HIRSCHMANN
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WP 1004HE – Part 1

White Paper – Data Communication in Substation Automation System (SAS)

Introduction of modern substation communication

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1. Introduction Communication in Substation

1.1 What is the Substation Automation System (SAS)?

An electrical substation is a subsidiary station of an electric power generation, transmission and distribution system. Voltage will be transformed in SAS between power generation and transmission from a lower level (e.g. 11 KV) to higher a level (e.g. 110 KV, 220 KV, 500 KV, 715 KV or even 1000 KV). Power will be transmitted over long distances to another SAS where electricity will be transformed from high voltage back to low voltage (e.g. 100 KV, 10 KV, 1 KV or 220 V) for power distribution and consumption.

The substation is the node in the electrical power network. Functions of substation are control and monitoring of the switch yard, recording, protection of the power equipment, revenue metering and automation functions for energy management and assert management. Conventional substation is composed with interlocking logic, RTU (Remote Terminal Unit), Relays, conventional switchgear and CT/PT (current/potential transformers). Each component is hardwired connected with parallel Cu wires.

Modern substation automation is structured in three basic levels. The station level provides an overview across the whole station and is located in a shielded control room. Station level includes HMI Workstation, Master Station Computer, Backup Station Computer and GPS (Global Positioning System) receiver, etc. The bay level conducts maintenance work only within one bay and it is usually close to the switchgear. Bay level includes protection and control IEDs (intelligent electrical devices) of different bays such as circuit breakers, transformers, and capacitor banks. Equipment in bay level and station level are called secondary equipment. Process level provides the interface between the substation automation system and the switchgear. Process level includes switchyard equipment (also primary equipment) such as CTs/PTs, remote I/O, actuators, merging units etc.

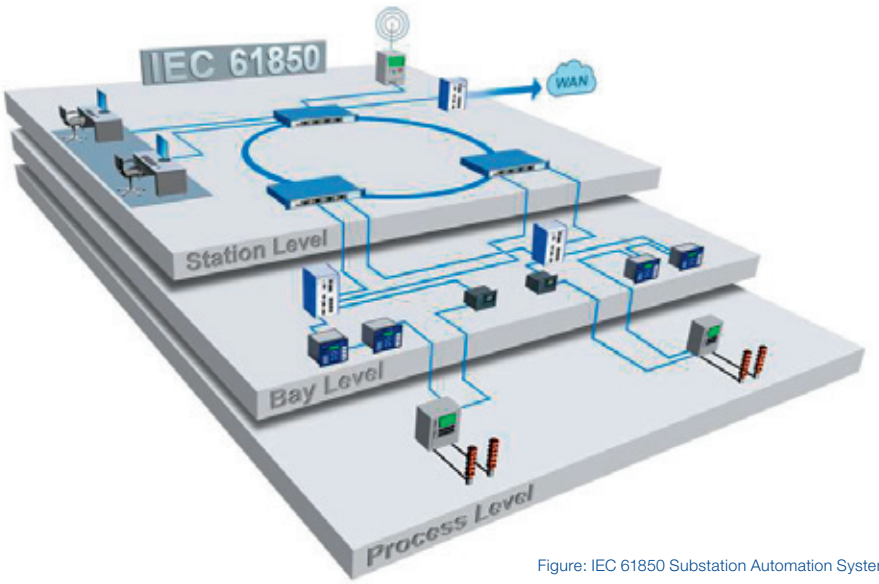

Figure: IEC 61850 Substation Automation System

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1.2 What is the Data Communication in SAS?

Substation data communication system plays a critical role in the real time mission critical operation of substation automation system. All secondary equipment within a substation is interlinked with communication buses. In conventional substation, legacy communication devices typically relied on one-way communication. Serial communication buses or proprietary communication media with associated protocols are used for local HMI, as well as for remote SCADA (Supervisory Control and Data Acquisition) communication. Modern communication in substation is data transmission inside and between station level, bay level and process level. The data information includes control, report, log GOOSE, SV, etc.

Communication between these 3 levels is called vertical communication and connected by high-speed Ethernet station bus and process bus. Station bus facilitates communication between station level and bay level. Process bus will be used for time critical messages between process level and bay level. Most of the substation protection and control functions will rely on the performance of the process bus.

Communication within one level is horizontal communication. In station levels, the time based data from multiple bays or substation level database will be analyzed and processed. The control commands for the primary equipment (e.g. circuit breakers) will be submitted and data like voltage, current and power factor will be collected. In bay level, protection unit and control unit collect data from bays and perform actions on the primary (e.g. power circuit) equipment. In process level, performance and condition information are read from essential station equipment. Control commands from bay level will be received and executed in the equipment at the process level.

1.3 Which Standard and Protocols are Used?

Communication protocols define the architecture of substation automation communication systems. They determine the way of information traffic between control stations, IEDs and other communication devices.

Generally there are 3 different standards categories for substation communication:

- Proprietary/vendor specification, e.g. UCA and DNP3, etc.
- National standard, e.g. IEEE 1613, etc.
- International standard, e.g. IEC 60870-5-101/104, IEC 60870-6-TASE.2, IEC 61850, etc.

