

بسم الله الرحمن الرحيم

الجمهورية الجزائرية الديمقراطية الشعبية

REPUBLIC OF ALGERIA DEMOCRATIC AND POPULAR  
DEPARTMENT OF HIGHER EDUCATION AND SCIENTIFIC RESEARCH



Ref: ....

**Discuss the graduation thesis in order to obtain the degree of:**

**MASTER**

**Field: Automatic Control**

**Option: Automatic Control and Industrial Engineering**

**Subject**

---

**Automation of an X-RAY Collimator using a programmable logic controller**

---

**Presented by: AOUI YAKOUB & ABIR OUSSAMA**

**Advisor: Dr.Toufik Madani Layadi**

**Co-Advisor: Dr.Issam Meghlaoui**

**Promotion 2020/2021**

## **Dedication**

In the Name of Allah, the merciful, the most Merciful

First all I would like to thank the almighty for giving me the courage and patience to get to this point in order to carry our this work

I dedicate

To my dear mother, who never stopped praying for me.

To my dear father, for his encouragement.

To my dear brothers

To my dear wife

To all my family: Aoufi

To my best friends

To all my friends from the ELECTROMECHANICS master's degree Automation and Industrial Computing

At the end I warmly dedicate this Thys to my teacher

Mr. Layadi Toufik

To all those who have helped me from near or far for the realization of this modest work

Aoufi Yakoub

## **Dedication**

In the Name of Allah, the merciful, the most Merciful

First all I would like to thank the almighty for giving me the courage and patience to get to this point in order to carry our this work

I dedicate

To my dear mother, who never stopped praying for me

To my dear father, for his encouragement.

To my dear brothers

To all my family: Abir

To my best friends each in their name

To all my friends from the ELECTROMECHANICS master's degree Automation and Industrial Computing

At the end I warmly dedicate this Thys to my teacher

Mr. Layadi Toufik

To all those who have helped me from near or far for the realization of this modest work

Abir Oussama

## **Acknowledge**

First and foremost, praises and thanks to Allah, the Almighty, for His showers of blessings throughout my research work to complete the research successfully. We would like to express our deep and sincere gratitude to our research supervisors, Mr. TOUFIK MADANI LAYADI & Mr.ISSAM MEGHLAOUI for giving us the opportunity to do research and providing invaluable guidance throughout this research. His dynamism, vision, sincerity and motivation have deeply inspired us our thanks also go to the members of the jury for honoring us by accepting to judge our modest work. Without forgetting the Imaging center of Mr. Kadri Abid for giving us this opportunity to do this work .

We thank all the teachers of our departments for their help and effort during the training.

Finally, we thank all those who directly or indirectly contributed significantly to the development of this work specially Benjbel Hicham.

## Chapter 01

<b>1.Introduction .....</b>	<b>2</b>
<b>2.Radiography definition .....</b>	<b>3</b>
<b>3.Brief historical view of radiography .....</b>	<b>3</b>
<b>4.Radiography types.....</b>	<b>5</b>
<b>1.Industrial Radiography .....</b>	<b>5</b>
<b>2.Medical Radiography .....</b>	<b>6</b>
<b>3.Projectional Radiography .....</b>	<b>6</b>
<b>4.Computed Radiography.....</b>	<b>7</b>
<b>5.Dual energy X-ray absorptiometry .....</b>	<b>7</b>
<b>6.Fluoroscopy .....</b>	<b>8</b>
<b>7.Contrast radiography.....</b>	<b>8</b>
<b>5.1.What is a Digital Radiography .....</b>	<b>8</b>
<b>5.2.Components of a digital radiography system.....</b>	<b>9</b>
<b>5.3.Digital image receptor .....</b>	<b>9</b>
<b>5.4.Image Management System.....</b>	<b>9</b>
<b>5.5.Patient Information System.....</b>	<b>9</b>
<b>5.6.Imaging Processing.....</b>	<b>10</b>
<b>5.6.1.Digital Image Storage.....</b>	<b>10</b>
<b>5.6.2.Communications Network .....</b>	<b>10</b>
<b>5.6.3.Digital Image Display and Display Control .....</b>	<b>10</b>
<b>Conclusion.....</b>	<b>10</b>

## Chapter 02

<b>1.Introduction .....</b>	<b>11</b>
<b>2.Programmable Logic Controllers (PLC).....</b>	<b>11</b>
<b>2.1.Definition.....</b>	<b>11</b>

2.2.PLCs history .....	12
2.3.Objectives.....	12
2.4.Types of PLC .....	13
2.4.2.Modular Type PLC .....	13
2.4.3.Rack Type PLC:.....	14
2.5.PLC architecture .....	14
2.6.Areas of plc's use .....	16
3.Concept of automation.....	16
4.General structure of an automated system .....	17
4.1.The operative part (P.O).....	17
4.2.The control part (P.C):.....	17
5.API programming languages.....	18
6.Human machine interface (HMI).....	18
6.1.History of the HMI.....	18
6.2.What is an HMI? .....	19
6.3.Basic Types of HMIs .....	20
6.4.How to Select an HMI .....	20
6.5.Physical Properties of a HMI .....	21
6.6.How does an HMI Work? .....	22
6.7.Environmental Aspects for an HMI.....	22
6.8.Programming Software for a HMI .....	22
6.9.HMI Applications .....	22
6.10.Advantages of an HMI .....	23
6.11.Interface Flexibility .....	23
6.12.HMI/PLC Combination .....	23
6.12.1.Wiring.....	24

# Chapter 03

1.Introduction .....	25
2.Collimator description .....	25
2.2.Specifications of the collimator .....	26

<b>3.Functionality</b> .....	26
<b>4.Material detail</b> .....	28
<b>4.1.Motors</b> .....	29
<b>4.1.1.Mechanical and electrical characteristics series SR motors</b> .....	29
<b>4.2.Potentiometers</b> .....	30
<b>4.2.1.Multi Turn Wire wound Potentiometer -533</b> .....	30
<b>4.2.2.Precision Rotative Transducers, Conductive Plastic, Economic Series (ECS)</b> .....	31
<b>4.3.Electromagnetic relay with finder (type 95.03):</b> .....	32
<b>5.Programing and Supervision</b> .....	32
<b>5.1.Programming</b> .....	32
<b>5.1.1.TIA Portal:</b> .....	32
<b>5.1.2.TIA portal advantages</b> .....	33
<b>5.1.3.Application on TIA</b> .....	33
<b>5.2.Supervision</b> .....	34
<b>5.2.1.Tasks of Vijeo designer</b> .....	34
<b>5.2.2.Software view</b> .....	34
<b>5.2.3.Communication between the PLC and the HMI</b> .....	38
<b>6.Functionality test</b> .....	38
<b>6.1.manual use</b> .....	40
<b>6.2.presets</b> .....	41
<b>7.Conclusion</b> .....	42
<b>General Conclusion and Perspectives</b> .....	43

# Table list

28.....	Tab. III. 1Material presentation
30.....	Tab. III. 2 Reference Data
30.....	Tab. III. 3 Electrical specifications
32.....	Tab. III. 4 Reference Data
38.....	Tab. III. 5 Vijeo designer



# Figure list

Fig.I. 1 Application of X-RAY on a chest.....	2
Fig.I. 2 A modern radiography of a knee.....	3
Fig.I. 3 Wilhelm RöntWilhelm Conrad Röntgengen.....	4
Fig.I. 4 Wilhelm Röntgengen first X-RAY ever.....	5
Fig.I. 5. Checking a valve using X-RAY.....	5
Fig.I. 6. Demonstrates Projectional radiography principle. ....	6
Fig.I. 7. Images generated from computed tomography.....	7

Fig. II. 1 Diagram of PLC.....	12
Fig. II. 2Diagram of Fixed type PLC Architecture.....	13
Fig. II. 3Diagram of Modular Type PLC Architecture.....	13
Fig. II. 4 Diagram of Rack Type PLC Architecture.....	14
Fig. II. 5Diagram of a PLC architecture.....	15
Fig. II. 6Diagram of a PLC hardware.....	15
Fig. II. 7 Diagram of internal architecture of a PLC.....	16
Fig. II. 8 Diagram of general stricter of an automated system.....	17
Fig. II. 9 Human machine interface (HMI).....	19
Fig. II. 10Architecture d'un système à base des API.....	19
Fig. II. 11 human machine interface.....	20
Fig. II. 12 a robust HMI.....	21

Fig. III. 1 A big presentation of the collimator.....	25
Fig. III. 2 all sides view of the collimator.....	26
Fig. III. 3 A real meterial used in the experimental tests.....	27
Fig. III. 4 General Operating scheme for the collimator.....	27
Fig. III. 5 Reading product code.....	29
<b>Fig. III. 6Faulhaber SR.....</b>	<b>30</b>
Fig. III. 7 Potentiometer -533.....	30
Fig. III. 8 Precision Rotative Transducers, Conductive Plastic.....	31
Fig. III. 9 Electromagnetic relay.....	32
Fig. III. 10 TIA portal software Interface.....	33
Fig. III. 11 side by side sub programs view.....	33
Fig. III. 12 Vijeo designer.....	34
Fig. III. 13 the first window you see in Vijeo designer.....	35
Fig. III. 14 creating a project steps 1.....	35
Fig. III. 15 creating a project steps 2.....	36
Fig. III. 16 creating a project steps 3.....	36
Fig. III. 17 creating a project steps 04.....	37

Fig. III. 18 the main view of the Vijeo designer.....	37
Fig. III. 19 equipment configuration .....	38
Fig. III. 20 home screen of the HMI .....	39
Fig. III. 21 manual control panel of the HMI .....	39
Fig. III. 22 presets panel .....	40
Fig. III. 23 example of the iris opening buttons on the HMI.....	40
Fig. III. 24 example of the iris closing buttons on the HMI.....	41
Fig. III. 25 preset example .....	41
Fig. III. 26 scale module .....	42

# Abbreviation list

**HMI:** humane interface machine

**PLC:** programmable logic control

**TIA:** totally integrated automation portal

**TCP:** transmission control protocol

**IP:** internet protocol

**LAN:** Local Area Network

**WAN:** Wide Area Network

**IEEE:** Institute of Electrical and Electronic Engineers

**DR:** digital radiography

**GRR:** Gamma Ray Radiation

**CT:** computed tomography

**CR:** computed radiography

**CCD:** charged coupled device

**MRI:** magnetic resonance imaging

**FDD:** focus to detector distance

## Abstract

This work concerns automation of a X-RAY Collimator. The automation is based on the use of a programmable logic controller and a Human Machine Interface. The programming of the system was using TIA Portal for the plc and the Vijeo designer for the HMI, using an Ethernet protocol to communicate between the PLC and the HMI

**Key words:** Digital Radiography X-RAY system, X-RAY Collimator, automation, Human Machine Interface, simulation, programming software and realization.

## ملخص

يتمحور هذا المشروع حول اتمتة مسدد الاشعة X. حيث تم المشروع باستعمال حل الأتمتة استنادا الى نوع PLC و واجهة مستخدم باللمس اما بالنسبة للبرمجة استخدمنا اداة TIA PORTAL بالنسبة ل PLC اما بالنسبة للواجهة فقد تمت البرمجة باستعمال برنامج VIJEO DESIGNER يتم توفير الاتصال بين وحدة التحكم بالبرمجة ونظام التحكم من خلال شبكة اتصالات Ethernet

الكلمات المفتاحية: مسدد الاشعة X، التصميم ، واجهة مستخدم ، البرمجة ، الاشعة X، الأتمتة

## Résumé

L'objectif de ce mémoire est l'automatisation d'un Diaphragme. La conception de ce système est basée sur un cahier des charges bien défini. La commande basée sur automate programmable de siemens (S7-300). Le logiciel d'automatisation TIA Portal. L'interface home machine Magelis Schneider utilisant Vijeo Designer. Sans oublier auer la connexion est réalisée utilisant un Protocol Ethernet

**Mots clés:** Radiographie Digital, système X-Ray, diaphragme, Automatisation, interface homme machine, Simulation, Programmation et réalisation

# General Introduction

Automation has always been a dream for the human kind, we always want to make things easier and faster. In this century everything is automated from the smart houses that getting developed day after day to the self-driving cars. But the most domain that are getting the most interest are the military and the medical field. Talking about the medical field lead us to the automation of the biomedical instruments

Radiography is the art and science of using radiation to provide images of the tissues, organs, and bones which all made from some machines like Radiographic systems. One of the part that are in charge of the making of those photos is the collimator, it is mainly used to limit the radiation range of the X-RAY beam, reduce the radiation to the patient. Collimation in radiology is an electromechanical optical device installed in front of the output window of the X-RAY tube. Its main function is to control the illumination field of the X-RAY tube output line, so as to meet the requirements of X-RAY imaging and diagnosis. Reduce the projection range, avoid unnecessary doses; and absorb some scattered rays to improve the clarity of the effect. But unfortunately all those systems are not automated and manual in our project.

The objective of this project is to develop an automated solution for the collimator based on a Siemens S7-300 PLC and a Schneider HMI module. This project is developed in collaboration with the Imaging center of Mr. Kadri Abid which is located in Bordj Bou Arreridj city-Algeria.

The organization of this manuscript is given as follow:

In the first chapter the state of art about radiography and the types of radiography is presented. Then, the hardware used for the automation such as the PLC and the HMI is presented in the second chapter. After that, we illustrate the main components and the operating principal of the collimator. Finally, several experimental simulation tests with discussions and perspectives are given.

# Chapter 01: Radiography State of Art

## 1. Introduction

The desire to see the inside of an object in a way that is nondestructive, is a very important requirement in the world of medicine, geology, security and industrial systems. The latest method is to see the inside of an object, using a radiographic method. The application of this method in industry is to find out whether there is a defect in an industrial product. Thus, this method used tends to control the quality of industrial products.[1]

Right now, almost all of industrial product quality controls use the method of X-RAY or Gamma Ray Radiation (GRR). From the results, obtained 2D images (dimensions), because radiation is done just in one side / one direction only.

Radiographic devices that have been developed have 2D images in the form of digital data, so they can be directly stored on a computer. Digital data obtained by this device is projected data on objects illuminated by X or gamma rays. Fig I.1 shows X-RAY use in medical field.



**Fig.I. 1** Application of X-RAY on a chest.

## 2. Radiography definition

Radiography is an imaging technique using X-RAY, gamma rays, or similar ionizing radiation and non-ionizing radiation to view the internal form of an object. Applications of radiography include medical radiography (diagnostic and therapeutic) and industrial radiography. Similar techniques are used in airport security (where "body scanners" generally use backscatter X-RAY). To create an image in conventional radiography, a beam of X-RAY is produced by an X-RAY generator and projected toward the object. A certain amount of the X-RAY or other radiation is absorbed by the object, dependent on the object's density and structural composition. The X-RAY that pass through the object are captured behind the object by a detector (either photographic film or a digital detector). The generation of flat two dimensional images by this technique is called projectional radiography. In computed tomography (CT scanning) an X-RAY source and its associated detectors rotate around the subject which itself moves through the conical X-RAY beam produced. Any given point within the subject is crossed from many directions by many different beams at different times. Information regarding attenuation of these beams is collated and subjected to computation to generate two dimensional images in three planes (axial, coronal, and sagittal) which can be further processed to produce a three dimensional image.



**Fig.I. 2** A modern radiography of a knee

## 3. Brief historical view of radiography

The history of radiology timeline covers the Origins of Radiology from 1895. It all started when Wilhelm Röntgen (shown in Fig. I.3) discovered X-RAYS. On 28 December 1895 his manuscript "On a New Kind of Ray" was submitted to the Würzburg Physical Medical Institute who earned the Nobel Prize in Physics in 1901. Through to the decades of the 1920s, 1930s, 1940s, 1950s and 1960s. During this period, patients experienced quite invasive tests and knowledge of the dangers of radiation was growing. The

1970s are known as the “golden decade” of radiology when the CT scanner opened up new opportunities and discoveries which were further developed in the 1980s and 1990s.[2]



**Fig.I. 3 Wilhelm Rönt**Wilhelm Conrad Röntgen

Each decade is subdivided into areas of interest with focuses on radiology, radiography, radiotherapy, radiobiology, medical physics and diagnostic imaging. Each subsection is complemented by relevant content from the BIR (British institute of radiography), our flagship journal selected by Dr Adrian Thomas BIR Honorary Historian and Chair of the BIR’s History of Radiology Working Party. In many ways, radiography has changed little from the early days of its use. We still capture a shadow image on film using similar procedures and processes technicians were using in the late 1800’s. Today, however, we are able to generate images of higher quality and greater sensitivity through the use of higher quality films with a larger variety of film grain sizes. Film processing has evolved to an automated state, producing more consistent film quality by removing manual processing variables. Electronics and computers allow technicians to now capture images digitally. The use of "filmless radiography" provides a means of capturing an image, digitally enhancing, sending the image anywhere in the world, and archiving an image that will not deteriorate with time. Technological advances have provided industry with smaller, lighter, and very portable equipment that produce high quality X-RAYS. The use of linear accelerators provide a means of generating extremely short wavelength, highly penetrating radiation, a concept dreamed of only a few short years ago. [Fig. I.4](#) gives an example of X-RAY use.





