input</td>
</tr>
<tr>
<td></td>
<td>Analog inputs</td>
</tr>
<tr>
<td>ii)</td>
<td>Heavy Activity</td>
</tr>
<tr>
<td></td>
<td>Each user</td>
</tr>
<tr>
<td></td>
<td>Status inputs</td>
</tr>
<tr>
<td></td>
<td>Analog inputs</td>
</tr>
</tbody>
</table>

Values given are for example only. It is recommended that the user select values that represent the user's system characteristics and operating procedures.

Manual operation sequences to be performed during tests shall be described in detail to provide a repeatable test scenario and a way to measure improvements in performance (for example, five people requesting one-line diagrams and two people requesting menu displays simultaneously). Test steps should simulate all normal user operations.

Response performance shall be measured in seconds. All measurements shall be recorded for analysis after
the tests. Software utility programmes are available from most system suppliers for finding CPU utilization and loading (for example, feature of the computer operating system or a separate programme available from computer manufacturer, or both) and if used by supplier the system loading of the programs shall be provided to user with proof. Automatic measurement of other test parameters can be done by special purpose software.

9.5.1 Data Acquisition Performance

Data acquisition sub-system performance measures the following:

a) The time for a status change or analog change at the RTU to be displayed to the user at the master station (for example, monitor, logger or mimic).

b) The time to query all RTUs on a per channel basis.

A cyclic status point input of 2 or more times faster the system RTU scan rate can be used to detect a missed scan due to overloading. The status input simulator should be connected to an input of one RTU. The alarm associated with the toggled input shall appear on the logger with a time tag of approximately twice the scan rate. A system overload causing an extension of the scan cycle is obvious from the printout because one or more status changes is missed.

9.5.2 Control Performance

Control performance measures the elapsed time between a control request by a user at the master station and the control output contact closure at the RTU. This test shall also be performed in the field. The field test will provide realistic measurements, using user installed RTUs and communication facilities.

9.5.3 User Interface Performance

The user interface performance is a measure of the response time to satisfy user requests for information. To measure display response time, measure the time from the instant a request is made until the result of the request is completely displayed on a CRT screen, printed on a logger, or shown on a mimic panel. Different classes of displays (one-line diagrams, alarm summaries, menus, tabular, etc) may have different display response times due to the amount of data to be gathered and computations required before a display request can be completed.

9.5.4 Computer and Disk Performance

The computer and disk performance shall be checked using the supplied programmes from computer manufacturers to ascertain that CPU and Disk utilization is within acceptable limit as specified by user.

9.5.4.1 Computer link response time

Computer to computer link response times should be measured and evaluated during performance tests under varied loading conditions.

9.5.4.2 Computer LANs utilization

LANs that connect application computers together should be measured and evaluated during performance tests under varied loading conditions.

9.5.4.3 Computer reconfiguration, power fail and restart tests

On master stations with redundant equipment, reconfiguration tests should be performed to confirm the ability to failover from one CPU to another (reconfigure the real-time database) and to switch peripheral equipment to the primary system, the secondary system, or off-line (that is out-of-service).

Power fail tests measure the time to recover from a complete or partial power failure until the system is fully operational.

Because normal maintenance procedures and equipment failure cause downtime of the master station, restart tests are to assure the system will recover in a timely manner. Existing data shall consist of all scanned and manually entered data (that is pipeline system tags, manual overrides, limit changes, etc). Downtime of the system or parts of the system should be measured during these tests to confirm the length of these outages can be tolerated by the user.

The time required to load a system from mass storage and initiate operation should be measured. This time should be less than the acceptable system outage time.

9.6 Test Run

The user shall require an availability test to be run after the system is installed and placed in operation (see 7.3). An availability test takes place over a specified length of time during which the equipment shall operate correctly and reliably for at least a specified percentage of that time. The length of the test shall be sufficient to verify that the equipment can be expected to perform its intended functions reliably and correctly over its intended lifetime.

The availability test shall be run under conditions mutually agreeable to the user and supplier. In general, the supplier shall be responsible for making the necessary repairs. Downtime should not include delays over which the supplier has no control.

This is followed by analyzing the number and types of failures, and their effects on system operation. The test time should be selected so that the total number of
device operating hours for each type of system-critical device is representative of the predicted MTBF for that device to obtain statistically significant failure data. Specific rules for accumulation of uptime, downtime, maintenance time, and administrative time shall be agreed upon before the test (see 7).

9.7 Maintainability Test

The user shall require a maintainability test to be run to evaluate the supplier’s design, documentation, training, and recommended spare parts. Maintainability will directly affect the availability of the SCADA system and therefore the reliability of the system (see 7.2). Computer hardware maintenance and long-term repair support are difficult to evaluate without actual experience. Discussions with other utilities regarding their experience is one way to acquire a certain degree of knowledge about the maintainability of specific equipment and systems.