Communication networks in substations will often have lower-level data link, physical layer protocols and multiple application layer protocols running "on top of" TCP/IP.

In the past and present, there are over 50 communication protocols for legacy substation automation systems. These include Modbus TCP, ProfiNet, EthernetIP, OPC-DA, and LON for example. Many of these topologies are vendor specified and have serial interface, low bandwidth, limited network devices, serial interfaces and inflexible data, etc. Their communication architecture does not fit to the corporate communication technology and are not able to expend the network. Most representative protocols are DNP3 and IEC 60870-5-104. Both of them are master/slave based fieldbus communication and can only be implemented till station level and bay level.

Nowadays many substation vendors are moving away from serial to Ethernet based IEC 61850 which is a client/server communication standard. It fully supports the interoperability among IEDs supplied by different vendors in the substation and can be applied also in process level in substation automation.

1.4 What is IEC 61850?

IEC 61850 is a standard for communication networks and systems for power utility automation and is being produced by IEC Technical Committee 57 Working Groups 10. It is developed based on Utility Communications Architecture 2.0 (UCA2.0) which is based on the Manufacturing Message Specification (MMS).

IEC 61850 is a lower-layer object-oriented protocol being implemented over TCP/IP and Ethernet networks. It defines a vendor independent communication infrastructure allowing seamless IEDs integration.

Compare to DNP3 or IEC 60870-5-104, IEC 61850 is not only another way of providing the same functions as a traditional SCADA protocol, it also provides information modes, configuration languages and abstract services in substation communication.

Main features of IEC 61850 are as follows:

- It translates all in the information in the real substation into information models in the form of standard naming conventions structures and formats for easy information management.
- It provides Abstract Communication Service Interface (ACSI) and makes it possible for applications and databases to be unchanged with changes in the communication protocols and media.
- It standardizes a Substation Configuration description Language (SCL) to describe substation topology, information models, binding to process, communication and data flow, etc. SCL can be used to exchange an IED's communication configuration information and software from different manufacturers.
- It provides communication protocols of TCP/IP based SCADA, real time Generic Object Orientated Substation Event (GOOSE) and Generic Substation Status Event (GSSE) and real time sample measured value (SMV). GOOSEs support system protection applications and run directly over Ethernet.
- It defines process bus which is supported by GOOSE and can minimize substation wiring requirements in the yard by converting data of CTs/PTs to digital information.

1.5 What is the Benefit of Using IEC 61850?

IEC 61850 is the comprehensive standard for all communication functions in utility applications. It is non-proprietary technology with multiple vendors and provides interoperability between devices and application functions through standardized data models and information exchange. It realizes a highly flexible configuration of communication networks and can greatly simplify substation automation architecture, optimize the selection of devices for curtain application and increase efficiency.

IEC 61850 is a future proof standard for safe investment. By implementing IEC 61850, the application model and communication stack can be separate. The applications can be modified and extended without changing of the communication stack. It meets utilities' requirements to combine products from a variety of manufactures for long term system exchangeability of equipment and expandability.

2. Environmental Conditions

2.1 Why Should we be Concerned About Environmental Conditions?

Communication devices like Ethernet Switches, IEDs and MUs (Mergin Unit) in substation are installed normally in harsh and critical environmental conditions. Equipment in substation like transformer, bay and other electrical devices will create themselves electric fields and magnetic fields. Electrostatic discharge, vibration and high energy power surges will occur during the substation operation.

In order to keep highly precise, real-time communication and avoid catastrophic failures, power substations require necessary resistance of the communication systems against environmental influences of mechanical, thermal, electromagnetic compatibility or other harsh operating conditions.

2.2 Which Standards Should be Applied?

The general environment requirements for the industrial environment are considered not sufficient for substations. Communication devices in substation must be in compliance with environmental conditions described in following standards:

IEC 61850-3:2002

IEC 61850-3 is the main standard for substation environmental conditions. It lists out the environmental requirements such as supply voltage, EMI immunity, temperature, humidity, barometric pressure, mechanical, seismic, pollution, and corrosion, etc. Many other IEC standards like IEC 60870-2(environmental climatic conditions) and IEC 60694 (high voltage area application) are referred in IEC 61850-3.

IEEE 1613

IEEE 1613 presents IEEE standard environmental and testing requirements for communications networking devices in electric power substations. Communication devices can be specified here in terms of temperature and humidity, power supply, high voltage resistance, EMC and radiated immunity, vibration and shock, or altitude, etc. These two standards define the overall environmental requirements in substations, no matter indoor or outdoor, or how critical or uncritical situation. Devices mounted in different situations in substations can meet different classes of requirement in the standard. End user should clarify the class level of the devices even the devices are compliance with these standards.

2.3 What are the Environmental Conditions of a Substation?

EMI Immunity

In substations various types of Electromagnetic interference will be generated by electromagnetic disturbances, by lightning and switching surges, by discharges and strokes of electricity, by damped oscillatory wave or burst, etc. Communication equipment should be able to withstand these EMI phenomena. Two classes of EMI immunity for communication devices are defined. In class 1, devices may experience some data errors, loss, or delays under EMI stress conditions. Class 1 is adequate for network supervision. In class 2, devices must not experience any data errors, delays or loss under EMI stress conditions. Class 2 is essential for IED to IED communication in substations.

