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Spécialité
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Solution de connectivité pour les automates industriels

Réalisé par

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Connectivity solution for industrial PLC

Realized by

Yannis AMMER
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University year 2021 –2022

Dedication

“

*To my dearest mother **Nabila**, the one that always believes in me, supports me, guides me and the source of my happiness,*

*To my life inspiration, my dear father **Samir**, for his encouragement, support, and especially for the sacrifices he made to see his son grow and be the man i am today,*

*To my little sister **Tinhinene**,*

*To **AMMER** and **GADOURI** families,*

*To my closest friends **Ali, Ahmed, Anis, Djamel, Imad, Nassim, Sisaleh, Tayeb, Youcef** and many other friends whom i encountered during my journey to be among the people who want to see me succeed,*

*And finally, To my supervisors, **Abdelmalek BELLOULA** and **Abdelhalim ZAOUI** for their guidance and support throughout this project.*

Thank You.

”

- Yannis

“

”A loved soul never leaves us’.

I dedicate this modest work to my grand parents ” khedidja, Hadj Ali and hadj Bouzid ” who left us early. ,

To my mother Rabia, who supports me in all my projects and always present for my ups and downs to make me smile. My mother, I hope that this work will be the testimony of my gratitude and my deepest respect towards the support, the sacrifices and all the efforts that she made for me. May God keep you and protect you for us inchallah. ,

To my father Si Aissa, thank you for always being my ally in the wars with my life. I love you. Nothing in my life would have been possible without your fight. Nothing I can say can truly express how I feel. Nothing will show all the gratitude I have for you. Dad, It is because of you that I have never missed anything in life. ,

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To CHERGUI and BOUDJALEL families and all my friends ,

And finally, To my supervisors, ***Abdelmalek BELLOULA*** *and* ***Abdelhalim ZAOUI*** *for their guidance and support throughout this project.*

”

- Abdelmadjid

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List of Acronyms

AI	*Artificial Intelligence*
CPU	*Central Processing Unit*
CPS	*Cyber Physical Systems*
CPPS	*Cyber Physical Production Systems*
DCSs	*Distributed Control System*
HMI	*Human machine interface*
PLC	*Programmable Logic Controller*
I40	*Industry 4.0*
LED	*Light Emitting Diode*
IDE	*Integrated Development Environement*
I/O	*Input/Ouput*
IOT	*Internet of Things*
IIOT	*Industrial Internet of Things*
IT	*Information technology*
IPS	*intrusion prevention system*
ICSs	*Industrial control systems*
M2M	*Machine to machine*
OT	*Operational technology*

SM *Smart Manufacturing*

SCADA *Supervisory control and data acquisition*

SM *Smart manufacturing*

SOCs *Security operations centers*

UART *Universal asynchronous receiver-transmitter*

General introduction

General introduction

Industrial controls, and in particular, Programmable Logic controllers (PLC) presently shape a crucial technological foundation for the automation of industrial processes. Even with inside the age of industry 4.0 and commercial internet, it is able to be assumed that those controllers will remain required to a sizable volume for the manufacturing of tomorrow. When it involves programmable common-sense controller (PLC) tasks and PLC connectivity solutions, it's not unusual place for structures integrator to create custom solutions.

Industrial production is today driven by world competition and therefore the would like for quick adaptation of production to the ever-changing market requests. These necessities will be met solely by radical advances in current producing technology. Industry 4.0 could be a promising approach supported integration of industrial internet of Things (IIoT) to the industrial production systems. The industry 4.0 is thus based on the connections of Cyber-Physical Systems (CPS) building blocks. These blocks are embedded systems with decentralised management and advanced property that are grouping and exchanging real time information with the goal of identifying, tracking, monitoring and optimizing the assembly processes.

The development of a platform that gives open communication is fundamentally necessary for the advancement in keeping with the new technological reality. Enable any device to communicate seamlessly clear by proprietary protocols is crucial to realize an extremely integrated management surroundings that may be enforced unimpeded from the communicative perspective of the system.

Our work consists in Enabling PLC control via several communication methods in the remote-control systems. In addition to the possibility to communicate with other devices by developing advanced applications. Applications of mobile phone and interfaces using portable computer communication with PLC are established via wireless, serial port and Bluetooth communication methods that will be compliant with the requirements of Industry 4.0.

Our connectivity solution will answer globally to the same requirements expected for a classical remote-control system.

Our work is organized into two chapters:

Chapter I: represents a global view on the pillars of industry 4.0 with the IOT and IIOT and why should industries go for the IIOT and smart manufacturing.

Chapter II: we will discuss the most PLC's monitoring and connectivity solutions to have a general idea on how reliable that can be.

Finally, we will end this thesis with a general conclusion.

Chapter I

Industry 4.0

I.1 Introduction

Industry 4.0 refers to the intelligent networking of machines and processes for industry with the assistance of knowledge and communication technology (Platform Industry 4.0). It is a vision that evolved from an initiative to make the German manufacturing industry more competitive (‘Industry 4.0’) to a globally adopted term.

Industry 4.0 is used synonymously with the fourth industrial revolution and represents a new stage in the organization and control of the industrial value chain.

Cyber-physical systems form the basis of industry 4.0 (e.g., ‘smart machines’). They use modern control systems, have embedded package systems and dispose of a web address to attach and be self-addressed via IoT (the internet of Things). In this way, products and means of production are networked and can ”communicate”, which enables new forms of production, value creation and optimization in real time.

Cyber-physical systems create the capabilities required for smart factories. These are a similar capability we all know from the industrial internet of Things like remote monitoring or track and trace, to mention two. Industry 4.0 is often used interchangeably with the notion of the fourth industrial revolution. It is characterized by, among others,

- Even more automation than in the third industrial revolution.
- The bridging of the physical and digital world through cyber-physical systems, enabled by Industrial IoT.
- A shift from a central industrial control system to one wherever smart product define the production steps.
- Closed-loop information models and control systems, and personalization/customization of products.

The aim is to enable autonomous decision-making processes through early stakeholder engagement and vertical and horizontal integration, to monitor assets and processes in real time and to enable connected value creation networks in real time.



Figure I.1: Industry 4.0.[14]

I.2 Pillars of Industry 4.0

Industry 4.0 describes a future state of industry characterized by thorough digitization of economic and production flows. It needs horizontal combination at each step within the production process, in action with machines. within the globally interconnected world of industry 4.0, machines conjointly interact with one another.

- **Decentralization:** The first principle, decentralization, is known in industry 4.0 as the greater ability of local companies and specific operations, still as those applied by machines, to create their own decisions on their own. instead of using central computers or passing a decision hierarchically, enabling and permitting local operators to reply to modifications and readjust, this principle provides more flexibility and makes it easier to use expertise. this can be perceived as a decomposition of the classical production hierarchy for the change of companies as decentralized self-organizations. However, the principle of decentralization cannot be observed just for machines, because it refers to the autonomy granted to individuals as collaborators in industry 4.0. they have bigger freedom to spot aspects, analyze parameters, and carry out decision-making whenever necessary, aiming at the common good for their space of activity within the industry still as for its fullness.
- **Virtualization:** The principle of virtualization is that by using machine-to-machine (M2M) monitoring and communication, a virtual twin may be abstracted from the industry. The sensor data is connected to virtual plant models and simulation models. so, a virtual copy of the physical world can be created. just in case of failure, an employee can be notified. In addition, all necessary information, such as next work steps or security provisions, remains available. The virtualization in industry 4.0 is employed by individuals as extremely potential tools to aid human work. This principle streamlines the time, analysis, and decision-making of workers and established groups by providing, sharing, and synthesizing data virtually, quickly, and in real time.
- **Interoperability:** The principle of interoperability within the industry 4.0 manufacturing environment is that cyber-physical system (CPS) includes intelligent machines and intelligent storage systems and facilities capable of autonomously exchanging information, initiating actions, and controlling one another independently. The embedded manufacturing systems are vertically connected with business processes internal to industries, and horizontally, with the value chain, by connecting software package and programs. The interoperability is additionally linked to the work performed with H2M interaction, consisting also in the ability of individuals to work harmoniously with the machines, so that the committed effort is completed in sync in all industrial activities.
- **Modularity:** The principle of modularity involves modular systems that may flexibly adapt to dynamic needs by replacing or increasing individual production modules, creating adding or removing modules much easier. These modular systems can therefore merely be adjusted just in case of seasonal fluctuations or changes in product production needs, as within the case of including new technologies. Thus, production can continuously adjust to environmental, systemic, and changing client demands without error, lost productivity, or customer dissatisfaction.

- **Real-time capability:** To outline the principle of real-time capability, within the manufacturing process, intelligent machines with specific software system will automatically adapt to the process and decision-making by CPS to the productive needs, therefore monitoring the product quality in order to create choices at each moment of need. This interconnection will minimize misuse of resources, waste, material waste, and increase energy efficiency. The real-time capability principle is one in all the foremost outstanding aspects of industry 4.0 because it is responsible for guaranteeing that the industry has the most effective attainable response time to internal and external stimuli by sharing, receiving, and analyzing data and information in real time.

- **Service orientation:** The principle of service orientation, is characterized by the availability, through the Internet, of human, business services, and CPS, which might be employed by alternative stakeholders, facilitating the creation of product-service systems (PSS), additionally called product-service. they will be offered internally to and outside the organization. during this way, industry 4.0 preserves its network performance in partnerships with all its stakeholders, whether customers, partner industries, and suppliers, among several others. everybody can have access to helpful services, products, and information regarding the industry always using virtual and digital platforms accessible.[7]

Other groups such as The Boston Consulting Group have identified three other attributes as Industry 4.0 technological pillars:

- **Autonomous robots:** Long used to accomplish complex tasks, robots offer an ever-widening range of services and are becoming more autonomous, flexible, and collaborative. They interact with each other and safely work with humans (the term ”robotics” is used to describe robots that help operators complete their tasks). Eventually they will be able to learn from humans.

- **Cybersecurity:** The days of closed, unconnected operational management systems are over. property and communication protocols have become the norm. protective data systems and manufacturing lines from cybercrime threats is becoming a crucial issue. subtle identity and machine access management systems are going to be used to offer secure, reliable communications.

- **The Industrial Internet of Things:** Few machines are presently fitted with sensors and interconnected. With the industrial internet of Things, an ever-larger variety of products will incorporate intelligence and be connected using standard protocols. this will decentralize analytics and decision-making, enabling real-time responses.[11]

I.3 The Internet of Things (IOT)

The internet of things, or IoT, is a system of interconnected computing devices, mechanical and digital machines, objects, animals, or people that are provided with unique identifiers (UIDs)

and the ability to transfer data over a network while not requiring human-to-human or human-to-computer interaction.

