

Section 1    Introduction to Distributed Control Systems

1.1    Section 1: Aims

On completion of this section, you should:

- Have an appreciation of the impact of automated systems in modern manufacturing processes.
- Understand the three level hierarchical model of an automated manufacturing system.
- Have a basic knowledge of, and be able to define, what a Distributed Control System is.
- Understand the general benefits of Distributed Control Systems.

1.2    Introduction

Since the Introduction of computers into the manufacturing workplace, Information Technology (IT) and Automation Systems have revolutionised the way in which manufacturing industry operates. This applies to the general organisation and procedures adopted by manufacturing industry as well as specific methods and techniques of manufacture. These changes have brought about several benefits to industry:

- A decrease in processing time
- A reduction in production costs. e.g. by reducing waste
- The production of better quality products - reducing the number of defective products and lowering failure rates.
- It is now possible to replace workers in dangerous environments with machinery

However, this is not the complete story. Other advantages, which may be less direct but often have greater impact in the longer term include:

- A greater understanding of the manufacturing process, allowing easier identification of bottle-necks.
- Better production scheduling, making maximum use of the production facilities.
- Greater flexibility in response to changes in design, customer requirements and competition.
- Shorter 'lead times' in designing new products.
- Faster identification of faults in both product and processing machinery.
- Ability to identify deterioration in equipment before actual failure, reducing production 'down time'.
In a system that must be flexible, its individual components and processing systems must also be flexible. They must be capable of changing their operational parameters, tooling or processing operations at short notice, perhaps on a job to job basis. This is where computer based automation comes into effect.

Computer systems imply programmability and decision making capability, i.e. intelligence. Intelligent production systems, cells & work stations and even individual cell components are at the heart of the flexible capability of advanced manufacturing systems.

It is for these reasons that this new technology is considered an asset. However, as engineers it is the technology that interests us, for business it will be the advantages that the application of this technology can bring to production. This will be the driving force in bringing the technology to the work place.
1.2.1 The Factory as a Control System

To maintain a successful and competitive manufacturing industry, knowledge in the field of communication systems is crucial. Figure 1.1 shows a block diagram depicting the multiple communication links that, in general, are in operation within a factory environment. The communication link very much forms a control system consisting of multiple feedback loops.

![Figure 1.1 Communication within a manufacturing plant](image)

As can be seen from the diagram the factory and manufacturing system may be thought of as a control system consisting of several feedback loops:

1. Product design is based on externally obtained information
2. Product design drives manufacturing efforts
3. Manufacturing capabilities constrain and shape product design
4. Manufacturing requires materials input
5. Manufacturing output is delivered outside via distribution and sales
6. Marketing gathers internal and external information
7. Marketing feedback shapes product design, manufacturing and sales
8. Sales are fed through finance to corporate management
9. Corporate management shapes product design decisions

This obviously requires communication at all levels between one part of the system and the next.
1.2.2 Communication in a Factory Environment

Communication in a factory environment consists of different networking levels. These range from the simplest network inside a machine, to the network running around the shop floor, the design room, the management, finance departments and corporate level, where worldwide communication may be involved. It is certain that this communication will involve the Internet. In fact the 21st century may see the advance of a factory completely remotely controlled over the Internet from one central site elsewhere in the world.

According to the International Standards Organisation, an automated manufacturing system may be described as a three-level hierarchical model, This model is shown in Figure 1.2.

![Diagram of Factory Automation Hierarchy](image-url)

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**Figure 1.2 Factory automation hierarchy**
As shown in Figure 1.2, a hierarchy of communication systems is required to meet the needs of all the elements within a manufacturing environment.

**Higher level networks are not suitable to implement the communication mechanisms required in the shop floor. Similarly, lower level networks, such as CAN protocols, could not possibly be used to perform tasks that require a lot more than the simple interconnection of sensors and actuators on an automation cell.**

A typical production line consists of a transportation system and several flexible manufacturing cells. The transportation system itself will have various sensors and actuators mounted on it to control and monitor pallet positions and to log product information and process controllers. A typical flexible manufacturing cell consists of sensors, actuators, process controllers, manual stations, mechanical linkages and pneumatic components. All these elements need to communicate with each other e.g. sensors and actuators need to be connected to the process controller.

Even between process controllers linkage may be required to allow co-ordination of the whole manufacturing line. Consider the diagram in the Figure 1.3. In this simple system products are routed through different parts of the line depending on the product that is being made. The progress of the product through the system is monitored by sensors such as bar code readers that monitor its position in the production system at any moment in time thereby providing a quality control check.

![Figure 1.3 A typical production cell](image)

**1.2.3 Production Control Components**

Most equipment found in industry can be divided into four key categories:

- **Process Control Equipment (Control/Automation Level)** – programmable devices which control processes. These include, industrial computers, PLCs, specialist controllers for robots, CNC machines etc.
- **Mechanical Components (Discrete Process Level)** – conveyor belts, linear/rotary axes controlled by motors, automated guided vehicles
- **Actuators (Discrete Process Level)** – these include electric motors, pneumatic valves, pistons, maglev guides, and other similar devices which perform operations.
- **Sensors (Discrete Process Level)** – these are used for obtaining measurements and data from the environment. For example, the position of mechanical components, testing the quality of products.

### 1.2.4 Flexible Manufacturing Systems

Programmable devices and controllers have given the industrial user the ability to change the production cell simply by reprogramming the controller without having to change the wiring to the individual sensors and actuators. As a result, the manufacturing system is much more flexible. Furthermore, it has lowered system costs by reducing the time spent having to reconfigure manufacturing cells to produce new products. We will look at two types of flexible system.

**The centralised controller cell:** Figure 1.4 shows a system commonly known as a centralised control cell. Here, a number of control devices are connected to a central control system. This central controller is responsible for the overall operation of the cell. Each control device is mounted in a different location within the production cell and may require a different electrical interface to the controller.

![Centralised Controller Cell Diagram](image)

**Figure 1.4 Typical centralised controller cell**

As a result, there are several possible limitations to this configuration:

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The networked cell: To overcome the problems highlighted with the centralised controller system, a network solution is now typically employed in modern automation industry. A common approach is to employ a fieldbus solution, similar to that shown in Figure 1.5.

A fieldbus is simply a commonly shared communication medium, to which all devices and controllers may be connected. It then enables efficient communication between all the components of the production cell.
With the development of advanced IT systems and low cost microcontrollers with integrated network capabilities; all control components, from simple switches to complex systems such as electric drives, now have the capability to communicate with each other.

This arrangement offers significant advantages over the centralised controller system.

This is the concept behind distributed control systems. A distributed control system is a networked control system with a fieldbus at its heart. Several industry standard fieldbuses exist. CAN®, Profibus® and Modbus® are examples of popular fieldbus protocols currently available on the market and are currently being used widely in the manufacturing industry.

1.2.5 Definition of a Distributed Control System

A distributed control system may be defined as follows: