Evaluation Of Communication Structures For Nuclear-Specific Applications

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Abstract

This paper evaluates various implementations of communication structures associated with nuclear-specific applications. Establishing numerous network structures currently used in nuclear industry, this projects analyzes the functionality and reliability of different structures. The communication structures studied in this paper include Object Linking and Embedding process control (OPC), Dynamic Data Exchange (DDE) and Modbus Communication Protocol.
The experimental aspect of this project includes development and implementation of each network structure for NPP control and shutdown systems.
The results of the experimentations are used to identify the potential problems of applying such structures to nuclear industry, in order to introduce nuclear-specific network structures.

1. Introduction

Object Linking and Embedding process control (OPC) is one of the network structures used in the industrial automation and the enterprise systems. The OPC technology is in compliance with fundamental standards and technologies of the general computing market. This technology has not been investigated for its use in safety critical applications. Data Access Specification is the standard produced by OPC. This specification defined a standard set of objects, interfaces and methods for use in process control and manufacturing applications to facilitate interoperability between the devices.

DDE is an asynchronous network structure which operates when a client sends a Windows message to the server. Dynamic Data Exchange (DDE) is a network structure used to send data between applications using Windows messages according to a documented protocol.

Modbus is the first widely accepted Fieldbus standard. The Modbus communication interface uses messages to communicate data. Modbus is independent of the type of physical interface used.

2. Methodology

Following sections will introduce various implementation methodologies used to carry out the network evaluation:

2.1 Object Linking and Embedding process control (OPC)

OLE Process Control is used to provide a standards-based infrastructure for the exchange of process control data. OPC can be used for different data sources such as PLCs, DCSs, databases, gauges and RTUs. The connectivity is independent form communication protocols and can be used for serial, Ethernet and Radio transmissions. It is also platform-independent which makes it compatible with most of the operating systems such as Windows, UNIX, DOS and VMS.
The following figure shows some of the devices and connection types used in this experimentation:

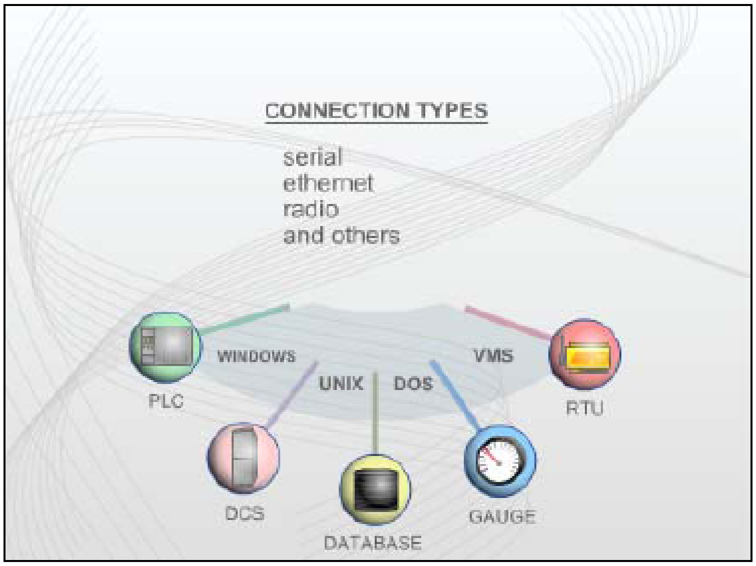

Figure 1 Connection Types

The methodology used for this project will utilize these advantages of OPC connectivity. The data initiated in any of the data sources mentioned above will be transferred to appropriate applications such as Human Machine Interface and any compatible data acquisition systems.

For the purpose of analysis, the experiment used in this project involves monitoring of information generated by a PLC using an HMI application.

2.2 Ontario Power Generation Desktop Simulator

In order to create a nuclear-related data processing system, the original data is generated by OPG Desktop Simulator. OPG CANDU Simulator is a commercial CANDU simulator provided by Ontario Power Generation. This simulator is capable of accurate and real-time simulation of Darlington and Pickering nuclear power plants for training purposes.

For simplicity, a single simulated value form the Darlington Nuclear Power Plant is used for monitoring purposes. Due to constant variation of steam generator level and its critical role in control mechanism of CANDU Nuclear Power Plants, this value was chosen for monitoring purposes.

The simulated plant initially runs in normal mode and full power. Accident scenarios are applied to evaluate the system response.

2.3 Tricon Hardware Controller

Tricon Hardware Controller is a Programmable Logic Controller (PLC) used control and shutdown applications. The controller used in this experimentation provides Triple Modular Redundant (TMR) architecture. For this purpose, a voting mechanism is used upon execution of control program on each independent channel. The control system is capable of transient and steady-state error detection through triple redundant design on the control system.

The data generated in the simulated environment is initially transferred to Tricon PLC as a buffer between the original data source and OPC-interfaced PLC. At this point, Tricon PLC will act as a buffer between the communication structure used and the original data source. In an industrial application of this experimentation the plant simulator will be replaced by the actual data originated from the plant and the Tricon PLC will be interfaced with the sensors and transmitter installed in the plant.

The Tricon Hardware Controller passes the data through its Ethernet port to a PC running TriStation. TriStation is a proprietary application used to configure the Tricon PLC.

2.4 Wonderware Human Machine Interface (HMI)

The Wonderware HMI Software uses industry standards-based ArchestrA software architecture which is used to facilitate integration and maintenance of production systems. Wonderware is an OPC-compatible Human Machine Interface. In this project Wonderware is used as user-end component of OPC communication structure. This software includes Wonderware Historian which is a high-performance historical database used in process industry. This application is used to verify the evaluations performed in this experiment.

Wonderware HMI is used to integrate acquired data with events and configuration data. Wonderware software will be used in parallel to other monitoring devices to evaluate a multi-device network structure similar to ones used in process control industry.

2.5 OLE Process Control (OPC) Communication Structure

In order for the experimented project to realistically represent an industrial network application in a nuclear power plant, the components are chosen to have variety in the communication protocols, platforms and even communication media.

In addition to the main components used in the communication path, additional data sources and data acquisition devices are added to increase the complexity of the network structure and introduce to concept of multi-device multi-standard network which is a key advantage of OPC structure.

The following figure presents the main and additional data source and data acquisition devices used in the experimentation:

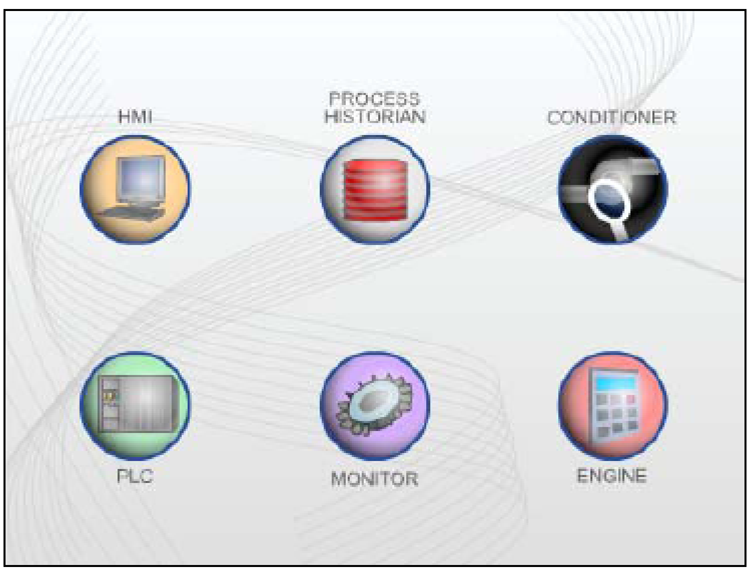

Figure 2 Data Components

Studying only the main data source we can see a lengthy process is required to connect the Tricon PLC via its proprietary communication protocol, TSAA, to the Wonderware HMI with TCP/IP protocol.

It should be mentioned that there are available methodologies to convert the data from one specific protocol to another. However, a dedicated conversion method is required for data conversion only between the Tricon PLC and the Wonderware HMI. This would create additional process of conversion for every device added to the system and also will unnecessary overhead to the communicated data. This traditional method is scalable in a satisfactory level and will not cost-justify for industry level applications.