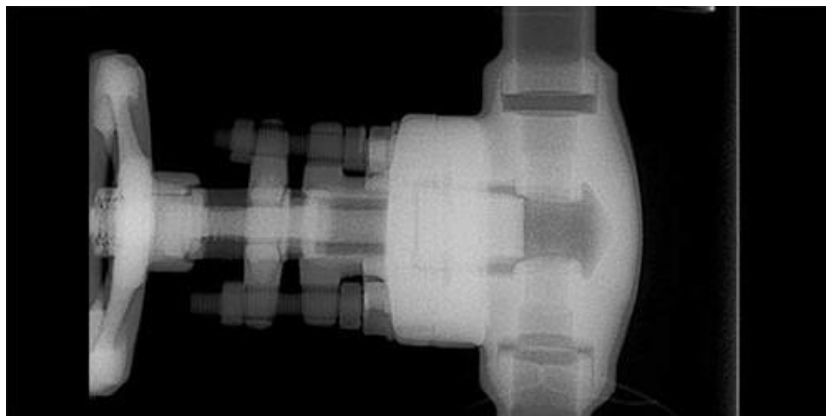
**Fig.I. 4** Wilhelm Röntgen's first X-RAY ever.

While the process has changed little, technology has evolved allowing radiography to be widely used in numerous areas of inspection. Radiography has seen expanded usage in industry to inspect not only welds and castings, but to radiographically inspect items such as airbags and canned food products. Radiography has found use in metallurgical material identification and security systems at airports and other facilities.

#### **4. Radiography types**

##### **4.1. Industrial Radiography**

Industrial radiography is a method of non-destructive testing where many types of manufactured components can be examined to verify the internal structure and integrity of the specimen. Industrial Radiography can be performed utilizing either X-RAYS or gamma rays.[3]



**Fig.I. 5.**Checking a valve using X-RAY.

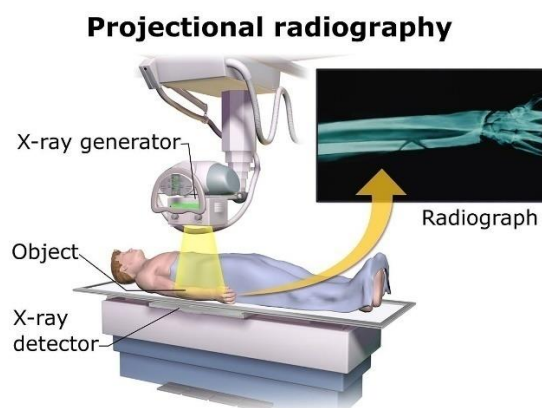
Both are forms of electromagnetic radiation. The difference between various forms of electromagnetic energy is related to the wavelength. X and gamma rays have the shortest wavelength and this property leads to the ability to penetrate, travel through, and exit various materials such as carbon steel and other metals. Specific methods include industrial computed tomography.

## 4.2. Medical Radiography

Since the body is made up of various substances with differing densities, ionizing and non-ionizing radiation can be used to reveal the internal structure of the body on an image receptor by highlighting these differences using attenuation, or in the case of ionizing radiation, the absorption of X-RAY photons by the denser substances (like calcium-rich bones). The discipline involving the study of anatomy through the use of radiographic images is known as radiographic anatomy. Medical radiography acquisition is generally carried out by radiographers, while image analysis is generally done by radiologists. Some radiographers also specialize in image interpretation. Medical radiography includes a range of modalities producing many different types of image, each of which has a different clinical application.

### 4.2.1. Projectional Radiography

The creation of images by exposing an object to X-RAYS or other high-energy forms of electromagnetic radiation and capturing the resulting remnant beam (or "shadow") as a latent image is known as "projection radiography." The "shadow" may be converted to light using a fluorescent screen, which is then captured on photographic film, it may be captured by a phosphor screen to be "read" later by a laser (CR), or it may directly activate a matrix of solid-state detectors (DR—similar to a very large version of a CCD in a digital camera). Bone and some organs (such as lungs) especially lend themselves to projection radiography. It is a relatively low-cost investigation with a high diagnostic yield.[4]

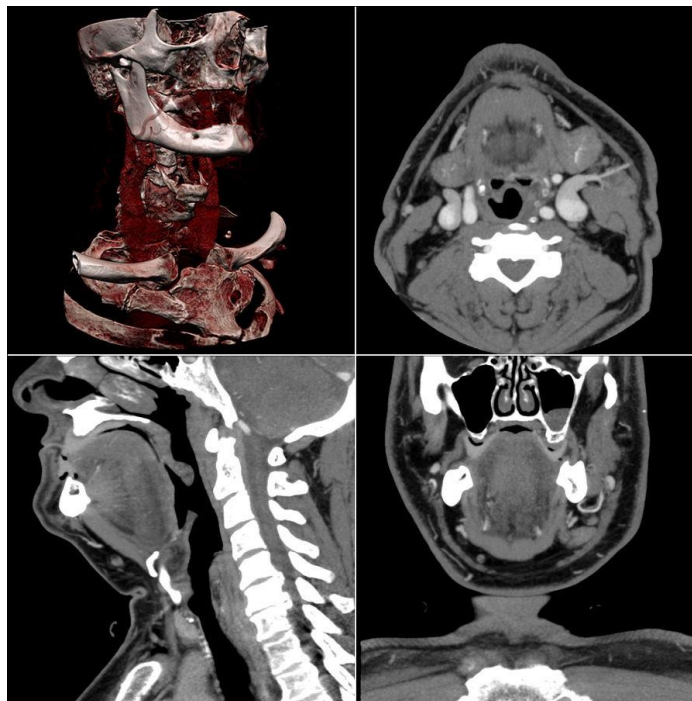


**Fig.I. 6. Demonstrates Projectional radiography principle.**

The difference between soft and hard body parts stems mostly from the fact that carbon has a very low **X-RAY** cross section compared to calcium.

#### 4.2.2. Computed Radiography

Computed tomography or CT scan (previously known as CAT scan, the "A" standing for "axial") uses ionizing radiation (X-RAY radiation) in conjunction with a computer to create images of both soft and hard tissues. These images look as though the patient was sliced like bread (thus, "tomography"-- "tomo" means "slice"). Though CT uses a higher amount of ionizing x-radiation than diagnostic X-RAYS (both utilizing X-RAY radiation), with advances in technology, levels of CT radiation dose and scan times have reduced. CT exams are generally short, most lasting only as long as a breath-hold, Contrast agents are also often used, depending on the tissues needing to be seen. Radiographers perform these examinations, sometimes in conjunction with a radiologist (for instance, when a radiologist performs a CT-guided biopsy). Some examples about computed tomography are given in [Fig. I.7](#).



**Fig.I. 7. Images generated from computed tomography.**

#### 4.2.3. Dual energy X-RAY absorptiometry

DEXA, or bone densitometry, is used primarily for osteoporosis tests. It is not projection radiography, as the X-RAYS are emitted in 2 narrow beams that are scanned across the patient, 90 degrees from each other. Usually the hip (head of the femur), lower back (lumbar spine), or heel (calcaneus) are imaged, and the bone density (amount of calcium) is determined and given a number (a T-score). It is not used for bone imaging, as the image quality is not good enough to make an accurate diagnostic image for fractures, inflammation, etc. It can also be used to measure total body fat, though this is not common. The radiation

dose received from DEXA scans is very low, much lower than projection radiography examinations.[5][6]

#### **4.2.4. Fluoroscopy**

Fluoroscopy is a term invented by Thomas Edison during his early X-RAY studies. The name refers to the fluorescence he saw while looking at a glowing plate bombarded with X-RAYS.[7]

The technique provides moving projection radiographs. Fluoroscopy is mainly performed to view movement (of tissue or a contrast agent), or to guide a medical intervention, such as angioplasty, pacemaker insertion, or joint repair/replacement. The latter can often be carried out in the operating theatre, using a portable fluoroscopy machine called a C-arm. It can move around the surgery table and make digital images for the surgeon. Biplanar Fluoroscopy works the same as single plane fluoroscopy except displaying two planes at the same time. The ability to work in two planes is important for orthopedic and spinal surgery and can reduce operating times by eliminating re-positioning.[3]

#### **4.2.5. Contrast radiography**

Contrast radiography uses a radiocontrast agent, a type of contrast medium, to make the structures of interest stand out visually from their background. Contrast agents are required in conventional angiography, and can be used in both projectional radiography and computed tomography (called "contrast CT").

Although not technically radiographic techniques due to not using X-RAYS, imaging modalities such as PET and MRI are sometimes grouped in radiography because the radiology department of hospitals handle all forms of imaging. Treatment using radiation is known as radiotherapy.

### **5. Digital Radiography**

Digital or electronic imaging has been available for more than a decade. The first direct digital imaging system, RadioVisioGraphy (RVG), was invented by Dr. Frances Mouyens and manufactured by Trophy Radiologie (Vincennes, France) in 1984 and described in the U. S. dental literature in 1989.[8]

#### **5.1. What is a Digital Radiography**

Digital radiography (DR) is an advanced form of X-RAY inspection which produces a digital radiographic image instantly on a computer. This technique uses X-RAY sensitive plates to capture data during object examination, which is immediately transferred to a computer without the use of an intermediate cassette. The incident X-RAY radiation is

converted into an equivalent electric charge and then to a digital image through a detector sensor.

## **5.2. Components of a digital radiography system**

A Digital radiography is performed by a system consisting of the following functional components: a digital image receptor, a digital image processing unit, an image management system, image and data storage devices, an interface to a patient information system, a communications network and a display device with viewer operated controls.[9]

## **5.3. Digital image receptor**

The digital receptor is the device that intercepts the X-RAY beam after it has passed through the patient's body and produces an image in digital form, that is, a matrix of pixels, each with a numerical value. This replaces the cassette containing intensifying screens and film that is used in non-digital, film-screen radiography.[9]

## **5.4. Cassettes**

Cassettes are rigid holders used in conventional and computed radiography (CR) for the screen film system and imagine plat respectively. The backside of the cassette has rubber or felt for adequate contact between the screen film systems or with the imaging plat. The front of the cassette is made of a low atomic number material (e.g. Plastic or carbon) to enable ease in passage of X-RAY and the back is made of high atomic number material (e.g. lead) to reduce backscatter.

The formats of the cassettes used in radiology are: 13×18 cm; 18×24 cm; 24×30 cm; 20×40 cm; 30×40 cm; 35×35 cm; 35×40 cm.

## **5.5. Image Management System**

Image management is a function performed by the computer system associated with the digital radiography process.

These functions consist of controlling the movement of the images among the other components and associating other data and information with the images.

Some of these functions might be performed by the computer component of a specific digital radiography device or by a more extensive Digital Image Management System (DIMS) that serves many imaging devices within a facility. Note: it is not unusual for the DIMS to be referred to by an older, and somewhat less appropriate name, PACS (Picture Archiving and Communications System).

## **5.6. Patient Information System**

The Patient Information System, perhaps known as the Radiology Information System (RIS), is an adjunct to the basic digital radiography system. Through the interface, information such as patient ID, scheduling, actual procedures performed, etc. is transferred.

## **5.7. Imaging Processing**

One of the major advantages of digital radiography is the ability to process the images after they are recorded. Various forms of digital processing can be used to change the characteristics of the digital images. For digital radiographs the ability to change and optimize the contrast is of great value. It is also possible to use digital processing to enhance visibility of detail in some radiographs. The various processing methods are explored in much more detail in another module.

### **5.7.1. Digital Image Storage**

Digital radiographs, and other digital medical images, are stored as digital data. Advantages (compared to images recorded on film) include: Rapid storage and retrieval, less physical storage space required and ability to copy and duplicate without loss of image quality.

### **5.7.2. Communications Network**

Another advantage of digital images is the ability to transfer them from one location to another very rapidly. This could be: Within the imaging facility to the storage and display devices, to other locations (Teleradiology) and anywhere in the world (by means of the internet).

### **5.7.3. Digital Image Display and Display Control**

Compared to radiographs recorded and displayed on film, i.e. "softcopy", there are advantages of "softcopy" displays. One major advantage is the ability of the viewer to adjust and optimize image characteristics such as contrast. Other advantages include the ability to zoom, compare multiple images, and perform a variety of analytical functions while viewing the images.

## **6. Conclusion**

Radiography was the biggest discovery in the last century, from discovering it in 1901 till the present day radiography made a big Impact on the science and industry field especially medical field, where it helped to make a big jump in both side theoretically and practically

# Chapter 02: Control and Automation

## 1. Introduction

Automatisms are everywhere around us (washing machine, dishwasher, the refrigerator with automatic defrost, and the drink dispensers ... etc.), and in particular represent nowadays the essential basis of constitution of most industries.

In the various sectors of industrial activity where competition is required, companies automate their production in order to improve performance in terms of quantity and especially quality and to take in consideration the areas where man cannot intervene directly, either because he would be obliged to evolve in an unhealthy or even deadly atmosphere, or because he would have to perform repetitive tasks, or because the reliability, speed and security of a process require it.

From the Fields of automation include machines and control panels, robotics and axis control, communication, etc.

The science which makes it possible to automate the tasks and the functions of a dynamic system, it is the Automatic, this discipline deals with the modeling the Analysis. Control and regulation, and its theoretical foundations are mathematics, signal theory and computer science. [10]

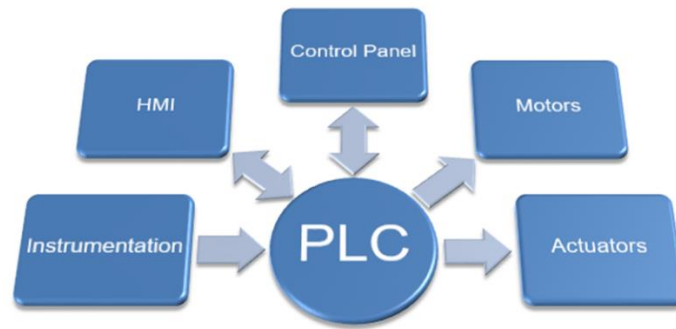
## 2. Programmable Logic Controllers (PLC)

### 2.1. Definition

An industrial programmable logic controller (PLC) is an electronic machine specializing in the real-time control and monitoring of industrial processes. It executes a series of instructions stored into its memories in the form of a program, and is therefore similar to information processing machines. Three fundamental characteristics distinguish it from IT tools:

- It can be directly connected to sensors and pre-actuators thanks to its Industrial inputs / outputs.
- Designed to operate in severe industrial environments (temperature, vibrations, micro-cuts in the supply voltage, interference, etc.)
- The programming languages specially developed for processing automation functions to facilitate its use and implementation. [11]

Fig. II.1 shows the equipment connected to a PLC.



**Fig. II. 1 Diagram of PLC**

According to the French standard EN 61131-1, a PLC is a digitally operated electronic system intended for use in an industrial environment, which uses a programmable memory for the internal storage of user-oriented instructions for implementing specific functions. , such as logic, sequencing, timing, counting and arithmetic calculation functions, to control various types of machines or processes by means of discrete or analog inputs and outputs. Associated peripherals designed to easily integrate into an industrial automation system and to easily get used in all their intended functions. [11]

## 2.2.PLCs history

Programmable Logic Controllers (PLCs) appeared in the United States in 1969, in the automotive industry, they were used in Europe about two years later. Its creation date started with the beginning of the era of the microprocessor and with the generalization of modular wired logic. The PLC is the first language machine, which one of the logic computers whose instruction set is oriented towards the problems of logic and systems with sequential evolution. [12]

## 2.3.Objectives

Automation makes it possible to add additional elements to the final stat of the object added by the system. These elements can be expressed in terms of objectives by:

- Productivity increase (profitability, competitiveness) of the system
- Production flexibility improvements
- Improve the quality of the product
- Adaptation to particular contexts such as hostile environments for mankind (toxic, dangerous, nuclear environment, etc.)
- Adaptation to physical or intellectual tasks that are hard for humans to do (handling heavy loads, parallel repetitive tasks, etc.)
- Increasing security. [11]

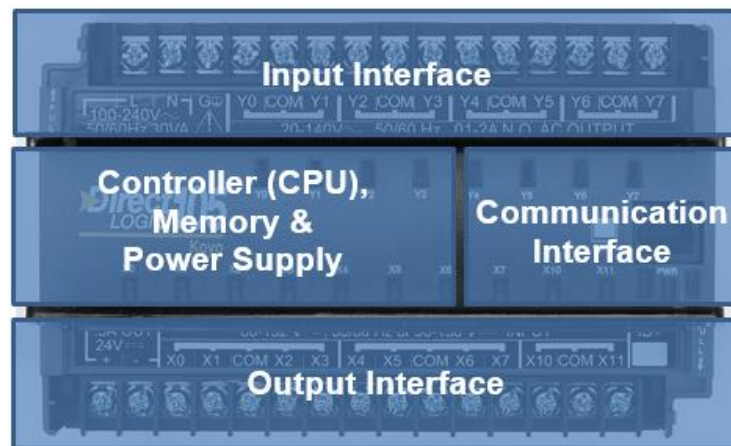


## 2.4.Types of PLC

The general classification of PLCs based on the number of inputs and outputs. So, we distinguished the following PLCs.

- Fixed type PLC
- Modular type PLC
- Rack type PLC

**2.4.1.Fixed type PLC:** in this type of PLC all the components of the PLC are as a single unit. The number of Inputs/Outputs supported by the PLC is defined by the manufacturer and cannot be changed. This type of PLC can support a small number of Inputs/Outputs. This PLC type is presented in Fig. II.2.



