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Introduction

Many people today hear the word Automation and think of modern day, ultra-advanced manufacturing systems consisting of AI (Artificial Intelligence), controlling robots to create the consumer products of tomorrow.

While this is a form of Automation, there are many simpler forms which span millennia into the history of Humanity, shaping the way that manufacturing developed through the ages.

The purpose of this engineering report is to define and compare the three recognised types of manufacturing automation: Fixed Automation, Programmable Automation, and Flexible Automation. As well as a historical summary of each type, advantages and disadvantages of each will be highlighted along with examples of the control systems and process variables that they require and use.

In their simplest terms, Fixed Automation is any form of automation which can not be changed during the manufacturing process. There is no distinct line separating Programmable Automation from Flexible automation as there is a point at which one becomes the other. For the purposes of this report it shall be assumed that Programmable Automation is a process in which variables can be changed during or in between productions to make slightly different processes or tweak them during production, and that Flexible Automation shall refer to a level of programmable automation in which different processes can be completed at the same time or different parts can be made on the same production line, at the same time. As there is no specific definition, please be aware that different texts and sources may define this line slightly differently.

A company producing flat-packed furniture in the modern era would likely produce a majority of their wares via automation. As an example of real-world manufacturing techniques, the way in which they would employ flexible automation will be discussed, with an emphasis on why they would use Flexible Automation rather than Fixed or Programmable.

A basic definition of automation is any technology or process which can be performed without the intervention of humans Groover, M. P. (2017. p 734). It is possible for humans to be present or influence the process and still be defined as automation. In simple terms, Automation is any process which completes an action for a human or company.

Automation in Manufacturing

For most of Human development, fixed automation has been used to make hard tasks easier. Early examples include the wheel (3200B.C.), Levers, Winches (600B.C.), CAMs (1000), Screws (1405) and gears. (Groover, M. P. (2014. p 85). Later on, with the development of watermills and windmills (650), Automation was able to aid Humans in the production goods such as flour with windmills and utilising more torque, watermills driving gears, pulleys and mechanical equipment, could be used to produce weaving machines and machine tools that were powered by nature and operated by humans.

For the sake of this report, Automation for Manufacturing shall be thought of as beginning with Henry ford, evolution of manufacturing via the Model T production line.

There are three key components to an automated system: Power, Programme of instructions and a Control System (See figure 1.) Groover, M. P. (2017. p 735). Power is the most obvious, there must be some way of making the system do work. In modern day systems this is normally provided in electrical form, although heat is also common. Examples of power usage in automation include Melting metal, providing physical force (such as forging) providing rotational torque (such as drilling), Injection moulding, Laser cutting and Welding. Groover, M. P. (2014. p 89).

The Program of instructions in most simple terms, defines the sequence of steps in order to complete the task. In simple systems, this would be something such as “maintain this temperature (or pressure)”, rotate the part 180 degrees, hold for 100 seconds, or drill hole to “x depth”. This can be for one part at a time or for multiple parts at the same time. This can be either one action, as in the above or a sequence of actions, for example following a recipe, step by step, as in (1) add flour, (2) add water, (3) add eggs, (4) mix, (5) apply heat, (6) hold for 1000 seconds, (7) cool down).

The control system can be thought of in layman’s terms as the brain of the system. All of the data is fed to the control system, which manipulates the process variables to achieve the desired output. There are two main categorizations of control systems for the purposes of manufacturing automation. Open loop (Figure 2) and Closed loop (Figure 3). Open loop systems do not consider feedback, while closed loop (also known as Feedback Control Systems) do take feedback into account. Open loop systems, which consist of a controller, an actuator, and perform a process. An example is a toaster; the process would be the temperature dial, the actuator would be the heating coil and the process would be the bread being toasted.

In a closed loop system, there are still a controller, an actuator and a process plus another element, a feedback sensor. For example, in a central heating system, the controller is the analogue or digital adjuster, the actuator would be the heat source, the process is the temperature of the room changing. The feedback sensor then measures the output and compares it to the desired output, then amends then input as necessary to bring the temperature within the tolerance of the desired output. Examples of sensors that could be used include pressure, temperature, amps, voltage, ohms or displacement among others and can be electrical or mechanical or a combination of both. These are usually in the form of transducers, which converts a physical variable measurement into a readable/ usable form for the control system, usually as an electronic signal. Groover, M. P. (2014. p 131).

