Part I

Design Principles of Modern Industrial Automation Systems
Introduction

In the past years before the personal computer (PC) was widely incorporated into industrial automation systems, all the faults that occurred in industrial processes were checked and dealt with by trained or experienced operators. For example, in the condition monitoring systems for the natural gas pipeline network, all operations were handled in a manual or semiautomatic manner, which, however, had some major drawbacks. For instance, the operator had to do the majority of the work by hand, the abnormal conditions could not be monitored and handled in real time, the remote measurement parameters could not be effectively monitored, and operators were prone to make mistakes in recording and manipulating a large amount of data. Therefore, it is highly necessary to automate the measurement operations as well as to improve the operating efficiency.

In recent decades, this picture has been dramatically changed due to the wide adoption of industrial PC in a wide range of industrial applications. A typical industrial automation system, as illustrated in Fig. 1.1, is usually made up of the physical system, transducers, device drivers and data I/O, host computer, network server, and remote computers.

Information technologies have been rapidly developed in recent years, and they have provided sufficient technical support for building modern industrial automation systems with more open architecture with respect to the previous ones. It turns out that the computerized real-time monitoring analysis
and automated technologies can realize the full automation of an industrial measurement system. The combination of emerging information technologies with traditional condition monitoring systems allows for the continuous running status monitoring for essential equipment as well as comprehensive data processing and centralized resource management. It will significantly enhance the working efficiency of system operators and decision-makers. As a result, developing such systems with the aforementioned characteristics for achieving full industrial automation has a positive practical significance in both economy and technology perspectives.

1.1 DEVELOPMENTAL TRENDS

Considering the state of the art in industrial measurement and control fields nowadays, we can see that modern industrial automation systems have the following two evident developmental trends:

- One direction is to carry out industrial measurement and control using miniaturized, portable, and universalized instruments. This type of small handheld instrument allows workers on the floor to collect signals from the plant floor and to perform certain simple computation using the general-purpose software burned in the system itself. Then, through the general instrument buses, like IEEE-488 and RS-232, the instrument is connected to a personal computer for further data processing by fully utilizing the more powerful computing capability. This type of instrument is being developed very rapidly.

- Another direction is to develop continuous, online, real-time measurement and control systems. The functions of such systems are more comprehensive as compared with the handheld-instrument-based measurement, but the cost is much higher. And such systems are generally more suited for monitoring the key plant equipment. The existing products primarily include the following several components:
  - Devices have the powerful capability for data acquisition and signal preprocessing using electrical circuits such as operational amplifiers and filters. This part of electric circuits must ensure that the gath-
ered data can truly reflect the running status of various complex and ever-varying plant operating conditions.

- Dedicated signal analyzers are employed to perform the real-time signal processing for the data collected from factory floor. For instance, the widespread application of Fast Fourier Transform (FFT) technique enables easy and fast analysis of signal characteristics. Furthermore, more and more novel algorithms are being invented for more effective signal processing.

- The advantages provided by Internet or Intranet can be fully exploited by building the networked industrial automation systems. The master computer, which is the system heart, is primarily responsible for collecting data transmitted through the network. The master computer also conducts data manipulation and analysis tasks using its installed software in order to facilitate the appropriate decision-making. In the 1980s, many companies and colleges began developing the measurement and control software. But the majority of the developed software was based on the DOS platform or the earlier 16-bit Windows platforms, and their functions are far from satisfying user's ever-changing requests.

In this book, only the latter measurement and control systems are addressed. In an information-rich world, the tighter integration of various disciplines is the trend for modern industrial automation systems. The trend is the convergence of communication, computing, and control technologies. For instance, the well-known C4ISR (command, control, communications, computers, intelligence, surveillance, and reconnaissance) is one of its typical applications. The future industrial automation system will involve more interactions among system components as well as with the physical environment.

1.2 CLASSIFICATIONS AND EXISTING PRODUCTS

From the technical perspective, the application of industrial automation software can be classified into the following categories:

- Industrial measurement and control
- Remote measurement, communication, and control
- Monitoring and alarming of industrial process parameters
- Industrial parameters acquisition, processing, presentation, search, and network sharing

From the perspective of application domains, industrial automation software can be applied to the following fields:
• Measurement and control of process parameters in industrial production
• Parameter monitoring for public utilities such as city LPG pipeline, power transmission, and water supply
• Integrated management system for intelligent buildings such as building equipment monitoring and security management
• Power management in telecommunication systems
• Environment monitoring and protection
• Condition monitoring for large rotating machinery
• Products quality testing and analysis
• Supervision of food and beverage assembly
• Safety-critical aerospace applications

In recent years, some industrial automation software packages have been successfully developed and are being used in various industrial application fields. At the time of writing, the major software packages commercially available in global market include Intouch of Wonderware, Fix of Intellution, Genesis of Iconics, WIZCON of PCSOFT, Cimplicity of GE, and so forth. According to their developers, these software packages can be classified into three types, namely, the software which is developed by the professional software companies, hardware/system companies, and industrial manufacturing companies, respectively.

• The industrial automation software developed by professional software companies occupies the majority of the global industrial automation software market. The typical software products are listed as follows:

  – Intouch of Wonderware (U.S.A.): Wonderware Intouch is a Microsoft Windows-based, object-oriented, graphical human–machine interface (HMI) application generator for industrial automation, process control, and supervisory monitoring. Types of application include discrete, process, DCS (Distributed Control System), SCADA (Supervisory Control and Data Acquisition), and other industrial environments.

  – Fix of Intellution (U.S.A.): FIX Dynamics provides automated, fully integrated industrial solutions that combine together plant-floor and business data. It is designed based on industry standards for integration, interface, and communications technologies.

  – Genesis of Iconics (U.S.A.): Genesis32 offers a totally nonproprietary set of open and scalable automation tools. It is suited for many applications requiring supervisory control, data acquisition,
advanced alarming, report, visualization, and much more. It also seamlessly integrates with other commonly used software products such as MS SQL and MS Office.

- Other commercial software packages developed by professional software companies include ONSPEC of Heuristics (U.S.A.), PARAGON of IntecControl (U.S.A.), Citech of CiT (Australia), AIMAX of T. A. Engineering (U.S.A.), FactoryLink of U.S. Data (U.S.A.), WIZCON of PCSOFT (Israel), and so on.

- In the recent years, some hardware/system manufactures also began to develop their industrial automation software products. The representative products primarily include Cimplicity of GE (U.S.A.), RSView of AB (U.S.A.), WinCC of Siemens (Germany), and so on. Some DCS manufactures such as Rosemount and Honeywell also developed powerful industrial automation software for their advanced control systems and field-bus products.

- Products of industrial automation software developed by industrial manufacturing companies have occupied more and more market portions in recent years. The main reason is that the expensive software packages are apparently not suited for the numerous small and medium-sized companies worldwide, where software cost is their major concern. In practice, these companies are not able to afford to study, take courses, and buy consultation for building and maintaining the complex large-scale software for long periods of time. Furthermore, the software that they need should be especially suitable for the field environments in specific practical applications so that the software can be easily operated even by common technicians. Therefore, it is believed that developing such a software package can help those companies to develop their projects in a cost-effective fashion as well as provide complete plug-and-solve functionality for the new plant. The major theme of this book is concerned with the development of such software packages for different industrial applications in a cost-effective fashion.

1.3 FUNCTIONALITY OF INDUSTRIAL AUTOMATION SYSTEMS

Modern industrial automation systems should be capable of conducting real-time online data acquisition and manipulation, centralized system resource management, and networked data sharing. It must have the flexible configuration capability. It should be capable of flexibly setting up general local area network (LAN) and wide area network (WAN) to meet specific industrial measurement and control requirements. It should also be able to build comprehensive monitoring network integrating various functions such as data collection, condition monitoring, fault diagnosis, resource management, and
decision-making. Such an industrial automation system should be suitable for operation and management at different levels such as workshop, branch factory, and corporation. Basic requirements for such an industrial automation system are listed as follows:

- It should be able to effectively conduct the desired measurement and control tasks in order to ensure the proper operations of industrial process. By uninterrupted system monitoring and recording, the database stores gathered information on plant operation status. These data can be used later on for further analysis and diagnosis of plant conditions.

- It should be able to effectively utilize various signal processing techniques to analyze the gathered data from different measurement points (channels). Moreover, appropriate and effective data processing algorithms need to be incorporated into the industrial automation software so as to fully exploit the merits of computation resources provided by modern computers as well as satisfy real-time constraints on data manipulation. By doing so, real-time measurement and thorough data analysis can be effectively accomplished.

