



IEEE Standard for SCADA and Automation Systems

IEEE Power Engineering Society

Sponsored by the
Substations Committee

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IEEE Standard for SCADA and Automation Systems

Sponsor
Substations Committee
of the
IEEE Power Engineering Society

Approved 5 December 2007
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Abstract: The requirements for SCADA and automation systems in substations are defined. This standard defines the process of substation integration as the design process that is the foundation for substation automation. Functional and environmental requirements are provided for all IEDs located in the system. Tutorial material is included in the annexes to address common issues with systems without introducing requirements. Information is also presented in the annexes regarding SCADA masters.

Keywords: automatic control, data acquisition, IED, Intelligent Electronic Device, SCADA, substation integration, substation automation, supervisory control

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Introduction

This introduction is not part of IEEE Std C37.1-2007, IEEE Standard for SCADA and Automation Systems.

This standard applies to systems used for monitoring, switching, and controlling electric apparatus in unattended or attended stations, generating stations, and power utilization and conversion facilities. It does not apply to equipment designed for the automatic protection of power system apparatus or for switching of communication circuits. The requirements of this standard are in addition to those contained in standards related to the individual devices (e.g., switchgear).

This document is a significant revision of IEEE Std C37.1-1994. This revision reflects current technology that is generally being provided to meet the requirements of utilities. Originally, this standard was a section of ANSI C37.2-1970, which also contained device function numbers. ANSI C37.2-1970 was revised into two standards: IEEE Std C37.1-1979, IEEE Standard Definition, Specification, and Analysis of Manual, Automatic, and Supervisory Station Control and Data Acquisition, and IEEE Std C37.2TM-1979, IEEE Electric Power System Device Numbers. Previous editions were approved by the IEEE in 1962, 1956, 1945, and 1937. The original work on this subject was done by the American Institute of Electrical Engineers (now the Institute of Electrical and Electronic Engineers) and published in 1928 as AIEE No 26. The latest revision of the standard on Electrical Power System Device Function Numbers is IEEE Std C37.2-1996 (Reaff 2001) [B11].^a

This standard applies to rapidly changing technology. It is anticipated that frequent revision may be desirable. This revision was prepared by the Electric Network Control Standards Working Group of the Data Acquisition, Processing, and Control Systems Subcommittee of the IEEE Power Engineering Society Substations Committee. The revision is an attempt to bring the standard up to date and further broaden its applicability with respect to control, supervisory, and telemetry.

IEEE Tutorial Course Text EHO 337-6 PWR referenced in the previous revision of this standard is no longer available from the IEEE service center. In addition, the corresponding Tutorial Video Tape HVO 245-1-POT referenced in the previous revision of this standard has been discontinued by the IEEE. The following special publications and tutorial texts are available from the IEEE service center:

- a) IEEE Tutorial “Substation Automation Tutorial” [B17] is recommended for those not familiar with substation automation systems
- b) IEEE Tutorial “The Protective Relay IED in the Automation World” [B18]
- c) IEEE Tutorial “Adding New Life to Legacy SCADA Systems” [B16]

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IEEE Standard for SCADA and Automation Systems

~~IEEE Standard Definition, Specification, and Analysis of Systems Used for Supervisory Control, Data Acquisition, and Automatic Control~~

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1. Overview

1.1 Scope

This standard applies to, and provides the basis for, the definition, specification, performance analysis, and application of SCADA and automation systems in ~~of systems used for supervisory control, data acquisition or automatic control, or both, in attended or unattended~~ electric substations, including those associated with generating stations and power utilization and conversion facilities. ~~Systems covered by this standard typically use processors in the master station and in the remote stations. Such processors provide facilities for incorporating automatic control functions, either by the supplier or by the user, after the system is installed.~~

~~This standard does not apply to electromechanical or static, protective relaying equipment (see IEEE Std C37.90-1989, IEEE Std C37.90-1989, IEEE Std C37.90.2-1987, IEEE Std C37.91-1985, IEEE Std C37.93-1987, IEEE Std C37.95-1989, IEEE Std C37.96-1988, and IEEE Std C37.97-1979).~~

1.2 Purpose

The purpose of this standard is to provide guidance to the engineer responsible for the design and specification of SCADA and automation systems.

1.3 Use

The designer/specifier may use this standard in the design, procurement, and implementation of all or a portion of a system. This document is a generic standard for SCADA and Automation Systems. The designer/specifier shall select those portions of this document that are applicable to a specific system. This may include the modification of tables and requirements contained herein.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

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[ANSI S12.10, Acoustics—Measurement of airborne noise emitted by information technology and telecommunications equipment—ISO 7779:1999.](#)

ANSI X3.1, ~~1987 (R1992)~~ Information Systems—Data Transmission—Synchronous Signaling Rates.²

~~ANSI S12.10-1985, (R1990) Methods for the Measurement and Designation of Noise Emitted by Computer and Business Equipment~~

~~ANSI X3-TR-1-1983, American National Standard Dictionary for Information Processing.~~

~~ANSI X3.4-1986 (R1992), Coded Character Set—7 Bit American National Standard Code for Information Interchange.~~

~~ANSI Y14.15-1966 (R1988), Electrical and Electronics Diagrams (includes Supplements ANSI Y14-15a-1971 and ANSI Y14.15b-1973).~~

~~ANSI Z24.21-1957 (R1989), Method for Specifying the Characteristics of Pickups for Shock and Vibration Measurement.~~

~~ANSI/EIA-334-A-1985, Signal Quality at Interface Between Data Terminal Equipment and Synchronous Data Circuit Terminating Equipment for Serial Data Transmission.~~

~~ANSI/EIA-404-1985, Start Stop Signal Quality Between Data For Nonsynchronous Data Terminal Equipment.
ANSI/ISO-5807-1985, Information Processing—Documentation Symbols and Conventions for Data, Program and Systems Flowcharts, Program Network Charts, and System Resource Charts (revision and redesignation of ANSI X3.5-1970).~~

~~ANSI/NFPA 70-1993, the National Electric Code (NEC) Handbook.~~

EIA/ECA-310, ~~ANSI/EIA 310-D-1992~~, Cabinets, Racks, Panels, and Associated Equipment.³

IEC 60529, Degrees of Protection Provided by Enclosures (IP Code).⁴

IEC 60870-6, Telecontrol Equipment and Systems.

IEC 61131-3, Programmable Controllers—Part 3: Programming Languages.

IEC 654-3, Operating Conditions for Industrial Process Measurement and Control Equipment, Part III, Mechanical Influences.

IEC 61850, Communication Networks and Systems in Substations.

IEEE Std 487TM, IEEE Recommended Practice for the Protection of Wire-Line Communication Facilities Serving Electric Supply Locations.^{5, 6}

IEEE Std 525TM, IEEE Guide for the Design and Installation of Cable Systems in Substations.

IEEE Std 1379TM, IEEE Recommended Practice for Data Communications between Intelligent Electronic Devices and Remote Terminal Units in a Substation.

IEEE Std 1588TM, IEEE Precision Clock Synchronization Protocol for Networked Measurement and Control Systems.

IEEE Std 1590TM, IEEE Recommended Practice for the Electrical Protection of Communication Facilities Serving Electric Supply Locations Using Optical Fiber Systems.

IEEE Std 1613TM, IEEE Standard Environmental and Testing Requirements for Communications Networking Devices Installed in Electric Power Substations.

IEEE Std 1615TM, IEEE Recommended Practice for Network Communication in Electric Power Substations.

IEEE Std 1646TM, IEEE Standard Communication Delivery Time Performance Requirements for Electric Power Substation Automation.

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² ANSI X3.1 was withdrawn in 1997; however, copies can be obtained from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

³ EIA publications are available from Global Engineering ~~1990 M Street NW, Suite 400, Washington, DC, 20036~~, Documents, 15 Inverness Way East, Englewood, CO 80112, USA (<http://global.ihs.com/>).

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~~EIA IEB-12-1977, Application Notes on Interconnection Between Interface Circuits Using RS-449 and RS-3232-C.³~~

~~EIA-TIA-232-E-1991, Interface Between Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange.~~

~~EIA-363-1969, Specifying Signal Quality for Transmitting and Receiving Data Processing Terminal Equipments Using Serial Data Transmission at the Interface with Non-Synchronous Data Communication Equipment.~~

~~EIA-423-A-1978, Electrical Characteristics of Unbalanced Voltage Digital Interface Circuits.~~

~~EIA-TIA-530-A-1992, High Speed 25-Position Interface for Data Terminal Equipment and Data Circuit-Terminating Equipment, Including Alternative 26-Position Connector (Replaces EIA-449 and EIA-449-1).~~

~~IEC 654-3 (1983), Operating Conditions for Industrial Process Measurement and Control Equipment.~~

~~IEEE Std 91-1984, IEEE Standard Graphic Symbols for Logic Functions (ANSI).⁵~~

~~IEEE Std 91a-1991, Supplement to IEEE Standard Graphic Symbols for Logic Functions (ANSI).~~

~~IEEE Std 100-1992, The New IEEE Standard Dictionary of Electrical and Electronics Terms (ANSI).~~

~~IEEE Std 200-1975 (Reaff 1988), IEEE Standard Reference Designations for Electrical and Electronics Parts and Equipment (ANSI).~~

~~IEEE Std 280-1985 (Reaff 1991), IEEE Standard Letter Symbols for Quantities Used in Electrical Science and Electrical Engineering (ANSI).~~

~~IEEE Std 315-1975 (Reaff 1989), IEEE Standard Graphic Symbols for Electrical and Electronics Diagrams (ANSI).~~

~~IEEE Std 315A-1986, IEEE Standard Graphic Symbols for Electrical and Electronics Diagrams (Supplement to IEEE Std 315-1975) (ANSI).~~

~~IEEE Std 344-1987, IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations (ANSI).~~

~~IEEE Std 422-1986, IEEE Guide for the Design and Installation of Cable Systems in Power Generating Stations (ANSI).~~

~~IEEE Std 525-1992, IEEE Guide for the Design and Installation of Cable Systems in Substations (ANSI).~~

~~IEEE Std 999-1992, IEEE Recommended Practice for Master/Remote Supervisory Control and Data Acquisition (SCADA) Communications (ANSI).~~