In addition to the mentioned problems, once the network infrastructure is established the performance of the communication will be negatively affected. Each data source will require providing data lines for each data acquisition device and excessive number of data requests will overwhelm the data source devices which in turn will reduce the performance quality of the devices and the network.

The following figure represents the traditional network structure. It should be noted that the communication lines driven from each data source device are capable of communicating to a single data acquisition device and consequently will produce a tremendous amount of complication in the infrastructure of the network in large nuclear-specific applications. In addition it is noted what each device will produce a separate data request package which will overwhelm the data source:

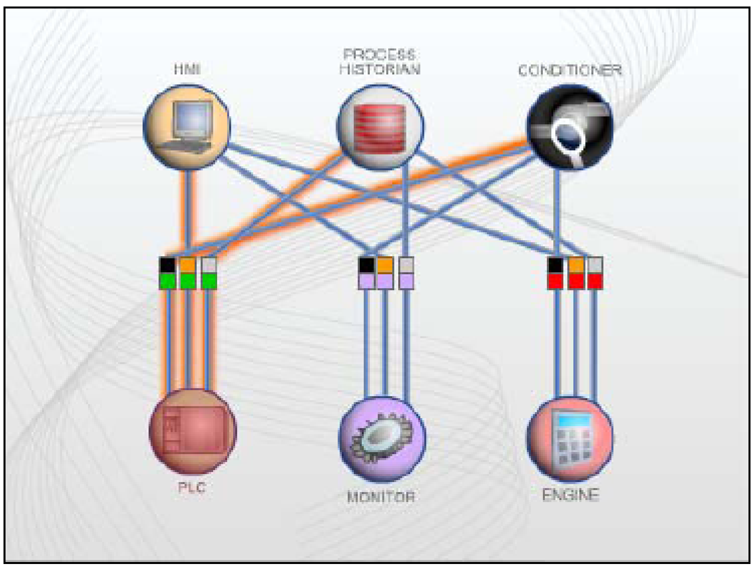

Figure 3 Network Connections

In this experimentation, using OPC, the network structure is independent from the device specifications including protocols and platforms. OPC is compatible with both Tricon PLC and Wonderware HMI and consequently will act as a communication bridge between two devices with its interoperability capabilities.

The universal structure introduced by OPC assisted us to interface with all the data acquisition devices separately and to optimize the network performance due to the simplicity of the infrastructure.

The data originated from the OPG Desktop Simulator are communicated to the Tricon PLC using Ethernet protocol. Since the network between the simulator and the hardware controller involved a single communication protocol, the use of OPC network structure was unnecessary for this connection. The connection under study in this experimentation involves the communication of data from the Tricon PLC through OPC to the Wonderware HMI. As mentioned earlier, additional devices are introduced into the structure for a realistic representation of a complex nuclear-specific industry application.

The data originated in the simulator passes the PLC hardware controller and gets transferred to a PC running TriStation. As mentioned earlier, TriStation is software used for configuration of Tricon PLC. The OPC application which is used to interface Tricon PLC is installed in the same machine to facilitate making changes required in the configuration while the data acquisition is in process. The data are communicated to another machine running the Wonderware HMI. The connection is established without the need to introduce any conversion method between the devices.

The Wonderware HMI receives the data packages sent by OPC and produces graphical presentation of the data acquired for plant operators.

The following figure represents the same data sources and acquisition devices which were previously connected in the traditional fashion. However, in this figure the connections are established through OPC and as it is shown, the interface application is connected to the data source devices using a single data line. In this case, if three different data request are sent to the interface application for the same device, the application will send a single data request package to the device reducing the process performed in the data source and improving the overall performance of the system and the network:

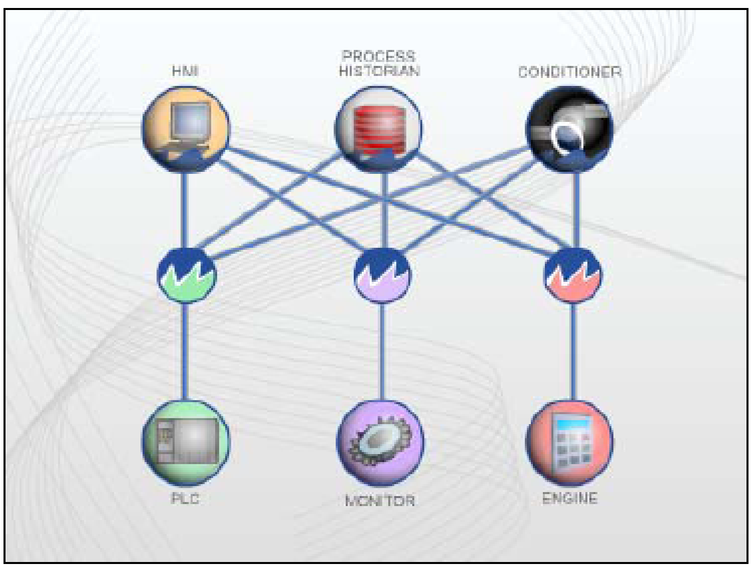

Figure 4 OPC Network Connection

2.6 Dynamic Data Exchange (DDE)

Dynamic Data Exchange (DDE) is a network structure used to send data between applications using Windows messages according to a documented protocol. This method will restrict the communication based on its platform. However, protocol interoperability can be obtained in this method. DDE is an asynchronous network structure which operates when a client sends a Windows message to the server. Windows holds the message and sends it to the server when the server is ready to process it. This will prevent the wait times on the client side since the client need not to wait for subroutine call is returned.

This communication method is used in the experimentation due to its simplicity and efficiency due to the small amount of overhead and processing time. The inter-platform compatibility of OPC is not required in this case since the Tricon PLC and Wonderware HMI are both Windows based applications. The original data is generated using the OPG Desktop simulator with operates under UNIX operating system. However, the connection between the simulator and Tricon is done through Ethernet and is not studied in this project.

In comparison to the OPC implementation of the network structure DDE gives less flexibility in using different data source and acquisition devices. However, the high efficiently and minimal overhead used in this method makes DDE a good choice for this experimentation.

2.7 Modbus Communication Protocol

Modbus is the first widely accepted Fieldbus standard. The Modbus communication interface uses messages to communicate data. Modbus is independent of the type of physical interface used. The same protocol can be used regardless of the connection type. A device can also communicate with several Modbus nodes at once, even if they are connected with different interface types, without the need to use a different protocol for every connection.

These capabilities are considered as advantages of using Modbus as the communication structure over the simpler structures such as DDE.

The method can be used for TCP/IP communication over Ethernet. The Modbus messages are embedded in packets with the format necessary for the physical interface.

Modbus and other types of connections can co-exist at the same physical interface at the same time. This also gives an advantage to Modbus over the OPC implementation as Modbus can be integrated into an already existing structure with different networking protocols and infrastructures.

The messages used for communicating the data over to the destination use four basic elements. The communication is always started by a master in the Modbus network which is represented by the PC running TriStation. The PC running the Wonderware software represents the slave in this communication set up. Due to the use of additional devices in the system, the addressing information is necessary to be included in the message format. Only the device with the matching address will accept the package.

The following table illustrates the standard format used in the Modbus messages:

Field	Description
Device address	Address of the receiver
Function code	Code defining message type
Data	Data block with additional information
Error check	Numeric check value to test for communication errors

Table 1 Mudbus Message Format

3. Conclusion

The network structures used in these experimentations have shown to be suitable for simulated case study. The designed case study was intended to realistically represent an industrial network application in a nuclear power plant. The network components were chosen to have variety in the communication protocols, platforms and even communication media in order to be compatible with wide verity of industrial applications. In the overall evaluation, OPC is proven to be the easiest implementation for the structures which are being established originally by this method. OPC was also compatible with wide rang of platforms and protocols which made it a flexible choice for industrial applications.

DDE was concluded to be the most efficient communication methodology with the least overhead. This is particularly desirable for safety critical applications with higher data acquisition rate and for data sources with high processing load. However, this method is not compatible with different platform which can restrict the use of various devices.

Finally, Modbus communication protocol is a flexible and compatible protocol to be used in industrial level applications. The advantage of this methodology is the capability of this protocol to co-exist with other protocols in the same network structure and even in the same physical interface. This protocol is suitable to be used in an already established network structure with various devices involved in the data acquisition process.

4. References

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