Software, database, and display maintainability is also critical to the successful operation of a SCADA system. Tests to be witnessed should include the following:

System generation tests (measure time to complete, and amount of manual intervention required)

a) Database maintenance
   1) Adding an alarm point (time to make operational) should be demonstrated,
   2) Deleting or changing text on an alarm point should be demonstrated, and
   3) Changing an analog scale factor should be demonstrated.

b) Display maintenance
   1) A new one-line diagram should be added and linked to the database (a specific example in the specification should be provided), and
   2) A line and new devices should be added to an existing one-line diagram including analogs, tags, etc.

c) Equipment maintenance
   1) A monitor should be replaced,
   2) A modem should be replaced, and
   3) A disk drive should be replaced.

9.8 Expandability Tests

Expansion capability of a new system shall be analyzed (see 7.5). For example

a) RTU I/O point expansion (both hardware and software changes required);

b) Addition of RTUs;

c) Master station expansion:

1) Peripherals, diskspace, memory,
2) CPU capacity (percent utilization),
3) User interface (work station additions), and
4) Database and display expansion.

9.9 Documentation Verification

The final phase of the testing programme is to verify that the documentation being supplied is an accurate description of the equipment, including all corrections resulting from the tests. Final issue of completed documentation shall be provided as soon as practical after shipment and acceptance of the equipment.

10 DOCUMENTATION

The documentation for control and data acquisition equipment shall cover five basic areas as follows:

a) Design,
b) Installation,
c) Operating instructions and records,
d) Maintenance instructions and records, and
e) Test (including QA & QC test plans).

In general, all final documentation provided by a supplier shall reflect the actual equipment as accepted by the user, and all subsequent equipment changes shall be recorded as document revisions by the user.

If users desire to have the information on reliability as described in 7, they shall collect information on failures and repairs for all subassemblies. This data on operating performance shall then be periodically provided to the supplier.

Documentation described in 10.1 to 10.6 may be subject to user review or approval. Documentation may be structured in alternate fashion, but shall cover all five areas. The documentation may be supplied in one or more of several forms-printed, computer stored, or electronic media. In the latter case, the supplier shall either identify or supply the supporting word processing software used to prepare the documentation.

10.1 Design Documentation

Design documentation is the responsibility of the supplier. For example, expansion methods for adding points to hardware assemblies and software programmes or tables shall be described and illustrated. Block diagrams shall be included to describe control and data acquisition equipment and external equipment. Layout and wiring drawings shall also be included to define external interconnection needs at each facility. Text, photographs, and illustrative material shall accompany these drawings in sufficient detail so that functional performance and design may be readily understood.
For example, functional block diagrams and explanatory text shall be used to describe each major assembly and software programme contained in the equipment configuration. A document describing the communication process between the master station and the RTUs shall be provided. The supplier shall be responsible for providing outline drawings, mounting requirement details, customer connection details, environmental requirements, size, weight and any other information need for the user to prepare installation documentation.

10.2 Installation Documentation
Installation documentation is the responsibility of both the supplier and user and shall define the following:

a) Electrical power, data, control, and communications interface wiring procedures;
b) Floor, rack and shelf mounting, drilling, and bolting methods necessary to secure the equipment in place;
c) Safety precautions or guards;
d) Grounding and bonding procedures;
e) Clearances for access and ventilation;
f) Testing and alignment methods;
g) Weather proofing, dustproofing, and other environmental procedures; and
h) Other procedures needed to properly install the equipment.

10.3 Operating Instructions and Records
Instruction information shall be developed for operating personnel who use the control and data acquisition equipment.

10.3.1 Supplier Operating Instructions
The supplier shall publish instructional information defining the equipment and how it shall be operated. This instructional information shall consist of a general description of the equipment configuration provided and shall state its intended use and its major performance characteristics. Whenever a user interface such as a console, indicating/control panel, or printing device is involved, the operational documentation shall detail in step-by-step fashion the operational sequences required to use these interface devices. Adequate illustrative material shall be included to identify and locate all control and indicating devices.

10.3.2 User Operating Instructions and Records
The equipment supplier shall publish operating procedures defining the system and include user detailed instructions and responsibilities. These user instructions shall be based on the supplier's instructional information and the nature of the system being monitored and controlled. Procedural instructions, that state routine and emergency procedures, safety precautions, and quantitative and qualitative limits to be observed in the starting, running, stopping, switching, and shutting down of control equipment, shall be included. Whenever operating procedures or adjustments are to be performed in a specific sequence, step-by-step instructions should be stated.

10.3.3 Records
Records shall be prepared by both operating and maintenance personnel to support the availability/reliability calculation defined in 7.1 to 7.3.

10.4 Maintenance Instructions and Records
Maintenance documentation for personnel skilled at the electronic technician level shall be developed and provided by the supplier, and shall include the following information listed in 10.4.1 to 10.4.4.