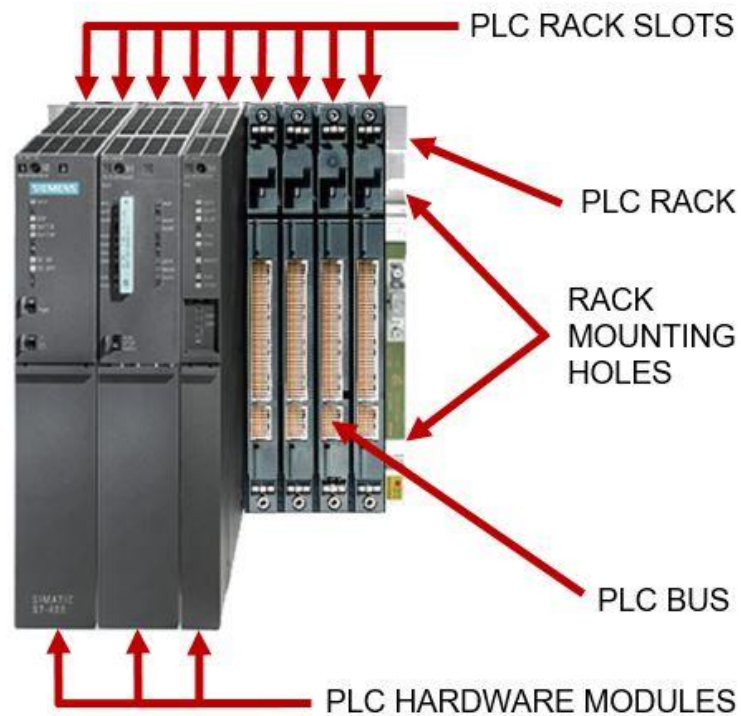
**Fig. II. 2**Diagram of Fixed type PLC Architecture

**2.4.2.Modular Type PLC:** In modular type PLC the number of Inputs/Outputs can be increased by addition of modules to the existing PLC. Fig. II.3 shows this PLC type.



**Fig. II. 3**Diagram of Modular Type PLC Architecture

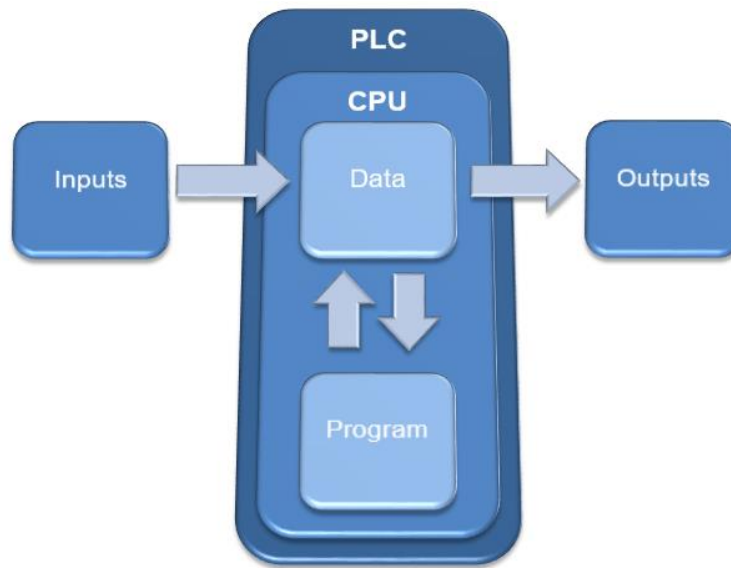
**2.4.3. Rack Type PLC:** In rack type PLC all the components of the PLC are as separate modules and are assembled to form one unity by mounting the individual components on a rack. This PLC can support up to thousands of Inputs/Outputs.



**Fig. II. 4** Diagram of Rack Type PLC Architecture

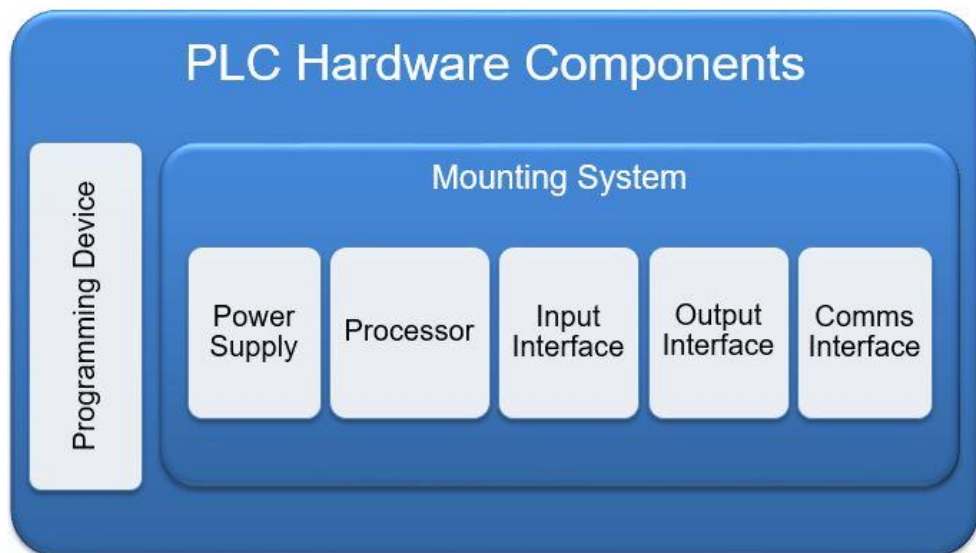
### 2.5. PLC architecture

PLC Architecture consists of two core assemblies, internal and external. Designing a complete system will require exploring the many architecture options available.[13]



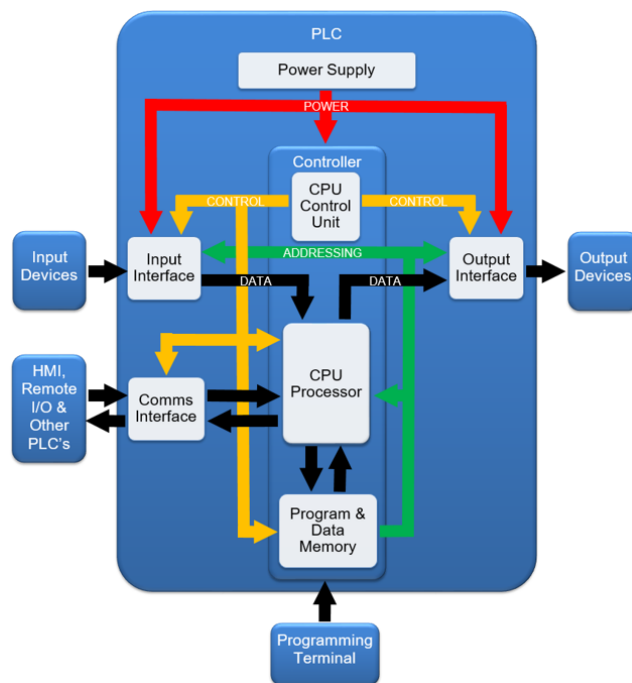
**Fig. II. 5**Diagram of a PLC architecture

**2.5.1.External architecture:** The main components of a PLC consist of a central processing unit (CPU), power supply, programming device, and input-output modules.[13]



**Fig. II. 6**Diagram of a PLC hardware

**2.5.2.Internal architecture:** While the external components are important for the layout and design, internal PLC architecture, from processing power, memory consumption, current load, and the number of I/O devices, will impact the size and cost of a system.[13]



**Fig. II. 7** Diagram of internal architecture of a PLC

### 2.5.3.How PLCs work

PLCs are complex and powerful machines for computing. But, we can describe the function of a PLC in simple terms. The PLC takes inputs, performs logic on the inputs in the CPU and then turns on or off outputs based on that logic. The main operating cycle of a PLC is given as follow:

- **Acquisition task:** the CPU monitors the status of the inputs (ex. switch on, proximity sensor off, valve 40% open, etc.).
- **Computing task:** the CPU takes the information that it gets from the inputs, performs logic on the inputs.
- **Execution task:** the CPU operates the outputs logic (ex. turn off motor, open valve, etc.)

### 2.6.Areas of plc's use

PLCs are used in all industrial sectors for controlling machines (conveying, packaging, etc.) or production lines (automotive, food processing, etc.) or they can also perform process regulation functions (metallurgy, chemicals). ). They mostly used in the building sector (tertiary and industrial). For control of heating, lighting, security or alarms.[10]

### 3.Concept of automation

An automatism is a sub-assembly or an organ of machines intended to carry out an automated system, a usual and predefined action or decision, without human intervention whose tasks are generally simple and repetitive requiring precision.

#### 4.General structure of an automated system

The automated system can be divided down into main two parts as given in Fig.

II.8:

- The operative part (PO) which contain the actuators, processes and the sensors
- The control part (PC) which affect the actions from the received information

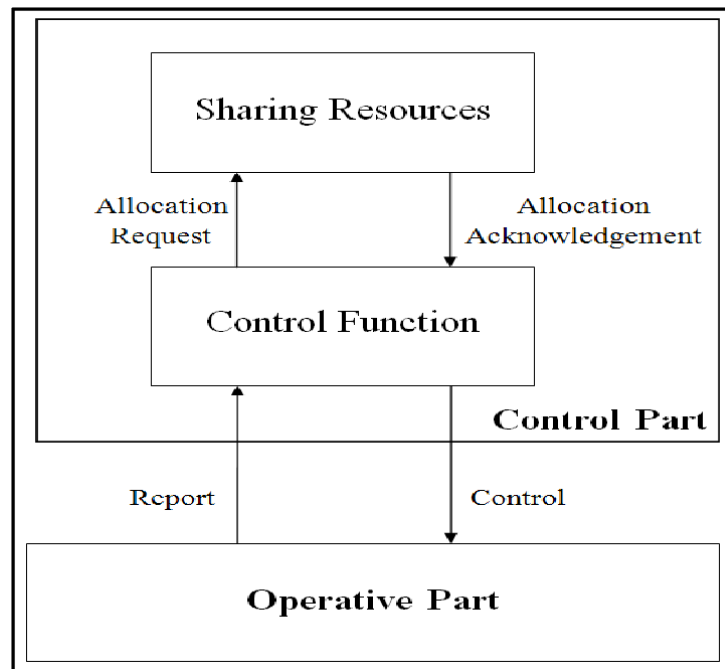


Fig. II. 8 Diagram of general structure of an automated system

#### 4.1.The operative part (P.O)

The operational part carries out operations (mechanical, thermal, etc.), on the nature or on the shape of the products, treated by the machine or the installation, and makes them undergo transformations. In general, it provides processed products with benefit of an economic nature. The operating part is also characterized by a significant use of energy; this energy is implemented by actuators (motors, jacks, etc.).[13]

#### 4.2. The control part (P.C):

The control part performs information processing at a low energy level. The information or the orders will be intended to drive pre-actuators, in order to act on the operative part.

Different technologies are offered for the control part (electrical control, pneumatic control, programmable logic controllers, electronic cards, micro and mini computers, etc.), which can be complementary, i.e. several types of technology, in the same company, because

the choice of the control technology must be adapted for each machine or for each installation allows to obtain an optimal result. [13]

## **5. API programming languages**

Each PLC has its own languages. On the other hand, the manufacturers offer a whole software interface meeting the CEID 1131-3 standard. This standard defines five programming pitches that can be used, which are GRAFCET or SFC Block diagram or FBD Ladder diagram or LD Structured text or ST and List of instructions or IL.[11]

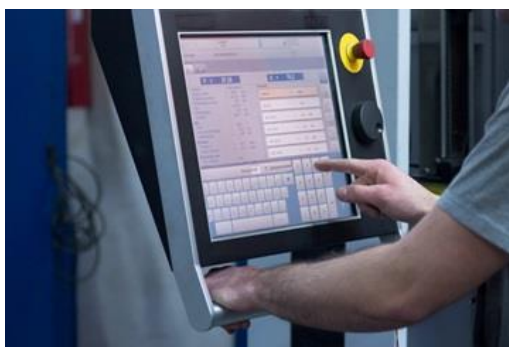
## **6. Human machine interface (HMI)**

Human machine interfaces (HMIs) are used as an operator control panel to PLCs. HMIs replace manually activated switches, dials, and other controls with graphical representations of the control process and digital controls to influence that process. HMIs allow operators to start and stop cycles, adjust set points, and perform other functions required to adjust and interact with a control process. Because the HMI is software based, they replace physical wires and controls with software parameters, allowing them to be adapted and adjusted very easily.

### **6.1. History of the HMI**

HMI products originated from the need to make machinery easier to operate, while producing optimal outputs. Predecessors of HMI include the Batch Interface (1945-1968), Command-Line User Interface (1969-Present), and the Graphical User Interface (1981-Present). The Batch Interface is a non-interactive user interface, where the user specifies the details to the batch process in advance, and receives the output when all the processing is done. This batch process does not allow for additional input once the process has begun, is problematic in modern manufacturing lines. The Command-Line Interface is a mechanism that interacts with a computer operating system or software by typing commands to perform specific tasks. The concept of the Command-Line interface originated when teletypewriter machines were connected to computers in the 1950s, and offered results on demand; a big downfall of Batch Interface because it could not deliver results on demand. A basic example of Command-Line Interface would be windows Disk Operating System "DOS" which dominated the 1980's. Over time, interfaces became highly complex and extremely easy to use. One such interface would be the Graphical User Interface (GUI). Graphical User Interface allows people to interact with programs in more ways than typing, such as computers, hand-held devices such as MP3 Players, Portable Media Players or Gaming devices, household appliances, and office equipment with images, rather than text commands. Human Machine Interface stems directly from Graphical User Interface, and comes from the need to control and operate machinery much more effectively. Human Machine Interface formerly known as Man Machine Interface,

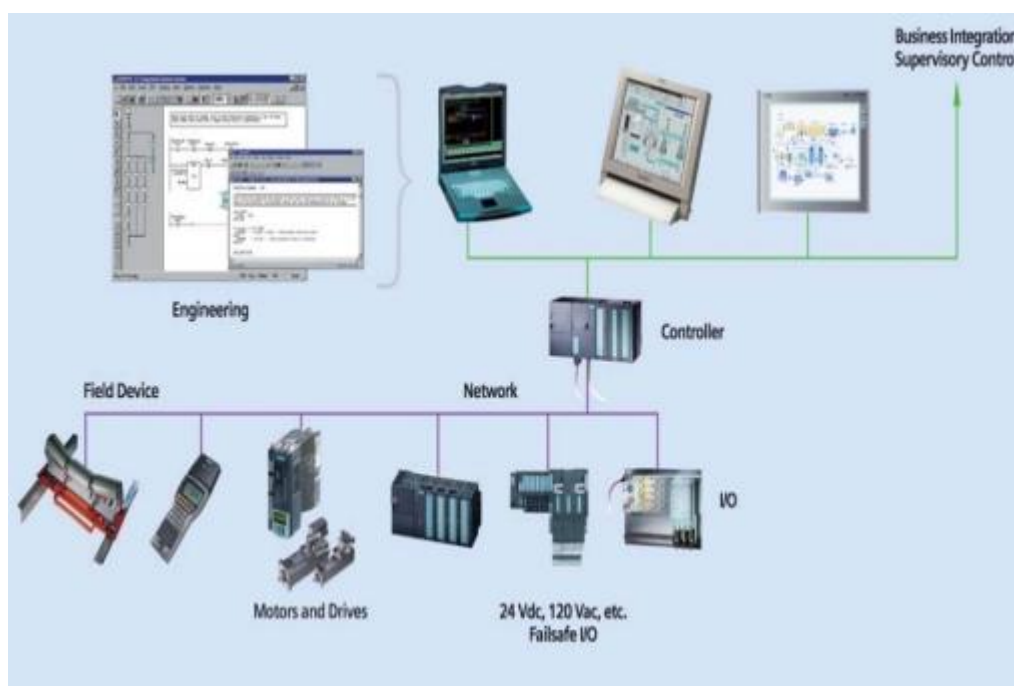
is now leading the way in the control of manufacturing processes as an extremely user-friendly device. [14].Fig. II.9 presents an example of a Human machine interface.



**Fig. II. 9 Human machine interface (HMI)**

## 6.2. What is an HMI?

HMI is the acronym for Human Machine Interface, and can be designed as just that; an interface between the user and the machine. An HMI is considered an interface; a very broad term that can include MP3 players, industrial computers, household appliances, and office equipment. However, an HMI is much more specific to manufacturing and process control systems. An HMI provides a visual representation of a control system and provides real time data acquisition. An HMI can increase productivity by having a centralized control center that is extremely user-friendly.[14]



**Fig. II. 10 Architecture d'un système à base des API**

A Human Machine Interface (HMI) is exactly what the name implies; a graphical interface that allows humans and machines to interact. Human machine interfaces vary widely, from control panels for nuclear power plants, to the screen on an iPhone. However, for this discussion we are referring to an HMI control panel for manufacturing-type processes. An HMI is the centralized control unit for manufacturing lines, equipped with Data Recipes, event logging, video feed, and event triggering, so that one may access the system at any moment for any purpose. For a manufacturing line to be integrated with an HMI, it must first be working with a Programmable Logic Controller (PLC). It is the PLC that takes the information from the sensors, and transforms it to Boolean algebra, so the HMI can decipher and make decisions.

### 6.3. Basic Types of HMIs

There are three basic types of HMIs: the pushbutton replacer, the data handler, and the overseer. Before the HMI came into existence, a control might consist of hundreds of pushbuttons and LEDs performing different operations. The pushbutton replacer HMI has streamlined manufacturing processes, centralizing all the functions of each button into one location. The data handler is perfect for applications requiring constant feedback from the system, or printouts of the production reports. With the data handler, you must ensure the HMI screen is big enough for such things as graphs, visual representations and production summaries. The data handler includes such functions as recipes, data trending, data logging and alarm handling/logging. Finally, anytime an application involves SCADA or MES, an overseer HMI is extremely beneficial. The overseer HMI will most likely need to run Windows, and have several Ethernet ports.