- It should be able to increase the software versatility by allowing for flexible configuration of a variety of system parameters. The principles and main functions of industrial automation software may remain unchanged for different industrial applications. However, the details for any specific application can be redefined by modifying the configuration database according to any specific user requirement. Finally, by combining configuration database with the fixed system modules, system configuration for the specific application is accomplished and thus the industrial automation software with desired functionality is built.

- Human–machine interfaces (HMIs) should be designed according to the current popular development trends. User-friendly graphical user interfaces (GUIs) are always beneficial to improve software quality because they make user operations more convenient and pleasant. For instance, using the multimedia provided by the modern computer technology, all of the plant statuses can displayed in an animated form as their corresponding industrial parameters are updated in real time.

- It should have comprehensive alarming and reporting capability. The alarm module in the industrial automation software compares the gathered data with the user-set parameters. Audiovisual alarms and exception reports are generated for immediate remedial action if the data levels detected exceed the preset parameters. The alarming function should be able to provide various alarming patterns in order to promptly inform the corresponding technical and management personnel in the presence of emergent situations. These flexible alarming modes include vivid screen indicator, speaker, automatic telephone dialing, beeper,
e-mail, fax, and so on. E-mails can be sent to the cell phones of corresponding people in the form of SMS messages, informing them of plant emergencies in a timely manner, which cuts machine downtime. All of these functions can be made available without needing extra prohibitive telemetry investments.

- It should be able to directly perform various measurement and control tasks using commonly used Web browsers. Previously, the special-purpose industrial automation software package had to be installed on the industrial computer beforehand in order to conduct the tasks. The networked system provides the network server, which allows the user to accomplish industrial measurement and control in the global scope through the network Web browser (for example, Internet Explorer or Netscape). It avoids the installation of any special-purpose software. Thus, software maintenance becomes more convenient, and such systems should be more economically priced. Using the network technologies, an industrial automation system is no longer an “island of automation” and only confined to a stand-alone local or dedicated network. The remote management activity allows operators anywhere to access the real-time data from the factory floor. Internet-enabled industrial automation systems also allow for automatic software upgrades and remote maintenance.

1.4 ABOUT THE BOOK

A modern industrial automation system is made up of a variety of independently functioning but interacting modules. It opens a new window of opportunity to increase productivity and management effectiveness of industrial processes. The wider use of distributed supervisory control and data acquisition across a factory floor turns out to be able to enhance the productivity and profitability significantly. Future trends in this field include improving the industrial automation system reliability/availability, responsiveness, scalability, expandability, flexibility, interoperability, and so on. To achieve these objectives, we believe that next-generation industrial automation systems will be based on a few key design principles:

- Virtual instrumentation
- Component technology
- Object-oriented software engineering
- Graphical user interface
- Database management
• Systematic software testing

• Other emerging technologies

In the subsequent chapters of the book, first some of the key design principles are introduced (some other design principles are discussed throughout the case studies of practical industrial automation system designs). And then five representative real-world applications are discussed in great detail. Application engineers seeking to develop similar applications will find these practical design cases of interest.

• In Chapter 10, an object-oriented reconfigurable software for industrial measurement and control is presented since the capacity of highly flexible reconfiguration is crucial for modern industrial automation software. The developed software turns out to be able to work a wide range of industrial application scenarios.

• In Chapter 11, a flexible measurement point management scheme is implemented in an industrial measurement and control system. It provides a solid basis for constructing modern industrial automation systems with high configuration capability.

• In Chapter 12, a VxD-based automatic blending system is detailed. To satisfy the system communication requirements in the presence of a large volume of data, a multithreaded programming technique is adopted to avoid the data transmission bottleneck.

• In Chapter 13, an automatic test system for large rotating turbine machinery is discussed. It is used to ensure the machine quality by fully automating its testing procedure. Rotating turbine machinery is now being used in a variety of industrial processes, and its design quality is of particular importance. Thus, such an automatic test system is highly desired.

• In Chapter 14, a networked online real-time condition monitoring system is discussed because Internet-based industrial automation systems are the developmental trend for different industry applications. This system is also developed based on the concept of modular design and functional decomposition.

In the final chapter, emerging technologies which are being or may be used for building more powerful industrial automation software are introduced, which include middleware, Unified Modeling Language (UML), agent-based software development, and agile methodologies.