DIGITIZED COPPER – ADVANTAGES, DISADVANTAGES AND OUTLOOK OF A POWER AND PROCESS INTEGRATED CONTROL SYSTEM USING IEC 61850

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Abstract - The safe and reliable supply of electricity for ensuring a continuously running process, and the feedback and data exchange from the one side to the other, is of crucial importance to the Oil & Gas Segment. It is typical that Transformers, HV, MV and LV distribution equipment as well as the wells, field compressor stations and central processing plants with their motors and pumps are physically spread across a large area. Traditionally, ensuring a safe, reliable and continuously running plant, came hand in hand with a large amount of hardwired cabling and the site ending up with two or more automation system for process control and power distribution, with several protocols and interfaces. Although IEC 61850 is well known a standard, it has just recently emerged as and will take further steps in fully enfolding its benefits via the seamless connection of the electrical and the process side. The unification of both power and process automation via one Ethernet Standard enables one centralized and optimized main control system for monitoring and protecting an entire plant. This paper compares two model project set-ups – one using the traditional power and process automation approach, the other based on a common IEC 61850 technology – In terms of safety and flexibility, performance and reliability, time and costs.

Index Terms — IEC 61850, interoperability, GOOSE

I. INTRODUCTION

In industries like Oil & Gas, uninterrupted power supply is of vital importance. The critical operations involved in the functioning of oil & gas platforms call for better energy management through process and power automation systems. Traditional platforms achieved this through extensive hard wiring which is both costly and complicated due to the amount of cabling and engineering efforts involved. Modern Industrial Ethernet standards such as IEC 61850 can now be utilized to provide better visibility of assets, large amounts of diagnostic data and an integrated alarm/event and asset management system.

The integrated control and safety system (ICSS) provides a single operator interface to control and monitor process and power systems in the oil & gas platform. By using IEC 61850 communication protocol to define the communication between field devices and ICSS, hardwired interfaces and serial cabling can be replaced with an intelligent interface which provides time synchronization, file transfer and engineering tool access on one physical cable.

II. MODBUS RTU

Modbus RTU communication interface normally perform in a master-slave configuration. The master or PLC sends “Query messages” to the slave device and receives response from the slave in “Response messages”. The standard structure of a Modbus message is:

- Device address – address of the message receiver
- Function code – this code defines the message type
- Data – Data block with additional information
- Error check – Numeric check value to test for communication errors

If there are a number of slaves connected to the master device, the address in the message header determines which slave responds to the message. The slaves whose address field doesn’t match the address field in the message ignores the message.

The device addresses range from 0….247, where 0 is the broadcast address and 1…247 are assigned to individual Modbus devices. The function codes contain one byte of information which defines the message type and the type of action required by the slave

01	read coil status
02	read input status
03	read holding register
04	read input register
05	force single coil
06	preset single register
07	read exception status
15	force multiple coils
16	preset multiple registers
17	report slave ID

For example, when a slave receives a Modbus message with function code 01, it collects the necessary output values and constructs an answer message. The length of this message depends on the number of values to be returned to the master.

Modbus RTU uses RS-485 connections for communication between Master and Slave. This speed limitation makes the protocol unsuitable for time critical plant operations like load shedding. The typical speed of a Modbus link is 19200 baud. Furthermore, the Modbus interfaces does not provide redundancy to enhance the safety and reliability of the plant as only one client can be connected.

III. PROFIBUS

In a Profibus interface, cyclic or acyclic data collected from the actuator is fed back to the PLC. It supports cyclic as well as acyclic data exchange, diagnosis, alarm-handling and isochronous messaging. Profibus DP is a performance optimised version of the interface that is used for time critical communication between master and slave. The Profibus master is a main controller which exchanges information cyclically with the slaves. A slave is a peripheral device such as a sensor or actuator which collects data. The data transfer between the master and the slave consists of three phases – parameterization, configuration and data transfer. The master device follows the sequence below during startup to exchange data with a slave:

- Station address
- Request for diagnostics
- Slave parameterization
- Diagnostic request check before cyclic data exchange
- Cyclic data exchange
- Global control

When the master and slave devices are connected using RS 485, 32 devices can be connected per segment without the use of repeaters. The devices may be daisy chained and each segment must have a termination resistor at the end. Each element of the network has an associated GSD file or configuration file that defines the characteristics of each equipment. The data read from the Profibus device is in bytes which is then unpacked by using suitable code in the controller and identified by comparing it with the device manual.

Profibus interfaces have communication speeds of about 1Mb, which is faster than Modbus RTU but still slower than Ethernet links. The devices can have only one client or process controller and therefore does not support redundancy.

IV. IEC 61850

The IEC 61850 standard uses Ethernet for data transmission. It is fast and reliable and provides the basis to use new and evolving technologies. As IEC 61850 is based on Ethernet technology it allows large set of different network topologies which can be used depending of the system architecture. IEC 61850 standard technical report 90-4 gives network engineering guidelines to help users to select appropriate network design by describing different reference topologies. Intelligent electronic devices or IEDs is the main component of IEC 61850 interfaces.

They not only collect data from field devices but also acts as the control interface which can execute commands issued by the control system. The IEDs can either communicate with the process automation system through an OPC server via MMS (Manufacturing Message Specification) or they can communicate to process controllers directly through high speed GOOSE (Generic Object Oriented Substation Event) messages. The IEDs also transfer data via IED-IED GOOSE messages and is capable of intelligent decisions based on the system status. They can work efficiently in a decentralized control architecture or a centralised one.

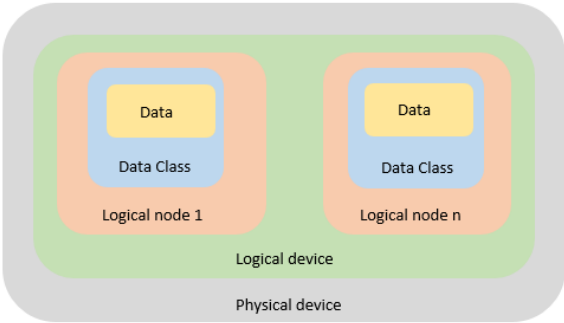

Fig. 1 IEC 61850 Logical Node structure

The data is exchanged using functions residing in the devices. The exchanged data is grouped into Logical Nodes (LN) belonging to functions. The IEC 61850 standardises the name and the data contained in a particular logical node. Logical devices (LD) groups the logical nodes that can be managed together. For example, the standardized data for motor temperature supervision is STMP.Alm.stVal, where STMP is the Logical node, Alm is the data and stVal is the attribute.

IEC 61850 engineering is based on standardized XML language which guarantees interoperability when configurations are transferred between software tools, for example, between protection relay and station controller tools.

Additionally, IEC 61850 has a wide set of communication services defined: object–oriented data model browsing, event reporting, horizontal communication GOOSE, file transfer, time synchronisation among many. This enhances interoperability and standardized behaviour. IEC 61850 standard also supports multiple vertical MMS clients allowing easy application of redundancy concept at the client or process controller level.

V. COMPARISON

If we consider a simple compressor motor connected to the ICSS, the diagnostic data and control available to the operator is significantly better when the communication interface between the motor and ICSS is an Ethernet based IEC 61850 interface rather than a hardwired interface. An IEC 61850 interfaced motor can communicate to the ICSS using vertical MMS communication or horizontal GOOSE messages. In vertical communication, an IEC 61850 OPC server collects data from the intelligent electronic device (IED) controlling and monitoring the motor. This data is then transferred to the ICSS in the form of regular OPC data items.

The ICSS has direct access to time stamped voltage and current measurements, alarms and events and can send control commands to the IED. The MMS telegrams are acknowledged and normally, no data is lost as telegrams with errors are re-sent. In time critical operations, vertical communications might provide a slower response than necessary. In such situations, horizontal GOOSE messages can be employed for transferring analogue values needed in controller applications and for fast tripping of field devices. GOOSE provides a high speed IED to IED data transfer. Control and protection information can be transferred between IEDs or between IED and the controller in less than 10ms using GOOSE messages. Instead of data being sent to ICSS through OPC link, GOOSE messages can be sent directly from the IED monitoring a field device to a process controller. To achieve the same level of control and monitoring, the amount of hardwiring required is extremely high, if not impossible. Furthermore, the diagnostic data available at the ICSS provides a wider perspective to the operator to take informed decisions. Additionally, as all GOOSE connections are continuously monitored, the receiving device can identify anomalies as soon as they arise and take corresponding action such as shifting into fail safe mode or blocking some functionality.

In hardwired communications, hard wired signals must go through an output contact on the sending relay and then an input contact on the receiving relay. In IEC 61850 communications using IEDs, the IED can be programmed to send a report to the ICSS as soon as it detects a change in the monitored data. As the data is transferred over Ethernet link operating at 100 Mbit/s, exchanges of Sequence of Events (SoE) and commands between devices are faster than hardwired/serial/field bus protocols. Furthermore, special network switches can be used to prioritize GOOSE telegrams to pass critical real time data ahead of other network traffic. One additional benefit with IEC 61850 is the possibility to standardized redundant Ethernet using PRP and HSR protocols. Redundancy at the device level coupled with redundancy at the process controller level improves reliability and availability of the plant.

During the lifecycle of the plant, if the communication philosophy needs to be changed, the mapping from the data model to the full MMS stack is the only component to be revised. This ensures long term adaptability to future technological developments. In such scenarios, data modelling remains but underlying communication technology can change to Gigabit wireless or fast Bluetooth without changing the IED application. There is also a life-cycle benefit that Ethernet being a stable technology, we can easily connect to older 10Mb half-duplex networks if needed. Interoperability of IEDs throughout the plant is another advantage of the IEC 61850 communication. IEC 61850 protocol allows IEDs from different manufacturers to be used in the same plant, as per client requirement, without the need of protocol converters or human interpretation.