**Fig. II. 11** human machine interface

### 6.4. How to Select an HMI

An HMI is a substantial purchase, so it is important to know exactly what is required of it. An HMI is used for three primary roles: a pushbutton replacer, data handler, and overseer. The pushbutton replacer takes the place of LEDs, on/off buttons, switches or any mechanical



device that performs a control function. The elimination of these mechanical devices is possible because the HMI can provide a visual representation of all these devices on its LCD screen, while performing all the same functions. The Data Handler is used for applications that require constant feedback and monitoring. Often these Data Handlers come equipped with large capacity memories. The last of the HMI three types is referred to as the overseer, because it works with SCADA and MES. These are centralized systems that monitor and control entire sites or complexes of large systems spread out over large areas. An HMI is usually linked to the SCADA system's databases and software programs, to provide trending, diagnostic data, and management information.

### 6.5. Physical Properties of a HMI

The actual physical properties of an HMI vary from model to model and among manufacturers. It is important that one makes the appropriate selection. An HMI that is located in a water plant might have various water seals around its perimeter, as opposed to an HMI that is located in a pharmaceutical warehouse. The actual size of an HMI is also a key physical property that will vary, because not all applications require a large, high-resolution monitor. Some applications may only require a small, black and white touch screen monitor. When it comes to selecting an HMI, the physical properties are extremely important because one must take into consideration the operating environment, and what safety measures the HMI needs to protect itself. Also, a specific size may be needed due to space limitations. Lastly, physical properties include the processor and memory of the HMI. It is important to make sure that the processor and memory capabilities are sufficient enough to control a system.



**Fig. II. 12 a robust HMI**

## **6.6. How does an HMI Work?**

First consider the other components that are necessary to make a manufacturing control system operate. The production line consists of all the machinery that performs the work required in the production of the product. Next, consider the various input/output sensors that monitor temperature, speed, pressure, weight and feed rate. Third, decide on the programmable logic controller (PLC) that will receive the data from the input/output sensors, and converts the data into logical combinations.

## **6.7. Environmental Aspects for an HMI**

The operating environment should always be considered when selecting an HMI. For example: for use in a warehouse that has excessive noise or vibration, one might decide on a heavy-duty HMI. If used in the food processing industry or somewhere that might need to be washed down, select a water-protected HMI. One must also consider temperature as a factor in the selection process. If used in a steel plant, next to a furnace, one would want something that can withstand extreme temperatures.

## **6.8. Programming Software for a HMI**

When considering which programming software to use, there are three main categories to choose from: proprietary, hardware independent and open software. Proprietary software is the software that the manufacturer provides, which is typically easy to use and allows for quick development. The drawback is that proprietary software will only run on that specific hardware platform. Hardware-independent software is third party software developed to program on several different types of HMIs. This type of software gives the developer much more freedom for the HMI selection. The downside to hardware independent software is that it is not as user-friendly as the proprietary. Open Software should only be selected by the advanced programmer. It allows the developer to have complete openness in the design process.

## **6.9. HMI Applications**

The HMI is used throughout various industries including manufacturing plants, vending machines, food and beverage, pharmaceuticals, and utilities, just to name a few. HMIs along with PLCs are typically the backbone of the production line in these industries. The integration of the HMI into manufacturing has vastly improved operations. The HMI allows for supervisory control and data acquisition in the entire system, so parameter changes are feasible as the operator's choosing. For example, in metals manufacturing, an HMI might control how

metal is cut and folded, and how fast to do so. An HMI offers improved stock control and replenishment, so the fewer journeys are required out to the vendors. HMIs are used in bottling processes to control all aspects of the manufacturing line, such as speed, efficiency, error detection and error correction. Utility companies may use HMIs to monitor water distribution and waste water treatment.

### **6.10. Advantages of an HMI**

The greatest advantage of an HMI is the user-friendliness of the graphical interface. The graphical interface contains color coding that allows for easy identification (for example: red for trouble). Pictures and icons allow for fast recognition, easing the problems of illiteracy. HMI can reduce the cost of product manufacturing, and potentially increase profit margins and lower production costs. HMI devices are now extremely innovative and capable of higher capacity and more interactive, elaborate functions than ever before. Some technological advantages the HMI offers are: converting hardware to software, eliminating the need for mouse and keyboard, and allowing kinesthetic computer/human interaction.

### **6.11. Interface Flexibility**

One of the most convenient features of an HMI is the ability to personalize the interface. An HMI can fully support the most complex applications, with multiple screens and several routines running. If the user is looking to program an HMI with something more simplistic, he/she can have instructions for the controller directly written onto the HMI. Every HMI comes with different features; some may play sound, play video, or even may have remote access control. The design of the actual interface should be optimized for specific applications, taking into consideration all the capabilities of the typical user, as well as the environmental aspects such as noise, lighting, dust, vision and technological curves.

### **6.12. HMI/PLC Combination**

How can a PLC be controlled without ladder logic? How does an HMI replace the standard software a PLC comes with? Ladder logic is simply conditional programming. For example, if input 1 is energized, then coil 1 will be powered. A statement has to be true for the output to be executed. The same can be achieved with C programming. However, in order to program an HMI to operate a PLC properly, all the registers of the PLC must be known. A good way to learn how to program a PLC via an HMI is to first start working with the PLC and the software it came with. This helps build an understanding of how to operate the PLC without the HMI. That knowledge will easily transfer over when the user is ready to connect the two units together.[15]

### 6.12.1. Wiring

Wiring an HMI into a system may be an easy task if a PLC is already being used. This connection is as simple as connecting a USB, RS-232, RS-485, Ethernet between the HMI and PLC. In some instances, both units are equipped with wireless features, making the connection even easier. Although the wiring between the PLC and HMI may be an easy task, the wiring between the PLC and the actual automation line could be chaotic. Depending on the size and complexity of the application, profibus extensions may be required for the PLC. A profibus extension is similar to a power strip that extends one input/output to multiple input/outputs by connecting to the expansion port of the PLC. A wiring schematic from the production line to the PLC is highly recommended, so that programming the HMI is speed up drastically.

Ethernet is a family of wired computer networking technologies commonly used in local area networks (LAN), metropolitan area networks (MAN) and wide area networks (WAN). It was commercially introduced in 1980 and first standardized in 1983 as IEEE 802.3.

The original 10BASE5 Ethernet uses coaxial cable as a shared medium, while the newer Ethernet variants use twisted pair and fiber optic links in conjunction with switches. Over the course of its history, Ethernet data transfer rates have been increased from the original 2.94 megabits per second (Mbit/s) to the latest 400 gigabits per second (Gbit/s). The Ethernet standards comprise several wiring and signaling variants of the OSI physical layer in use with Ethernet.

### 7. Conclusion:

In this chapter we saw a generality about PLCs and HMI. Defining the plc by giving the types of the common PLCs in the market, as we talked also about the architecture, programing the PLCs and how they work going and describing the HMI and talking about all the main points as we did with the PLC.

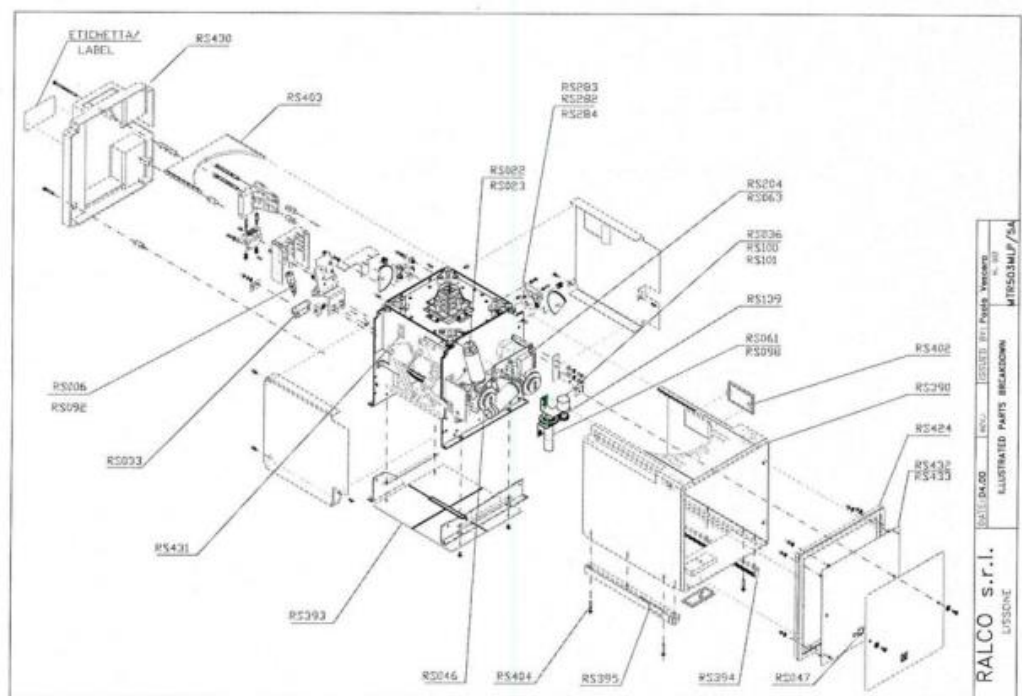
# Chapter 03:X-RAY Collimator Automation

## 1. Introduction

In this chapter we describe the components and principle of the X-RAY collimator. To develop the control strategy, the actuators and sensors of the system have been defined. Then, by hybridization between Siemens and Schneider equipment's and devices the automation solution has been developed. For the simulation and development many software are used.

## 2. Collimator description

The medical studied system which is used in radiography is called a collimator. In order to improve the design of the collimator illustrated in Annex A, many modifications have been realized. These modifications concern mechanical design, control strategy and component elements. All these changements allow improving the basic configuration of the collimator. The studied collimator is given in Fig. III.1. The main parts of the collimator are presented in Fig. III.2



**Fig. III. 1** A big presentation of the collimator.



**Fig. III. 2 all sides view of the collimator**

## 2.2. Specifications of the studied collimator

The changes that have been made for the improved collimator are given as follows:

- Using an ABS fire-retardant plastic cover instead of the metal.
- Radiation leakage is controlled by lead-plating.
- Round and square-field X-RAY collimator for use in connection with an Image Intensifier, a Spot Film Device and a Potter Bucky.
- The square field is multilayered while the round field is single-layered.
- The round field is defined by 12 lead shutters and is located between the two sets of square shutters positioned approximately half-way within the collimator casing.
- The square field is defined by six pairs of lead-lined shutters. Two pairs of shutters are positioned near the focus, two near the entrance window of the collimator and two pairs near the exit window of the collimator.
- Maximum X-RAY rating is 150 kVp.
- Minimum inherent filtration 2 mm.
- Aluminum equivalent. (1mm on request)
- High luminosity provided by a quartz iodide lamp.
- Timer limiting protection lamp exposure time to 30 seconds thus extending lamp life and preventing overheating.
- Mirror regulation is effected externally
- Movement of shutters is motorized and shutter positioning is controlled by potentiometers.
- Continuous film coverage: square field from 0x0 to 43x43 cm at 100 cm FFD; round 10 cm (4") to 43cm (16") at 100 cm FFD [16].

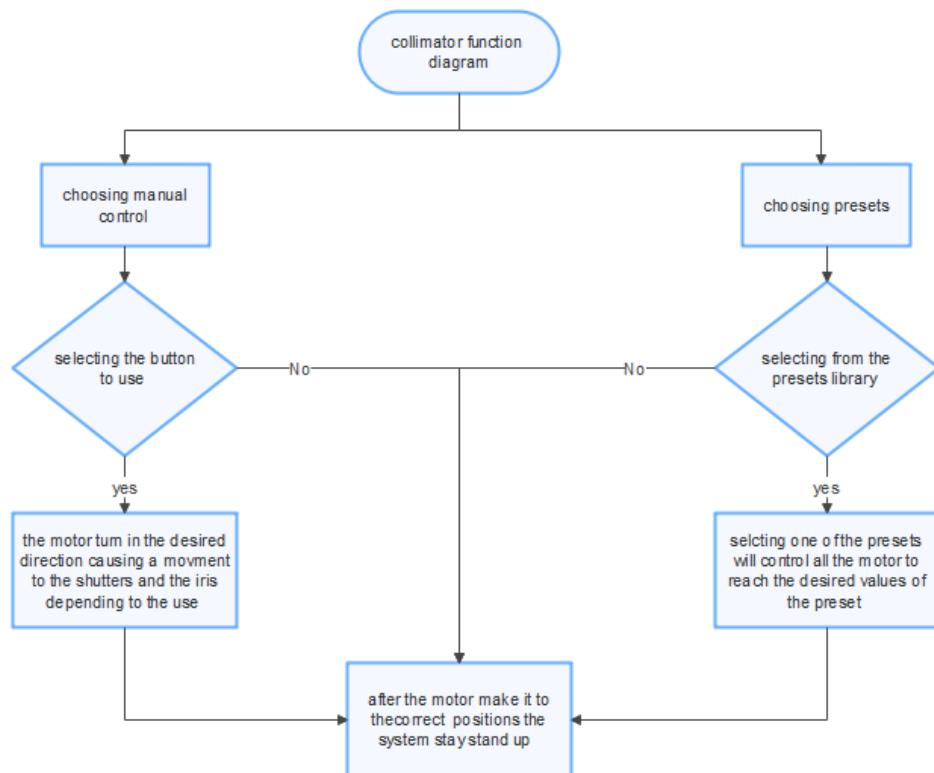
## 3. Functionality

To explain the operating principle of the system it is important to present its main components. So, the main components of the collimator are summarized by actuators and

sensors. The collimator contains three actuators and three sensors. Fig.III.2 shows the motor positions on the system. The operating bloc of the system is given in Fig.III.4



**Fig. III. 3** A real material used in the experimental tests



**Fig. III. 4** General Operating scheme for the collimator

Square and round field X-RAY collimator, designed for installation on rotating or fixed anode X-RAY tubes (EN 60601-1-3 par 29.202.3), provides the motorized stepless adjustment

of the X-RAY field dimension to the size of the image receptor or to that of the anatomical area of interest. Adjustment is also possible from the collimator itself if the version is provided with a remote control.

Six pairs of lead-lined shutters, moved into the beam at right angles to each other, collimate the square field. Two pairs of lead-lined shutters are positioned near the X-RAY and limit secondary radiation; two pairs are located at the X-RAY beam inlet port and the other two pairs of shutters are positioned at the X-RAY beam outlet port of the collimator and accurately limit the X-RAY field.

The round field is defined by twelve lead shutters, iris-arranged, move within the X-RAY beam in a circle to collimate the circular field. All twelve shutters are positioned between the two sets of square shutters approximately midway in the collimator housing.

The direct visualization of the X-RAY field is given by a light beam which correspond to the X-RAY beam, within a tolerance of two percent of the selected distance. The light-field center is provided by the intersection of two perpendicular silk-screened lines into the Lexan window and projected on the light field by the light beam.

Field illumination is provided by a quartz iodide lamp (150W-24V) switched on by an electronic timer or through a remote control if this is available. Illumination time is limited to 30 seconds.

Average illumination is not less than 160 lux (16 foot-candles), edge contrast ratio is four to one .[16]

Fig.III.4. X-RAY field adjustment

#### 4. Material detail

Tab. III. 1Material presentation

Material specification	value	Description
<b>Motor faulhaber mini motor 1524EO24S(9800 tr/min)</b>	24V DC	Opening and closing the collimator-iris
<b>2×Motor faulhaber mini motor2224R024S (6400 tr/min)</b>	24V DC	Motors for move Cross and move Long (MC/ML)
<b>SENSOR 1 2× POT CROS</b>	10KΩ	Rotational, conductive plastic



(SFERNICE)		
<b>SENSOR 2POT IRIS (VISHYSPECTRDL 533-1-1)</b>	10 KΩ	Rotational, multi turn wire wound
<b>Lamp</b>	150W	Limiting the X-RAY field
<b>7×relay</b>	24V	Open and close control

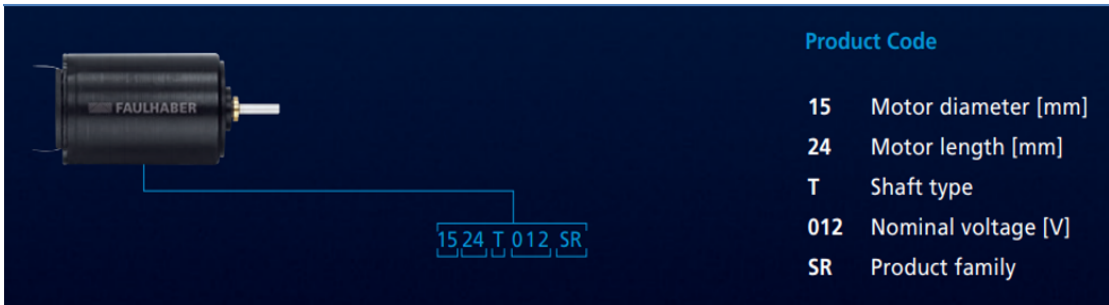
#### 4.1. Motors

The DC motors are the most compact in the industry today and most types feature integrated high-resolution. Its small size, low contact resistance and clean low noise commutation signal characterize the commutation system. It is ideal for use in battery operated applications where current is at a premium. Combinations with a wide variety of gearheads and controllers make it possible to create the best system solution for even the most challenging applications.[17]

##### 4.1.1. Mechanical and electrical characteristics series SR motors

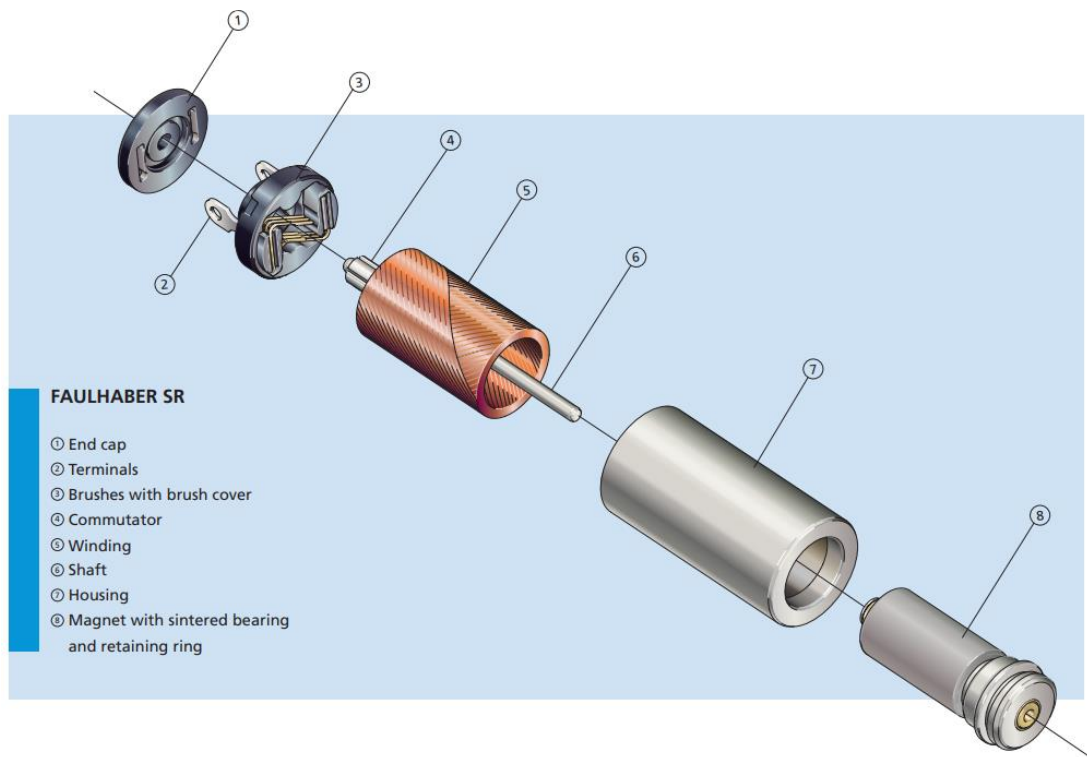
To understand the motor specifications the Fig. III.5. is used. The motor devices are shown in Fig.III.6.