~~IEEE Std C37.2-1991, IEEE Standard Electrical Power System Device Function Numbers.~~

~~IEEE Std C37.90-1989, IEEE Standard for Relays and Relay Systems Associated with Electric Power Apparatus (ANSI).~~

~~IEEE Std C37.90.1-1989 (Reaff 1991), IEEE Standard Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems (ANSI).~~

~~IEEE Std C37.90.2-1987, IEEE Trial Use Standard Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers (ANSI).~~

~~IEEE Std C37.91-1985 (Reaff 1991), IEEE Guide for Protective Relay Applications to Power Transformers (ANSI).~~

~~IEEE Std C37.93-1987, IEEE Guide for Power System Protective Relay Applications of Audio Tones over Telephone Channels (ANSI).~~

~~IEEE Std C37.95-1989, IEEE Guide for Protective Relaying of Utility-Consumer Interconnections (ANSI).~~

~~IEEE Std C37.96-1988, IEEE Guide for AC Motor Protection (ANSI).~~

~~IEEE Std C37.97-1979 (Reaff 1990), IEEE Guide for Protective Relay Applications to Power System Buses (ANSI).~~

~~IEEE Std C37.100-1992, IEEE Standard Definitions for Power Switchgear (ANSI).~~

~~MIL-HDBK 217D-1991 (Change Notice 1992), Reliability Prediction of Electronic Equipment.⁶~~

~~MIL-STD 471A-1978 (Interim Notice No. 2-1978), Maintainability Demonstration.~~

~~⁶MIL publications are available from the Director, U.S. Navy Publications and Printing Service, Eastern Division, 700 Robbins Avenue, Philadelphia, PA 19111, USA.~~

~~MIL-STD 1472D-1989 (Change Notice 1992), Human Engineering Design Criteria for Military System Equipment and Facilities.~~

IEEE Std C37.98TM, ~~1987 (Reaff 1991)~~ IEEE Standard Seismic Testing of Relays.

IEEE Std C37.115TM, IEEE Standard Test Method for Use in the Evaluation of Message Communications between Intelligent Electronic Devices in an Integrated Substation Protection, Control, and Data Acquisition System.

IEEE Std C37.118TM, IEEE Standard for Synchrophasors for Power Systems.

IEEE Std C37.231TM, IEEE Recommended Practice for Microprocessor-Based Protection Equipment Firmware Control.

IRIG Standard 200, IRIG Serial Time Code Formats, Telecommunications and Timing Group, Range Commanders Council, U.S. Army White Sands Missile Range.⁷

NEMA 250-~~1991~~, Enclosures for Electrical Equipment (1000 Volts Maximum)~~(ANSI)~~.⁸

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[TIA/EIA 404-B, Standard for Start-Stop Signal Quality for Non-Synchronous Data Terminal Equipment.](#)

[TIA/EIA 422-B, Electrical Characteristics of Balanced Voltage Digital Interface Circuits.](#)

[TIA/EIA 423-B, Electrical Characteristics of Unbalanced Voltage Digital Interface Circuits.](#)

[TIA-485-A, Electrical Characteristics of Generators and Receivers for Use in Balanced Digital Multipoint Systems.](#)

[TIA-530-A, High Speed 25 Position Interface for Data Terminal Equipment and Data Circuit-Terminating Equipment, Including Alternative 26-Position Connector.](#)

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this standard, the following terms and definitions apply. *The Authoritative Dictionary of computer IEEE Standards, Seventh Edition* [B10], should be referenced for terms ~~refer to~~ not defined in this clause. ~~ANSI X3-TR-1-1983.~~

3.1.1 accuracy: The difference between the actual value of a measurement and the indicated value of the measurement.

⁷ See <https://wsnrc2vger.wsmr.army.mil/rcc/PUBS/pubs.htm>

⁸ NEMA publications are available from Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112, USA (<http://global.ihs.com/>).

⁹ TIA publications are available from Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112, USA (<http://global.ihs.com/>).

NOTE—Accuracy is usually expressed in terms of percentage deviation from a reference value, commonly full scale of the measuring device and less commonly the actual value at the input. Note that accuracy for power measurements are expressed with an applicable power factor range. (Real power measured at less than 10% power factor or reactive power measured at greater than 90% power factor tend to have significant errors) Note also that if the “measuring device” is a current transformer, its full scale rating may be significantly larger than the displayed value (e.g., a 3000 ampere 0.3% CT measuring a 300 ampere load current). In this case, its accuracy is $0.3\% \times 3000$ or ± 90 amps, so the accuracy of a 300 amp load measurement is actually 300 ± 90 amps or $\pm 30\%$ of the measured value.¹⁰

3.1.2 availability: Availability (A) is defined in the following as the ratio of uptime to total time (uptime + downtime). It is customary to express availability in percentage, usually as 99.xxx, where xxx are numbers that complete the percentage.

NOTE—See 8.3.

3.1.3 chatter filter: A facility that is used to disable a digital input point if the number of state changes of that point during a defined time interval is excessively high.

3.1.4 clear time: The amount of time that the select relay will continue to operate after the master trip or close has operated. Clear time can also mean operating time.

3.1.5 control arm time-out: The maximum amount of time that a device will wait to receive an execute command after receiving a select or arm command. Refer to select command.

3.1.6 debounce period: The amount of time for which the state of a digital input point shall be detected in a valid “on” or “off” condition before it is considered to be in that position.

3.1.7 diagnostics: Programs executed to check the health of the device on either a periodic or random interval.

3.1.8 double-point status: A pair of digital input points that can assume four different states. States 1 and 2 may be described as NORMAL or VALID states, and states 3 and 4 may be described as TRAVELLING or ABNORMAL or INVALID states. Purpose is to detect complete changes of state (transitions), while ignoring any incomplete transitions.

3.1.9 Form A Counters: A single-point type of digital input that counts rising-edge changes of state (or transitions).

3.1.10 Form C Counters: Also known as KYZ pulses. A pair of digital inputs that count the transitions from one valid state to the next valid state, while ignoring any transitions to invalid states. An increase in the count occurs when both inputs change to the opposite state (one turns on, one turns off).

3.1.12 latency: The time between when sensor outputs are present at the physical interface of a measuring device until its value is available to the first user or program.

3.1.11 local area network (LAN): A LAN is a network normally designed for a limited geographical area, such as a utility substation or an office area. It is generally capable of transmitting data, voice, and image and video information. In most cases a LAN is considered to be an integral part of the facility, and is owned by the facility owner. A substation LAN may have sub-networks or segments to manage information flow and access. Segments may also be added to accommodate passing messages over distances exceeding the basic messaging distance inherent in the media. Serial networks can often be implemented over a LAN by embedding the serial messages in a network protocol. ~~A communication network to interconnect a variety of intelligent devices (e.g., personal computers, workstations, printers, file storage devices) that can transmit data over a limited area, typically within a facility.~~

3.1.13 lock-out period: A parameter that defines the length of time that a device or point will be disabled from operation after exceeding a pre-defined error condition.

¹⁰ Notes in text, tables, and figures are given for information only, and do not contain requirements needed to implement the standard.

3.1.14 pseudo points: System data points generated internally by a software application. They often represent the results of a calculation, or the internal state of a process.

3.1.15 recloser: Abbreviated name for automatic circuit recloser.

3.1.16 resolution: The smallest increment of a value that can be resolved, often expressed as percent of full scale. It is better expressed in engineering units of the measured value.

NOTE—If the resolution of a 1000 full scale value is 0.1% of full scale, then values displayed on a CRT or report should only be whole numbers (no decimal values).

3.1.17 scan (interrogation): The process by which a data acquisition system interrogates intelligent electronic devices (IEDs) for points of data.

3.1.18 scan cycle: The time in seconds required to obtain a collection of data (e.g., all data from one IED, all data from all IEDs, or all data of a particular type from all IEDs).

3.1.19 Scan Enable: A feature that allows or disallows a particular input point to be scanned.

3.1.20 Select Before Operate: Two-part command sequence used to achieve high communications security and hardware verification before the control is actually executed. See Annex D for more information.

3.1.21 single point/multiple point control: The control of a single point versus global control of multiple points.

3.1.22 time skew: The elapsed time between when the first value in a set of measurements is taken until the last value of the same set of measurements is taken. The data set may consist of measurements made in a close proximity, as within a single substation, or across a large geographic area as in the flow measurements for a large transmission network.

3.1.23 unavailability: The ratio downtime/(uptime + downtime). The ratios of downtime to total time (uptime + downtime), or downtime/(uptime + downtime). It is often expressed as a maximum period of time during which the variable is unavailable, e.g., 4 h per month.

3.1.24 update periodicity: The time between updates, sometimes expressed as the rate at which a measurement is updated (frequency).

3.1.26 virtual input/output (I/O): An I/O point such as status, control, or analog that is not physically wired to an IED.

3.1.25 wide area network (WAN): A WAN provides long-distance transmission of data, voice, and image and video information over a large geographical area. A WAN can be owned by a utility or WAN services can be leased from telecommunication providers. WANs connect LANs together. For automating substations, an enterprise WAN connection may become the pathway to link the substation to the enterprise.

3.2 Acronyms and abbreviations

<u>AGA</u>	<u>American Gas Association</u>
<u>API</u>	<u>application programming interface</u>
<u>CPU</u>	<u>central processing unit</u>
<u>CRC16</u>	<u>16-bit cyclic redundancy check</u>
<u>CSMA/CD</u>	<u>collision sensing multiple access/collision detection</u>
<u>CT</u>	<u>current transformer</u>
<u>DISCO</u>	<u>distribution company</u>
<u>DMS</u>	<u>Distribution Management System</u>
<u>DNP/DNP3</u>	<u>Distributed Network Protocol, version 3.0</u>
<u>DPI</u>	<u>double-point information</u>
<u>EMC</u>	<u>electromagnetic compatibility</u>
<u>EMI</u>	<u>electromagnetic interference</u>
<u>EMS</u>	<u>Energy Management System</u>
<u>EPROM</u>	<u>erasable programmable read-only memory</u>
<u>FAT</u>	<u>factory acceptance test</u>
<u>FMEA</u>	<u>failure modes and effect analysis</u>
<u>FPGA</u>	<u>Field Programmable Gate Array GAL Generic Array Logic</u>
<u>GENCO</u>	<u>generation company</u>
<u>GPR</u>	<u>ground potential rise</u>
<u>HMI</u>	<u>Human Machine Interface</u>
<u>I/O</u>	<u>inputs/outputs</u>

<u>ICCP</u>	<u>Inter-Control Center Communication Protocol</u>
<u>IED</u>	<u>intelligent electronic device</u>
<u>IRIG-B</u>	<u>Inter Range Instrumentation Group format B</u>
<u>ISA</u>	<u>Instrumentation, Systems, and Automation Society</u>
<u>ISO</u>	<u>Independent System Operator</u>
<u>IT</u>	<u>information technology</u>
<u>ITU</u>	<u>International Telecommunication Union</u>
<u>LAN</u>	<u>local area network</u>
<u>LCD</u>	<u>liquid crystal display</u>
<u>LED</u>	<u>light emitting diode</u>
<u>MTBF</u>	<u>mean time between failure</u>
<u>MTTR</u>	<u>mean time to repair</u>
<u>NERC</u>	<u>North American Electric Reliability Corporation</u>
<u>NIM</u>	<u>network interface module</u>
<u>NTP</u>	<u>Network Time Protocol</u>
<u>ODBC</u>	<u>Open Database Connectivity</u>
<u>PLC</u>	<u>programmable logic controllers</u>
<u>POSIX</u>	<u>Portable Operating System Interface</u>
<u>PROM</u>	<u>programmable read-only memory</u>
<u>PSTN</u>	<u>Public Switched Telephone Network</u>
<u>PT</u>	<u>potential transformer</u>
<u>RAID</u>	<u>redundant array of inexpensive disks or redundant array of independent disks</u>
<u>ROM</u>	<u>read-only memory</u>
<u>RTO</u>	<u>Regional Transmission Organization</u>
<u>RTU</u>	<u>remote terminal unit</u>
<u>SAT</u>	<u>site acceptance test</u>
<u>SCADA</u>	<u>Supervisory Control and Data Acquisition</u>
<u>SNTP</u>	<u>Simple Network Time Protocol</u>
<u>SOE</u>	<u>sequence of events</u>
<u>SPI</u>	<u>single-point information</u>
<u>SQL</u>	<u>structured query language</u>
<u>SWC</u>	<u>surge withstand capability</u>
<u>TASE</u>	<u>Telecontrol Application Service Element</u>
<u>TCP/IP</u>	<u>Transmission Control Protocol/Internet Protocol</u>
<u>TRANSCO</u>	<u>transmission company</u>
<u>UHF</u>	<u>ultra high frequency</u>
<u>UPS</u>	<u>uninterruptible power supply</u>
<u>UTP</u>	<u>Unshielded Twisted Pair</u>
<u>VDU</u>	<u>video display unit</u>
<u>Wan</u>	<u>wide area network</u>

~~The definitions of terms contained in this standard are not intended to embrace all legitimate meanings of the terms. They are applicable only to the subject treated in this standard.~~

~~Supervisory control and data acquisition systems use computers.~~

~~Definitions from IEEE Std 100-1992 are indicated with an asterisk (*) following the definition.~~

3.1 accumulator point interfaces: Master station or RTU (or both) element(s) that accept(s) a pulsing digital input signal to accumulate a total of pulse counts.

3.2 accumulator SCADA function: The capability of a supervisory system to accept and totalize digital pulses and make them available for display or recording, or both.

~~**3.3 alarm condition:** A predefined change in the state or condition of equipment or the failure of equipment to respond correctly. Indication may be audible or visual, or both.[‡]~~

~~**3.4 alarm point interfaces:** Master station or RTU (or both) element(s) that input(s) a signal to the alarm function.~~

~~**3.5 alarm SCADA function:** The capability of a supervisory system to accomplish a predefined action in response to an alarm condition. *See also:* 3.3, **alarm condition**.~~

~~**3.6 analog device:** A device that operates with variables represented by continuously measured quantities such as voltages, resistances, rotations and pressures.[‡]~~

~~**3.7 analog function check:** Monitor a reference quantity. A check of master and remote station equipment by exercising a predefined component or capability.~~

~~**3.8 analog point interfaces:** Master station or RTU (or both) element(s) that input(s) or output(s) an analog quantity.~~

~~**3.9 analog quantity:** A variable represented by a scalar value (see 4.2.3.1).[‡]~~

~~**3.10 analog SCADA function:** The capability of a supervisory system to accept, record, or display, or do all of these, an analog quantity as presented by a transducer or external device. The transducer may or may not be a part of the supervisory control system.~~

~~**3.11 analog telemetering:** Telemetering in which some characteristic of the transmitter signal is proportional to the quantity being measured.[‡]~~

~~**3.12 analog to digital (A/D) conversion:** Production of a digital signal whose magnitude is proportional to the value of an analog quantity.[‡]~~

~~**3.13 automatic:** Pertaining to a process or device that, under specified conditions, functions without intervention by a human operator.[‡]~~

~~**3.14 automatic control:** An arrangement of electrical controls that provides for switching or controlling, or both, of equipment in an automatic sequence and under predetermined conditions.[‡]~~

[‡]NEMA publications are available from the National Electrical Manufacturers Association, 2101 L Street NW, Washington, DC 20037, USA.

~~**3.16 backup:** Provision for an alternate means of operation if the primary system is not available.[‡]~~

~~**3.17 backup, degraded:** A backup capability that does not perform all of the functions of the primary system.[‡]~~

~~**3.18 baud:** The signaling speed, that is, keying rate of the modem. The signaling speed in baud is equal to the reciprocal of the shortest element duration in seconds to be transmitted. The terms “bit rate” and “baud” are not synonymous and shall not be interchanged in usage. Preferred usage is bit rate, with baud used only when the details of a communication modem or channel are specified.~~

~~For example, in the following table, the signaling speed is calculated from the signaling element duration. In addition, the distinction between bit rate and baud for two different types of modems is illustrated.[‡]~~

	Signaling technique	
	Modem one	Modem two
Signaling element duration	0.833 ms	
Signaling speed	1200 baud	
Information transmitted per element duration	1-b	2-b
Bit rate	1200 b/s	2400 b/s

3.19 bit rate: The number of bits transferred in a given time interval. Bits per second is a measure of the rate at which bits are transmitted.[Ⓜ]

3.20 buffer: A device in which data are stored temporarily, in the course of transmission from one point to another; used to compensate for a difference in the flow of data, or time of occurrence of events, when transmitting data from one device to another.[Ⓜ]

3.21 burn-in: A period, prior to on-line operation, during which equipment is continuously energized for the purpose of forcing infant mortality failures.[Ⓜ]

3.36 data: Any representation of a digital or analog quantity to which meaning has been assigned.[Ⓜ]

3.37 data acquisition: The collection of data.[Ⓜ]

3.38 data acquisition system: A system that receives data from one or more locations.[Ⓜ]

3.39 data logging: The recording of selected data on suitable media.[Ⓜ]

3.40 data rate: The rate at which a data path (e.g., channel) carries data, measured in bits per second (b/s).[Ⓜ]

3.41 data test: a) The recorded results of test.

b) A set of data developed specifically to test the adequacy of a computer run or system. They may be actual data taken from previous operations or artificial data created for this purpose.

3.42 deadband: The range through which an analog quantity can vary without initiating response.[Ⓜ]

3.43 degraded backup: See: 3.17, **backup, degraded.**

3.44 device (electrical equipment): An operating element (e.g., relay, contactor, circuit breaker, switch, valve, or governor) used to perform a given function in the operation of electrical equipment.[Ⓜ]

3.45 diagnostics, self: Programs automatically executed, at predetermined intervals, in the master station or RTU, to check the health of the system.

3.46 differential mode interference: See: 3.75, **interference, differential mode.**

3.47 digital quantity: A variable represented by a number of bits.[Ⓜ]

3.48 digital telemetering: Telemetering in which a numerical representation is generated and transmitted; the number being representative of the quantity being measured.[Ⓜ]

3.49 digital to analog (D/A) conversion: Production of an analog signal whose magnitude is proportional to the value of a digital quantity.[Ⓜ]

3.50 disable: A command or condition that prohibits some specific event from occurring.^{*}

3.51 display, graphic: A hardware device (e.g., CRT, VDT, liquid crystal display (LCD), mapboard, plasma panel, arrays of lamps, or light emitting diodes) used to visually present information.^{*}

3.52 distributed : A design in which data is processed by more than one processor.^{*}

3.53 downtime: The time during which a device or system is not capable of meeting its functional requirements^{*} (see 7.3).

3.54 echo-checkback message: A communication technique assuring that a message received at the termination point in a system is the same message as originally transmitted. The received message is retransmitted to the sending device and matched to ensure that the original message was received properly.^{*}

3.55 (EMC): A measure of equipment tolerance to external fields(see 6.6.2).

3.56 electromagnetic interference (EMI): A measure of electromagnetic radiation from equipment^{*} (see 6.6.1).

3.57 enable: A command or condition that permits some specific event to occur.^{*}

3.58 engineering unit: A unit of physical measurement (e.g., volts, amperes).^{*}

3.59 event: A discrete change of state (status) of a system or device.^{*}

3.60 expendability: The capability of a system to be increased in capacity or provided with additional functions^{*} (see 7.5).

3.61 failover: The transfer of a function or functions to a backup device.

3.62 failure: An event that limits the capability of equipment or a system to perform its function(s)^{*} (see 7.1).

3.63 failure distribution: The manner in which failures occur as a function of time; generally expressed in the form of a curve with the abscissa being time.^{*}

3.64 frequency type telemeter: A telemeter that employs the frequency of a periodically recurring electric signal as the translating means.^{*}

3.65 graphic : See: 3.51, **display, graphic**.^{*}

3.66 hardcopy: A paper record of information (e.g., reports, listings, logs, and charts).^{*}

3.67 infant mortality failures: A characteristic pattern of failure wherein the number of failures per unit of time decreases rapidly as the number of operating hours increase.^{*}

3.68 I/O: Input/output points.

3.69 indication: An audio or visual signal that signifies a particular condition.^{*}

3.70 indication (status) function: The capability of a supervisory system to accept, record, or display, or do all of these, the status of a device. The status of a device may be derived from one or more inputs giving the following two or more states of indication:

- a) *Two-state indication.* Only one of the two possible positions of the supervised device is displayed at one time. Such display may be derived from a single set of contacts.
- b) *Three-state indication.* One in which the transitional state or security indication as well as the terminal positions of the supervised device is displayed. Such a display is derived from at least two sets of initiating contacts.
- c) *Multistate indication.* Only one of the predefined states (transitional or discrete, or both) is indicated at a time. Such a display is derived from multiple inputs.
- d) *Indication with memory.* An indication function with the additional capability of storing single or multiple changes of status that occur between scans.