10.4.1 Performance Information
This information shall include a condensed description of how the equipment operates (derived from 10.1) and a block diagram illustrating each major assembly and software programme in the configuration. Message sequences, including data and security formats for each type of message, shall be included in the condensed description and illustrated whenever such messages are used between stations, or locally at a station. The operational sequence of major assemblies and programmes shall be described and illustrated by functional block diagrams. Detailed logic diagrams and flowcharts shall also be provided as necessary for troubleshooting analysis and field-repair actions.

10.4.2 Preventive Maintenance Instructions
These instructions shall include all applicable visual examinations, software and hardware test and diagnostic routines, and resultant adjustments necessary for periodic maintenance of control equipment. Instructions on how to load and use any test and diagnostic programme, and any special or standard test equipment shall be an integral part of these procedures.

10.4.3 Corrective Maintenance Instructions
These instructions shall include guides for locating malfunctions down to the spare parts replacement or field-repair level. These guides shall include adequate details for quickly and efficiently locating the cause of an equipment malfunction, and shall state the probable sources of trouble, the symptoms, probable cause, and instructions for correcting the malfunction.
These guides shall explain how to use any on-line test and diagnostic program and any special test equipment if applicable.

Corrective maintenance instructions shall also include explanations for the repair, adjustment, or replacement of all items. Schematic diagrams of electrical, mechanical, and electronic circuits; parts location illustrations, or other methods of parts location information; and photographs, and exploded and sectional views giving details of mechanical assemblies shall be provided as necessary to repair or replace equipment. Information on the loading and use of special off-line diagnostic programmes, tools, and test equipment, and any cautions or warnings which shall be observed to protect personnel and equipment, shall also be included.

10.4.4 Parts Information

This information shall include the identification of each replaceable or field repairable module. Parts shall be identified on a list or drawing in sufficient detail for procurement of any repairable or replaceable part. These parts shall be identified by their industrial, generic part numbers, and shall have second source referencing whenever possible.

10.5 Test Documentation

Test documentation by the supplier shall consist of a system test plan, test procedures, and certified test reports on tests described in 9. The test plan shall state what equipment configuration will be tested, when it will be tested, which tests will be run, and who will conduct and witness the tests. The test procedures shall define the operating steps and expected results. The test report shall record all test results.

10.6 Channel Loading Calculation

The vendor should provide channel loading calculations.

ANNEX A

(Clause 2)

LIST OF REFERRED STANDARDS

SP 30 : 1985 National Electrical Code (NEC)
IS 1885 (Part 50) : 1985 Electrotechnical vocabulary: Part 50 Telecontrol
IS 1885 (Part 52) : 1980 Electrotechnical vocabulary: Part 52 Data processing
IS 2309 : 1989 Code of practice for the protection of buildings and allied structures against lightning
IS 3043 : 1987 Code of practice for earthing
IS 9000 Series Basic environmental testing procedures for electronic and electrical items
IS 10315 : 1997 7 bit encoded character set for information interchange
IS 12746 (Part 1/Sec 3) : 1993 Telecontrol equipment and systems: Part 1 General considerations, Section 3 Glossary
IEC 60068 Series Environmental testing
IEEE Green Book Standard 142 : 1991 IEEE Recommended practices for grounding of industrial and commercial power systems

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ANNEX B
(Clause 4.1)
MASTER STATION/RTU INTERCONNECTIONS

B-1 SINGLE MASTER STATION

**Fig. 8** Single Master Station, Single RTU

**Fig. 9** Single Master Station, Multiple RTU(s), Radial Circuit

**Fig. 10** Single Master Station, Multiple RTU(s), Party-Line Circuit
B-2 MULTIPLE MASTER STATIONS

![Diagram showing dual master stations with multiple RTUs looped party line](image)

**FIG. 11** DUAL MASTER STATIONS, MULTIPLE RTU(S), LOOPED PARTY LINE

B-3 MULTIPLE MASTER STATIONS, MULTIPLE RTU(S)

![Diagram showing dual master stations with multiple RTUs](image)

**FIG. 12** DUAL MASTER STATIONS, SINGLE DUAL PORTED RTU, RADIAL CIRCUIT

**FIG. 13** DUAL MASTER STATIONS, MULTIPLE RTU(S) [SINGLE PORTED RTU(S)]
Figure 14: Dual Master Stations, Multiple RTU(s) [Dual Ported RTU(s)]

B-4 Combination Systems

Figure 15: Single Master Station, Single Sub-master Station Multiple RTU(s)
NOTE — Sub-master stations could communicate with one another.

**FIG. 16** SINGLE MASTER STATION, MULTIPLE SUB-MASTER STATIONS
MULTIPLE RTU(s)

**FIG. 17** SINGLE MASTER STATION, RTU(s) AND END STATION LINK
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Review of Indian Standards

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This Indian Standard has been developed from Doc: No. LTD 25 (2059).

Amendments Issued Since Publication

<table>
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