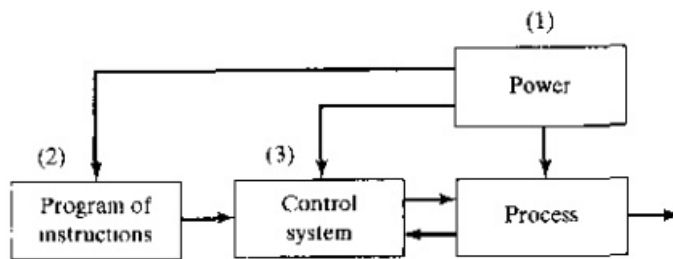


Figure 3.2 Elements of an automated system: (1) power, (2) program of instructions, and (3) control systems.

Figure 1: Elements of an automated system: (1) Power, (2), Program of instructions, (3) Control Systems. BrainKart (n.d.)

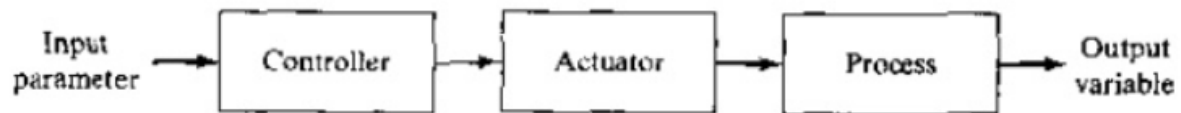


Figure 2: An Open Loop Control System Control Systems. BrainKart (n.d.)

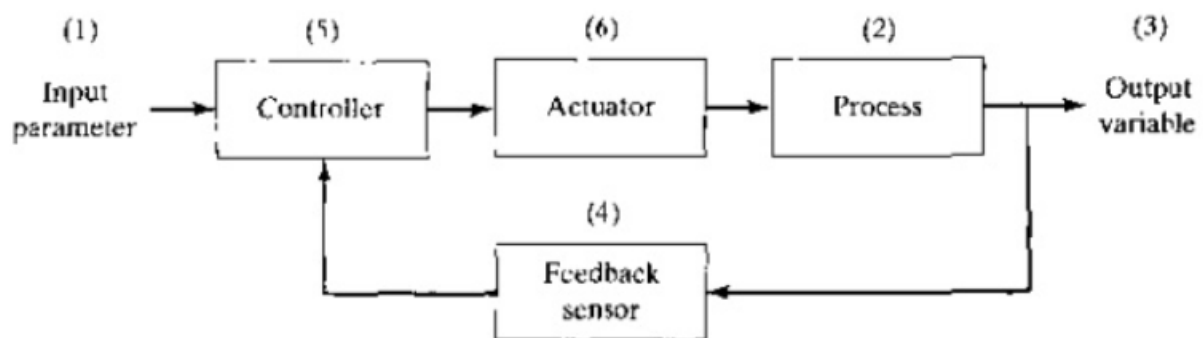


Figure 3: A Closed Loop Control System Control Systems. BrainKart (n.d.)

History and Overview

Fixed Automation

Although for the sake of this report, fixed automation for manufacture will be classified as beginning with the industrial production line, as this was when the term “Automation” was coined to describe the banks of automatic transfer devices and feed mechanisms used within the Model T production line developed by Henry Ford. Groover, M. P. (2014. pp 85-86); it is still important to show ode to the predecessors to Automation devices before the term was coined, from the wheel to the steam engine, to the steam locomotive and beyond. All automation up to and slightly passed this point is classed as fixed automation. Fixed automation usually takes one or more simple actions and repeats them in the same way every time.

Programmable Automation

With the invention of Numerical Control (NC) in the 1950s, A breakthrough in Automation began. Numerical control is a number based positional control system which allowed Automated systems to develop a basic level of flexibility. This means by changing the numbers, the part can be changed. Hence, Programmable automation (Also known as Soft Automation) is now possible. Further to this, in 1968, Programmable Logic Controllers (PLCs) are developed, allowing even more control over individual processes, replacing Programmable Hardware with Programmable Software. With the introduction of PLCs, Closed loop, or Feedback control systems become more prominent. Although they are not always required as they are usually significantly more expensive, greater control is possible through use of these systems ensuring that outputs match the desired outputs. Kalpakjian, S., & Schmid, S.R. (2014. Pp 67-68)