3.71 indication (status) point interfaces: Master Station or RTU (or both) element(s) that accept(s) a digital input signal for the function of indication.

The input/output elements of a SCADA system provide the physical interface to external devices. It is preferred that a point serve one of the functions described below. In some earlier applications, a Control and Indication (C and I) point has been used to specify a combination control and indication point for a specific device (e.g., circuit breaker). The functions are:

- a) *Two-state indication.* Only one of the two possible positions of the supervised device is displayed at one time. Such display may be derived from a single set of contacts.
- b) *Three-state indication.* One in which the transitional state or security indication as well as the terminal positions of the supervised device is displayed. Such a display is derived from at least two sets of initiating contacts.
- c) *Multistate indication.* Only one of the predefined states (transitional or discrete, or both) is indicated at a time. Such a display is derived from multiple inputs.
- d) *Indication with memory.* An indication function with the additional capability of storing single or multiple changes of status that occur between scans.

3.72 inhibit: To prevent a specific event from occurring (e.g., alarm inhibit).^{*}

3.73 intelligent electronic device (IED): Any device incorporating one or more processors with the capability to receive or send data/control from or to an external source (e.g., electronic multifunction meters, digital relays, controllers).

3.74 interference, common mode: a) Interference that appears between both signal leads and a common reference plane (ground) and causes the potential of both sides of the transmission path to be changed simultaneously and by the same amount relative to the common reference plane (ground).^{*}

b) A form of interference that appears between any measuring circuit terminal and ground.^{*}

3.75 interference, differential mode: Interference that causes the potential of one side of the signal transmission path to be changed relative to the other side.^{*}

3.76 interference, normal mode: A form of interference that appears between measuring circuit terminals.^{*} See also:

3.75, interference, differential mode.

3.77 interposing relay: See: 3.106, relay, interposing.

3.79 logging function check: Accomplished when results of the control function check are logged. A check of master and remote station equipment by exercising a predefined component or capability (see 7.4.1).

3.80 log: A printed record of data.^{*}

3.81 manual control: Control in which the system or main device, whether direct or power aided in operation, is directly controlled by an operator.^{*}

3.82 master station: See: 3.129, station, master.

3.83 master terminal unit (MTU): Refers to the master station of a supervisory control system.^{*}

3.84 mean time between failure (MTBF): The time interval (hours) that may be expected between failures of an operating equipment (see 7.1).^{*}

3.85 mean time to repair (MTTR): The time interval (hours) that may be expected to return a failed equipment to proper operation (see 7.2).^{*}

~~**3.86 modem:** A MOdulator/DEModulator device, which converts serial binary digital data to and from the signal form appropriate for the respective communication channel.[Ⓢ]~~

~~**3.87 multibit point interface:** Multibit (e.g., BCD, gray code) point. Master Station or RTU (or both) element(s) that inputs a series of multibit quantities in parallel.~~

~~**3.88 normal mode:** See: 3.76, **interference, normal mode/**~~

~~**3.89 offset:** A predetermined value modifying the actual value (e.g., the use of a 4 mA signal to represent zero in a 4 mA to 20 mA system).[Ⓢ]~~

~~**3.90 open loop control:** A form of control without feedback.[Ⓢ]~~

~~**3.91 panel, control:** An assembly of user interface devices (see 5.6).[Ⓢ]~~

~~**3.92 partial automatic control:** Control that is a combination of manual and automatic control.[Ⓢ] For example, to cause a voltage reduction, the local automatic load tap changing closed loop control may be biased by way of a supervisory control command.~~

~~**3.93 point test:** A predefined location within equipment or routines at which a known result should be present if the equipment or routine is operating properly.~~

~~**3.94 poll function check:** Accomplished when analog function is performed with all remotes. A check of master and remote station equipment by exercising a predefined component or capability. See also: 3.7, **analog function check**.~~

~~**3.95 polling (data request):** The process by which a data acquisition system selectively requests data from one or more of its RTUs. An RTU may be requested to respond with all, or a selected portion of, the data available.[Ⓢ]~~

~~**3.96 polling supervisory system:** A system in which the master station periodically interrogates each RTU to request data.[Ⓢ]~~

~~**3.97 primary:** An equipment or subsystem that is normally on line and performing system functions. See also: 3.16, **backup**.[Ⓢ]~~

~~**3.98 processor:** A system or mechanism that accepts a program as input, prepares it for execution, and executes the process so defined with data to produce results.[Ⓢ]~~

~~**3.99 programmable equipment:** An RTU or master station having one or more of its operations specified by a program contained in a memory device.[Ⓢ]~~

~~**3.100 protocol:** A strict procedure required to initiate and maintain communication.[Ⓢ]~~

~~**3.101 pulse type telemeter:** A telemeter that employs characteristics of intermittent electric signals, other than their frequency, as the translating means.[Ⓢ]~~

~~**3.102 quiescent supervisory system:** A system that is normally alert but inactive. It transmits information only when a change in indication occurs at the RTU or when a command operation is initiated at the master station.[Ⓢ]~~

~~**3.103 random failures:** The pattern of failures for equipment that has passed out of its infant mortality period and has not reached the wear out phase of its operating lifetime. The reliability of an equipment in this period may be computed by the equation:~~

$$R = e^{-\lambda t(t)}$$

where

λ is failure rate

t is time period of interest

3.104 ratio-type telemeter: A telemeter that employs the relative phase position between, or the magnitude relation between, two or more electrical quantities as the translating means. Examples of ratio-type telemeters include ac or dc position matching systems.*

3.105 re-encoded checkback message: Message from the initiating end that is re-encoded by the receiving end. A new message is sent to the initiating end to verify error-free receipt and proper interpretation of the message. In typical applications the initiating end is the master station and the receiving end is the RTU. Preferred usage is re-encoded, which 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 (see 7.4).

3.106 relay, interposing: A device that enables the energy in a high-power circuit to be switched by a low-power control signal, provides isolation, and/or provides contact multiplication.*

3.107 remote control: Control of a device from a distant point.*

3.108 remote station: See: 3.130, station, remote.

3.109 remote terminal unit: See: 3.130, station, remote.

3.110 report-by-exception: The reporting of data (e.g., from RTU to master station) only when the data either changes state (e.g., for a status or digital input point) or exceeds a predefined deadband (e.g., for an analog input point).

3.111 resolution: The least value of the measured quantity that can be distinguished.*

3.112 response time: The time between initiating some operation and obtaining results.*

3.113 RTU: See: 3.130, station, remote.

3.114 SCADA: See: 3.136, supervisory control and data acquisition.

3.115 SCADA channel: See: 3.25, channel, SCADA.

3.116 scan function check: Accomplished when control function check has been performed with all remotes. A check of master and remote station equipment by exercising a predefined component or capability.

3.117 scan (interrogation): The process by which a data-acquisition system interrogates RTUs for points of data.*
See also: 3.95, polling (data request).

3.118 scan cycle: The time in seconds required to obtain a collection of data (e.g., all data from one RTU, all data from all RTUs, or all data of a particular type from all RTUs).*

3.119 scanning supervisory system: A system in which the master station controls all information exchange. The normal state is usually one of repetitive communication with the RTUs.*

3.120 self diagnostics: See: 3.45, diagnostics, self.

3.121 semi-automatic station: See: 3.131, station, semi-automatic.

3.122 sequence of events (SOE): Digital input points that are time tagged to include relative or absolute time of occurrence.

3.123 sequence of events point interface: Master station or RTU (or both) element(s) that accept(s) a digital input signal to perform the function of time tagging the occurrence of an event. See also: 3.122, sequence of events (SOE).

3.124 sequence of events SCADA function: The capability of a supervisory system to recognize each predefined event, associate a time of occurrence with each event, and present the event data in order of occurrence of the events.

3.125 serial communication: A method of transmitting information between devices by sending all bits serially over a single communication channel.[‡]

3.126 settling time: Time required by channel or terminal equipment to reach an acceptable operating condition.

3.127 spare only point interface: Point for which cabinet space only is provided for the future addition of wiring and other necessary plug-in equipment.

3.128 spare point interface: Point equipment that is not being utilized but is fully wired and equipped.

3.129 station, master: The entire complement of devices, functional modules, and assemblies that are electrically interconnected to affect the master station supervisory functions. The equipment includes the interface with the communication channel but does not include the interconnecting channel. During communication with one or more remote stations, the master station is the superior in the communication hierarchy.[‡]

3.130 station, remote: The entire complement of devices, functional modules, and assemblies that are electrically interconnected to affect the remote station supervisory functions. The equipment includes the interface with the communication channel but does not include the interconnecting channel. During communication with a master station the remote station is the subordinate in the communication hierarchy.

3.131 station, semiautomatic: A station that requires both automatic and manual modes to maintain the required character of service.[‡]

3.132 station, sub-master: A station that can perform as a master station on one message transaction and as a remote station on another message transaction.

NOTES:

Examples of station equipments include

1—*Hardwired.* Station supervisory equipment that is comprised entirely of wired logic elements.

2—*Firmware.* Station supervisory equipment that uses hardware logic programmed routines in a manner similar to a computer. The routines can only be modified by physically exchanging logic memory elements.

3—*Programmable.* Station supervisory equipment that uses software routines.

