EVALUATION OF NETWORK STRUCTURES AND PROTOCOLS FOR NUCLEAR-SPECIFIC APPLICATIONS

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Abstract

The evaluation of industrial implementations of network structures associated with nuclear-specific applications is the main focus of this paper. Establishing numerous network structures currently used in nuclear industry, this project analyzes the functionality and reliability of different structures. The communication structures studied in this paper include Fieldbus and Modbus Communication Protocols, Object Linking and Embedding process control (OPC), Dynamic Data Exchange (DDE) and Net-DDE.

This paper focuses on identifying the potential problems in applying various network structures to nuclear industry to enable a nuclear-specific network structure to be developed for the fast growing nuclear industry.

1. Introduction

The fast growing industry of nuclear energy has been greatly affected by the technological advancements of the modern era. These technological advancements have changed the standards, methodologies and tools used in nuclear industry. Nevertheless, the nuclear industry, in many ways, is a unique industry amongst other power generation and production industries. The safety criticality of this industry may be the most significant difference between the nuclear industry and other evolving industries in the modern world. These unique characteristics come with unique responsibilities, requirements and regulations. Consequently, a greater deal of care needs to be taken when evaluating and assessing new technologies, tools and standards for this industry.

Network structures and communication protocols are well established technologies of the modern world that are extensively used in many different applications and industries. They are evolving technologies that have been relied on in many different industries for many different applications including safety critical applications. Network technologies have been an inevitable part of new control and safety critical mechanisms in many power generation industries. However, due to the special regulations concerning the nuclear power generation industry, this technology is a relatively new and even often abandoned technology for this industry.

The fast growing technological advancement comes with greater and more restricted regulations as their fulfillment becomes more and more feasible with such advancements. These changes in the regulations along with the advancements in the competing methods of power generations has forced the nuclear industry to investigate more in adopting to new technologies.

Networking technologies and communication protocols are inevitable parts of there required new technologies to the nuclear industry. A careful study in the capabilities, limitations and special

characteristics of each of these new technologies is essential to an informed and appropriate assessment of such technologies for the nuclear applications.

2. Evaluation of Network Structures and Protocols

Network structures and communication protocols have been evolving drastically in the last two decades, changing the general perception of the safety critical industries about their reliability and performance. The evolvement of these network technologies has categorized such technologies extensively such that only a limited number of these technologies are recognized as industry grade network technologies. This paper will focus on evaluating the most widely used technologies in safety critical industries.

2.1 Fieldbus Technology

One of the most widely used industrial network systems for real-time distributed control is Fieldbus. Fieldbus is a technology that connects instruments of manufacturing plants. Fieldbus technology is used on network structures including daisy-chain, star, ring, branch, and tree network topologies. Traditionally 4-20 mA communication method would require that each device has its own communication point at the controller level, while the Fieldbus requires only one communication at the controller level and allow multiple of analog and digital points to be connected at the same time, reducing both the length of the cable required and the number of cables required. Devices that communicate through Fieldbus require a Microprocessor and multiple points are typically provided by the same device. Most Fieldbus devices support control structures such as PID control on the device side instead of forcing the controller to perform the processing.

IEC 61158 allows 8 technologies of Fieldbus to be used in industrial applications. IEC 61158 forced the following under the general title of digital data communications, measurements and control:

1. Overview and guidance for the IEC 61158 series
2. Physical Layer specification and service definition
3. Data Link Service definition
4. Data Link Protocol specification
5. Application Layer Service definition
6. Application Layer Protocol specification

IEC 61158 is a respected standard in many industrial applications. However, the nuclear industry and its commissioning procedure require individual assessment of the application of this technology.

Despite the many advantages that makes this network structure a popular industrial chose for many industries the following reasons can make this technology less desirable for nuclear-specific applications:

1. Due to incompatibility of many versions of Fieldbus technologies, manufacturers have to offer different versions of their devices (e.g. sensors, actuators) resulting in additional cost of the devices and reduced availability.

2. Longer response time with Fieldbus, which can be extremely important specially in safety critical nuclear applications
3. Increased investment risk when implementing Fieldbus as one or more Fieldbus standards may predominate in future and others may become obsolete.
4. Users need to be extensively trained and highly qualified since Fieldbus systems are more complex.
5. The price of Fieldbus components are higher
6. Fieldbus test devices are more complex and expensive than traditional multimeter that can be used to read and simulate 4-20 mA analog signals.

Despite the above disadvantages, the safety measures that are included in Fieldbus can increase the desirability of these devices for nuclear-specific applications. Fieldbus can be used for safety critical applications that must meet safety standards like IEC 61508 or EN 954-1. Depending of the protocol, Fieldbus can provide measures like counters, echo, timeout, unique sender CRC's, and receiver ID's or cross check.

