Development of hybrid controller combining JAVA and IEC61131-3 on reliable hardware

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Abstract: This paper introduces the key features of NCS (Network based Control System), which is quite a new concept in the industrial automation market. Two control systems "DCS" and "PLC" have been recognized as control systems used for process and factory automation during the past decades. However, the market requires more complex functionality, such as monitoring and operation, alarm handling and notification from remote locations using the Web or e-mail. Besides enhancing functionality, interoperability between each device and system is highly required since network and engineering tools provided by many vendors do not cooperate with each others, so that lots of conversion, reconfiguration and reprogramming are required when expanding systems. NCS can meet this requirement, installing leading-edged IT technology using international standards for network and engineering environment. NCS, which is a harmony of web functionality, networkability and a reliable control function, enables information integration and responding to the market's requirements with agility and high reliability.

Keywords: NCS, TCP/IP, FOUNDATION Fieldbus, Redundant Network, IEC61131-3, Java

1. INTRODUCTION

Continuous mass volume production of a small range of products was common decades ago. Operators controlled whole factories from a central control room 24 hours a day, and manufacturing data was used for scheduling the production line and sent as a report to headquarters periodically. In that situation, DCS was regarded as the core control system. However in contemporary society, customer's tastes are wide-ranging and easily change while price competition is very severe. Responding to these market demands with agility, while reducing the cost of ownership, requires a new control system which improves manufacturing efficiency and integrates information. NCS "Network based Control System", which inherits the reliability of DCS and uses cutting edge IT technology, is a new generation of control systems that extends the possibility of the manufacturing systems.

NCS covers the following features.

- Networkablity
  Connecting to the proper control and information networks improves interoperability between control systems and field devices.
- Autonomous function
  Autonomous function improves the diagnostic functions of the plant and devices/equipments and proper alarm handling.
- Standardized engineering
  The IEC61131-3 standardized engineering environment enables encapsulating logic for reusable application programming.

2. NETWORK ABILITY

One of the important requirements for any control system is the ability to be easily expanded and refitted when needed without conflicting with the existing manufacturing system and network. This section explains the networkability from the control network and field network side.

2.1 Control Network

TCP/IP, which is now a de facto standard in the IT area, is ideal as a control LAN protocol which is used for connecting controllers with other controllers and SCADAs. By installing a TCP/IP base control LAN, all manufacturing information is integrated on the same network since TCP/IP is normally used for an information network between SCADA and MES. Other advantage of using TCP/IP base control LAN is that the existing network infrastructure such as FTTH, ISDN, xDSL can be adopted to the control network.

Besides network integration, network reliability is essential for a control network. To increase the reliability of COTS LAN, redundant network configuration on TCP/IP is required, as shown in figure 1.

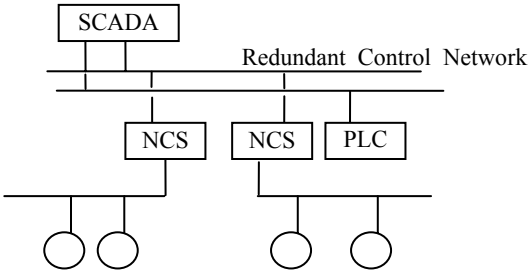

Fig. 1 Redundant Control Network

In the redundant configuration, one network (network A) is used as a control network, and the other (network B) becomes a stand-by network and is not used for communication routing, as shown in figure 2.

Network status is managed through the network status table embedded in the control network function of each node. Network status is periodically monitored and stored in this network table. If the network fails, the routing table is automatically changed and the stand-by network becomes the control network. This routing table method is commonly used for TCP/IP network switch. Within this architecture, applications do not depend on the configuration of the network, single or redundant.

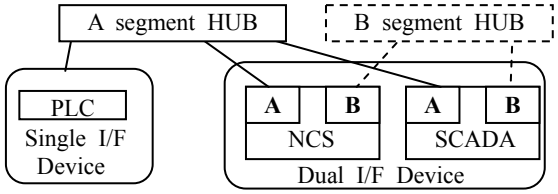

Fig.2 Redundant Network Configuration

2.2 Field Network

As a field network, a digital network avoiding A/D conversion is desirable for more accurate sensing. The FOUNDATION fieldbus is a bi-directional communication protocol used for communications among field devices and control systems. Field devices and systems from a variety of vendors can be connected using a FOUNDATION fieldbus without disrupting communications, so that new devices can be added without waiting for plant shutdown.