Flexible Automation

According to Groover, M. P. (2014. P 86) Ingersoll Rand were the first to incorporate Flexible Manufacturing Automation (also known as Soft Automation) into a production line in the USA (1960) to machine multiple different parts at the same time. This even predates PLCs, with this comes the invention of Computer Numeric Control (CNC), still used to this day in a significant number of the worlds engineering workshops. CNC allows for unique parts to be made on the same production line, following a computer-controlled set of instructions individual to each unique part. This can either be operated individually by microprocessors or by Direct Numerical Control (DNC) which is a central hub that controls all of the CNC machines in a production line. Kalpakjian, S., & Schmid, S.R. (2014. P 1069)

There is no direct line drawn between Programable and Flexible automation as they are both different levels of Soft Automation (In that they are not Fixed). The separation can be broadly defined as Flexible Automation is the point at which Programmable automation can make multiple different parts on the same production line, without the need for human interaction (With the exception of telling them what to make and providing the instructions.

Pros, Cons and Comparisons

This section of the report provides information sourced from Noori, H. (2008. pp. 232-233).

Fixed Automation

The initial investment for Fixed Automation (Also known as Hard Automation) is high, therefore the number of parts produced in order to break even is also high. Due to the simple and repeatable actions of a fixed Automation System high production rates are possible. Once the production line is assembled, it will make one product at a fast pace with high repeatability. This type of production line is poor at accommodating changes, such as changing or modifying the product being created as the whole production line would need to be physically replaced.

In economic terms, as shown in Figure 4, products with a very high demand and a low variety are most suited to fixed production as the more identical parts made, the more economically viable this method becomes.

Programmable Automation

When a medium number of individual parts are required or variance in some of the required parts is necessary, programmable automation is often the recommended Automation method. This is because equipment that already exists can be modified to suit the needs of the required parts. The production rates are lower than Fixed automation and have less initial investment.

In economic terms, as shown in Figure 4, products with medium demand, and medium variety between parts are prime candidates for Programmable Automation.

Flexible Automation

Flexible Automation has a high cost per part and a low production volume. However, it is extremely variable. Even when parts are being designed for mass production, Flexible Automation such as CNC or Additive Manufacture will be used for prototyping, jigs and moulds. It is possible for every part on a flexible production line to be completely different.

In Economic terms, as shown in figure 4, Flexible automation is best suited to small production runs with high variability. Where there aren't many parts being made, it simply is not financially viable to create an entire production line just for that product.

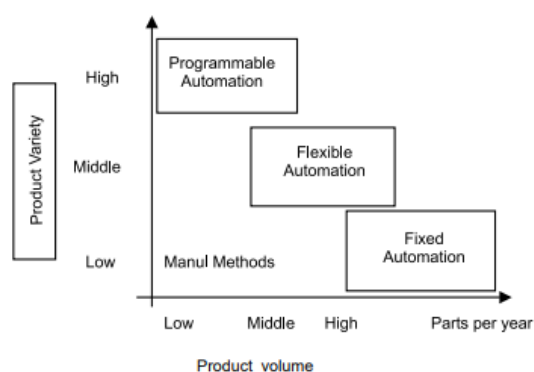


Figure 4: Production Automation Comparison.
Noori, H. (2008).

Flexible Automation real world Analysis

By definition: Flat-Packed Furniture, is furniture which is purchased unassembled from a company then assembled on site. (Collins, n.d.). A company creating this kind of furniture would not just be making one chair and nothing else. They would need variability of products.

Many flat packed furniture solutions either incorporate or are made of wood, many others use plastic and metals such as stainless steel/ aluminium. Flexible automation has the advantage in which these materials can be incorporated simultaneously and interchanged as necessary without significant delay or restructuring of the production line.

In traditional furniture design, bespoke pieces are hand carved by artisans and their apprentices. These same pieces can now be mass produced by Flexible Automation and made much more quickly and much cheaper than possible by human artisans. They can also be made identical to one another without flaws that may be caused by human error. This may be seen as a negative by some as it takes jobs away from skilled humans, this however is not the point of this essay and may be considered separately.

In mass production of furniture, more than one specific design is required. While some parts from different projects may be utilised to save on design time, overall, lots of different parts will be required. In a flexible production system, not only could they all be created on the same production line without interruption, but they could also actually be created on demand. With modern integration through the Internet of Things (IoT), products could be ordered from the website, and this could be fed to a central processing unit and the production line could have the parts ready before the human operators may potentially know they have been ordered.

In summary, A flatpack furniture company would be able to make use of the versatility that Flexible production Autonomy can provide for low volume, diverse portfolios of goods.

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