2.2 Modbus

Modbus is a serial communications protocol introduced by Modicon along with its programmable logic controllers (PLCs). Modbus is now a popular communication protocol in industry and is now one of the most widely available protocols for connecting industrial electronic devices.
The followings are some of the main important advantages of Modbus communication protocols:

1. It is an open-source communication protocol
2. Industrial network deployment of this technology is easier than the competing technologies
3. Communication is done with less overhead and consequently has a better performance

Modbus communicates between devices connected to a single network. Modbus is often used to connect a supervisory computing system with a remote terminal unit (RTU) in supervisory control and data acquisition (SCADA, Lab VIEW) systems. Serial port and Ethernet communication can be used for Modbus communication.

Modbus RTU is a binary representation of the data and Modbus ASCII is readable by human. These constitute the serial communication of Modbus. ASCII format uses a longitudinal redundancy check checksum and the RTU format follows the commands/data with a cyclic redundancy check checksum. These versions are not compatible with each other.

Data model and function calls are similar for both methods. Only the encapsulation varies. Every device used to communicate by Modbus is given a unique address. Any device can send out a Modbus command. However, usually only one master device sends commands. A Modbus command contains the Modbus address of the device it is intended for.

Modbus commands include checking information ensuring that a command arrives undamaged. Modbus commands instruct an RTU to change a value in one of its registers, as well as commanding the device to send back values contained in its registers which can be one or more values.

The followings are the most common versions of the Modbus communication specifications:

1. 32 bit integer
2. 8 bit data
3. Floating Point IEEE
4. Mixed data types
5. Multipliers to change data to/from integer.
6. Bit fields in integers

2.3 Object Linking and Embedding process control (OPC)

Object Linking and Embedding process control (OPC) is an open standard specification developed by industrial automation. The standard specifies the communication of real-time plant data between control devices from different manufacturers and vendors.

While OPC is heavily used within the process industries, it can be, and is, widely used in discrete manufacturing as well. Hence, OPC is known for more than just its applications within process control.

The OPC Specification was based on the OLE, COM, and DCOM technologies developed by Microsoft. The specification defined a standard set of objects, interfaces and methods for use in process control and manufacturing automation applications to facilitate interoperability between the devices in different platforms.

One of the most important characteristics of OPC is that it can bridge Windows based applications and process control hardware and software applications. It is an open standard that permits a reliable method of accessing field data from plant devices. This method remains the same regardless of the type of data and the source.

OPC servers provide a method for many different software packages to access data from a process control device, such as a Programmable Logic Controller or Distributed Control System. The purpose of OPC is to define a common interface that is reused by any software packages or applications.

OPC server is written once for a particular device, and then it can be reused by any application that is able to act as an OPC client. OPC servers use OLE technology to communicate with clients.

2.4 Dynamic Data Exchange (DDE)

Dynamic Data Exchange uses the Windows Messaging Layer functionality within Windows, which is the same system used by the copy and paste functionality. Therefore, DDE continues to work even in modern versions of Windows.

The primary function of DDE is to allow Windows applications to share data. A data in Microsoft database can be connected to a value in another application in Windows and when the value changed, it would be automatically updated in the database. The data communication is established by a three-segment model. Each program is known to DDE by its application name. Each application could further organize information by topics and each topic can consist of different item that are accessible through other applications.

While newer technologies like COM offer features DDE doesn't have, there are also issues with regard to configuration that can make COM more difficult to use than DDE. These advantages that make DDE a simpler implementation can affect the desirability of the method in safety-critical industries such as nuclear industry.

Wonderware Incorporation developed an extension for DDE called NetDDE, which can be used to initiate and maintain the network connections needed for DDE conversations between DDE-compatible applications running on different computers in a network and exchange data through the existing network. In this method, a DDE conversation is an interaction between client and server applications.

3. Conclusion

The use of network structures and communication protocols are an inevitable part of modern industries including safety-critical industries such as nuclear industry. Nevertheless, the transition to this new technology has unique challenges to nuclear industry that should be explored individually.

The commissioning and regulatory rules applied to nuclear industry create the need to study the compatibility and compliance of such technologies in different nuclear applications.

Fieldbus and Modbus are two of the most commonly used protocols in modern industries for network applications. The standards such as IEC 61158 can ease the acceptability of such technologies in nuclear industry. However, the incompatibility of the veracity of versions of each of these technologies along with vendor specific differences makes these technologies less desirable to be used as the primary network protocol for nuclear-specific applications.

OPC has created a more standardized communication structure that can be used as a common interface for many different OPC clients to communicate to an OPC-compatible device. An OPC server needs to be written for every device to be able to communicate with OPC clients. Availability of OPC servers for all the devices are not guaranteed and can be developed long after the device is available and required to be used for a specific application.

4. References

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