Climatic Conditions

Mounted location of communication devices in substation could be in climate control room, in outside control cabinet or on the open explored bay itself. The surrounding temperature range during the operation could vary from very low degree to very high degree. Therefore the temperature requirement is also different.

According to IEC 60870-2-2, 4 following temperature classes are defined for substation communication devices:

- A*: air conditioned locations
- B*: heated or cooled enclosed locations
- C* sheltered locations
- D* outdoor locations

Substation end user must be aware of the real surrounding temperature requirements and select corresponding communication equipment according to different temperature classes. Hirschmann™ switch products are typically specified for sheltered locations C3 and specified for a long lifecycle without building fan design.

In sheltered locations, the devices must meet up to 100% rel. humidity requirement. Hirschmann™ switches are available with conformal coated PCBs to enhance the resistance against humidity. For instance, products with coating are required in high humidity application locations like seaside or places with heavy fog or high temperature variations. Coating is also required sometime under the Industrial clean air condition in substation.

Supply Voltage

Supply voltage of substation equipment may be different in different countries. Preferred DC power supply voltage values are 220VDC, 110VDC, 60VDC, 48VDC, 24VDC or 12VDC. Normally, a big standby battery should be equipped to provide power in case of voltage failures and continually charged and discharged from the substation network. The voltage of standby battery should be the same as those of IEDs in substation, e.g. 110VDC.

Many manufactures provide communication devices with redundant power supplies and hot-plug power modules to enhance the high reliability of product and accordingly network communication. When one power supply fails, another power supply will take over the energy supply. The hot plug power module can be exchanged during the application mode.

Mechanical Requirement

Four different classes of mechanical requirement are specified in IEC 60870-2-2:

- Class Am for light installation
  This class applies to equipment and systems installed in locations where no significant sources of vibration and shock are present, as in control rooms and residential areas.
- Class Bm for normal installation
  This class applies to equipment and systems installed in locations with vibrations of low significance and shocks, as remote terminals units in power plants, substations and industrial areas.
- Class Cm for severe installation
  This class applies to equipment and systems installed in locations with significant vibrations and shocks, as industrial areas with machines or nearby passing vehicles.
- Class Dm for critical installation
  This class applies to equipment and systems installed in locations where the level of vibrations and shocks is high as in close to heavy machines or in the proximity of reach of traffic of heavy trucks.

Normal locations of communication equipment in substations are in class Am and Bm. Hirschmann™ Ethernet Switches are in compliance with class Bm.

Barometric Pressure

Communication devices will be installed in the substation located in different altitude. Normally IEC 61850-3 defines an application altitude range from -400 meters (with 106 kPa) to 3000 meters (with 70 kPa).

If communication devices are used in regions with higher altitude, heat dissipation of the device is limited because of the thinner air. A derating of the maximum permissible ambient temperature must be considered in this situation.

For the substation applications whose altitude is higher than 2000 meters, the isolation distance in the switch electricity must be wider than the normal distance to guarantee the correct dielectric strength.

2.4 Summary and Outlook

The communication of devices might be broken down or destroyed by different environmental disturbances. Most critical environmental conditions in substation are EMC and climatic conditions. Thus, as mission-critical components, extremely robust, rugge-dized communication devices are required to ensure efficient signal transmission possibilities.

There is no fixed environmental condition requirement for the communication devices in a given substation application. Manufacturer can declare their products according to the different levels in the standard. In order to ensure high communication reliability, customers may determine which classes are required for product according to real application requirement and select equipment accordingly.

The Ethernet switch is installed in the same place as the control or protection IEDs and is essential information Hinge in the communication network in the substation. It must go through the same tests and comply a with the same standards as IEDs and Mus. Hirschmann™ has wide product portfolio for substation communication application under the standards IEC 61850 and IEEE 1613. Special requirements of substation environmental conditions can be covered by Hirschmann™ Ethernet switches.

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5. Hirschmann™ White Paper, Ethernet Enables The Smart Grid, at http://www.belden.com/docs/upload/Ethernet_Smart_Grid_WP.pdf
6. Hirschmann Service and support: http://www.beldensolutions.com/de/Service/index.phtml

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Appendix: Further Support

Technical Questions and Training Courses

In the event of technical queries, please contact your local Hirschmann™ distributor or Hirschmann™ office. You can find the addresses of our distributors on the Internet: www.hirschmann.com

Our support line is also at your disposal:

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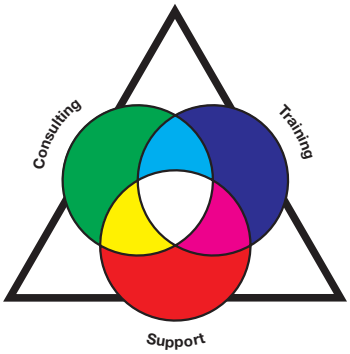
Fax +49 (0)7127 14-1551

Current training courses for technology and products can be found under http://www.hicomcenter.com.



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