<b>Motor diameter 8 ... 22 mm</b>	<b>Nominal voltage 3 ... 36 V</b>
<b>Motor length 16 ... 32 mm</b>	<b>Speed up to 17.000 min-1</b>
<b>Torque up to 10 mNm</b>	<b>Continuous output up to 8,5 W</b>

Product Code	
15	Motor diameter [mm]
24	Motor length [mm]
T	Shaft type
012	Nominal voltage [V]
SR	Product family

Fig. III. 5 Reading product code



**Fig. III. 6**Faulhaber SR

## 4.2. Potentiometers

The potentiometers used in our project are used as sensor to give the feedback of the positions of the motors

### 4.2.1. Multi Turn Wire wound Potentiometer -533



**Fig. III. 7** Potentiometer -533

**Tab. III. 2** Reference Data

<b>Sensor type</b>	<b>ROTATIONAL, multi turn wire wound</b>
<b>Output type</b>	Output by turrets
<b>Market appliance</b>	Industrial
<b>Dimensions</b>	7/8" (22.2 mm)

**Tab. III. 3** Electrical specifications

PARAMETER	MODEL 533
Resistance range - standard values	50 $\Omega$ to 20 k $\Omega$
Capability range	5 $\Omega$ to 60 k $\Omega$
Standard tolerance	$\pm 5 \%$
Linearity (independent)	$\pm 0.25 \%$
Rotation (electrical and mechanical)	1080° +10° -0°
Power rating (at 70°C)	1.0 W

#### 4.2.2. Precision Rotative Transducers, Conductive Plastic, Economic Series (ECS)



**Fig. III. 8 Precision Rotative Transducers, Conductive Plastic**

**Tab. III. 4 Reference Data**

<b>Sensor type</b>	<b>ROTATIONAL, conductive plastic</b>
<b>Output type</b>	Output by turrets
<b>Market appliance</b>	Industrial
<b>Dimensions</b>	7/8" (22.2 mm)

#### **4.3. Electromagnetic relay with finder (type 95.03):**

It is an Electrical device allowing to separate the power part from the control parts. Its allows the opening and closing of an electrical circuit by a second completely isolated circuit (galvanic isolation) and which can have different properties



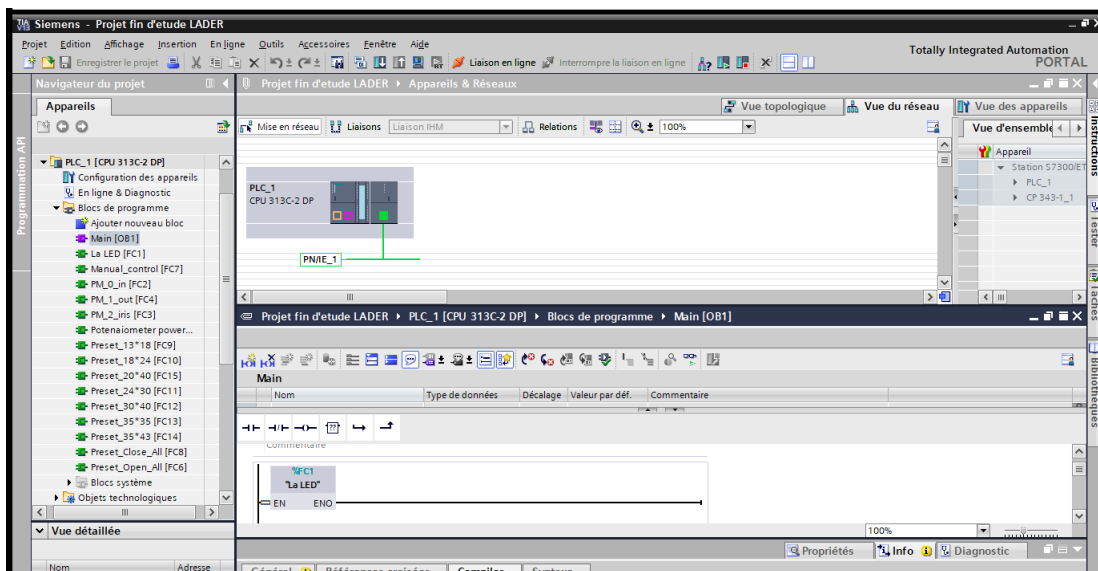
**Fig. III. 9 Electromagnetic relay**

## **5. Programing and Supervision**

### **5.1.Programming**

#### **5.1.1.TIA Portal:**

Totally Integrated Automation Portal (TIA Portal) gives you unrestricted access to the complete range of digitalized automation services, from digital planning to integrated engineering and transparent operation. Shorten your time to market with the aid of simulation tools, boost the productivity of your plant using additional diagnostic and energy management functions, and increase flexibility via connections to the management level. The portal view offers an overview of all project configuration steps and task-oriented access to your automation task.



**Fig. III. 10 TIA portal software Interface**

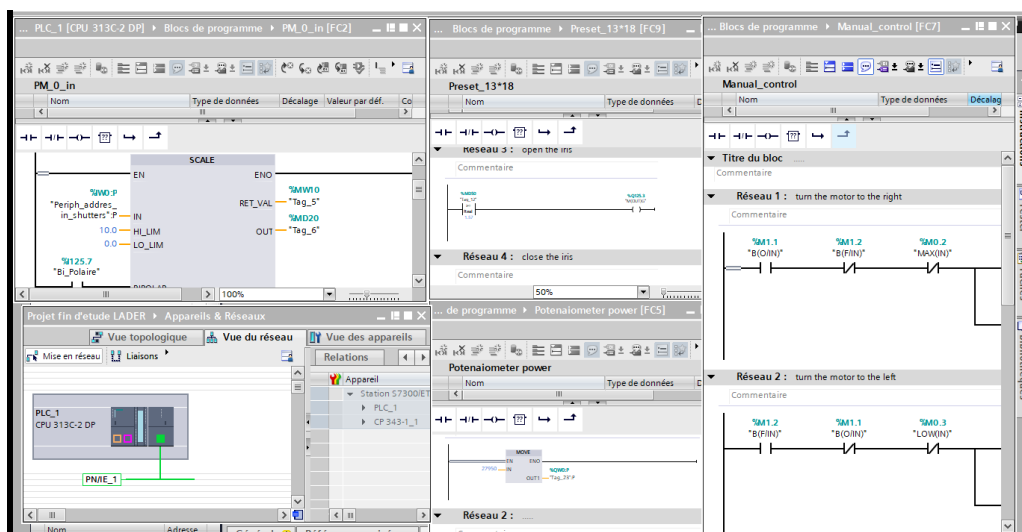
### 5.1.2. TIA portal advantages

#### Common data management

- Easy handling of programs, configuration data and data Visualization
- Easy mounting using drag-and-drop function -Easy upload of data to peripherals
- Easy update data to peripherals
- Easy to use graphics supported configured and diagnostic

### 5.1.3. Application on TIA

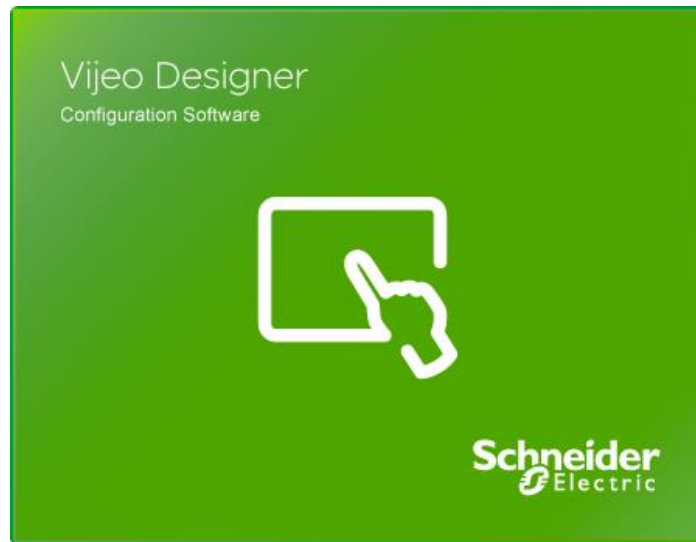
The example in this Getting Started shows how a complete automation task can be carried out, step by step with the TIA Portal V13.0 Professional. Each project configuration step is explained in detail in Getting Started. Images allow you to understand and easily follow the different steps of control



**Fig. III. 11 side by side sub programs view**

## 5.2. Supervision

For the supervision we used a Schneider HMI so we are using the Vijeo Designer which is the software that is used to create the visual aspect of our HMI. This software insure the visualization of the process. Its allow to write, read and archive all the data



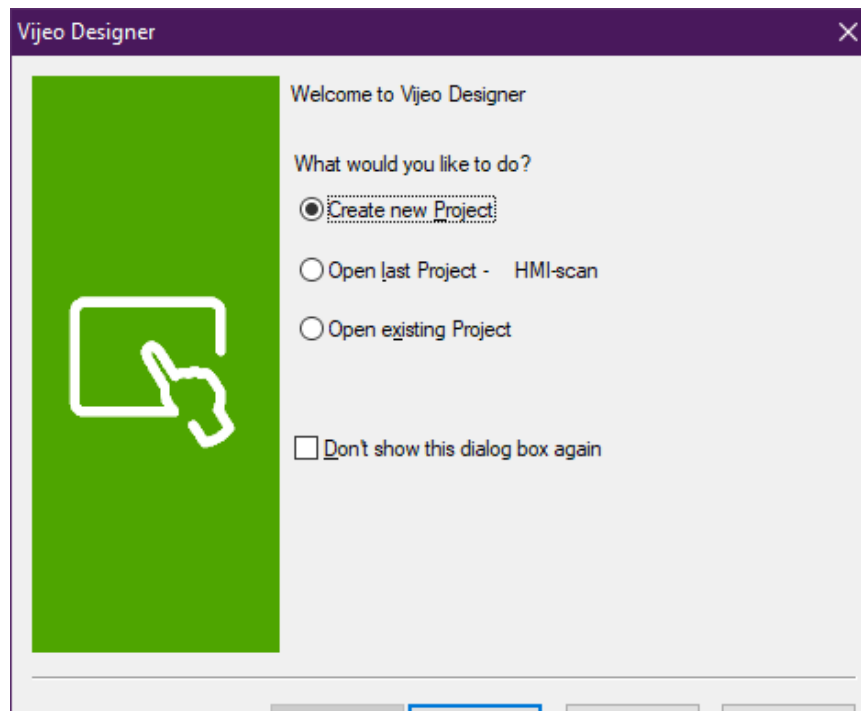
**Fig. III. 12** Vijeo designer

### 5.2.1. Tasks of Vijeo designer

- **Process visualization:** the process is shown on the interface and up to date with what's going on our system in real time
- **Process control:** the user can control the system using the interface
- **Alarms visualization:** in critical states of errors or system failures the alarms will be shown on the graphical interface
- **Alarm and process data storage:** the HMI system is able to save and store the alarms and the other values of the system process as history log

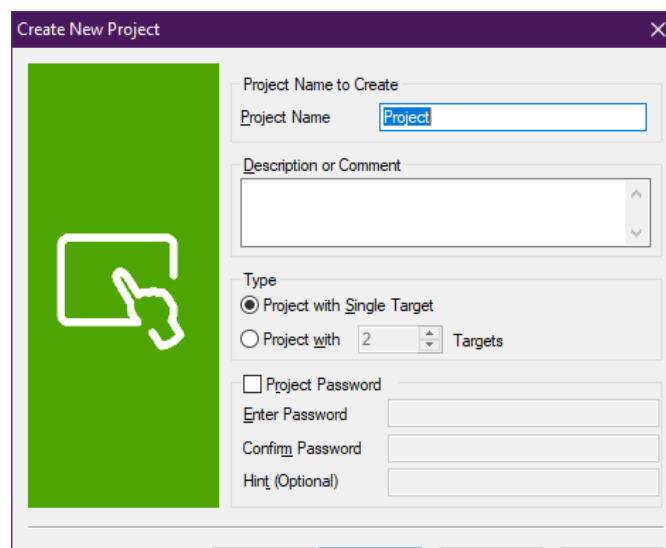
### 5.2.2. Software view

The first thing you see after opening the software is this window that give you the choices to open an old project or create a new one



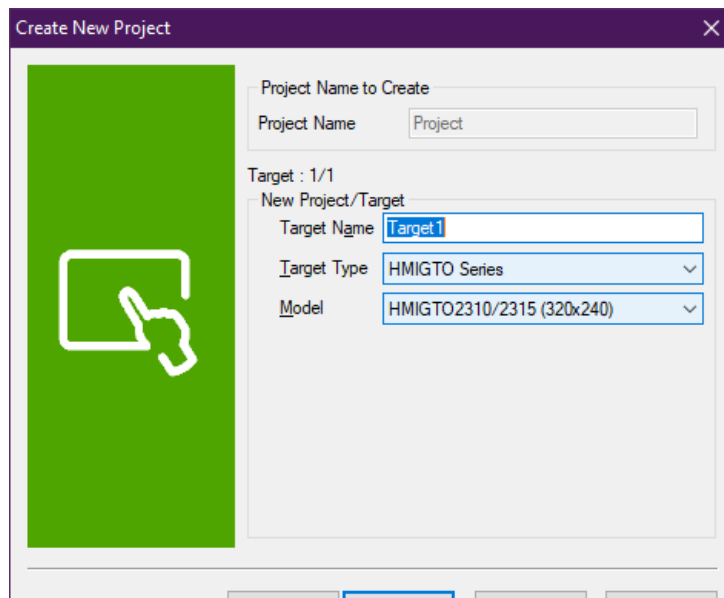
**Fig. III. 13** the first window you see in Vijeo designer

- Step 01: By checking the “create new project” and pressing next you get the next window that allow us to name and describe the project even creating a password and secure the project



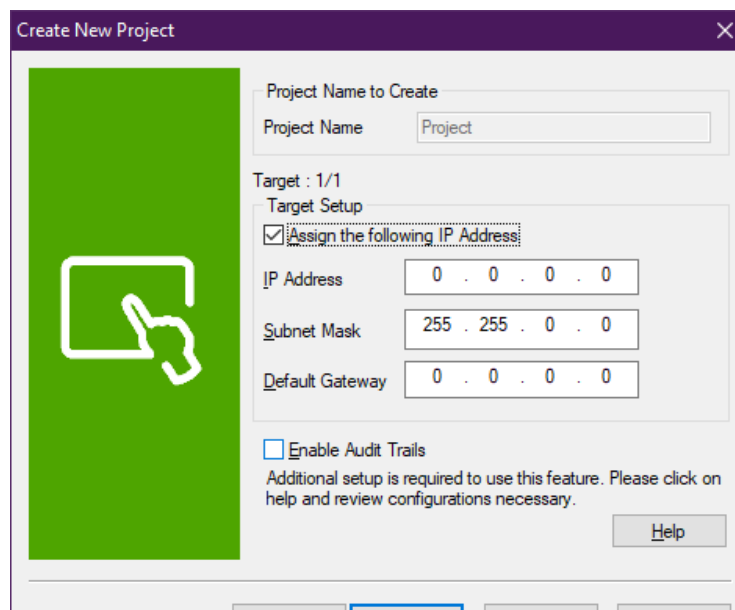
**Fig. III. 14** creating a project steps 1