Increasingly, organizations in a variety of industries are using IoT to control more efficiently, better understand clients to deliver enhanced customer service, improve decision-making and increase the worth of the business.[3]

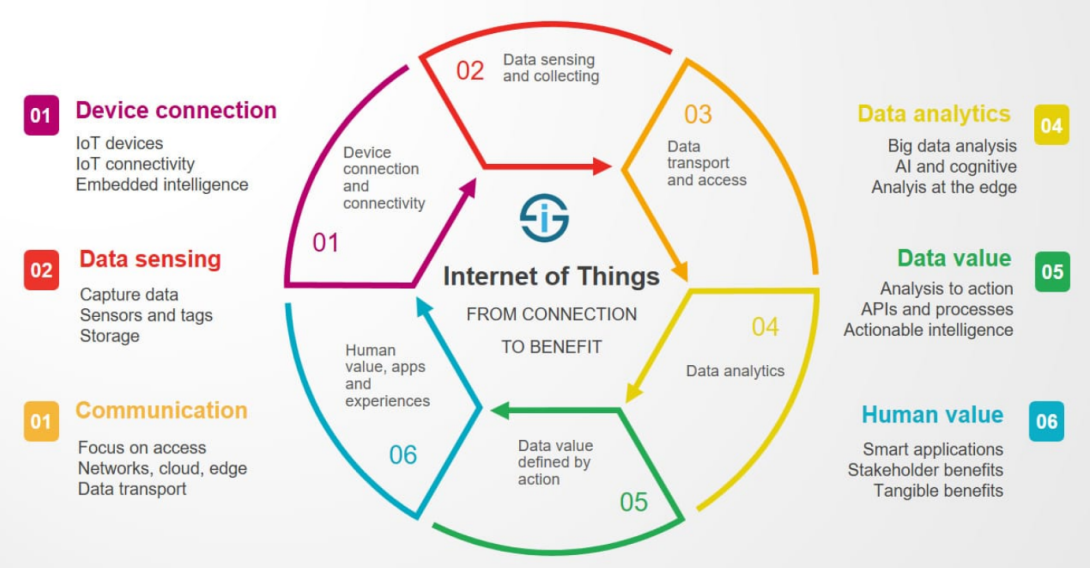


Figure I.2: IoT : From connecting devices to human value.[6]

I.3.1 How does IoT works?

An IoT system consists of web-enabled smart devices that use embedded systems, like processors, detectors, and communication hardware, to collect, send and act on information they acquire from their environments. IoT devices share the sensor data they collect by connecting to an IoT gateway or other edge device wherever data is either sent to the cloud to be analyzed or analyzed locally. Sometimes, these devices communicate with other related devices and act on the data they get from one another. The devices do most of the work without human intervention, although people will interact with the devices – for instance, to line them up, provide them instructions or access the data.

IoT can also make use of artificial intelligence (AI) and machine learning to aid in making data collecting processes easier and more dynamic.[3]

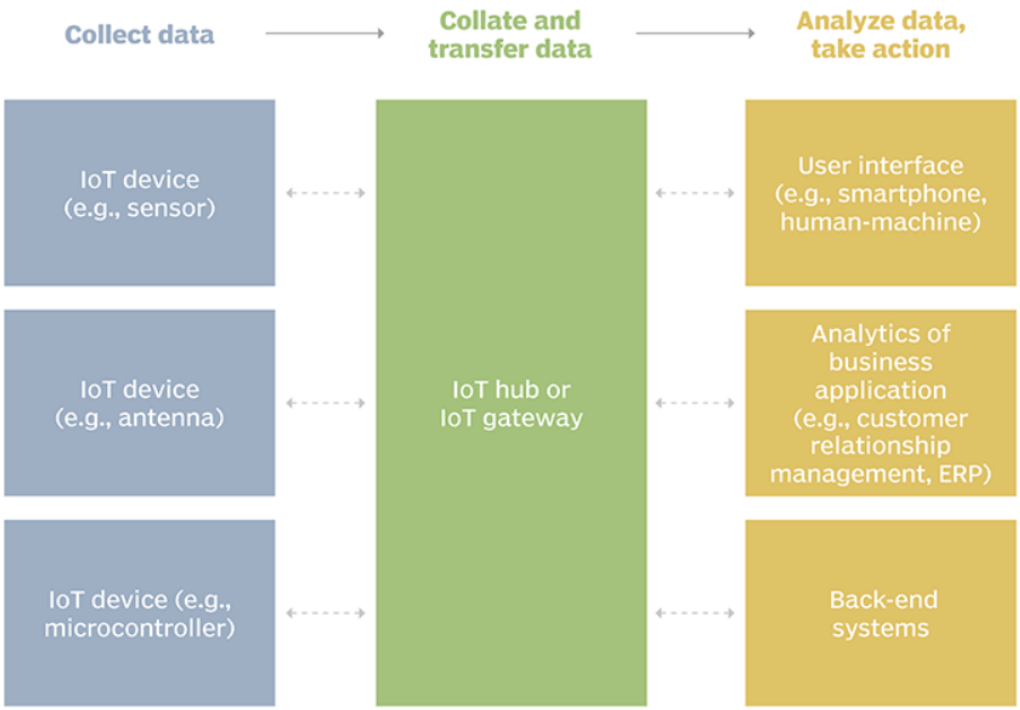


Figure I.3: Example of an IoT system.[3]

I.3.2 Benefits of IoT to organizations

The internet of things offers many advantages to organizations. Some benefits are industry-specific, and a few are applicable across multiple industries. several the common benefits of IoT enable businesses to:

- Monitor their overall business processes.
- Improve the client experience (CX).
- Save time and money.
- Enhance employee productivity.
- Integrate and adapt business models.
- Build better business decisions and generate more revenue.[3]

I.3.3 IoT standards and frameworks

The Hardware components of a PLC include the following:

- **IPv6** over Low-Power Wireless Personal Space Networks (6LoWPAN) is an open standard outlined by the internet Engineering Task Force (IETF). The 6LoWPAN standard allows any low-power radio to communicate to the internet, as well as 804.15.4, Bluetooth Low Energy (BLE) and Z-Wave (for home automation).

- **ZigBee** is a low-power, low-data rate wireless network used especially in industrial settings. ZigBee is primarily based totally on the Institute of Electrical and Electronics Engineers (IEEE) 802.15.4 standard. The ZigBee Alliance created Dotdot, the universal language for IoT that allows smart objects to work securely on any network and understand each other.

- **LiteOS** is a Unix-like operating system (OS) for wireless sensor networks. LiteOS supports smartphones, wearables, intelligent manufacturing applications, smart homes and the Litters internet of vehicles (IoV). The OS also is a smart device development platform.

- **OneM2M** is a machine-to-machine service layer that may be embedded in computer code and hardware to connect devices. the worldwide standardization body, OneM2M, was created to develop reusable standards to enable IoT applications across totally different verticals to communicate.

- **Data Distribution Service (DDS)** was developed by the Object Management Group (OMG) and is an IoT standard for real-time, scalable and high-performance M2M communication.

- **Advanced Message Queuing Protocol (AMQP)** is an open source published standard for asynchronous electronic messaging by wire. AMQP allows encrypted and interoperable messaging between organizations and applications. The protocol is employed in client-server messaging and in IoT device management.

- **Constrained Application Protocol (CoAP)** is a protocol that specifies however low-power, compute-constrained devices can operate in the internet of things.

- **Long Range Wide Area Network (LoRaWAN)** is a protocol for WANs designed to support huge networks, such as smart cities, with millions of low-power devices.[3]

IoT frameworks include the following:

- **Amazon web Services (AWS) IoT** is a cloud computing platform for IoT released by Amazon. This framework is meant to enable smart devices to simply connect and firmly interact with the AWS cloud and different connected devices.

- **Arm Mbed IoT** is a platform to develop apps for IoT based on Arm microcontrollers. The goal of the Arm Mbed IoT platform is to produce a scalable, connected and secure environment for IoT devices by integration of Mbed tools and services.

- **Microsoft Azure IoT Suite** is a platform that consists of a collection of services that allows users to interact with and receive information from their IoT devices, moreover as perform numerous operations over data, such as multidimensional analysis, transformation and aggregation, and visualize those operations in an exceedingly way that's suitable for business.

- **Google Brillo/Weave** is a platform for the fast implementation of IoT applications. The platform consists of two main backbones: Brillo, an Android-based OS for the development of embedded low-power devices, and Weave, an IoT-oriented communication protocol that serves as the communication language between the device and the cloud.
- **Calvin** is an open source IoT platform released by Ericsson designed for building and managing distributed applications that enable devices to talk to each other. Calvin includes a development framework for application developers, moreover as a runtime environment for handling the running application.[3]

I.4 Industrial Internet of things (IIOT)

The extension and usage of the internet of things (IoT) in industrial sectors and applications is referred to as IIoT. The IIoT helps industries and companies to improve their efficiency and dependability in their operations by focusing on M2M[1] connectivity, big data, and machine learning. The Industrial Internet of Things includes robots, medical gadgets, and software-defined manufacturing processes.

The IIoT goes beyond the traditional consumer devices and inter-networking of physical devices sometimes related to the IoT. What makes it distinct is that the intersection of IT[2] & OT[3]. OT refers to the networking of operational processes and ICSs[4], together with HMI[5], SCADA[6] systems, DCSs[7], and programmable logic controllers (PLCs).

The convergence of IT and OT provides industries with bigger system integration in terms of automation and optimization, also as higher visibility of the supply chain and logistics. The monitoring and control of physical infrastructures in industrial operations, like in agriculture, healthcare, manufacturing, transportation, and utilities, are created easier through the utilization of smart sensors and actuators as well as remote access and control.

The IIOT[8] is critical to how cyber-physical systems and production processes are expected to reconfigure with the assistance of big data and analytic as part of the fourth industrial revolution, called industry 4.0. Real-time data from sensors and other data sources aids industrial equipment and infrastructures in ”decision-making,” resulting insights and actions. Machines are now better equipped to do and automate jobs that past industrial revolutions could not. In a larger sense, the IIOT is critical for use cases involving networked ecosystems or surroundings, such as how cities and factories become smart cities and smart factories.

The consistent capturing and transmission of data among smart devices and machines give industries and enterprises with several growth opportunities. the data permits industries and

[1] *Machine to machine*
[2] *Information technology*
[3] *Operational technology*
[4] *Industrial control systems*
[5] *Human machine interface*
[6] *Supervisory control and data acquisition*
[7] *Distributed Control System*
[8] *Industrial Internet of Things*

enterprises to choose up on errors or inefficiencies within the supply chain, for example, and straightaway address them, so pushing for day-after-day potency in operations and finance. proper integration of the IIoT also can optimize the employment of assets, predict points of failure, and even trigger maintenance processes autonomously.

By adopting connected and smart devices, businesses are enabled to assemble and analyze larger amounts of data at greater speeds. Not solely can this enhance scalability and performance; however, it may bridge the gap between the production floors and general offices. Integration of the IIoT can offer industrial entities a lot of accurate read of however their operations are moving on and help them build wise business decisions.[5]

I.4.1 What are the risks of IIOT?

Many of the IIoT's security challenges originate from a lack of fundamental security controls in place. Exposure of ports, poor authentication processes, and outdated apps all lead to the introduction of hazards. When you combine these factors with the network being directly connected to the internet, you have a lot of potential problems.

Businesses may have become used to the potential financial consequences of IT system failure due to cybercrime or malware infestation. The integration of IT and OT, on the other hand, offers a completely new important risk factor: real-world risks that might affect even civilians.

Unsecure IIoT systems will interrupt operations and result in financial losses, among other serious effects. There are additional security vulnerabilities in more linked environments, such as:

- Vulnerabilities in software that can be used to attack systems.
- Internet-connected gadgets and systems that are publicly searchable.
- Hacking, targeted attacks, and data breaches are all examples of malicious activities.
- Manipulation of systems that can interrupt operations (e.g., product recalls) or sabotage processes (e.g., production line stoppage).
- System failure that could result in device and physical facility damage, as well as injury to operators or persons nearby.
- As a result of the IT environment, OT systems are being held for extortion.

The December 2015 cyber-attacks against a power grid in Ukraine, where the attacker was able to infiltrate the IT infrastructure and shut down crucial systems, disrupting power to thousands of families, is a well-known example of an OT system attacked through the IT environment.[5]

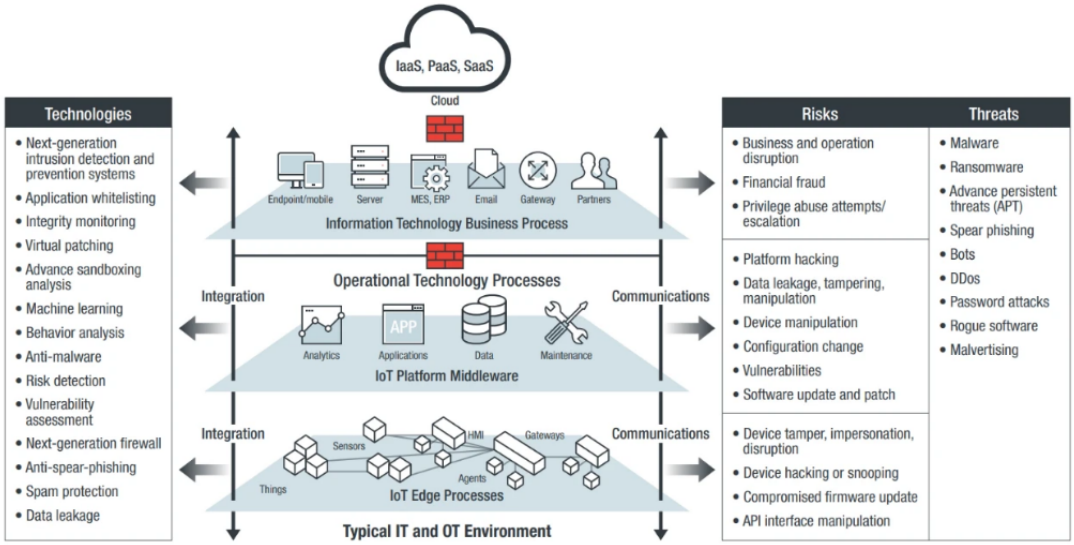


Figure I.4: Basic security reference architecture in the new IT/OT environment.[5]

I.4.2 How should industries and enterprises go about securing the IIOT?

A security operations center is essential for proactively monitoring and defending against the diverse threats that threaten networked settings. This centralized unit allows industries and businesses to keep track of the large number of notifications they may receive and respond quickly. SOCs[9] are particularly useful for facilities that require increased visibility and ongoing security analysis. The purpose of SOC teams is to detect security problems or any unusual activity and be able to respond quickly before a compromise occurs. This method tackles the problems that legacy systems, low system visibility, and slow reaction times might cause. Alerts will be prioritized and threat correlation will be improved with the help of a SOC.

- In the event of malware infection, regular monitoring and detection are required.
- Improved threat visibility and anomaly detection.
- Proactive threat and attack prevention between IT and OT.
- Data transport is encrypted.
- A next-generation IPS[10] to prevent assaults from exploiting vulnerabilities.
- Server and application security in the data center and cloud.[5]

[9] *Security operations centers*
[10] *intrusion prevention system*

I.5 Smart manufacturing

SM[11] is defined as fully-integrated, collaborative manufacturing systems that respond in real time to changing demands and conditions in the smart factory, supply network, and customer requirements.[2]

Smart manufacturing, also known as Industry 4.0 or industrial IoT, enables manufacturers to maximize the yield from existing production capabilities while also developing the next generation of production capabilities required to compete in a digital economy.

SM systems, for example, may be able to autonomously order extra raw materials as inventories run low, shift other equipment to production jobs as needed to finish orders, and arrange distribution networks after orders are completed.

The perspective at opportunities to establish and promote standards with diverse industry players, including technology businesses and manufacturers. The procedure is still in progress. Other difficulties include the high expense of widely deploying sensors and the complexity of constructing predictive algorithms.[9]

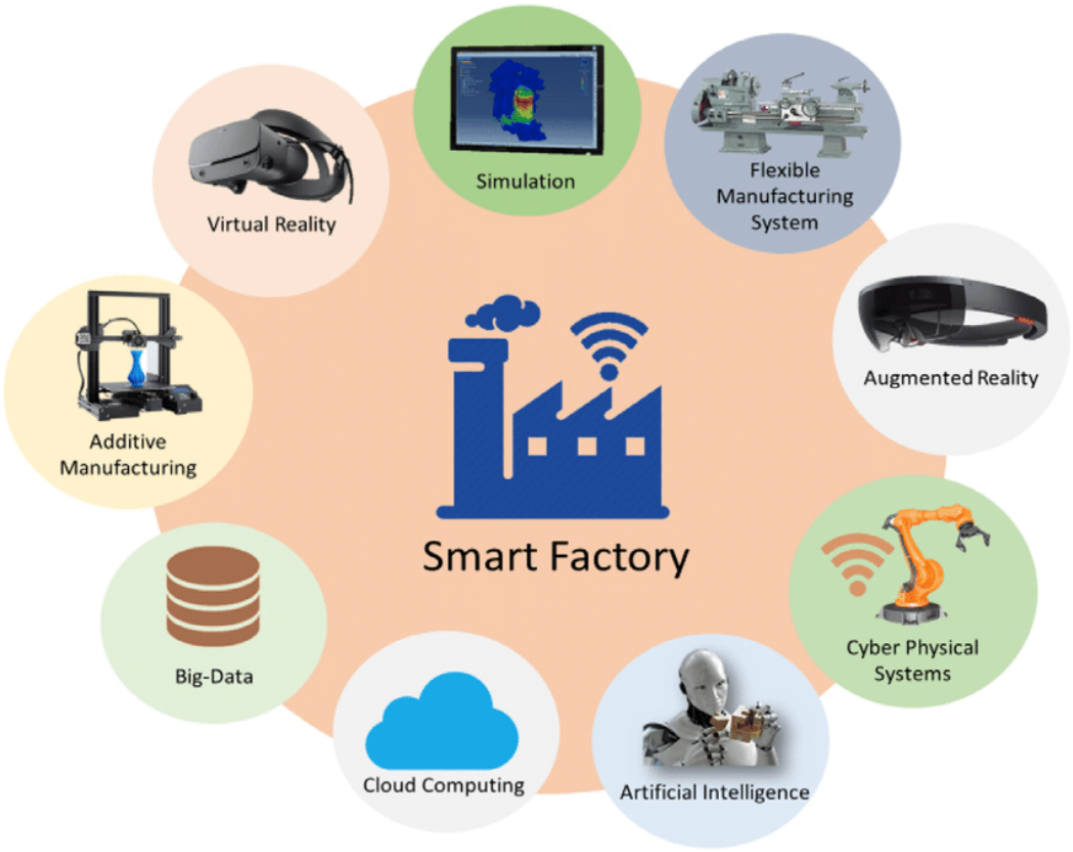


Figure I.5: Components of Smart Manufacturing System.[8]

[11] *Smart manufacturing*

I.5.1 Related technologies

Aside from the Internet of Things, several technologies will help enable smart manufacturing, including:

- **Artificial intelligence (AI)/machine learning** enables automatic decision-making based on the massive amounts of data collected by industrial organizations. AI/machine learning can examine all this data and make intelligent judgments based on it.
- **Drones and driverless vehicles** can boost production by lowering the number of personnel required to perform monotonous operations like moving vehicles around a facility.
- **Blockchain** The benefits of blockchain, such as immutability, traceability, and disintermediation, can provide a quick and effective means to record and store data.
- **Edge computing** enables firms to convert enormous amounts of machine-generated data into usable data in order to obtain insights and improve decision-making. It accomplishes this by utilizing network-connected resources like as alarms or temperature sensors, allowing data analytics to take place at the data source.
- **Predictive analytics** businesses can use massive volumes of data collected from all their data sources to foresee problems and enhance forecasting.
- **Digital twins** Businesses can utilize digital twins to virtualize their processes, networks, and machines, and then use them to foresee problems and increase efficiency and production.[9]

I.5.2 How SM differs from traditional manufacturing approaches

Predictive Traditional manufacturing methods, created during the period of mass production, emphasize economies of scale and equipment use. Companies believed that if a machine was idle, it was losing money, thus they kept it running constantly.

Traditional manufacturing organizations keep huge inventories on hand in order to fulfill possible orders and ensure customer satisfaction. As a result, these firms must keep their machines operating with specified settings for as long as possible in order to lower the expenses of manufacturing the parts. This is known as batch-and-queue processing – a mass production approach to operations in which parts are processed and transferred to the next step, whether they are required, and wait in a line (queue).

However, this strategy is inefficient for a few reasons, including:

- Because nothing is produced while a machine is offline, a longer machine set-up time equals more lost production time.
- The product's quality degrades because if pieces in a batch aren't created correctly, no one will know until the following operation. This means that the job must be redone, which is costly and wastes precious resources.

Smart manufacturing, on the other hand, is a collaborative, fully-integrated production system that adapts in real-time to changing factory circumstances and demands, as well as supplier network and customer needs.

The purpose of smart manufacturing is to optimize the manufacturing process via the use of technology-driven approaches that use Internet-connected gear to monitor the production process. Smart manufacturing helps firms to find potential for automation and to enhance production performance using data analytics.[9]

I.6 Conclusion

In this chapter, we have introduced the pillars of industry 4.0 with the IOT and IIOT, why should industries and enterprises go about securing the IIOT and what are the major risks of IIOT with an Introduced to smart manufacturing.

In the next chapter, we will discuss the most PLC's monitoring solutions to have a general idea on how reliable that can be.

Chapter II

PLC connectivity solutions

II.1 Introduction

PLC controllers, in particular, constitute a crucial technical foundation for the automation of industrial operations. Even in the age of I40[1] and the industrial internet, it is safe to expect that these controllers will continue to play an important role in future manufacturing. However, as a result of the increased manufacturing circumstances, the controllers must meet a number of extra requirements. When Industry 4.0 ideas are used, high-quality networked production systems based on CPS[2], also known as CPPS[3]. The future controllers employed in these systems must meet the pillars of Industry 4.0. Current PLC controllers cannot yet meet the majority of these needs, or can only do so in a simple or highly expensive manner.

II.2 PLC Hardware architecture

The modular PLC is a form of PLC that allows for various expansions of the PLC system by the use of modules, hence the word ”modular”.

Modules provide extra functionality to the programmable logic controller, such as an expanded number of I/O units, and they are often easier to operate because each component is independent of the others.

Starting from that, our PLC hardware architecture is shown below:

[1] *Industry 4.0*
[2] *Cyber Physical Systems*
[3] *Cyber Physical Production Systems*

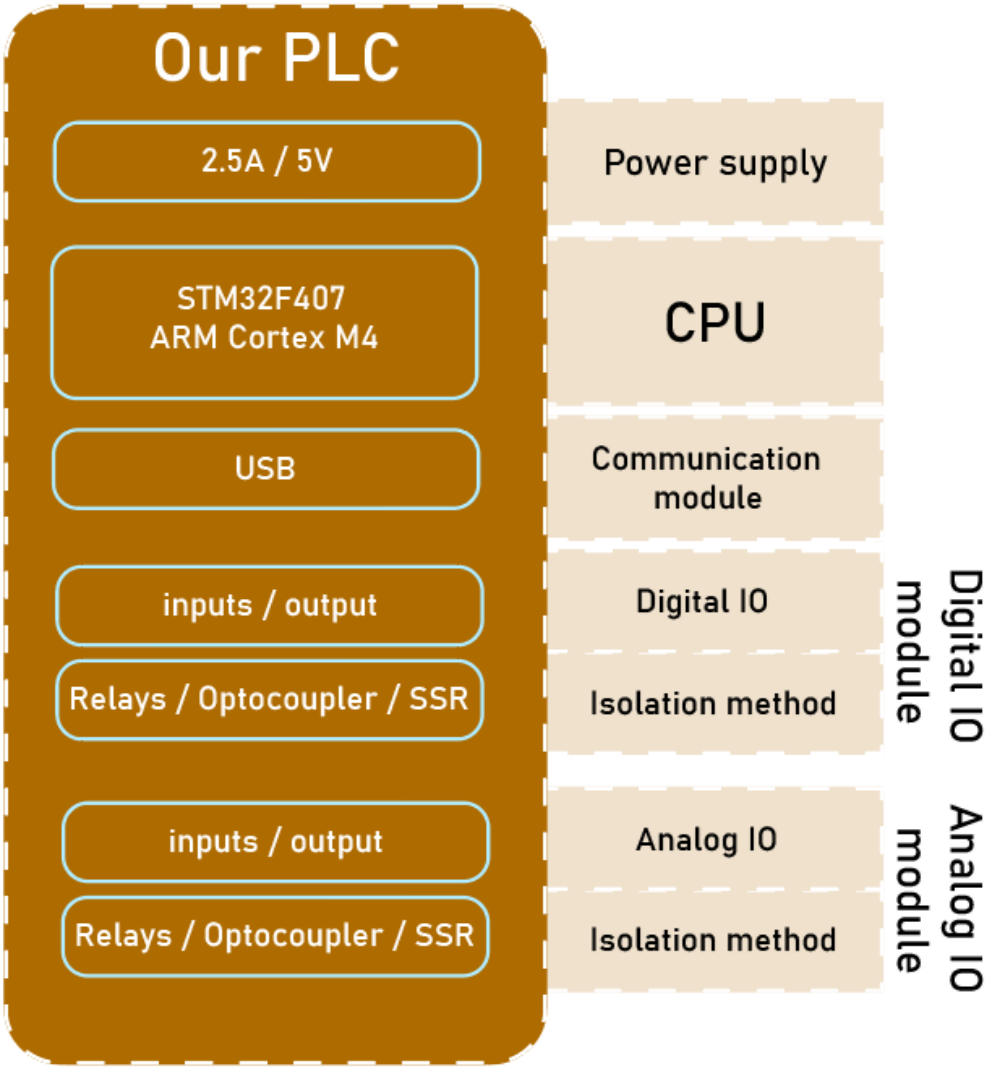


Figure II.1: PLC hardware architecture

II.2.1 Our project's communication module

The main protocols to debug and communicate with our PLC and allow it to communicate with its internal and external slave devices is:

Universal Serial Port (USB)

The most successful serial interface was USB, which had the following characteristics:

- Simplicity and adaptability (plug-and-play)
- Bi-directionality
- Accelerating speeds at a reasonable cost

The STM32 USB hardware and software are compliant with USB1.1 and USB2.0 specifications.

The flash memory of the microcontroller can be programmed through the mini USB port by the STlink interface.

STlink

The ST-LINK/V2 is an in-circuit debugger and programmer for the STM8 and STM32 microcontrollers. The ST-LINK/V2-ISOL features digital isolation between the PC and the target application board. It also withstands voltages of up to 1000 Vrms. [10]

In our case the STlink debugger is integrated in our PLC microcontroller board.

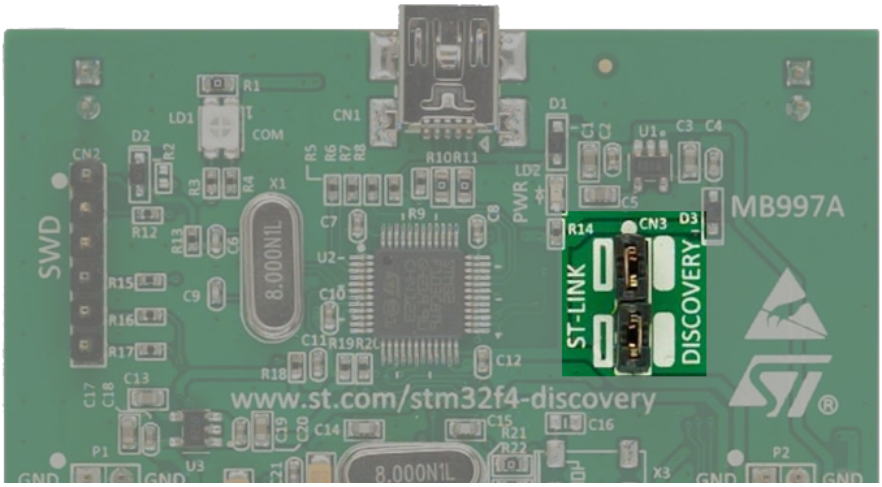


Figure II.2: STlink module.[12]

Device Firmware Update (DFU)

A firmware update will provide your gadget with advanced operational instructions without requiring any hardware upgrades. By updating the firmware, you will be able to explore new features introduced to the device as well as have a better user experience while interacting with it. A firmware update will improve the performance of the CPU by optimizing the performance of the firmware or device driver.

II.2.2 PLC software environment

Our project software architecture is illustrated below:

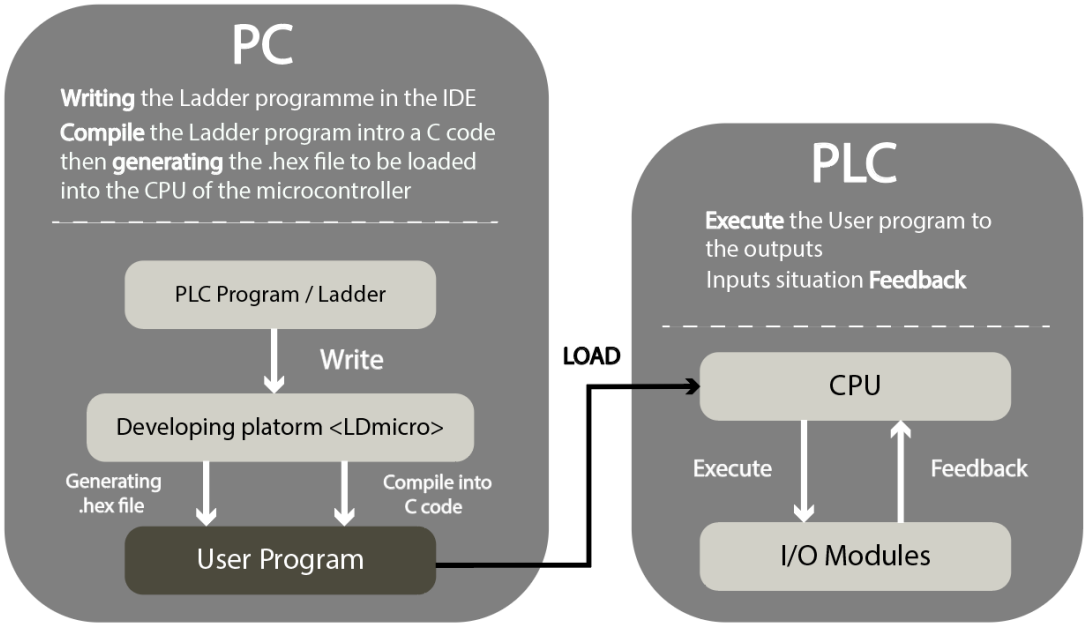


Figure II.3: PLC software architecture

II.2.3 User program

To begin with, the program is written in LADDER language. This later can be saved as LDmicro file (.ld) compatible with other computers containing LDmicro. The LADDER program is compiled into a C code file (.c) and built into a native hexadecimal file (.hex) to be deployed to our PLC's processing unit (CPU).

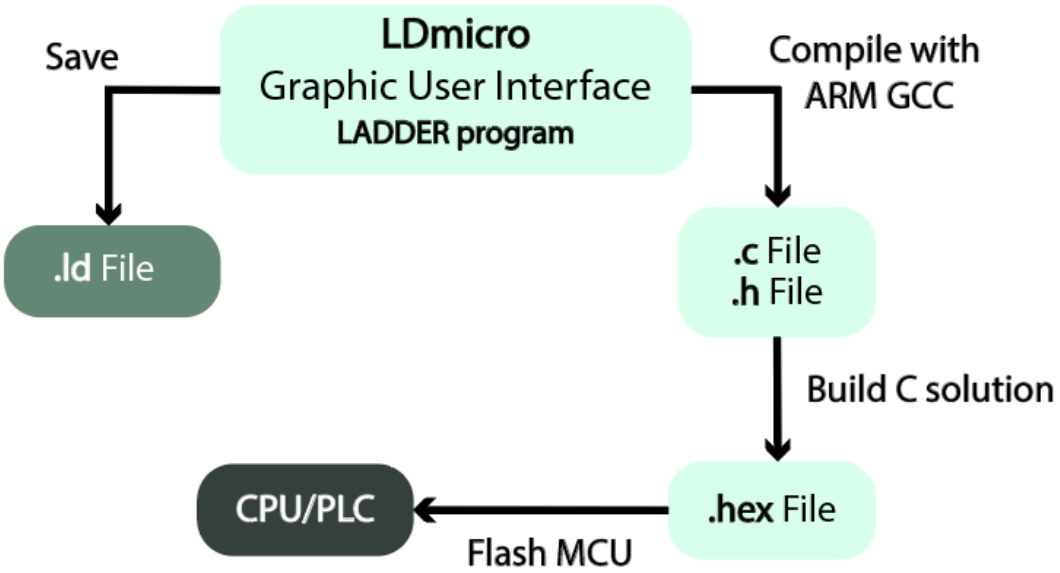


Figure II.4: The LDmicro architecture and deployment process

II.2.4 Integrated Development Environment IDE

In this project we are mainly going to be using the LDmicro developing software.

LDmicro software

Typically, we utilize software that generates programs in C, BASIC, or assembly language to generate code for a microcontroller. The code in this sort of programming is textual (list of instructions).

However, because this approach is problematic with PLCs, LDmicro provides a programming interface in Ladder language.

LDmicro is an application that allows you to create, build, and modify ladder diagrams, as well as simulate and compile ladder diagrams into native hexadecimal firmware code (.hex files) for ARM, Atmel AVR, and Microchip PIC microcontrollers. The program is represented graphically, using relay contacts (input) and coils (output).

The software has its own simulator that operates in real time, allowing us to evaluate the logic of our program before compilation.

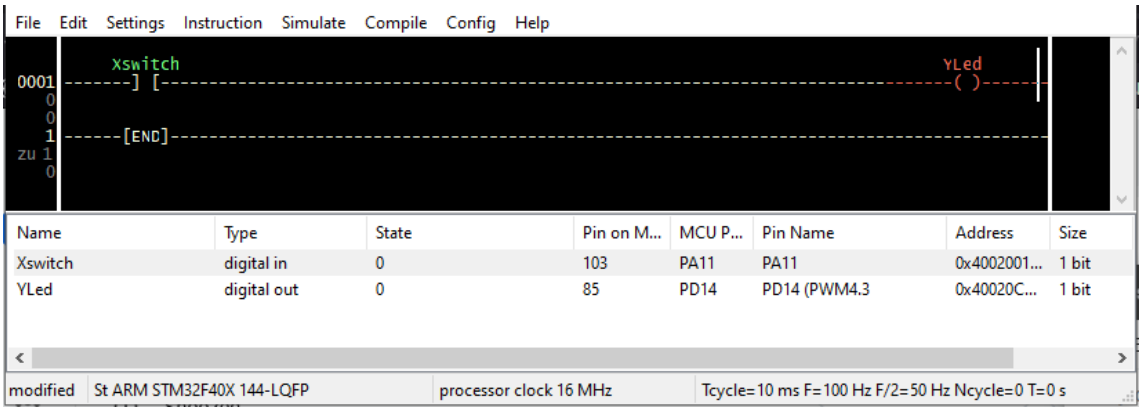


Figure II.5: LDmicro interface

Variable name	Signification
X name	Relay to a microcontroller input pin
Y name	Relay to a microcontroller output pin
R name	Internal relay: one bit in memory
T name	Timer; work time, rest time, or totalizer
C name	Counter or discounter
name	Generic variable (Integer)
A name	An integer read on an A/D converter

Table II.1: Commonly used variables on LDmicro.

Micset

Micset is a FREE ”All in Front” Innovative Technology Software for Powerful Automation with HMI (Human Machine Interface). Appropriate for businesses, scientific organizations, and students. Micset employs SCADA (supervisory control and data acquisition) technologies and an integrated development environment with XEdit Project Editor to create, build, and manage HMI/SCADA IoT applications. Native device connectivity - Device communications are incorporated into XEdit’s ”IDE.”

Micset is compatible with PLC, PIC, ARM, AVR, Raspberry Pi, and STM32 controllers, and it has an HTTP Web server with (User Access) and a User Defined REST Api with parameters for remote reading and writing Scada Resources ”Dataset Fields, Tags, Properties, Values, Topics.” It connects between Scada and devices or web-based applications through Bluetooth Classic, USBSerial, Serial, TCP, MODBUS TCP, MODBUS RTU, HTTP (Rest & xJT), and MQTT.

Micset Uses xLink and xBlock tools for Visual Programing, Binding and debugging. [1]

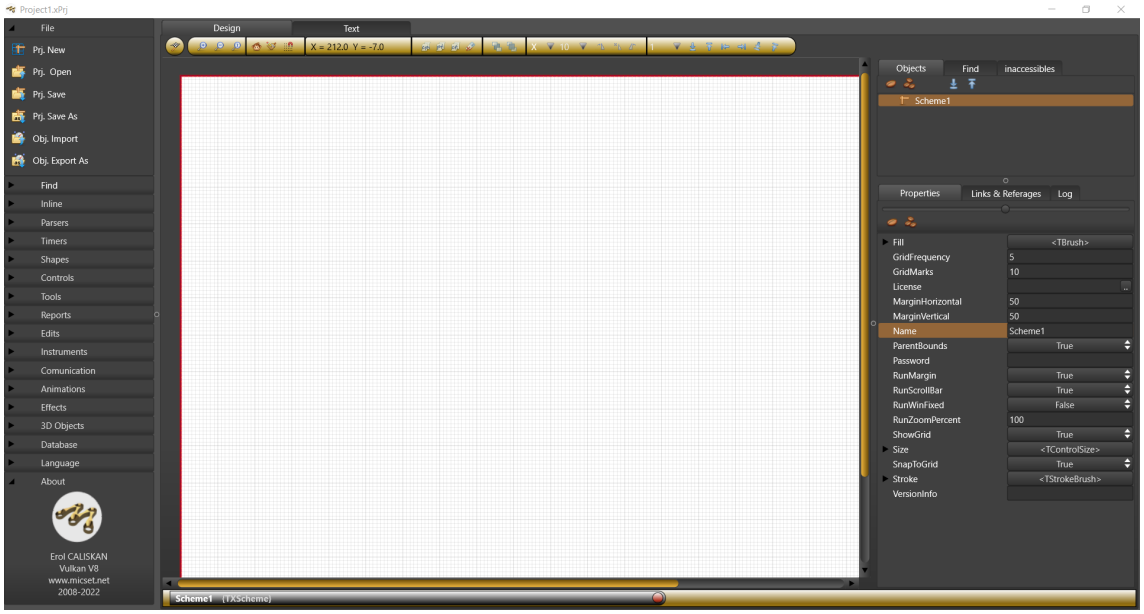


Figure II.6: Micset Interface

Micset software represents a great addition to our project in which will help supervise and control our PLC from long distances.

In order to make it work, we are going to be using Proteus to simulate the communication between a STM32 microcontroller, LDmicro and Micset.

II.3 Our PLC’s connectivity solutions

II.3.1 Serial communication

In this application, we will use two stm32f407 microcontrollers and establish a Master/Slave communication using the UART protocol as it is shown in the figure below:

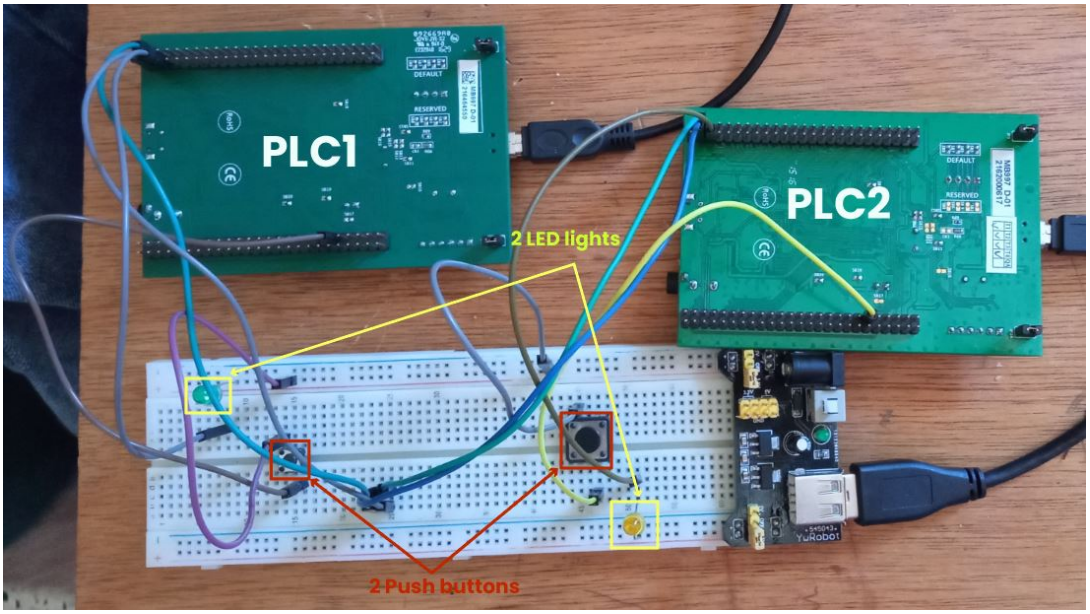


Figure II.7: 2 STM32 serial communication.

LADDER program

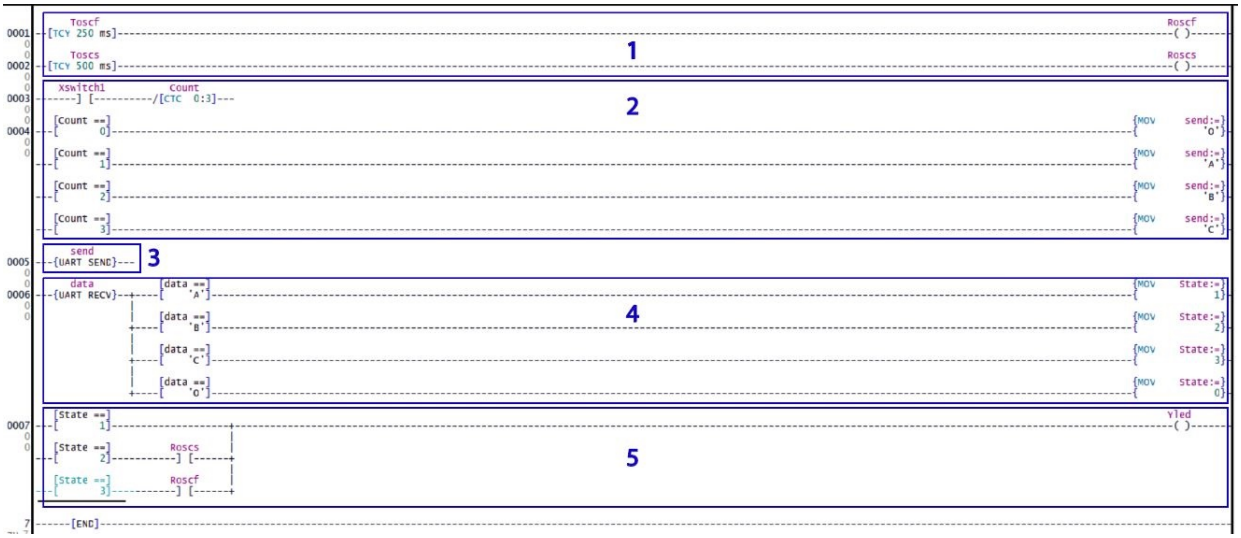


Figure II.8: Serial communication LADDER program.

1. We start of by inserting two **Cyclic Timers** in the first two rungs linked to an internal relay coil for each one of them and with the duration of 500ms for slow blinking and 250ms for fast blinking.

2. Initiate a ’0 to 3’ counter and insert a **Compare for Equal** instructions, each one of them gets a ’0, 1, 2 and 3’ respectively in line with the four **MOV** instructions with their destination values as “send” and the source values as ’O, A, B and C’.

3. Insert a **UART send** instruction with the source variable of “send”. This instruction transmits earlier stored characters in the “send” variable by the **MOV** instructions.

4. Insert a **UART receive** instruction with the destination variable of data then insert four **Compare for Equal** instructions in line with four **MOV** instructions after **UART RECEIVE**. The “data” variable stores the received UART data which is then compared to determine the required state of the LED.

5. Insert three **Compare for Equal** instructions in which each one of them will trigger the LED state based on the received information from the other STM32 microcontroller.

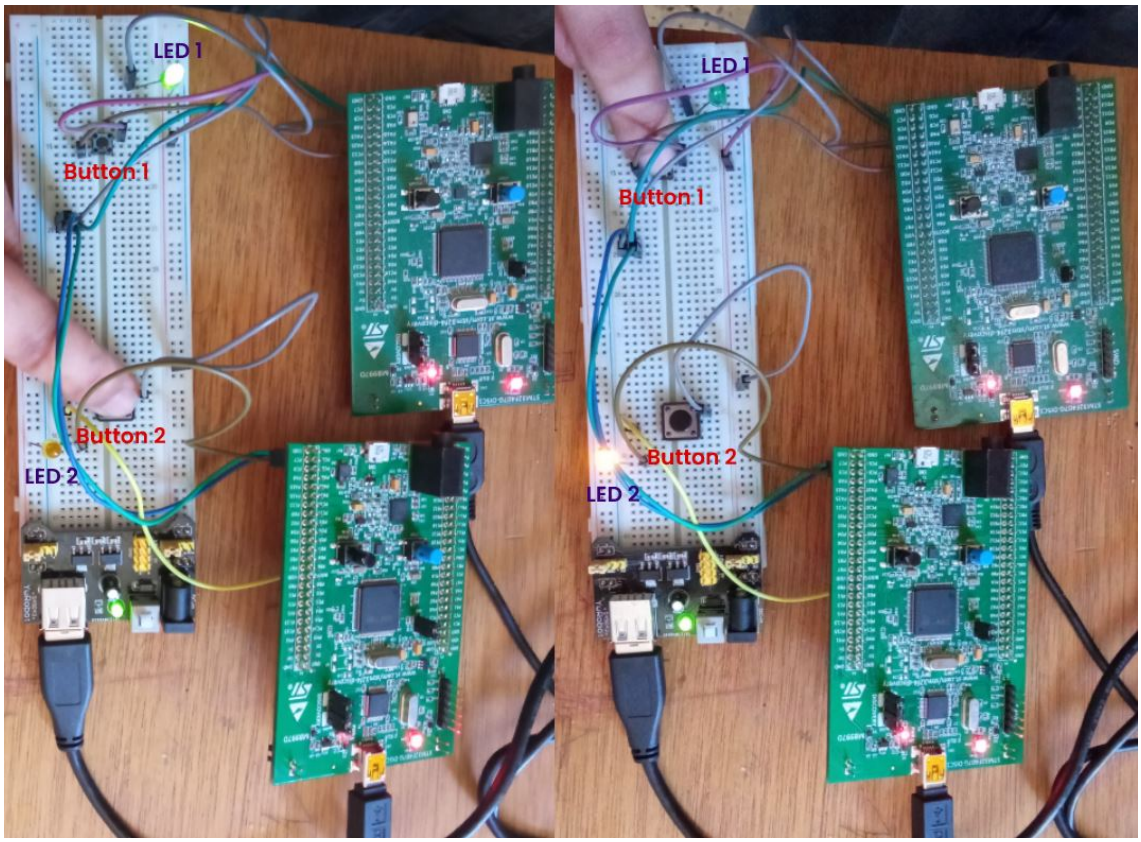


Figure II.9: Serial communication result.

So as a result, if we push on a Button of a PLC, this will send a ’A state’ which will cause the LED of the other PLC to turn on. If we push a second time, the LED will start blinking slowly (State ’B’). Finally, if we push the Button for a third time, the LED will start blinking rapidly (State ’C’). A Fourth push on the button will turn off the LED light.

II.3.2 Wireless communication using Bluetooth

The HC-05 Bluetooth modules are equipped with UART serial communication capability in full-duplex mode. It ships with a default name of HC-05, password of 1234 or 0000, slave data mode, a data baud rate of 9600 and AT Command baud rate of 38400. It has a push-button switch that is used to get into command mode and a LED for status indication.

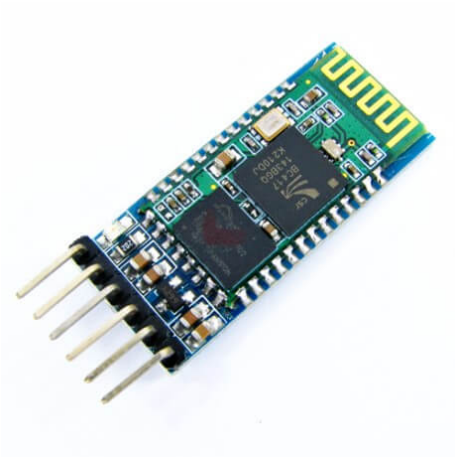


Figure II.10: HC-05 Bluetooth module.[13]

Serial terminal software is required for the configuration of the Bluetooth modules " CoolTerm in our case ". We also need a USB to TTL converter for the configuration. Connect the pins. Hold down the push button switch of the HC-05 module and plug the USB to TTL converter to the USB port of the computer, then release the switch. The LED on the module will start blinking slowly. This is an indication that the HC-05 module is now in AT command mode. Open the CoolTerm application. Click on the "Option" button from the "Tools Bar". Ensure that the correct port is selected. Select a Baud rate of 38400. Click on the "Terminal" Option by the left. Ensure that CR+LF is selected. Select "Local Echo" and click OK. Click on the "Connect" button to establish communication with the Bluetooth module. Type AT and press enter to verify the communication. An OK response provides confirmation.

Here are some commands:

- **AT+NAME?** displays the name of the module.
- **AT+PSWD?** displays the current password.
- **AT+ROLE?** Displays either 0, 1 or 2 where 0 is for slave, 1 is for master and 2 is loopback.
- **AT+CMODE?** displays the connection mode. Where 0 indicates pairing with a specific module and 1 is pairing with any module.
- Type **AT+ADDR?** To retrieve the hardware address of the module.[4]

Bluetooth communication between two PLCs

We need at first to initialize our bluetooth modules as MASTER/SLAVE devices :

- Rename the module with **AT+NAME=SLAVE**.
- Use **AT+PSWD=1234** to change the password if required.
- Set the module as slave with **AT+ROLE=0** if it is not already a slave. The modules by default are slave modules.

- Set the mode as **AT+CMODE =0** to ensure the security of your device.
- Connect the Master module as we did for the slave module.
- Rename it with **AT+NAME=MASTER**.
- Ensure the password is the same as the slave with **AT+PSWD?**.
- Set the role as master with **AT+ROLE=1**.
- Set the connection mode with **AT+CMODE=0**.
- Type **AT+BIND = 98D3,61,F62BD4** type in here the hardware address of the slave module replacing the colons with commas. This ensures that the master and slave are only paired with each other.

Note: This configuration can also be done with Arduino and the IDE terminal.

- Now, Insert the configured master and slave HC-05 modules beside each plc on the breadboard.
- Connect their VCC and GND pins to the positive and negative power rails, respectively.

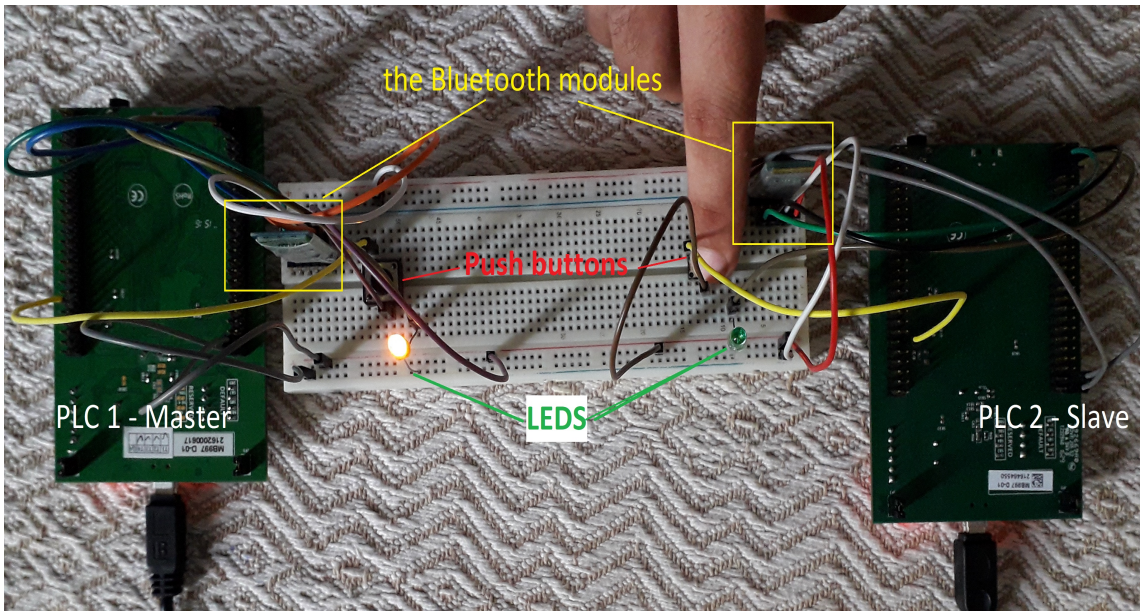


Figure II.11: 2 STM32 Bluetooth communication.

Observe that when the circuit is powered up, the master and the slave modules were initially blinking rapidly in discovery mode. Then, they start blinking twice in about two seconds when they are paired.

PLC and serial Bluetooth terminal application

We can set up the HC-05 module to communicate with a mobile phone. But first, set the slave module to pair with any device with AT+CMODE=0 command in the serial terminal and reconnect it to the PLC.

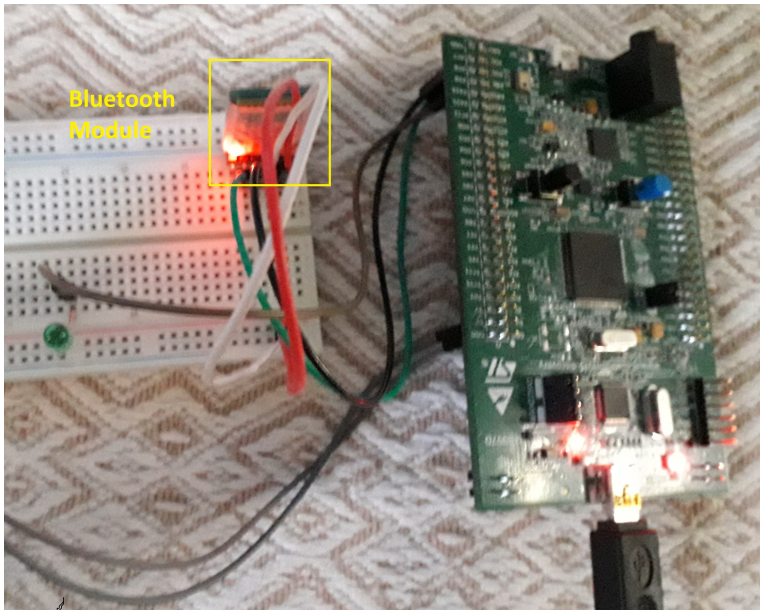


Figure II.12: 2 STM32- Serial Bluetooth terminal communication .

Observe that the LED in the module is blinking fast to indicate it is in discovery mode. To pair the Bluetooth module with your phone, search for slave in the Bluetooth settings of your mobile phone, and pair with a password of “1234” or “0000” as the case may be.

By using “Serial Bluetooth Terminal” android application we will be able to connect to the Bluetooth module. The module LED will start blinking slowly to indicate successful pairing with the phone.

Type capital later “A” to turn on the LED. Sending capital letter “B” will cause the LED to blink slow. Capital letter “C” blinks the LED fast and finally capital letter “O” turns-off the LED.

The feedback response of small letters of “a”, “b”, “c” and “o” were received to confirm the two-way communication.

LADDER program

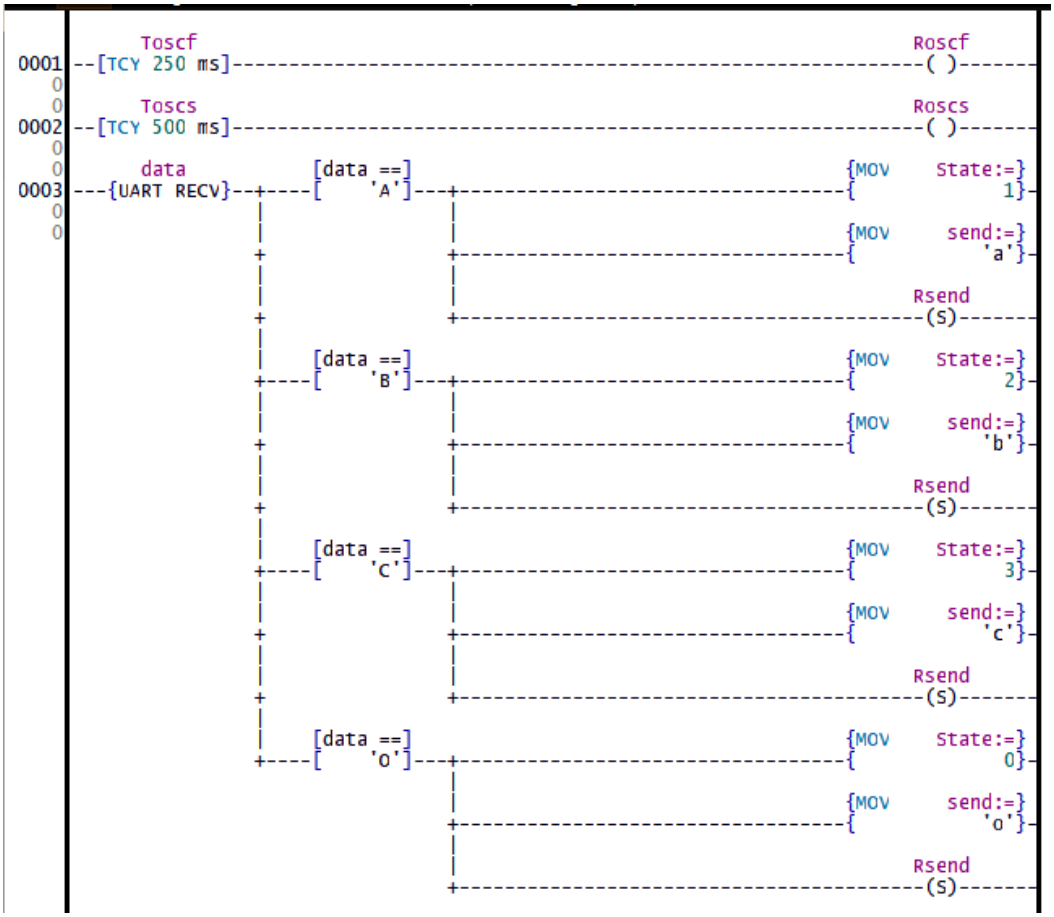


Figure II.13: Bluetooth communication LADDER program.

II.4 Our project monitoring

As mentioned in the upper statements, we will be using the Micset SCADA software to supervise and control digital I/Os through virtual serial port communication between our PLC and HMI then, simulate the results in Proteus software.

Note: this time, we will be using the stm32f401-ve because our mainly focused MCU (stm32f407) package is not yet available in Proteus.

LADDER program

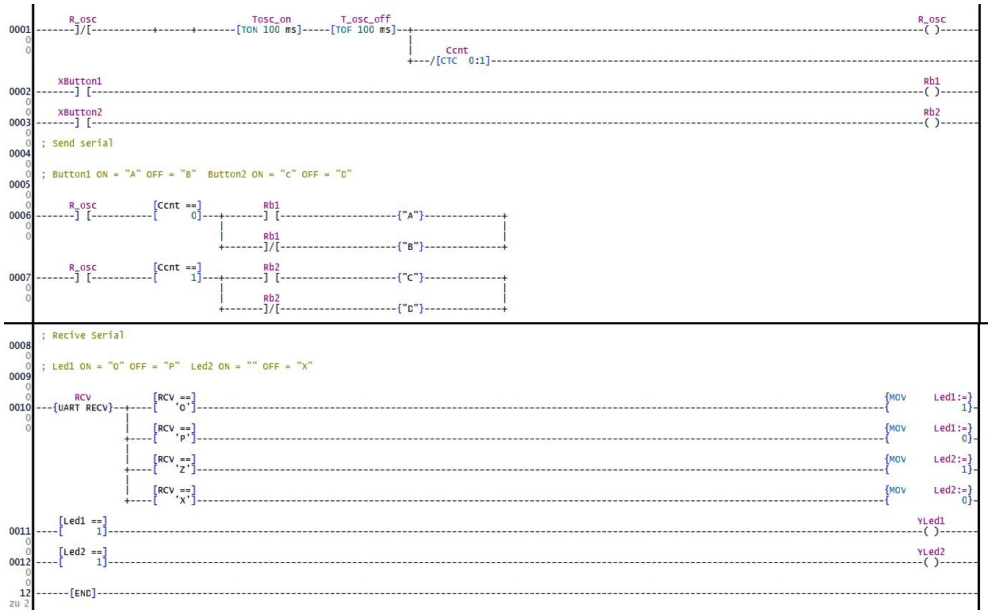


Figure II.14: Digital I/Os test program.

- Rung 1: we begin by including some delay with a circular counter incrementor to refer the used push buttons.
- Rung 2-7: sending serial: letter A and C the buttons 1 and 2 are ON and sending B and D the buttons are off.
- Rung 8- 12: receiving the commands from our interface the letters O and Z to set the LEDs on and P and X to reset them.

Creating our HMI

We start by creating the buttons switches to test the LEDs state and creating the display buttons state and configuring them to test them through Proteus.

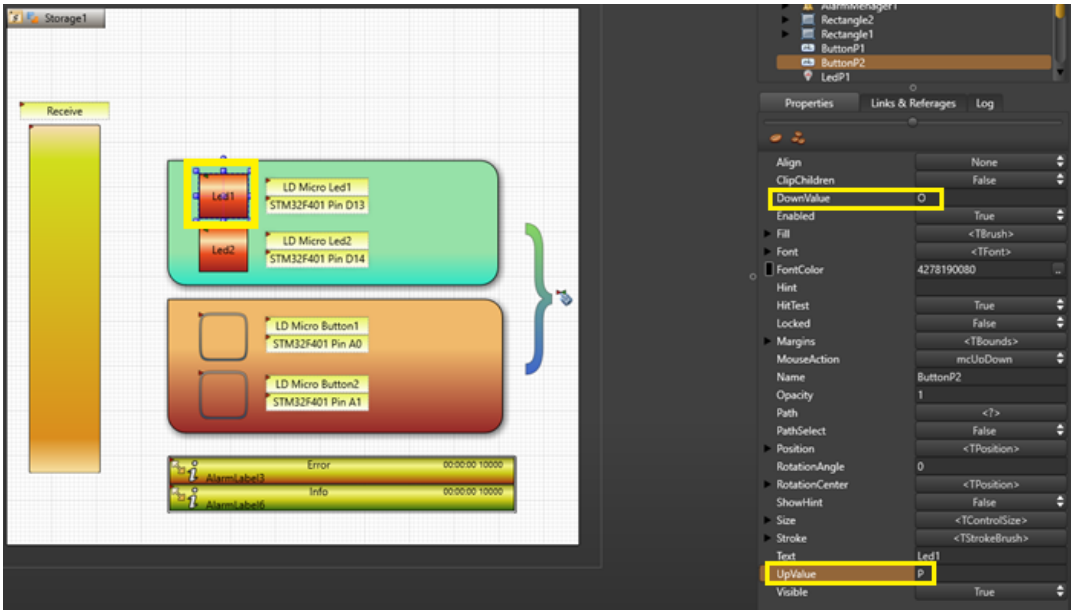


Figure II.15: Buttons configuration.

then, we test buttons functionality with the letters A and B on the Value case in the parameters

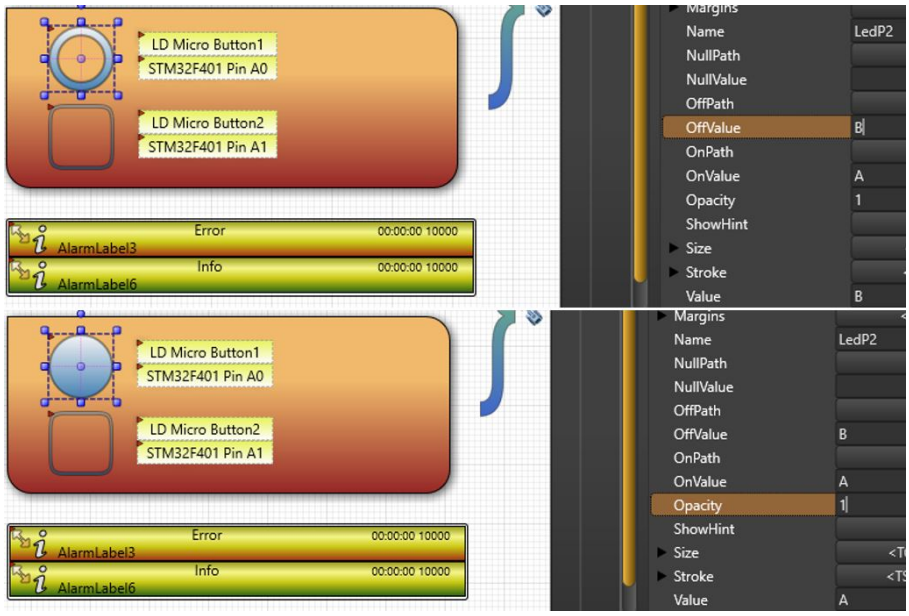


Figure II.16: Testing buttons functionalities values.

Finaly, we set the LEDs buttons and the switches logic into the storage menu and send the commands through the Serial port.