Similar to control networks, field networks can be redundant to improve reliability

3. AUTONOMOUS FUNCTION

Autonomous function is a key feature. NCS can calculate data such as KPI (Key Performance Indicator) and send them autonomously to other systems. With this intelligence, NCS can be a core system for integrating information. To realize this autonomous function, Java capability is installed in NCS. By adopting this advantage to applications, proactive maintenances such as reverse osmosis diagnosis, blocked pipeline are enabled.

This section explains the implementation of the Java function.

3.1 Java Runtime Environment

Java applications, which are widely used for sending information via Web, e-mail or FTP, do not have control function. However NCS is not just a remote monitoring system but also the control system, Java functions need to run with control functions in NCS. To secure the steady operation in critical process, control applications run at a higher priority than Java applications and also run in a different memory space. With this software configuration, Java applications do not interfere with the control function. Figure 3 shows the software configuration.

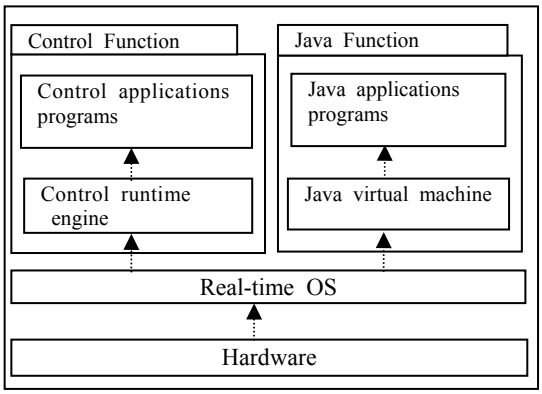

Fig.3 Software Configuration

However, Java applications generally can not access the real-time OS functions such as hardware drivers. Therefore engineers have to write the large amount of extra code to access the real-time OS functions and IEC61131-3 data. To improve the engineering efficiency by reducing code, an application frame work called JEROS “Java Embedded Real-time Operating System” is developed in NCS. The JEROS service provides the hardware driver, network computing functions, application framework and multi task management.

To communicate with JEROS service, the following Java class libraries are provided, including Java standard libraries, as shown in figure 4.

- JEROS system class library;
  Class library for JEROS interface
- Java standard class library
- Control data access library
  Class library accessing control application data programmed by IEC61131-3

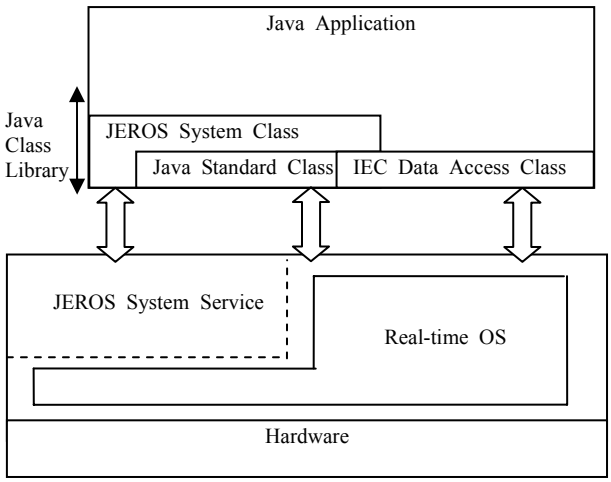

Fig. 4 Java Application Configuration

3.3 Java Development Environment

As a standard programming kit, JDK (Java Development Kit) provided by Sun Microsystems can be used for developing Java applications. However, Java programming is an issue for control system engineers since the Java application programming language is different from control applications.

A GUI-based Java development environment is developed for control engineers to make Java programming easier and to be an interface with JEROS. By using this, applications can be developed without requiring any Java programming knowledge and the following application modules can be created, as shown in figure 5.

- Web module; Operation and monitoring page on Web
  Embedded web server processes HTTP requests from created web page and embeds the control data in it.
- E-mail module; Alarm notification via e-mail
  Embedded SMTP (Simple Mail Transfer Protocol) client function enables sending e-mail.
- Data set module; IEC61131-3 data acquisition setting
  Setting parameters on a web client enables data acquisition.

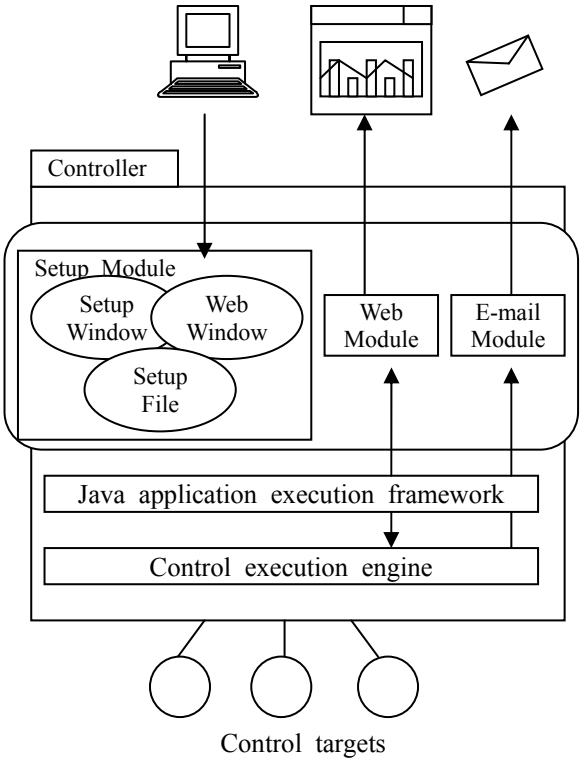

Fig. 5 A GUI-based Java Development Environment

4. STANDARDIZED ENGINEERING METHOD

A standardized engineering method is the core of any engineering environments. The proprietary engineering environments provided by many vendors have prevented the reuse of applications and increased engineering efforts. A standardized engineering environment needs to be complaint with international standards. This section explains efficient engineering using IEC61131-3.

4.1 IEC61131-3 international standard language

The IEC611-3 standard developed by International Electrotechnical Commission is the most suitable programming language for control logic. IEC61131-3 consists of five languages, FBD (Function Block Diagram), LD (Ladder Diagram), SFC (Sequential Function Chart), ST (Structured Text) and IL (Instruction List), as shown in figure 6.

By employing an international standard language, control applications do not depend on the platform and can be easily ported to other systems without losing application know-how.

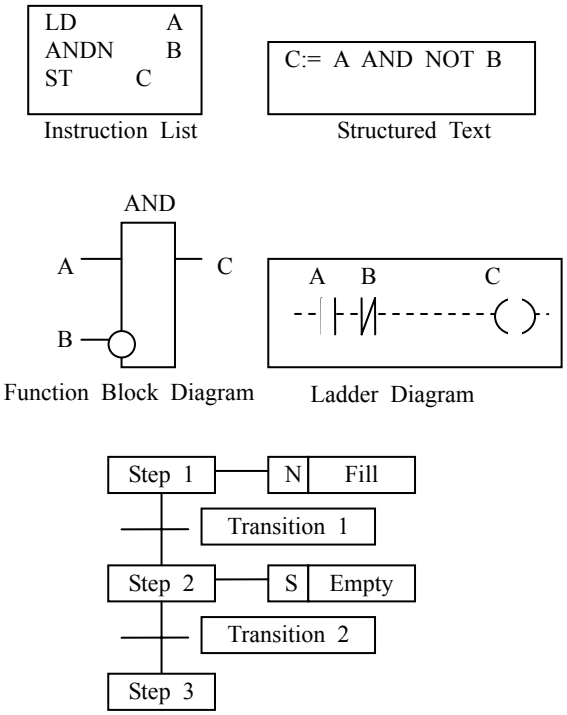

Fig. 6 IEC61131-3 5 languages

4.2 Encapsulation

Programs are encapsulated in a Program Organization Unit (POU). Using POUs, application know-how can be encapsulated as a library called an application portfolio and reused for similar applications. Thus engineering efforts are drastically reduced.

However, application know-how is the vendor's intellectual property, so that concealing source code is as important as the reuse of POUs. To meet this requirement, a password can be set on each POUs, thus only the developer can modifying their logic without disclosing the logic behind each application.

4.2 Protection

Vendor can easily provide their know-how to users by encapsulating their POUs as Application Portfolio (APPF). However providing APPFs without any security has a great possibility of distributing vendor's know-how free of charge. To avoid this situation, a license system is adopted. Without a license corresponding to the APPF, the execution of APPF becomes invalid.

4.3 Example of Application Portfolio

Since IEC61131-3 is popular in the PLC industry, not all POUs required for regulatory control are provided and even if they are, some of the functions do not match the regulatory control system. To meet DCS (Distributed Control System) application requirements, POUs for regulatory applications, called PAS POU, are provided.

4. CONCLUSION

The core value of NCS is reliable control and information transmission while employing international standard languages and protocols. Taking full advantage of both functions without confliction is the design policy of NCS. NCS introduces the new possibility to industrial automation market.

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