- Step 02: After naming and describing the project the software show another window for choosing the target machine, mean that we will choose the same HMI that we are working on



**Fig. III. 15** creating a project steps 2

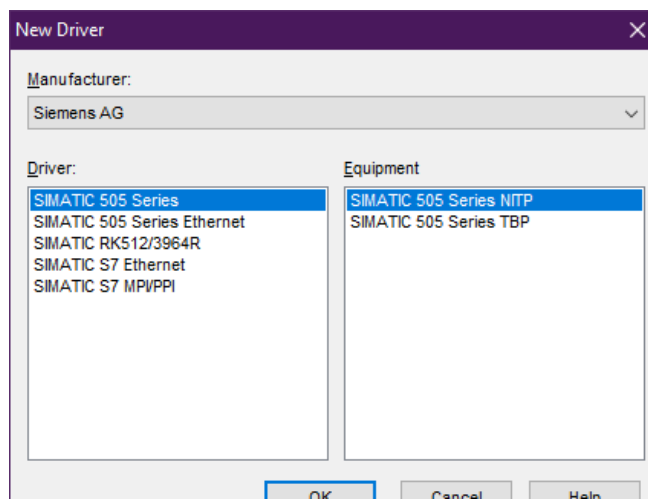
- Step 03: after that we will type the target IP address which is our HMI



**Fig. III. 16** creating a project steps 3

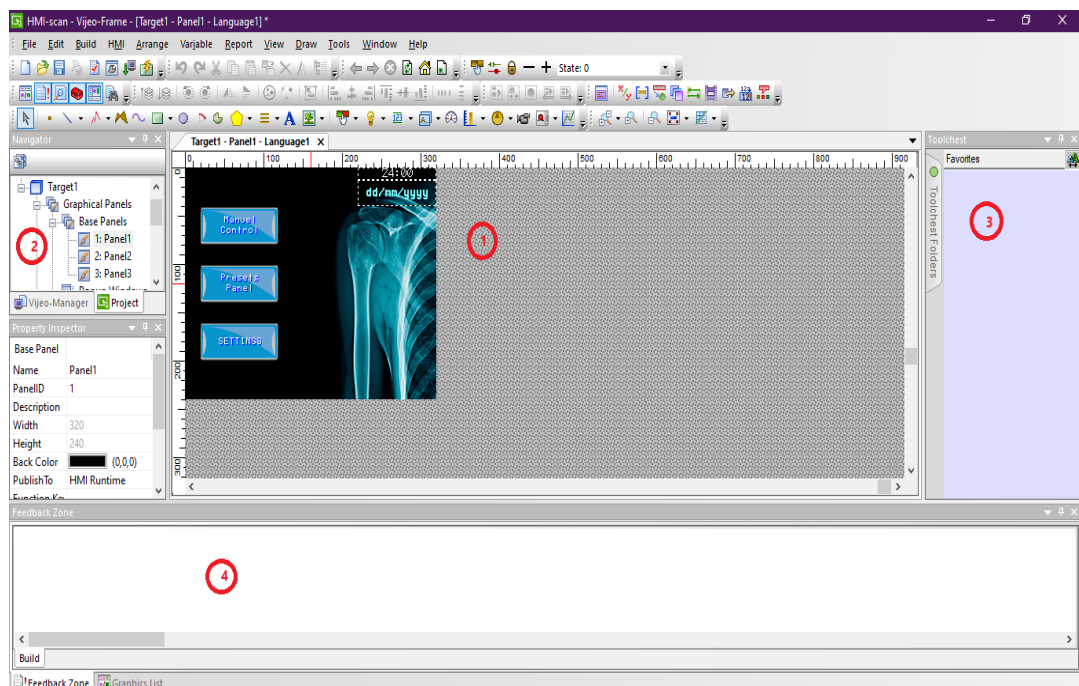
- Step 04: the last step is the most important step and its choosing the PLC manufacturer that we are using and the PLC model too, generally Schneider HMI's are compatible with most of PLC's





**Fig. III. 17** creating a project steps 04

After creating the project we will see the main view of the Vijeo Designer which have 4 main area on the screen that can be used during working on a project



**Fig. III. 18** the main view of the Vijeo designer

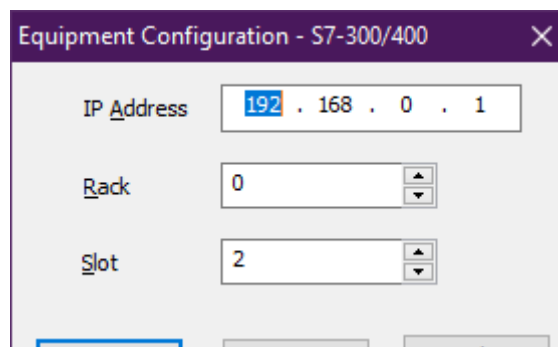
- 1- The work space
- 2- Navigator
- 3- Tools chest
- 4- Feedback zone

**Tab. III. 5 Vijeo designer**

<b>1- The work space</b>	The work space is for editing the project. All the bars and element of the Vijeo designer are arranged around the work zone
<b>2- navigator</b>	We can call it project tree it's the most important element in the project treating all the windows and the parameter of the project are displayed on it
<b>3- tools chest</b>	In this window we find all the necessary tools that we need in our project.it had a library that include buttons lights, etc.
<b>4- feedback zone</b>	This zone is responsible of showing the errors and the problems that is made on the project

### 5.2.5.Communication between the PLC and the HMI

To configure the communication between the PLC and the HMI we set the IP address for the PLC in Vijeo designer as follow.



**Fig. III. 19 equipment configuration**

### 6.Functionality test

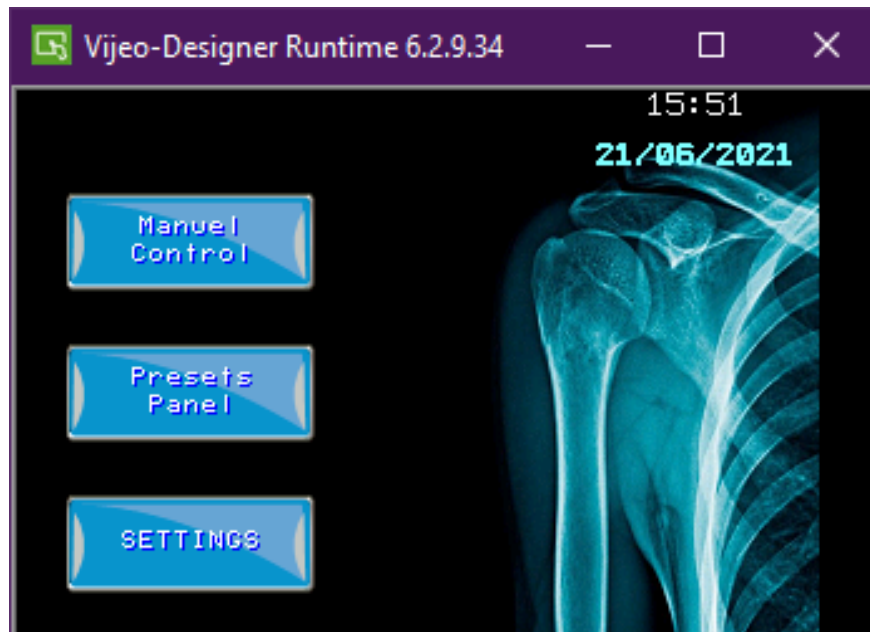
Going through all those chapters we are in the last step finishing our system and putting it under some tests that we will show the values we are getting from coupling a Siemens plc with a Schneider HMI. We started by programming the PLC using TIA portal with a ladder language and grafcet after that the development of our HMI with Vijeo Designer that we practically could make

The most important task of the HMI that we developed is the ability to control our system. The HMI have 3 panels

- home screen that have 3 buttons

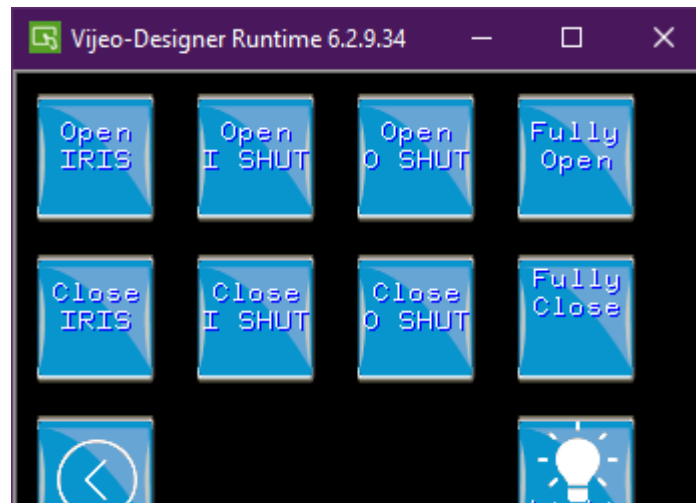
- a screen for the manual control
- a screen of the presets

The home screen have already a 3 buttons manual control, presets panel and settings with a clock and date at the top right corner



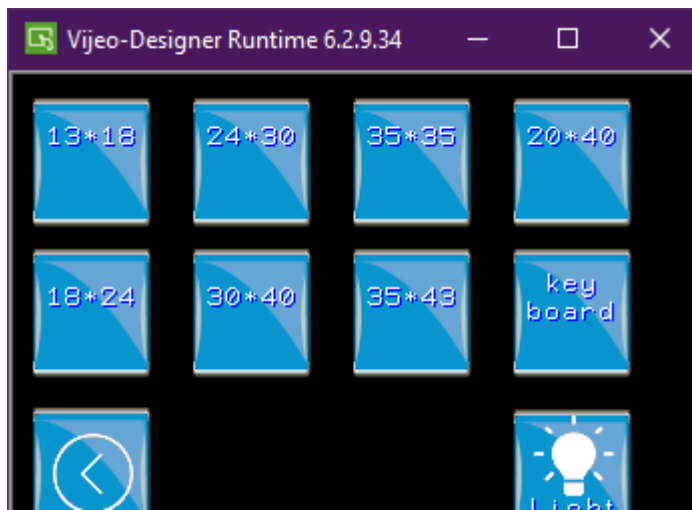
**Fig. III. 20** home screen of the HMI

When we press on the manual control button we see 10 new buttons 8 are for controlling the motors, button` for turning the light on and the last one to return to the home screen



**Fig. III. 21** manual control panel of the HMI

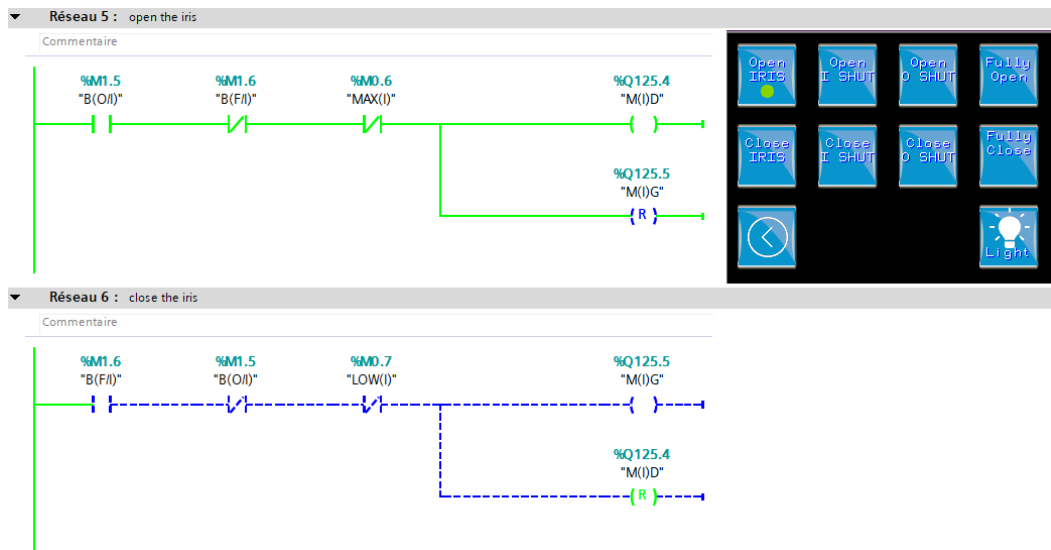
For the presets panel we have also 10 buttons but this time 8 are for a calculated function that make sure that the collimator is open exactly how we want



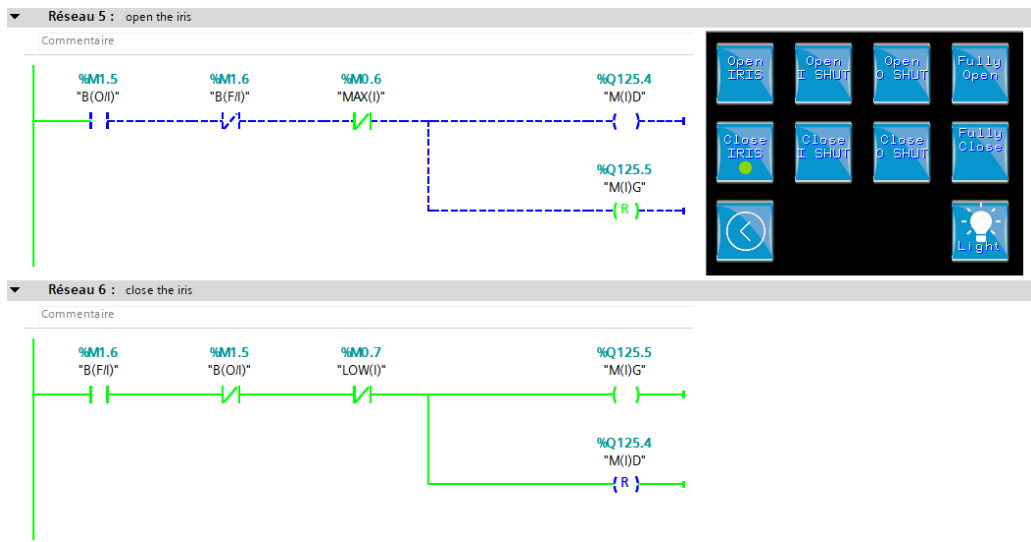
**Fig. III. 22** presets panel

### 6.1. Manual use

As we saw in the previous title our manual control panel have 8 buttons for controlling the system which is the collimator in our case, that for example the IRIS do two main movements that can happen by a combination of multiple gears and shafts to insure opening or closing the iris



**Fig. III. 23** example of the iris opening buttons on the HMI

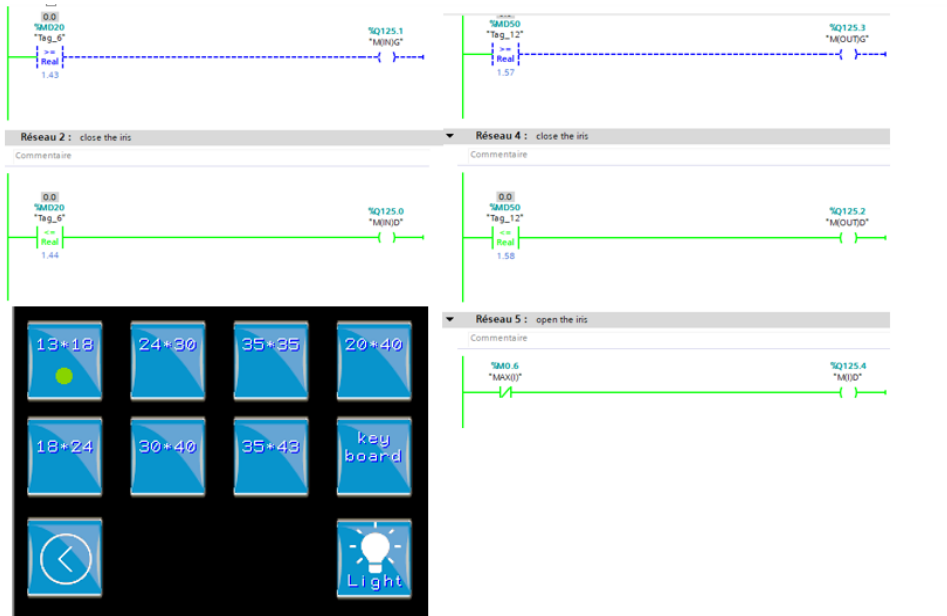


**Fig. III. 24** example of the iris closing buttons on the HMI

The responsible of this movements is the program that we made on TIA portal, it's based on ladder as it is shown in the figure below

### 6.2. Presets

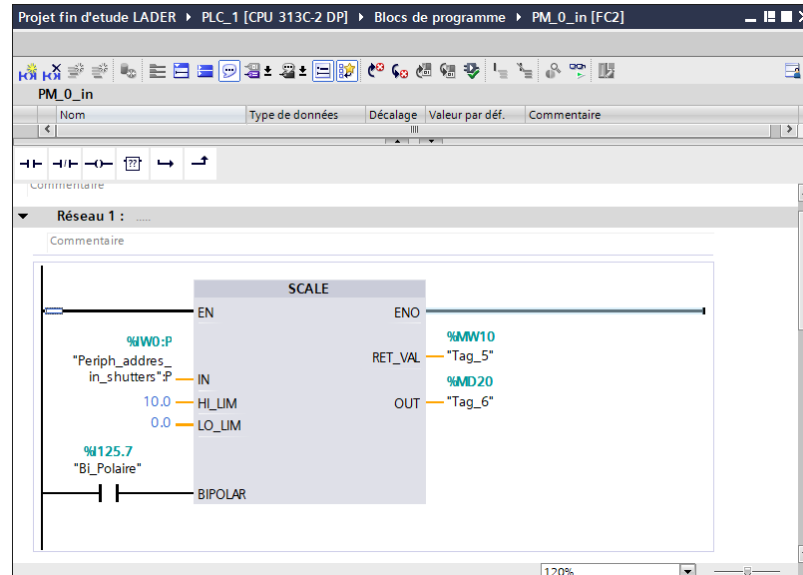
To make the system easy to use and we added something new to this kind of systems and it is a pack of presets that make the field of radiation exposer measured based on the cassettes found on the market (13\*18, 18\*24, 24\*30...) for example we will see the 13\*18 cassette



**Fig. III. 25** preset example

In the figure below we had the sample of a preset that we used in the system we could achieve those presets using potentiometers as an encoders to know the exact position of the shutters.