3.133 status: Information describing a logical state of a point or equipment.[‡]

3.134 sub-master station: See: 3.132, **station, sub-master.**

3.135 supervisory control: An arrangement for operator control and supervision of remotely located apparatus using multiplexing techniques over a relatively small number of interconnecting channels.[‡]

3.136 supervisory control and data acquisition (SCADA): A system operating with coded signals over communication channels so as to provide control of RTU equipment. The supervisory system may be combined with a data acquisition system by adding the use of coded signals over communication channels to acquire information about the status of the RTU equipment for display or for recording functions.[‡]

3.137 supervisory system: All control, indication, and associated telemetering equipment at the master station, and all of the complementary devices at the RTU(s).[‡]

3.138 system time: A coordinated value of time maintained throughout the control and data acquisition equipment.

3.139 tag: A visual indication, typically at the master station, to indicate a special condition associated with a device (e.g., unavailable for control).[‡]

3.140 telemetering selection point interface: Master station or RTU (or both) element(s) for the selective connection of telemetering transmitting equipment to appropriate telemetering receiving equipment over an interconnecting communication channel. This type of point is more commonly used in electromechanical or stand-alone type of supervisory control.

3.141 timer, watchdog: A form of interval timer that is used to detect a possible malfunction.*

3.142 transaction: That sequence of messages between master and remote stations required to perform a specific function (e.g., acquire specific data or control a selected device).*

3.143 transverse (differential) mode: See: 3.75, **interference, differential mode.**

3.144 troubleshoot: Action taken by operating or maintenance personnel, or both, to isolate a malfunctioned component of a system. Actions may be supported by printed procedures, diagnostic circuits, test points, and diagnostic routines.*

3.145 uninterruptible power supply (UPS): A system designed to automatically provide power, without delay or transients, during any period when the normal power supply is incapable of performing acceptably.*

3.146 uptime: The time during which a device or system is capable of meeting functional requirements* (see 7.3).

3.147 user interface (UI): A physical interface between the operator and the system equipment.

3.148 video display terminal (VDT): The visual equipment used as a user interface. See also: 3.147, *user interface (UI)*.

3.149 voltage type telemeter: A telemeter that employs the magnitude of a single voltage as the translating means.*

3.150 watchdog timer: See: 3.141, **timer, watchdog.**

3.151 wear-out failures: The pattern of failures experienced when equipment reaches its period of deterioration. Wear-out failure profiles may be approximated by a Gaussian (bell curve) distribution centered on the nominal life of the equipment.*

3.152 wired point interface: Point for which all common equipment, wiring, and space are provided. To activate the point requires only the addition of plug-in hardware for the specific point.

4. System overview

4.1 General

In recent years, network-based substation automation has greatly evolved with the use of IEDs. The processing is now distributed and functions that used to be done at the control center or remote terminal unit (RTU) can now be done by the IED or a group of networked IEDs. Despite the fact that many functions can be moved to the IED, utilities still need a master station for the operation of the power system. Due to the restructuring of the electric industry, traditional vertically integrated electric utilities are replaced by many entities such as: GENCO, TRANSCO, DISCO, ISO, RTO, etc. To fulfill their role, each of these entities needs a master station and/or control center to receive and process data and take appropriate control actions.

4.2 Master station (control center) architecture and functions

Modern Supervisory Control and Data Acquisition (SCADA) master stations have both software and hardware in a distributed architecture. The processing power is distributed among various computers and servers that communicate with each other through a real-time dedicated LAN in the control center.

Distributed systems have many advantages over centralized systems. Since the data processing is shared on the network, the various servers require less processing power than in a centralized system. In this way, the cost of computers can be reduced. It is also easier to upgrade or to add servers if additional processing power is required. Another advantage of distributed systems is that the failure of one server does not necessarily affect the whole system. Figure 1 shows an example SCADA master station system architecture without the inclusion of network security.

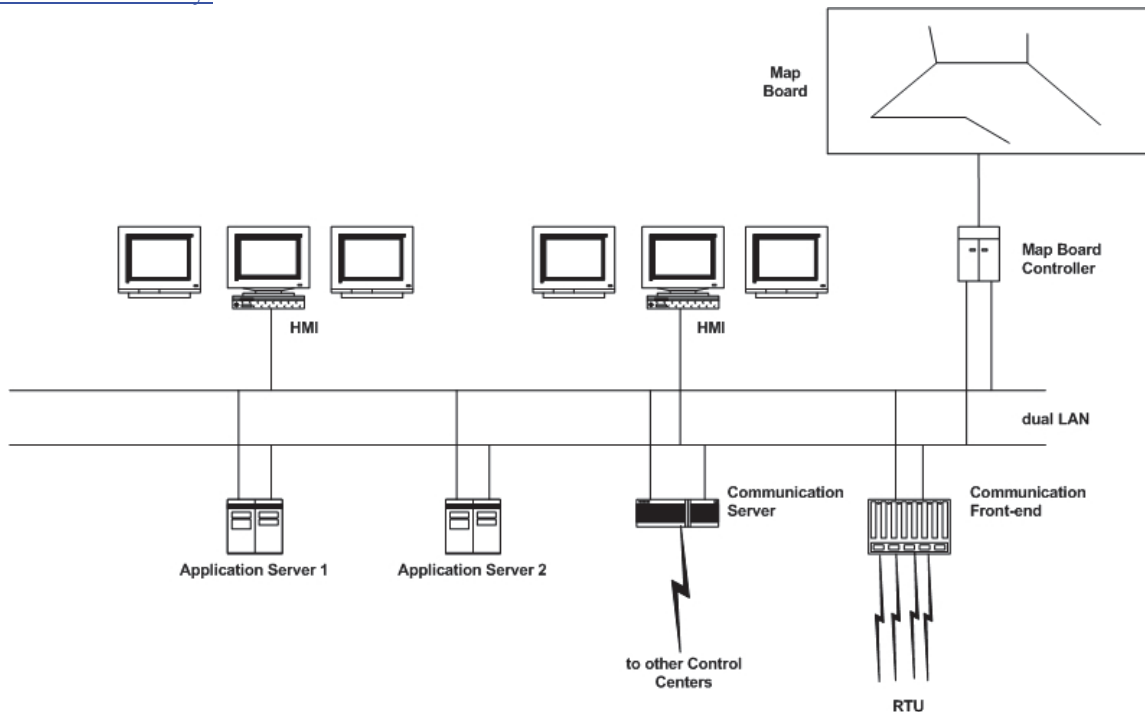


Figure 1—Example SCADA master station system configuration at a control center without network security shown

Modern SCADA master station systems can use open architecture features that support interconnections with other systems. Open system standards also support interfaces with other vendors' products.

To ensure the openness, the system should comply with international standards, such as POSIXTM, or industry's de-facto standards such as Microsoft[®] Windows[®], X Window,¹¹ and related products for the computer applications; IEC 60870-6 (TASE.2)¹² for communications to other control centers; and IEEE Std 1379 for remote terminal unit (RTU) communications. Despite the fact that most vendors offer open systems, they each develop their own application programming interface (API). This API enables software modules to communicate with each other by using common objects and data exchange mechanisms. The IEEE and the IEC are developing appropriate standards to ensure inter-operability at the API level.

The main elements of the SCADA system illustrated in Figure 1 are as follows:

– **Human Machine Interface (HMI):** This interface comprises the mimic board and multi video display unit (VDU) workstations:

– **Mapboard:** The mapboard (mimic board, or wall board displays an overview of the power system. It shows a simplified representation of the power system preserving as much detail as possible, and is arranged to approximated the geographical orientation of the power system. It is useful in observing major power system disturbances covering a large geographic area. Two different map board technologies are used in control centers.

The mosaic type mapboard uses small mosaic tiles with the static type information etched or taped on the tiles. Indicators are used for dynamic information such as breaker status. A matrix of light emitting diodes (LEDs) can also be inserted in the mimic board to offer animation capability. If a modification is needed, old tiles are replaced by new ones—a time-consuming activity.

Today, large screen displays (projection systems, large-scale LCD systems, plasma systems, etc.) are more commonly used in control centers. The system software prepares and sends to the mapboard controller the pictures to be displayed. This type of mapboard requires much less effort when the electric network configuration is modified. A new picture is edited and propagated to the mapboard. It is also significantly easier to ensure consistent display of the electric network configuration across multiple control centers.

One significant advantage of the mosaic tile mapboard is the fact that the network orientation and topology remains visible to a user even in the event of a total power failure, or a malfunction of the VDU driver or VDU itself.

– **Multi-VDU Interface:** These are workstations used to view the status of power system devices in more detail. In modern SCADA systems, multi-VDU workstations give operators easy access to a wide variety of application and control functions. These workstations can support four or more physical or virtual VDUs and offer full graphic capability with multi-window techniques such as pan, zoom, pop-up/pull-down menu and “drag and drop.” Interactive menu selection speeds up switching between applications.

– **Application servers:** SCADA systems have several different servers, as follows:

– **Core SCADA subsystems:** This server is used mainly for data processing functions and real-time operational process control.

– **Database subsystems:** This server supports the historical database and other system databases.

¹¹ This information is given for the convenience of the users of this standard and does not constitute an endorsement by the IEEE of these products. Equivalent products may be used if they can be shown to lead to the same results.

¹² Information on references can be found in Clause 2.

– **Advanced application subsystems:** These servers support all Energy Management System (EMS) or Distribution Management System (DMS) applications. The main characteristic of this server is its processing power. More than one server may be used for these applications.

– **Historical databases:** These servers support the database that contains all historical data. This information can also be used for system studies or operators’ training. Data are forecasted or estimated for future values.

- **Configuration and management:** This server is used for the control, management, and maintenance of the whole SCADA system. From this server, the operation mode of each server can be controlled and system backup functions can be ordered.
- **Communication front-end:** This system is used for data acquisition from RTUs and field equipment. It provides functions such as acquiring the RTU data, protocol conversion, security check, temporary storage of analog and digital data, and detection of analog value and digital state changes.
- **External communication server:** This server provides data exchange with other control centers. A standard protocol, such as IEC 60870-6 (TASE.2) should be used to exchange real-time and archive data. As this server provides a window into the master station, special attention should be paid to protecting unauthorized access via this server, and to the protection of the data residing in the master station database from unauthorized access or modification. See 5.5 for additional security requirements.

4.3 Remote site (substation) control system functions and architecture

Prior to using IEDs as the control and monitoring interface to the power system equipment, the substation RTU was the gathering point for substation data and control circuits. The substation protection and automatic controls provided the basic functions, and the RTU was an overlay to provide remote control and monitoring. With IEDs, the RTU may still be specified as all or as only a part of the substation control and data acquisition system and may still provide the communications interface to the master station. By using substation integration techniques to connect IEDs together using one or more communication networks, the traditional RTU functionality becomes more distributed within the substation with the result that the traditional RTU may not even exist. Once the substation IEDs are integrated together, it is then possible to accomplish substation automation.

The main elements of a substation automation system are similar to those in a SCADA master and should be specified for a substation automation system. The following elements may be contained in a system:

- **HMI:** This hardware interface runs software that creates graphics on a video display that replace the traditional mimic boards, analog displays, control switches, and selector switches. The hardware component usually includes an IEEE Std 1613 substation-hardened computer with a display terminal and keyboard that are mounted in a rack or panel. The HMI hardware may also be a commercially available computer that is appropriately isolated from the substation environment as required.
- **RTU:** The substation RTU may still be a traditional RTU with hard-wired inputs and outputs and communication with one or more SCADA masters. With the proliferation and increasing capabilities of IEDs, however, the RTU may actually combine several different elements into one device. For example, the RTU may provide the substation HMI, the data concentrator, and remote access controller.
- **Data Concentrator:** A data concentrator collects the required data from all substation IEDs, even the RTU as necessary, and provides data exchange with other systems (possibly even other SCADA masters). Different system configurations are possible such that the RTU, HMI, and data concentrator elements are in one device.
- **Remote Access Controller:** This IED enables remote access to the substation IEDs for remote configuration, access, and data retrieval. Different system configurations are possible, such that the remote access controller is the same IED as the data concentrator.

These elements perform at least the following functions in a substation automation system:

- a) Measurement
- b) Status monitoring
- c) Control
- d) Ancillary services

e) Time synchronization

f) Programmed logic

Clause 5 contains the specification for these functions and elements that the designer/specifier can use to specify a substation automation system. Many of these elements and functions are combined together into a block diagram, which the designer/specifier may require as part of the substation automation system. Figure 2 is a simplified block diagram taken from IEEE Std C37.115 that does not show any network security. It is an example of a substation automation system with all IEDs on a substation LAN. The example block diagram shows a single LAN and non-redundant IEDs. Other architectures may include redundant IEDs, LANs, and communication channels. IEDs that are not network enabled are typically connected to the substation LAN via a data concentrator or serial device server (serial port server), which is not shown in the figure.

Not shown or included in Figure 2 are separate connections to the maintenance ports of the IEDs for remote access. In the past, these ports were often connected to a port switch and an auto-answer modem connected to a dial-up phone line, providing an additional communications channel into the substation. Many IEDs still support this method of remote access. As IEDs have added network ports, as shown in Figure 2, remote and local access to IEDs can now be accomplished over the substation LAN. In Figure 2, the connection from the substation to the EMS and other users at engineering work stations is through a WAN. The connection from the WAN to the substation LAN is through a router and firewall.

Figure 2 shows a “dedicated channel” from the SCADA master to the RTU, which is not meant to imply either serial or network connectivity, but to convey the concept that substation control systems may have both an interface to a SCADA master (for control by a regional operating center) and to the corporate EMS. The diagram shows two methods of data acquisition and control. One is via IEDs connected to the substation power system equipment and sensors. The other is via direct connections to the substation RTU. In both cases, the data may be stored in a database server or a separate connection to a remote historian or database may be provided (not shown). Depending on the capabilities of the substation HMI, the database server and the HMI may be combined into one device. This reduces the database generation and maintenance effort and simplifies the system design.

Figure 2 does not show any communication message encryption devices for any internal or external communications, although the router could address external encryption and authentication.

Figure 2 does show wiring for a timing signal from an IRIG-B generator, which is typically a GPS satellite clock that distributes a time signal to the substation IEDs using a separate timing wire. Depending on the timing requirements, the timing wire may not be necessary if the IED clocks can be accurately set over the LAN using the NTP, SNTP, or IEEE Std 1588.

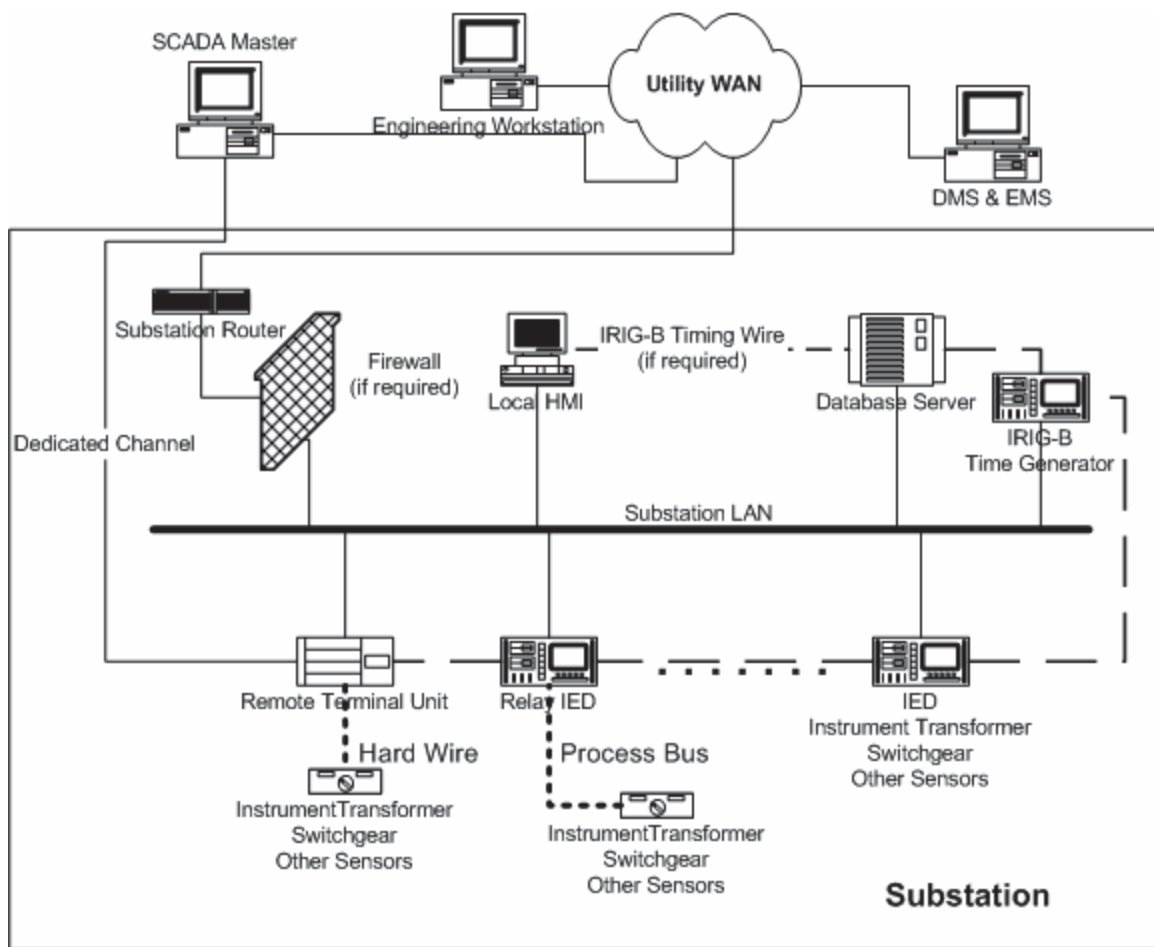


Figure 2—Example substation automation system architecture without security shown

The designer/specifier can use the following sections to specify the elements and functions of the system briefly discussed in 4.3.

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 (RTUs). Figure 1 illustrates the possible data and control flow between a master station and one or more RTUs.~~

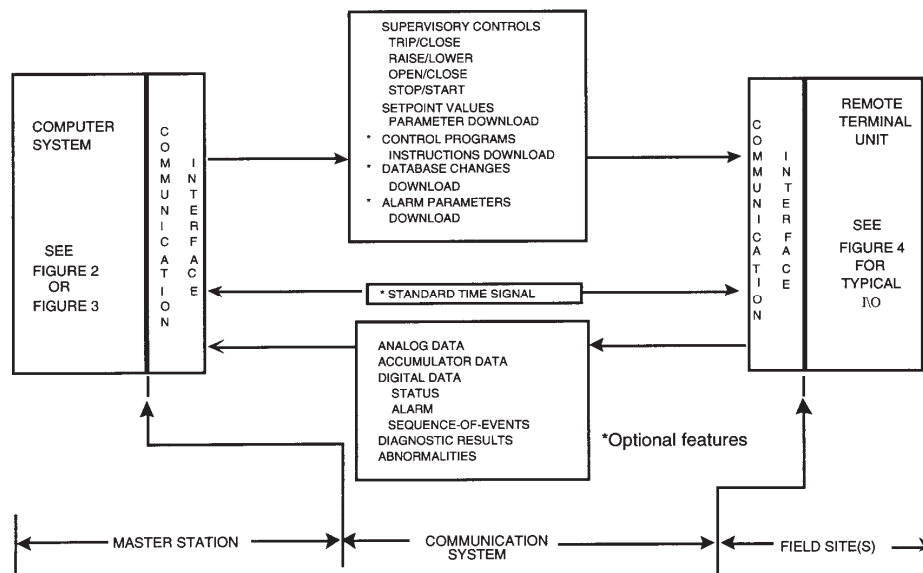


Figure 1—Master/RTU functional data/control flow

4.1 Typical equipment functional diagrams

Functional diagrams of typical RTU and master station equipment and configurations are illustrated within this subclause.

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. 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 IEEE Std 999-1992.

The functional components of a master station are illustrated in figures 2 and 3. A dual computer master station is illustrated in figure 2, however, a single computer master station may be adequate for some applications.

A distributed multi computer master station is illustrated in figure 3. Multiple master stations may perform different functions from another, i.e., one dedicated to Supervisory Control and Data Acquisition (SCADA) functions and another dedicated to sequence of events or fault analysis. Also, each computer in a distributed master station may typically be assigned to a specialized processing task separate and distinct from the others; i.e., one dedicated to SCADA, one or more to other application processing, etc. Application processing may include features like trend analysis, load profiling/forecasting, etc. The computer illustrated in figures 2 and 3 as a single box typically includes mass memory and various peripherals. The communication interface portion of figures 2 and 3 are used to interface the RTU communication channels to the master station computer system. The user interface (UI) portion is used to present information to, and accept inputs from, the user(s).