During the lifecycle of a plant, different instruments will need replacement and new components may get added to the plant. IEC 61850 communication interface ensures that interoperability can be maintained under such circumstances. This is possible as domain related model for both data and communication services are separated from the protocol in IEC 61850. Data model mapping to communication stack is also standardized to ensure interoperable communication. In a Profibus interface, any change in the sequence of data sent by the device at some point in the plant lifecycle will require rewriting the code at the controller level. The unpacking of data involves careful mapping of bits and if a device type is changed, new configuration file is required to set up the communication link. The engineering of Profibus interfaces is somewhat automated due to the use of GSD files, but signal level engineering is still required at the controller. Modbus interfaces behave in a similar way due to the unpacking and mapping of received data that is required at the Master level. The engineering requires accurate coding at the controller level and is prone to human errors. Any changes to the data registers will cause major changes in the engineering of the serial link. If a new device is to be added in between an existing set of devices, it requires a rearrangement of register addresses of all successive devices which will ultimately result in higher engineering effort.

Securing the oil & plant platforms from malicious outside interference is essential in today's world as web connectivity plays an important role in plant operations. If GOOSE messages are used for high priority data transfer, it can act as an additional security measure for critical data. GOOSE messages are sent at layer 2 of the ISO/OSI model and cannot be transmitted through routers or firewalls. This makes the system immune to rouge messages from outside the firewall. This is an important feature of IEC 61850 horizontal communication and is something that segregates the GOOSE data transfer from the local network traffic.

In the case of Modbus interfaces, the registers are mapped to particular devices and each bit is mapped to a particular signal. This is vendor specific and project specific and there is no standardized mapping which can be used across the various vendor devices. Similarly for Profibus devices, the GSD configuration file is vendor specific and will result in the same plant having different criteria to unpack the data received from different Profibus devices. Utilizing IEC 61850 communication technology helps the standardization of substation configuration, control logic and operational procedures. The standardized substation configuration language (SCL) helps in defining standardized libraries. It saves commissioning time and a redundant configuration provides high levels of availability and reliability. All data – both process and power system data - required by the plant operator to take strategic decisions is available at the operator workstation. This increases the productivity as well as make the plant better resistant to human errors.

VI. CONCLUSIONS

The IEC 61850 standard replaces the numerous buses and links used today by a hierarchy of well specified switched Ethernet networks. The long term benefits of IEC 61850 lies in its object oriented hierarchical data modal approach with its use of mainstream communication technology. The standardization of substation configuration, control logic, control libraries and operation procedures supports efficient running of the plant. This can also reduce the engineering and commissioning effort thereby reducing the time and cost involved.

IEC 61850 provides the customers the functional freedom in their process definitions and control philosophies and assures independence from any single supplier. IEC 61850 not only delivers savings by way of substation design, installation, commissioning, and operation, it also supports new capabilities that are not practical or cost effective using legacy approaches.

On one hand there are numerous advantages of fully utilizing the IEC 61850 protocol, but on the other hand, it has some challenges as well.

IEC 61850 standard specifies the data model to be followed for this communication protocol. However, the extent to which this is followed by specific manufacturers varies and this sometimes result in the requirement of interface data management between different vendors. This is an area where greater manufacturer collaboration will be advantageous to reduce engineering efforts. If we compare IEC 61850 to Profibus or Modbus, the amount of data management required is still smaller for IEC 61850 due to formal standardized engineering language.

IEC 61850 is a comparatively young communication protocol and the oil & gas industry has a shortage of relevant experience in this technology. The learning curve for operators can be steep while trying to meet the high reliability and availability expectations of the asset. At the same time, this is a valid point for all new technologies and technological advancement is inevitable in the modern world. While it will require extra efforts to introduce IEC 61850 protocol to established brown field projects, it will be well suited for green field projects with state of the art technologies where it can be a part of a new and improved working environment for the operator.

The reliability of an Ethernet network depends on the speed and reliability of the hardware components like Ethernet switches. This decides the effectiveness of the complete system. Even though many new installations use industrial grade Ethernet in power and process automation, this aspect might force the traditional users to adopt hardwired signals at least for critical trip functions.

The IEC 61850 devices are interoperable irrespective of the manufacturer. As interoperability is the basic philosophy of IEC 61850, interchangeability has not been in scope of the standard so far. If the user wants to replace a particular IEC 61850 device in the plant, it will require some engineering effort at the automation system level. The 'plug and play' concept is not yet available as a part of this standard. Version update of currently installed software or hardware may not support co-ordination with the existing versions from different manufacturers. This could lead to a need for updating the complete zone of functions which includes many devices of various manufacturers. It is important to note that version handling is a challenge that is common to all solutions based on different protocols.

EMI immunity, environmental challenges for outdoor installation, cybersecurity, cost and complexity aspects of IEC 61850 communication protocol are some topics on which further study is required. This is presently outside the scope of this paper.

VII. ACKNOWLEDGEMENTS

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VIII. VITA

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