To make the potentiometers work as an encoder we did feed them using a 10V from the PLC and read the values given using scale block in TIA portal.



**Fig. III. 26** scale module

The value we got from the scale block are the ones used to configure the position of the shutters and the iris.

## 7. Conclusion:

This chapter presents control of the collimator by using a Siemens PLC (S7-300) and a Schneider HMI (Magelis). So, the development of the control program is based on TiaPortal software V13. The HMI of supervision has been configured using Vijeo designer software.

## General Conclusion and Perspectives

In this project, automatic control has been proposed for controlling a medical systems. However, this study is limited on the control of a collimator which is used in radiography field. The development of the project is based on the following steps:

The first step concerns the description of the hardware (the collimator). So, from a real collimator the description has been performed. The main components of the collimator are defined clearly. These components are the sensors and the actuators. By using the manual of the collimator, its principal operating has been defined.

The second step deal with the material and software which are used to automate the studied collimator. In this study, many software have been used, Siemens and Schneider software. So, the global selected solution to automate the collimator comprises a Siemens PLC and a Human Machine Interface of Schneider technology. By hybridization between the both technologies (Siemens & Schneider) the automated solution is developed.

In the third step, many programs are developed in TiaPortal environment with considering the Vijeo designer software.

Finally, several experimental tests by connecting the PLC, the HMI the collimator are performed. The communication protocol used between the PLC and the HMI is the Ethernet protocol.

In order to optimize the cost and the size of the proposed solution, an embedded electronic system has been suggested as a perspective for the future work.

# Bibliography

- [1] R. Hijazi, D. Handoyo, F. Suryaningsih, and K. Kurnianto, "Engineering design of rotary table for digital radiography and gamma ray CT prototype in manufacturing industry," 2019, p. 020026, doi: 10.1063/1.5135535.
- [2] British institu of radigraphy, "History of radiology." <https://www.bir.org.uk/useful-information/history-of-radiology.aspx>.
- [3] B. A. Schueler, "The AAPM/RSNA Physics Tutorial for Residents General Overview of Fluoroscopic Imaging," *RadioGraphics*, vol. 20, no. 4, pp. 1115–1126, Jul. 2000, doi: 10.1148/radiographics.20.4.g00jl301115.
- [4] David C. Shelledy and Jay I. Peters, *Respiratory Care: Patient Assessment and Care Plan Development*. 2014.
- [5] V. Gilsanz, "Bone density in children: a review of the available techniques and indications," *Eur. J. Radiol.*, vol. 26, no. 2, pp. 177–182, Jan. 1998, doi: 10.1016/S0720-048X(97)00093-4.
- [6] International Atomic Energy Agency, "DEXA." <https://www.iaea.org/resources/rpop/health-professionals/other-specialities-and-imaging-modalities/dxa-bone-mineral-densitometry> visited June 2021.
- [7] Quinn B Carroll, *Radiography in the digital age: Physics - Exposure - Radiation Biology*, 2nd Ed. 2011.
- [8] E. T. Parks and G. F. Williamson, "Digital Radiography: An Overview," *J. Contemp. Dent. Pract.* vol. 3, no. 4, pp. 23–39, Nov. 2002, doi: 10.5005/jcdp-3-4-23.
- [9] U. Neitzel, "Status and prospects of digital detector technology for CR and DR," *Radiat. Prot. Dosimetry*, vol. 114, no. 1–3, pp. 32–38, May 2005, doi: 10.1093/rpd/nch532.
- [10] R. Khenfer, *Automatisation de systemes industriels*. 2015.
- [11] Y. Aoufi, "Commandd'unAscenseur parAutomat Programmable," bordj bou Arriridj University, 2019.
- [12] Z. F. Gharbi Younes, "Réalisation d'une maquette de simulation et de supervision pour un processus industriel," Université de Bordj Bou Arreridj, 2018.
- [13] A. Oussama, "Control De Temperature D'un Systeme Industriel al'aidd'un API," University Bordj Bou Arriridj, 2019.
- [14] E. D. Knapp and J. T. Langill, "Introduction to Industrial Control Systems and Operations," in *Industrial Network Security*, Elsevier, 2015, pp. 59–84.
- [15] E. Knapp, "How Industrial Networks Operate," in *Industrial Network Security*, Elsevier, 2011, pp. 89–110.
- [16] Ralco, "instruction manal MTR530; LP," 2005.
- [17] Faulhaber, "Technical Information." [https://www.faulhaber.com/fileadmin/Import/Media/EN\\_TECHNICAL\\_INFORMATION.pdf](https://www.faulhaber.com/fileadmin/Import/Media/EN_TECHNICAL_INFORMATION.pdf). Visited June 2021.

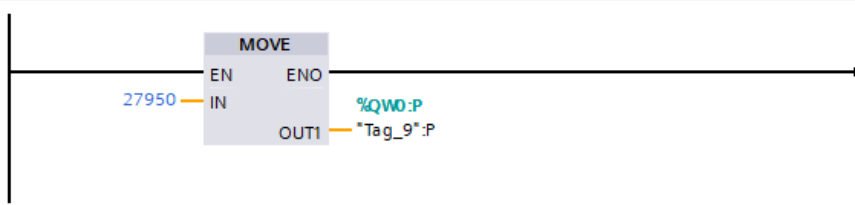


# Annex A

## Variable table

Table de variables standard							
	Nom	Type de données	Adresse	Réma...	Visibl...	Acces...	Commentaire
1	B(LED)	Bool	%M12...		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	light indicator of the radiation field
2	B(O/IN)	Bool	%M124.1		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	button opening of the interior shutters
3	B(F/IN)	Bool	%M124.2		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	button closing of the interior shutters
4	B(O/OUT)	Bool	%M124.3		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	button opening of the outer shutters
5	B(F/OUT)	Bool	%M124.4		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	button closing of the outer shutters
6	M(IN)D	Bool	%Q125.0		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	turn the motor to the right
7	M(IN)G	Bool	%Q125.1		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	turn the motor to the left
8	M(OUT)D	Bool	%Q125.2		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	turn the motor to the right
9	M(OUT)G	Bool	%Q125.3		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	turn the motor to the left
10	MID	Bool	%Q125.4		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	open the iris
11	MIG	Bool	%Q125.5		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	close the iris
12	B(O/I)	Bool	%M124.5		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	iris diaphragma:open
13	B(F/I)	Bool	%M124.6		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	iris diaphragma:close
14	LED	Bool	%Q124.6		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	LED turn on/off
15	Tag_1	Bool	%M0.0		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
16	Tag_2	Bool	%M0.1		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
17	potontionmetr iris	Int	%IW4		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
18	MAX IRIS	Bool	%M0.2		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
19	MIN IRIS	Bool	%M0.3		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
20	Tag_3	Word	%MW10		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
21	Tag_4	Real	%MD20		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
22	BIPOLAIR	Bool	%I125.7		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
23	potontionmetr IN shutter	Int	%IW0		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
24	Tag_6	Word	%MW30		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
25	Tag_7	Real	%MD40		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
26	MAX IN shutter	Bool	%M0.4		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
27	MIN IN shutter	Bool	%M0.5		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
28	Tag_5	Word	%MW50		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
29	Tag_8	Real	%MD60		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
30	MAX OUT shutter	Bool	%M0.6		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
31	MIN OUT shutter	Bool	%M0.7		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
32	potontionmetr OUT shutter	Int	%IW2		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
33	Tag_9	Int	%QW0		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
34	Tag_10	Int	%QW2		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
35	Tag_11	Bool	%M125.5		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
36	CALL	Bool	%M125.0		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
37	OALL	Bool	%M125.1		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
38	Tag_14	Bool	%I127.7		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
39	Tag_15	Word	%MW70		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
40	Tag_16	Real	%MD80		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
41	Tag_17	Bool	%M1.0		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
42	Tag_18	Bool	%I125.2		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
43	Tag_19	Word	%MW80		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
44	Tag_20	Bool	%M1.1		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
45	Tag_21	Bool	%I124.7		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
46	Tag_22	Bool	%Q124.7		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
47	HALF	Bool	%M125.2		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
48	PRSTE 13/18	Bool	%M126.0		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
49	PREST 18/24	Bool	%M126.1		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
50	PREST 20/40	Bool	%M126.2		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
51	PRESET 24/30	Bool	%M126.3		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
52	PREST 30/40	Bool	%M126.4		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
53	PRSET 35/35	Bool	%M126.5		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
54	PRSET 35/43	Bool	%M126.6		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	

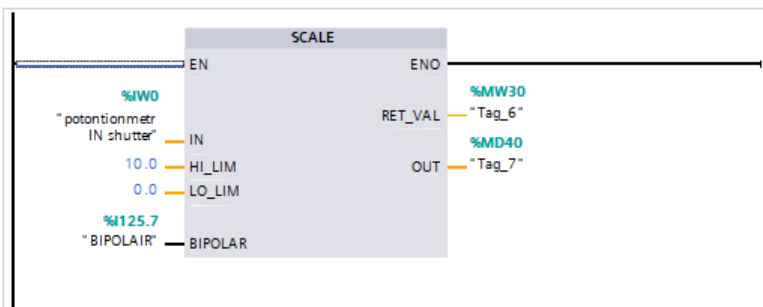
# Potentiometers power supply



# Comparing blocs for Shutters

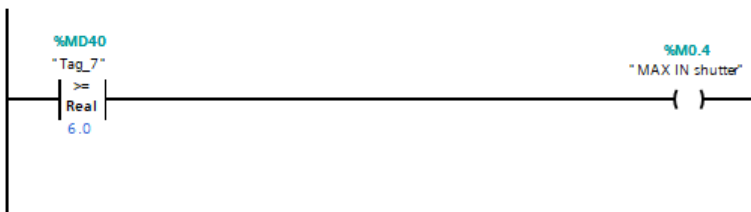
## ▼ Réseau 1 : .....

Commentaire



## ▼ Réseau 2 : .....

Commentaire



## ▼ Réseau 3 : .....

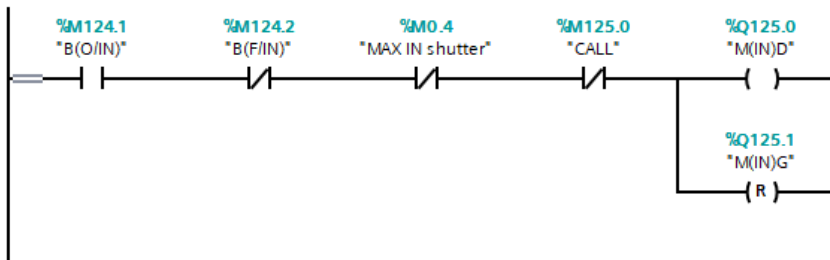
Commentaire



# Manuel control

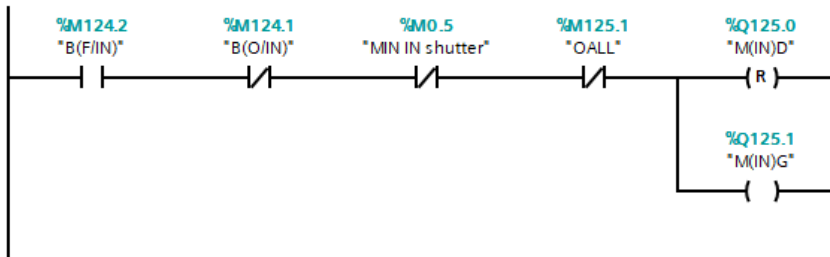
## ▼ Réseau 1 : button opening of the interior shutters

Commentaire



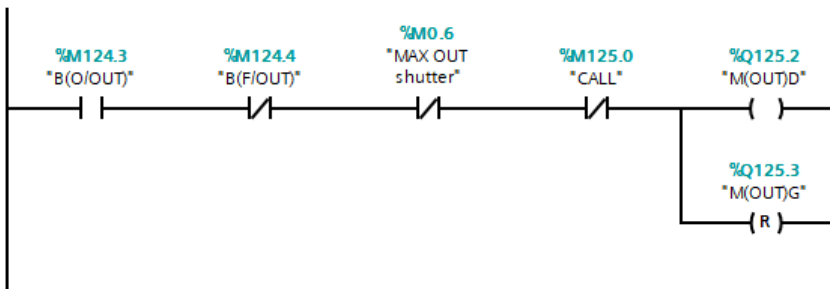
## ▼ Réseau 2 : button closing of the interior shutters

Commentaire



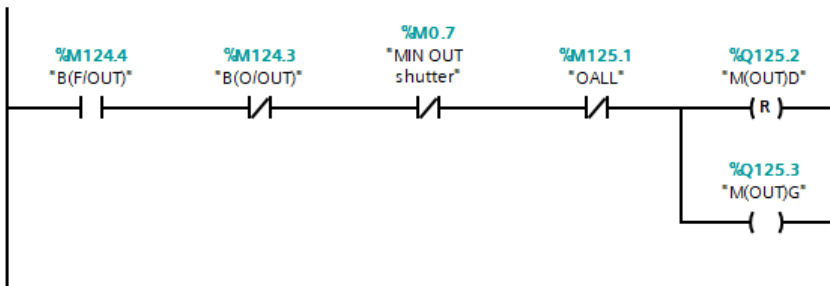
## ▼ Réseau 3 : button opening of the outer shutters

Commentaire

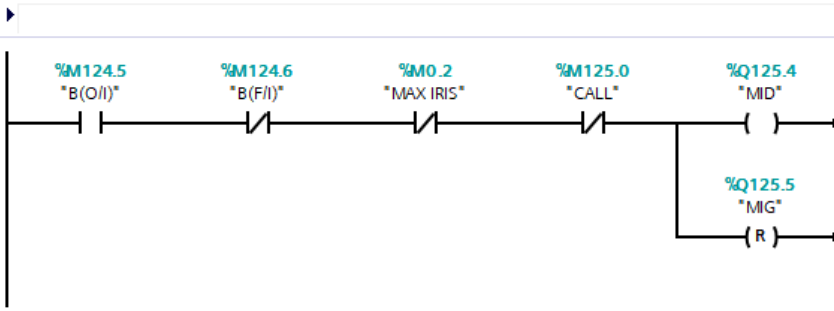


## ▼ Réseau 4 : button closing of the outer shutters

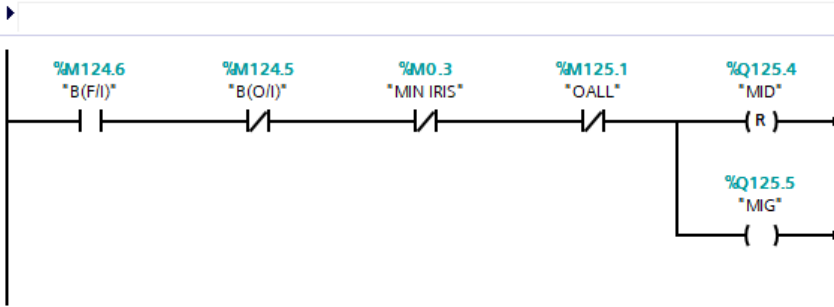
Commentaire



▼ Réseau 5 : button opening the iris



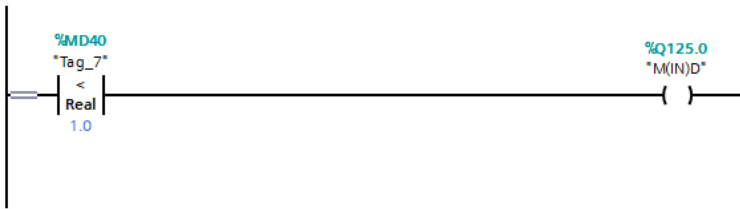
▼ Réseau 6 : button closing the iris



# Presets bloc

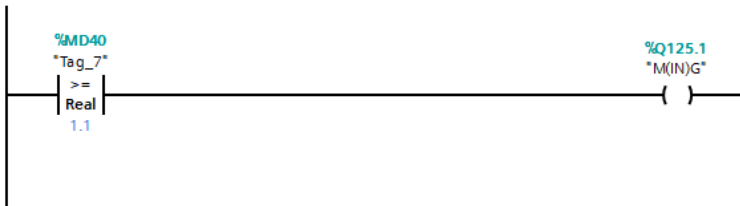
## ▼ Réseau 1 : turn the motor to the right

Commentaire



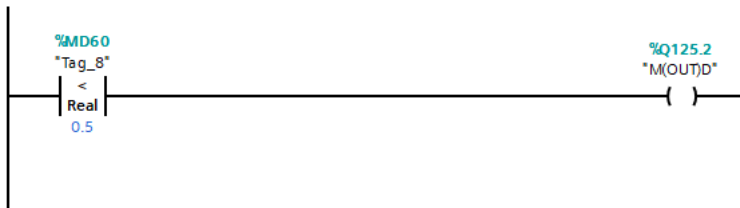
## ▼ Réseau 2 : turn the motor to the left