The functional components of an RTU are illustrated in figure 4. Various interconnections of master station(s) and RTU(s) are illustrated in annex A.

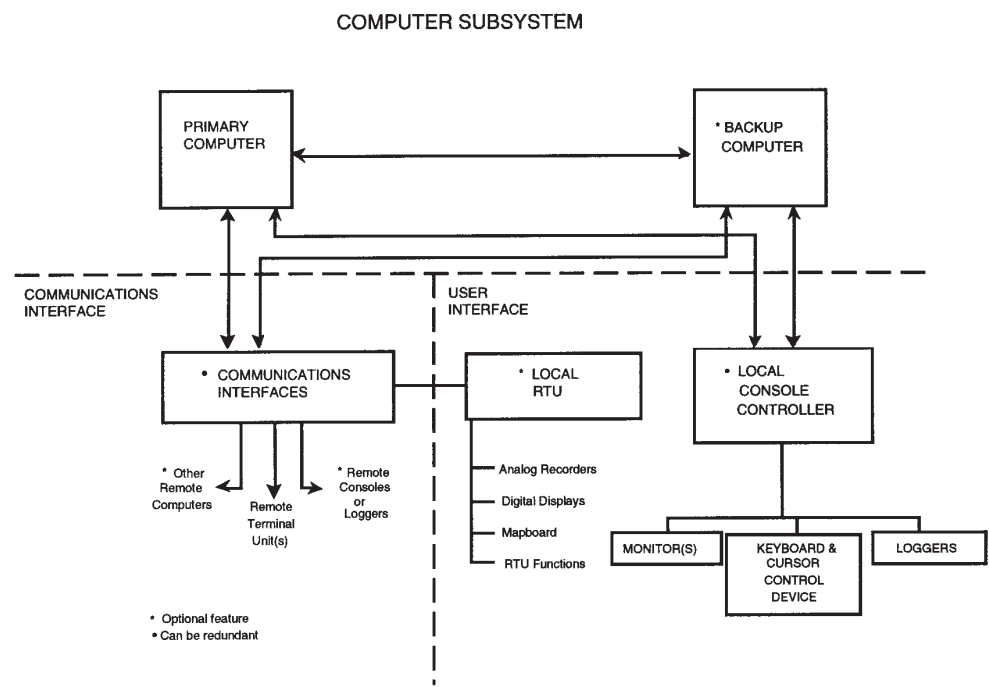


Figure 2—Master station functional block diagram (centralized functions)

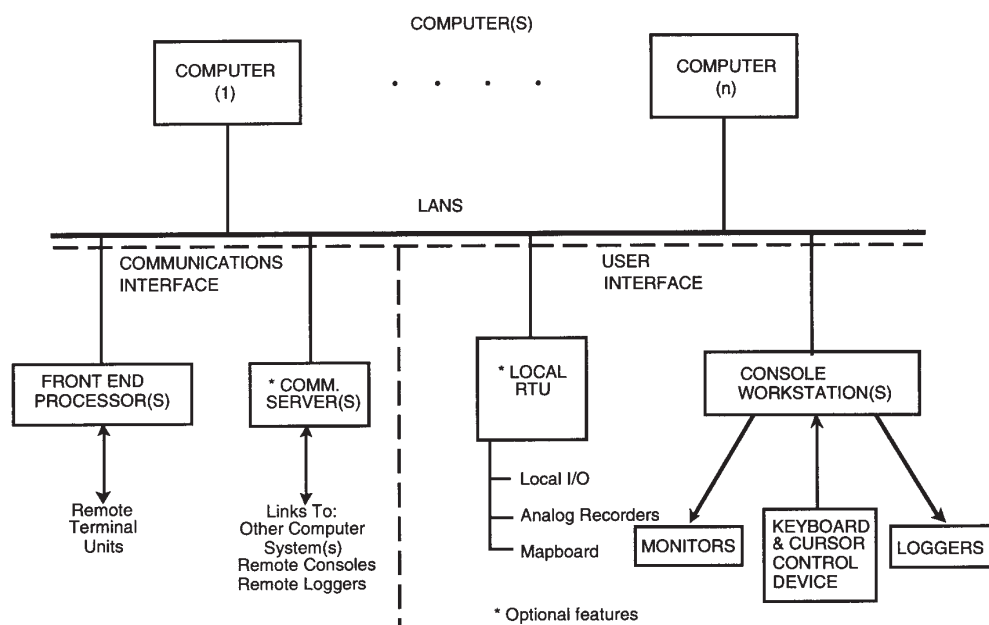


Figure 3—Master station functional block diagram (distributed functions)

4.2 System functional characteristics

This subclause 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.

The subclauses that follow shall be used as a checklist to help ensure adequate communication between the user and the supplier of control and data acquisition equipment.

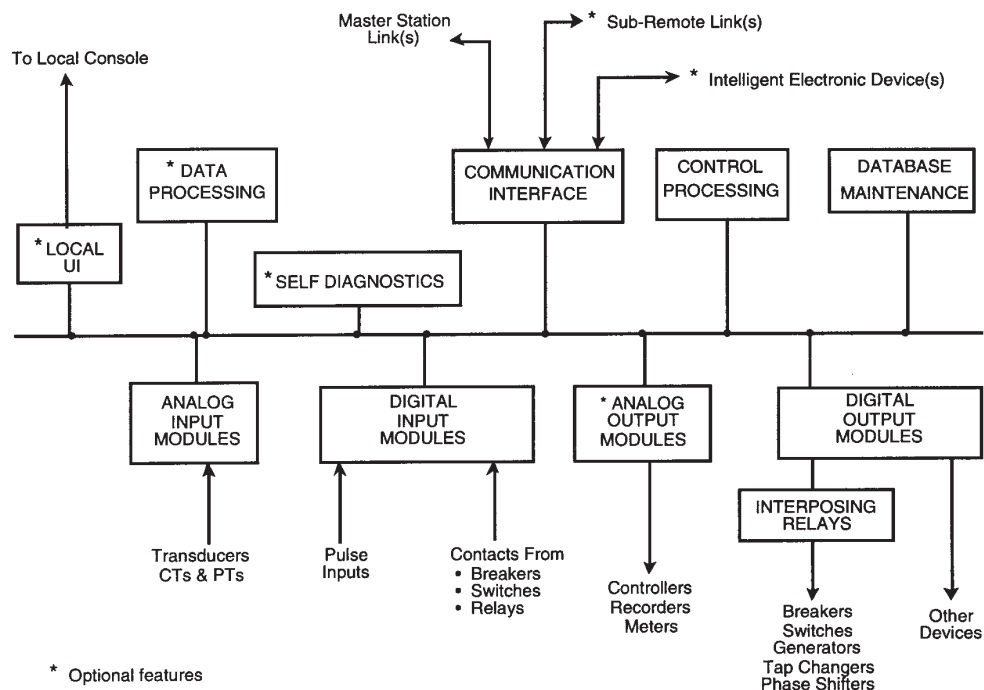


Figure 4—Remote terminal unit functional block diagram

When the feature or characteristic is fixed by the design of the equipment, the burden of definition rests on the supplier (e.g., number of inputs/outputs per card). However, variable features (e.g., 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 IEEE Std 999-1992 for an example of the definition of a communication protocol. The topics to be defined include

- a) Message protocol
- b) Number of channels
- c) Channel considerations (see 5.5.1.4)
- d) Error detection techniques

- e) Channel switching
- f) Number of RTUs per channel and/or channels per RTU
- g) Number of retries each attempt
- h) Time out value(s) by message type
- ~~i) Communication error reporting, failure criteria, and recovery~~
- ~~j) Channel quality monitoring (normal and backup)~~
- k) Channel diagnostic/test provisions
- ~~l) Equipment interfaces~~
- m) Report by exception polling or point scan

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

- a) Analog inputs
- b) Status inputs—two state
- ~~c) Status inputs—more than two state (more than two state status inputs are usually accomplished by using multiple two state status inputs)~~
- d) Status inputs—with memory
- e) Accumulator pulse inputs
- f) Sequence of events inputs
- g) BCD inputs multi-bit

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

- a) *Scan groups*. Number of scan groups, size of each group, points in each group.
- b) *Scan cycle*. Time to complete the acquisition of a scan group from all remotes on the communication channel. The communication hardware related performance capabilities used in the calculation of scan cycle shall be defined.

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 (e.g., 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 (i.e., voltage, current, shaft position, etc.) that normally varies in a continuous manner. The information content of an analog signal is expressed by the value or magnitude of some characteristic of the signal such as amplitude, phase angle, frequency, the amplitude or duration of a pulse, etc.

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 (e.g., 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 power system (e.g., overvoltage, fault conditions, emergency load limits).
- b) Data change detection may be a function included as an alternative to processing every input on every scan. Data change detection is accomplished by testing to see if the new value for each input is within N digital counts (e.g., deadband) of the last stored value for that input. The new value shall replace the last stored value only if the deadband 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:
 - 1) Location of processing, RTU or master station, or both
 - 2) Range of N, RTU or master station, or both
 - 3) Definition of N on an RTU, card, or point basis
 - 4) Technique for changing value of N
- c) Data filtering may be required to smooth data before it is used by other functions. When this function is included, the equation used shall be defined and the time delay, introduced by the filtering, specified.
- d) Data limit checking is typically included to determine if other downstream functions, such as alarm detection, or further processing are required. The number of high or low limits accommodated and associated return to normal deadband processing shall be defined. Specific attention shall be given the procedure for user specification and revision of limit and deadband values.
- e) The data report by exception function is used to eliminate communication of unchanged data from the RTU(s) to the master station or submasters. Its input is received from the change detection function. When the analog data report by exception function is included the following characteristics shall be defined:
 - 1) Percent of analog changes per scan that results in the channel load associated with reporting all analog points from the RTU.
 - 2) Description of logic in the master station that can be used to select between using the analog data report by exception function or the report all analog data functions when acquiring analog data from each RTU.
- f) Data conversion to engineering units is typically required before analog data is used by other software, printed, or displayed as output. The mathematical equation(s) used to convert analog values represented by digital counts into the corresponding engineering units shall be defined. Specific attention shall be given to sensor and transducer scale factors that may be provided by the user.
- g) Bad data techniques shall be defined that are used to
 - 1) Detect an open input to an analog channel
 - 2) Identify reasonable values
 - 3) Detect a drifted or faulty A/D converter
 - 4) Automatically calibrate an analog channel

4.2.3.2 Status data

Status data is used to describe a physical quantity (e.g., 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~~
 - 4) ~~Minimum current required for detection~~
 - 5) ~~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 or submaster. 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.~~
- e) ~~Status with memory may be a function implemented in the RTU. When this function is included, the number of status changes accommodated and legal bit combinations supported by the design shall be defined.~~

4.2.3.3 Accumulator data

The following characteristics shall be defined when pulse accumulation and 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)~~
- e) ~~Ranges of values (RTU and master station)~~
- d) ~~Nominal and maximum counting rates~~
- e) ~~Source of memory power~~
- f) ~~Input voltage if externally powered~~
- 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 (e.g., contact de bounce)~~
- i) ~~Data time skew (introduced by de bounce filters)~~
- j) ~~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)
- d) Downstream functions (e.g., 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 (e.g., flash, tone, etc.)
- d) Information in alarm messages
- e) Hierarchy of alarms (priority level)
- f) Size of alarm queue(s)
- g) Queue management (e.g., time ordered)
- h) Alarm limit(s)

4.2.3.7 Digital fault data

The RTU(s) and their microcomputers are becoming sophisticated enough that they can monitor power waveforms at such a rate as to be able to record high resolution 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 per cycle
- 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
- f) Means of reporting digital fault data

4.2.4 Supervisory control characteristics

When the capability to remotely control external apparatus 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:

- 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

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
- b) Number of relays that can be simultaneously energized in each type of RTU
- c) Processing actions (e.g., logging and alarm suppression)
- d) Ac or dc ampere and voltage ratings for relay contacts (see tables 1 through 8 in 5.4)

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 (e.g., limit check, equation, and alarms)
- 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
- d) Physical interface

4.2.5 Automatic control functions

When the capability to automatically control external apparatus is 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
- 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 either the master station or RTU is included. The interface functions shall be defined according to the following in 4.2.6.1 through 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
 - 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
 - 5) Assign/reassign 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
 - 6) Defining normal/abnormal status
- d) Control of alarm processing
 - 1) Enable/disable individual alarms
 - 2) Enter/edit alarm limit value(s)
 - 3) Enter/edit alarm deadband 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
 - 10) Override invalid alarms
- e) Control of function checks
 - 1) Enable/disable
 - 2) Change frequency
- f) Control of automatic control functions
 - 1) Enable/disable
 - 2) Modify criteria
 - 3) Add/delete control functions
 - 4) Reset to reference level or position

4.2.6.2 CRT display functions

The applicable characteristics shall be defined when the following CRT formats are included:

- a) Generation of display formats
 - 1) Format definition capabilities
 - 2) Symbols supported
 - 3) Memory per format
 - 4) Use of colors
 - 5) Use of special features (flash, inverse video, etc.)
 - 6) Control level of detail (declutter)
 - 7) Display call-up time
 - 8) 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~~
 - ~~10) Alarm inhibit summary~~
 - ~~11) Station notes format~~
- ~~c) Control of CRT and cursor~~
 - ~~1) Cursor operation~~
 - ~~2) Selection of formats~~
 - ~~3) Response time~~
 - ~~4) Update cycle (from database)~~
 - ~~5) Paging of multi-page formats~~
 - ~~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~~
 - ~~2) Update frequency~~
 - ~~3) Minimum value supported~~
 - ~~4) Maximum value supported~~
- ~~b) Analog displays~~
 - ~~1) Ranges~~
 - ~~2) Update frequency~~
 - ~~3) Minimum value supported~~
 - ~~4) Maximum value supported~~

4.2.6.4 Hard copy functions

~~When support of hard copy devices is required such as loggers, strip chart recorders, and video copiers, the applicable characteristics shall be defined as follows:~~

- ~~a) Device assignments~~
 - ~~1) Initial~~
 - ~~2) Automatic reassignment~~
 - ~~3) Manual reassignment~~
- ~~b) Generation of log formats~~
 - ~~1) On-line/batch capabilities~~
 - ~~2) Symbols supported~~
 - ~~3) Spooling capabilities~~

- e) Demand logs
 - 1) Standard formats
 - 2) Time for response
- d) Logged activities
 - 1) Alarms
 - 2) Standard events (e.g., user and device actions)
 - 3) System events (e.g., equipment failover and communication failure)
 - 4) Output from diagnostic routines
- e) Device performance
 - 1) Print speed (characters per second)
 - 2) Print quality (dots per inch)
 - 3) Color 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
- f) Other characteristics defined in this standard that may be applicable

4.2.8 Computer backup and failover

It is common practice today to reconfigure a system by switching peripherals or the total computer sub-system in order to recover from a peripheral or computer failure. In a distributed computer implementation, functions may be reallocated 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)
 - 3) Other uses of backup facilities
- b) Database update
 - 1) Data residency (bulk or main memory)
 - 2) Frequency of update (by data type)
 - 3) Other uses of update facilities
- c) Failure monitoring
 - 1) Method of failure detection
 - 2) Response time for detection
 - 3) Effect on a program or task in progress when failover occurs
- d) Failover
 - 1) Method of failover
 - 2) Time required for failover
 - 3) User interface response following failover
 - 4) User actions following failover
 - 5) Effect on a program or task in progress when failover occurs

4.2.9 Historical data

~~The appropriate characteristics shall be defined when the capability for historical data archiving and retrieval is included as follows:~~

- ~~a) Number of history files supported~~
- ~~b) Data quantities per file~~
- ~~c) Data intervals per file~~
- ~~d) Number of data intervals per file~~
- ~~e) Method of file management~~
- ~~f) Method of data archiving~~
- ~~g) Method of data retrieval~~
- ~~h) Data usage (e.g., displays, reports, applications, etc.)~~

4.2.10 Local area networks

~~Local area networks may be used to provide data exchange capability between the different functions at a site (e.g., solid state relays, 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 (e.g., RS-232, RS-485, etc.)~~
- ~~c) Equipment to be interconnected~~
- ~~d) Transfer rate (bytes per second)~~
- ~~e) Protocols (e.g., Ethernet, TCP/IP, etc.)~~
- ~~f) Redundancy~~
- ~~g) Reliability (e.g., sectionalizing for isolating failures)~~

5. System design

System design requires multiple steps and will most likely require multiple iterations. First, the designer/specifier should define the near and long-term system functionality. The most benefit from this definition will be obtained by using an analysis from an enterprise level such that corporate standards could be developed. This definition should be based upon the existing or planned electrical infrastructure. This definition should be based on reality. An overly aggressive plan may include components that will not be used or may be obsolete by the time such functions are implemented. The definition of requirements is usually based on perceived current needs and anticipation of future needs, and is therefore somewhat unconstrained. Confining the list to minimum requirements may leave users with unfulfilled requirements and the need for an upgrade sooner than desirable.

Once the functional requirements are defined, then decisions can be made regarding communication protocols (external and internal to the substation), IEDs, architecture, security, and availability. Conversely, selection of components and architectures is usually constrained by various elements such as pre-existing equipment, IED selection by other departments, equipment and procedure standards, costs, etc. Therefore, the system design may redefine previously established requirements, resulting in an iterative process in order to reach a satisfactory compromise.

This clause assumes the designer/specifier has a working knowledge of the functions common to SCADA and automation systems. The annexes of this standard provide important reference information on function implementation. The designer/specifier is encouraged to use these annexes to align the work with known common practices.

5.1 System function definitions

SCADA and Substation Automation systems can be viewed as providing specific key functions, such as the following:

- a) Measurements
- b) Status monitoring c) Control
- d) Ancillary services
- e) Time synchronism
- f) Programmed logic functions

The system design needs to include a definition of the required functions. Once the required functions are established, an assessment should be made to define the required performance.

CAUTION

To assist the designer/specifier, tables in this clause provide typical values representing industry consensus for a power transmission network. Requirements for particular transmission, distribution, or generation utilities are likely to be different. The system designer/specifier should determine the actual performance requirements.

These tables include the system functions previously listed. Not all functions require the same data set. The designer/specifier may find it useful to define subsets of measurements, status, and control points that have different performance requirements.

The tables in this clause also include the following typical performance requirements (whose definitions can be found in the definitions and annexes):

- Update periodicity (seconds)
- Accuracy (%)
- Unavailability (hours/month)
- Latency (seconds)
- Resolution (%)
- Time skew (seconds)

Typical is used in these tables to demonstrate that the values shown are for a specific example as previously discussed. If the designer/specifier is using these tables in a specification, then the word “typical” shall be removed from the tables. Where no values are present, no industry consensus was available.

System functions may have differing performance requirements specific to a group of users. These differences depend on the location, function, and needs of the users within the physical and organizational enterprise. It is valuable to group common requirements as requirement tiers within a function list so as to

fully understand how performance issues impact the system design. To recognize the differences, the tables have multiple-tier entries so that different performance requirements from users can be captured. Because of system, IED, or other limitations, implementers may need to use the most stringent requirements, which will impact performance requirements for some users.

The tables in this clause can be used as a basis for evaluating all aspects of system performance. For example, if the requirement is that power measurements be presented to the local substation HMI with only a two-second latency and refresh rate, the requirements for the local communications network and data handling of IEDs are bounded. These requirements may impose unreasonable communications network performance if the same performance is extended to the enterprise operation center or to the support staff workstations. A reasonable solution might be to allow longer, more suitable, latency and refresh for the operations center.

The designer/specifier should ensure that system testing requirements discussed in Clause 9 include confirmation of the performance requirements developed from this clause. The designer/specifier should also note that system alarms, discussed in 6.4.6, will be required in order to track performance requirements.

5.1.1 Measurement services

Table 1 is presented as a means to capture typical performance requirements for measurements.