Commentaire



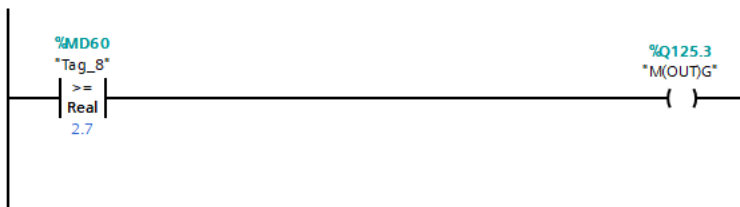
## ▼ Réseau 3 : turn the motor to the right

Commentaire



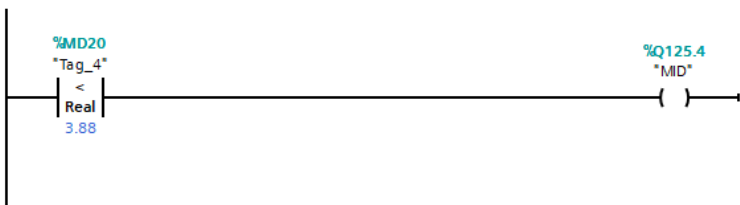
## ▼ Réseau 4 : turn the motor to the left

Commentaire



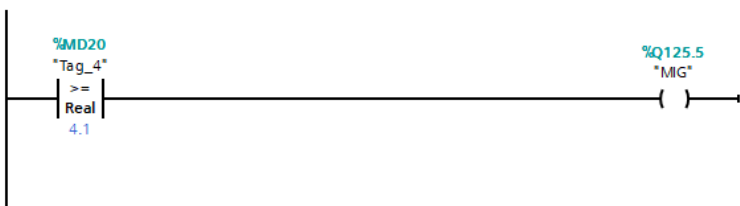
## ▼ Réseau 5 : open the iris

Commentaire



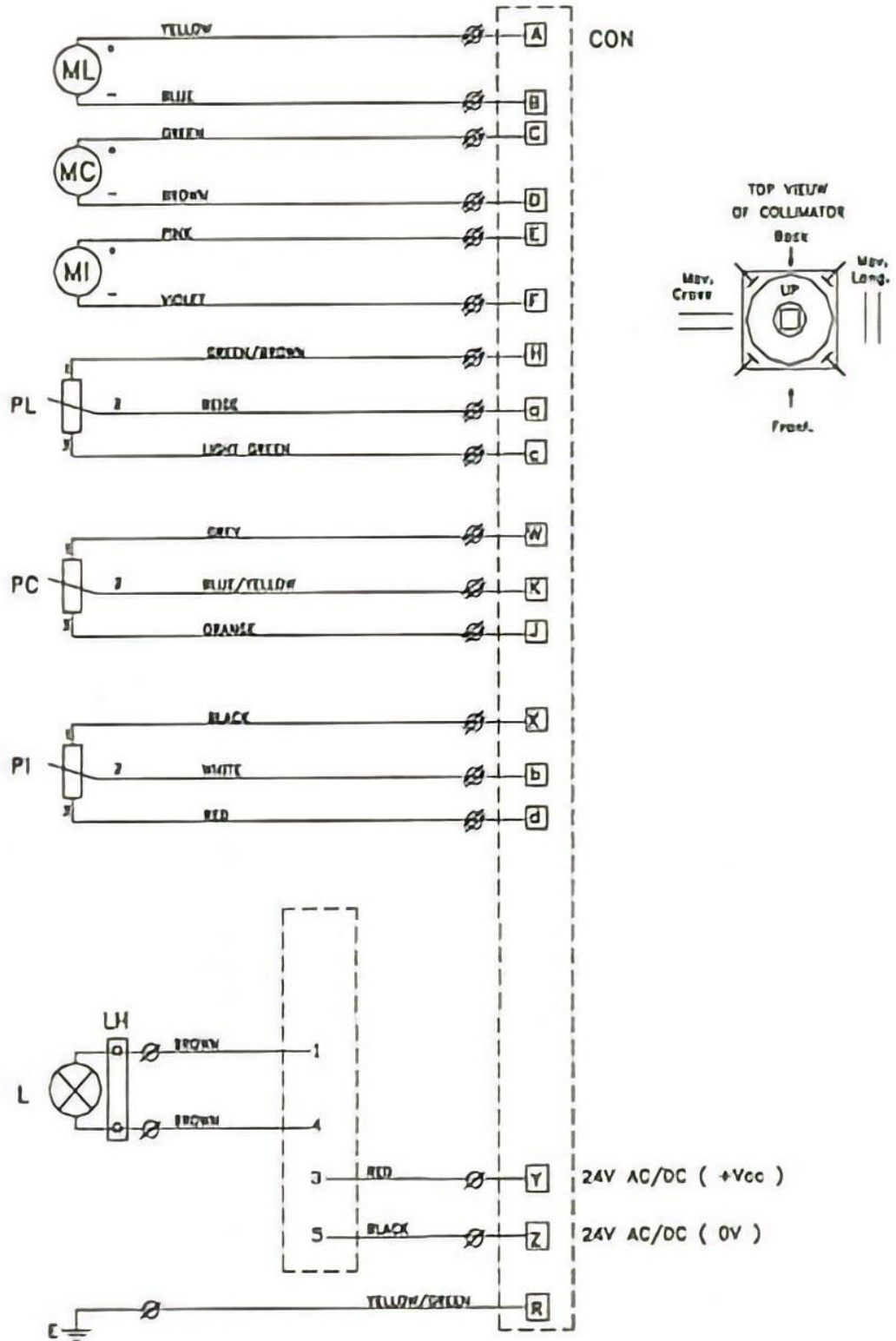
## ▼ Réseau 6 : close the iris

Commentaire

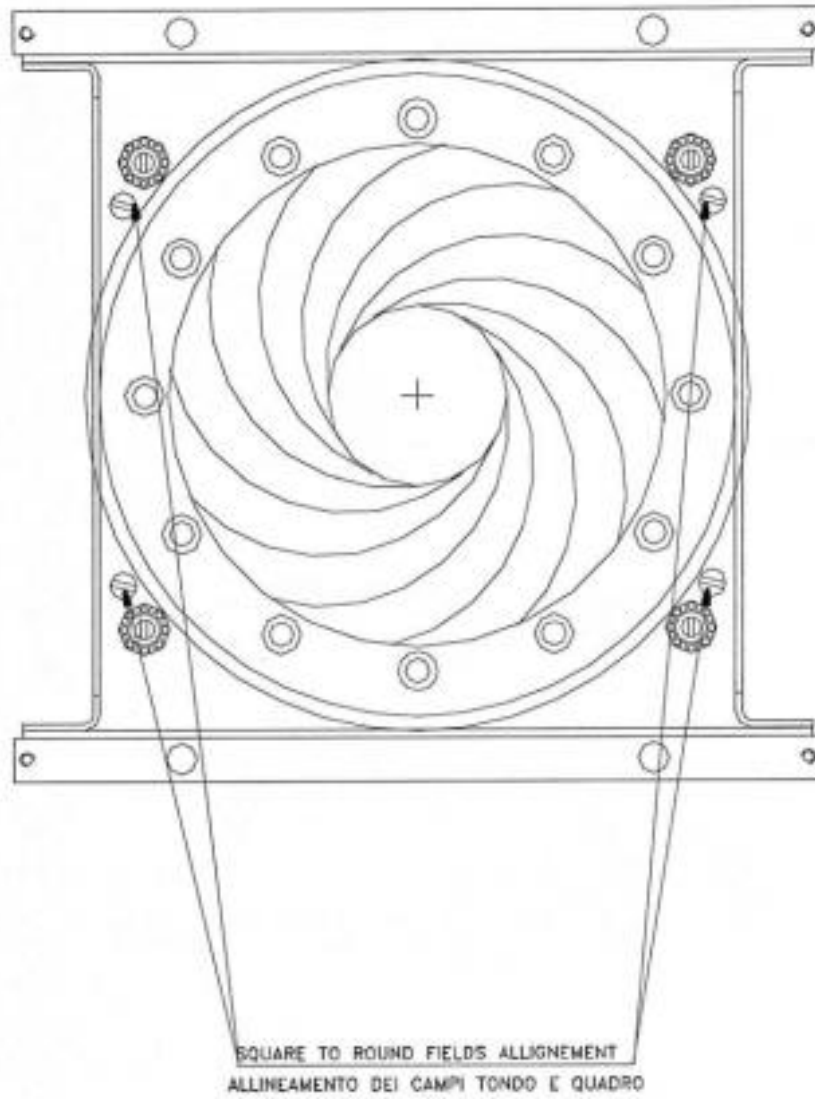


# Annex B

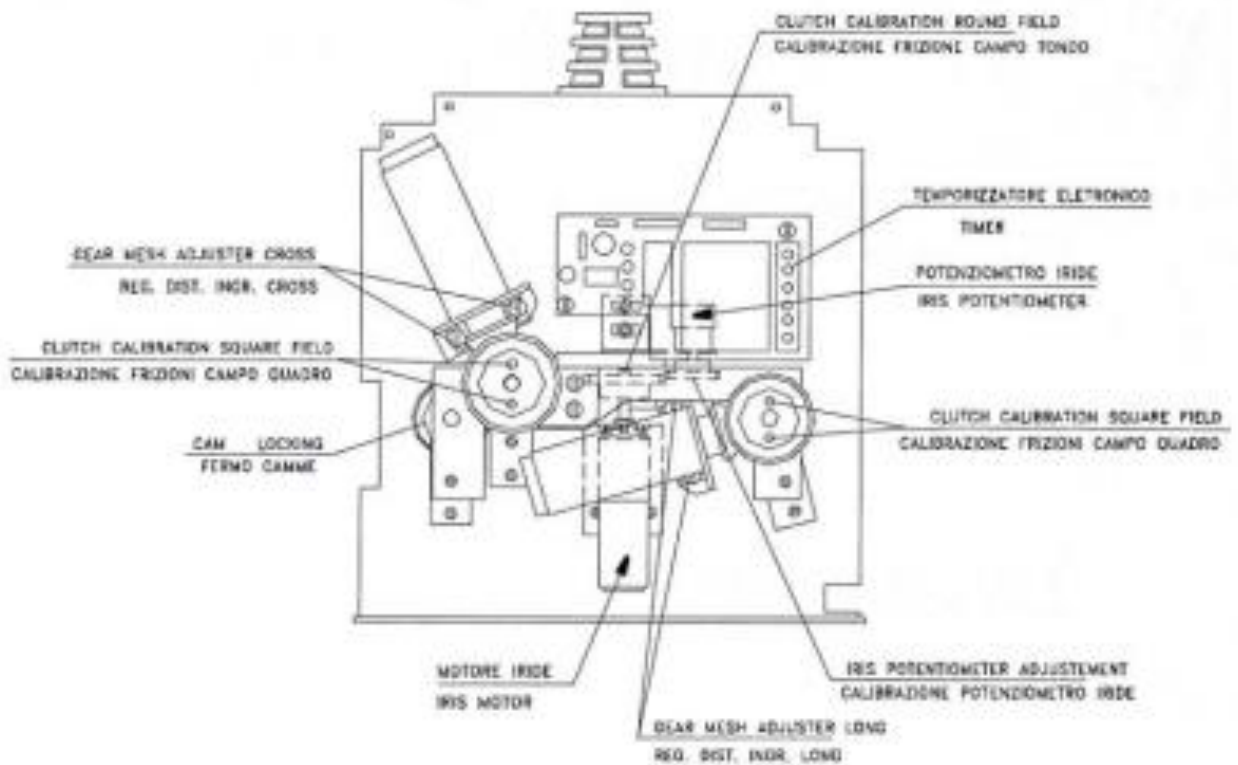
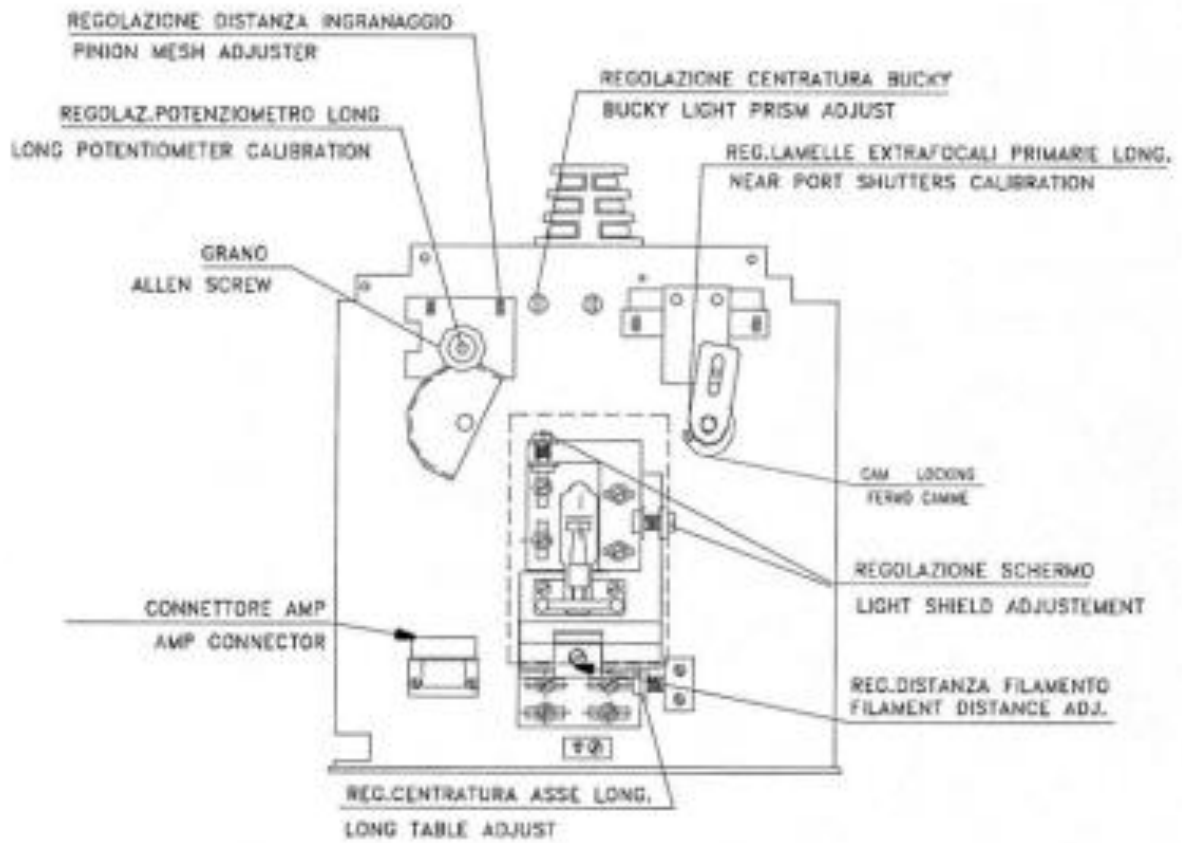
## Electrical scheme



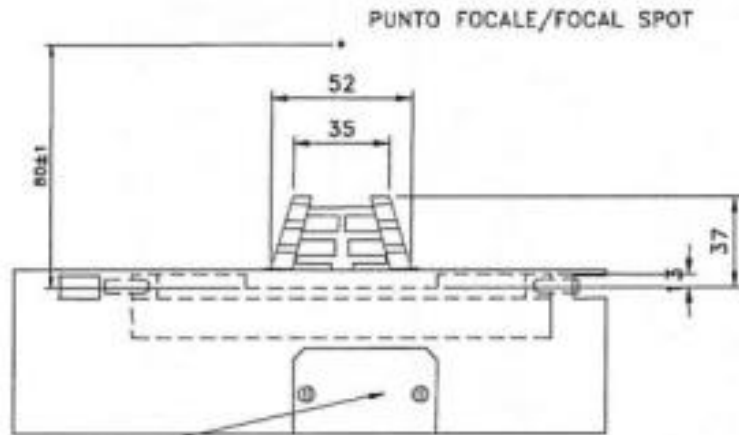




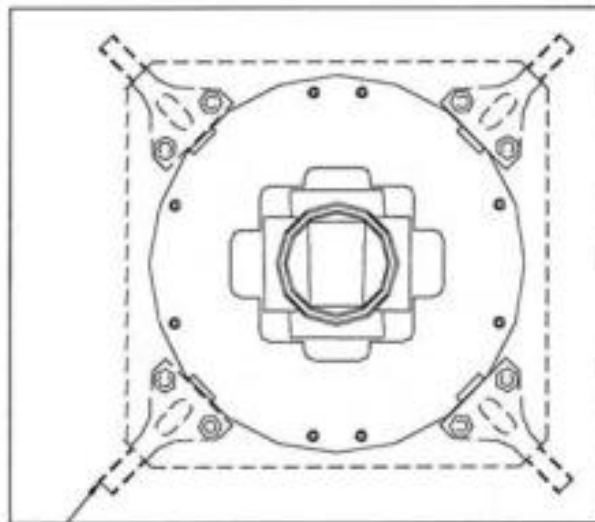




CONDIZIONE CON LAMELLE LIMITATRICI COMPLETAMENTE APERTE  
NEAR PORT SHUTTERS WITH SHUTTERS FULLY OPEN



ACCESSO REGOLAZIONE INCLINAZIONE SPECCHIO  
ACCESS TO MIRROR POSITION ADJUSTEMENT



4 VITI REGOLAZIONE E FISSAGGIO  
4 MOUNTING AND CENTERING ADJUSTEMENT SCREWS

## Real Pictures of the system