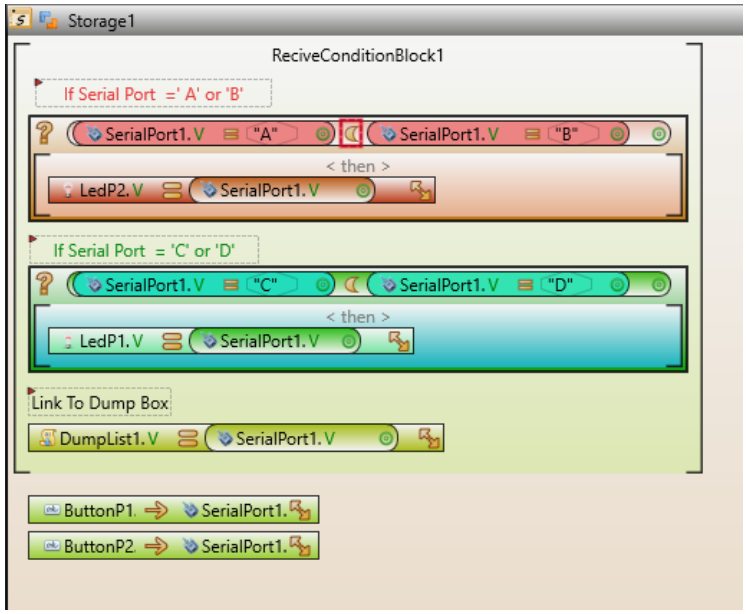


Figure II.17: Initializing the Serial port communication.

Simulation setup

In Proteus, we elaborate our setup as shown in the figure down below:

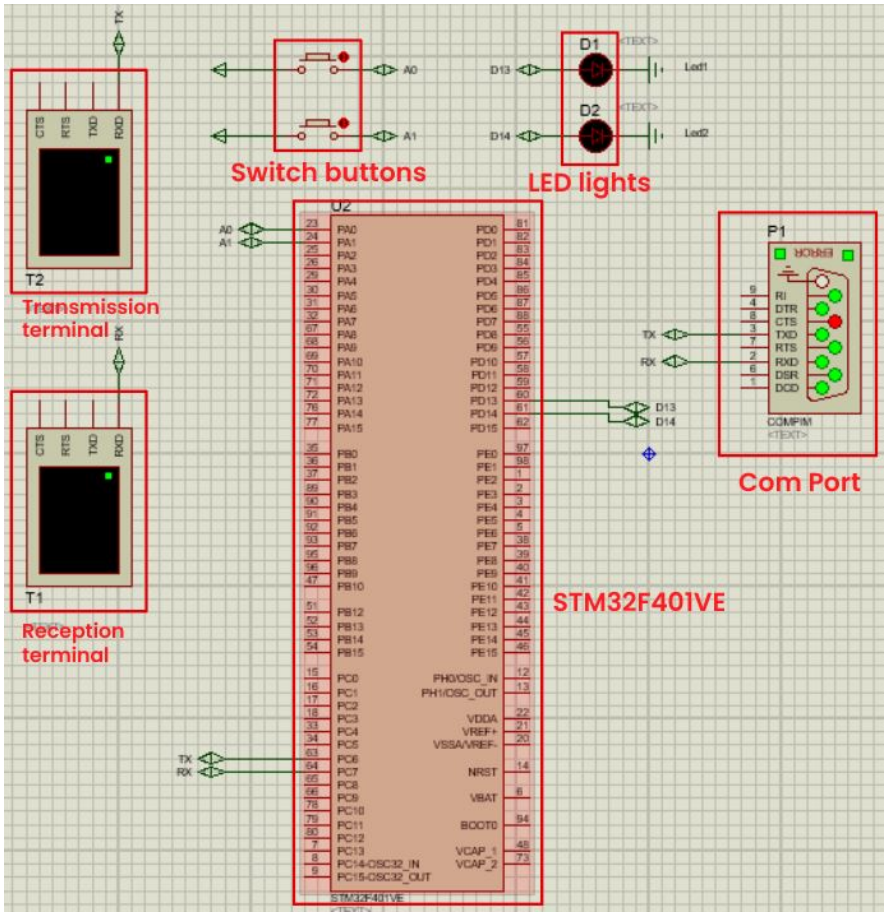


Figure II.18: Application setup.

Results of the Serial Port communication

In the final project part we did insert a new card to the LDmicro software and that because the Ldmicro support only STM32f407 and F405 and F415 from the the STM32F4 family and to the Proteus software doesn't have the STM32f407VGT6 package and has only STM32F401xx and STM32F103xx, thus we took advantage from that and kill two birds with one stone to add a new MCU to the LDmicro software and be able to test its performance via Proteus through Serial Port communication, and for that we did configure the com port in Proteus to a 9600 UART[4] baus rate and make sure to initialise the com pot to COM2 and with a virtual serial port tools we did make a virtual communication between COM1 (the HMI) and COM2.

As a result, if we push on switch button 2 on the Interface will send the letter 'z' and appear on the terminal T1 and we will notice that LED2 turns ON in Proteus simulation, the push buttons are in the normally open state and for that the serial will send 'ACACACA...' periodicly to the Interface indication of the NO state of the buttons.

on the HMI screen, we can see the Proteus push button's state received from Proteus simulation in the receive log in Micset.

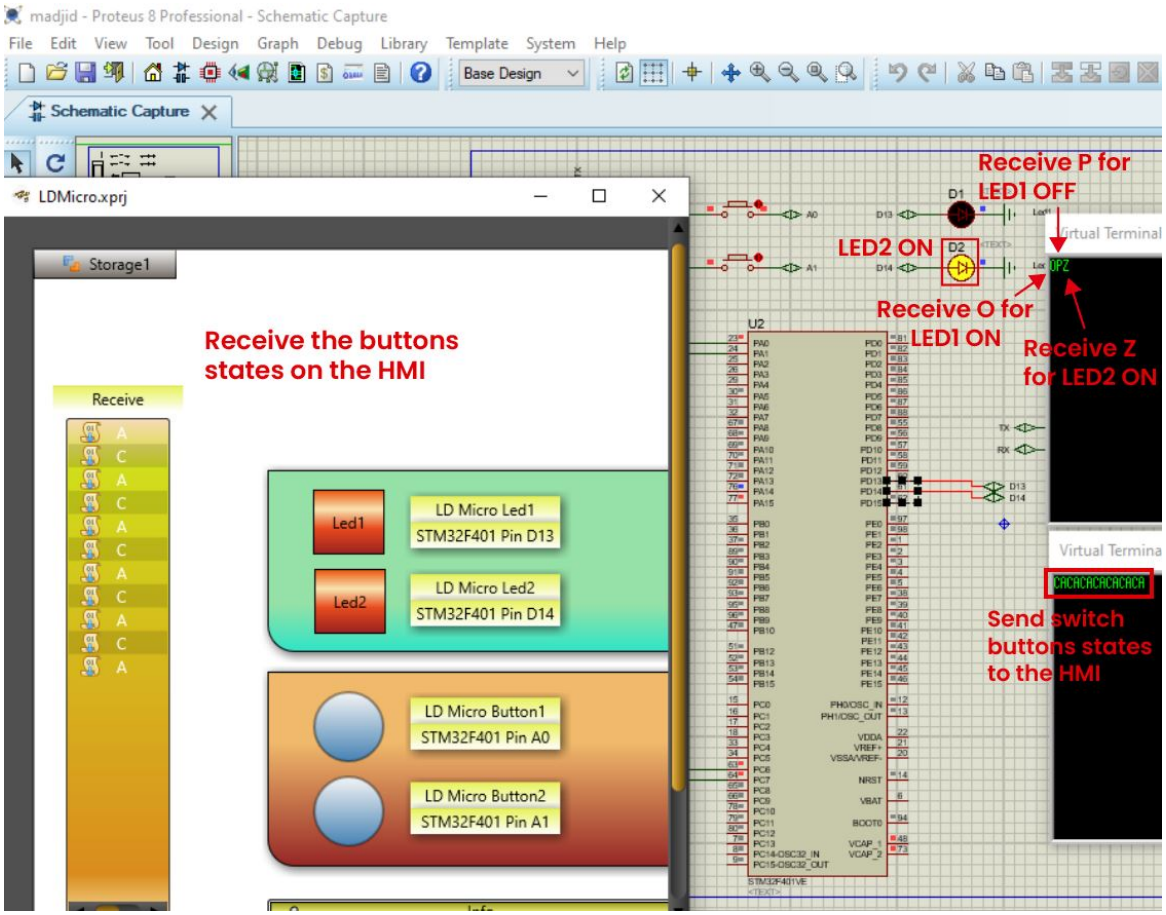


Figure II.19: HMI application results.

Note: Instead of using a virtual communication port with proteus, we can also use serial USB or Bluetooth.

[4] *Universal asynchronous receiver-transmitter*

Results of the Bluetooth communication

For the wireless monitoring part in this project we will use Bluetooth communication over Mic-set application, we will use the same interface used above with the modification of the communication parameters.

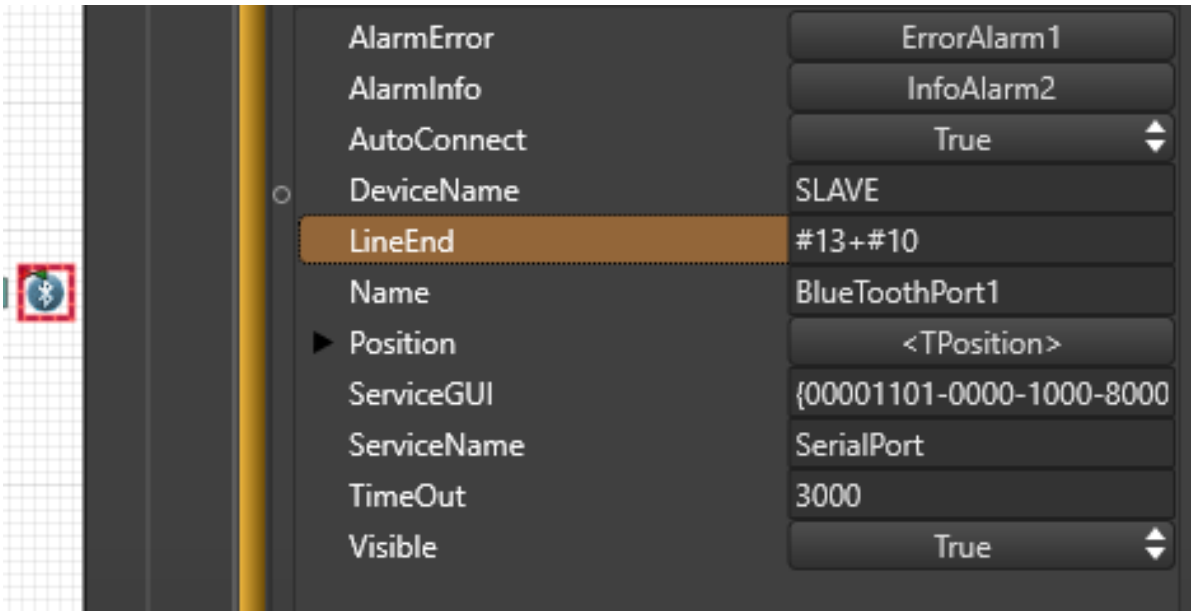


Figure II.20: Including the Bluetooth communication and its configuration.

After we configure the Bluetooth communication we will assure to select the Bluetooth port as referange in the Receive conditions blocks from the Bluetooth port in the storage box case .

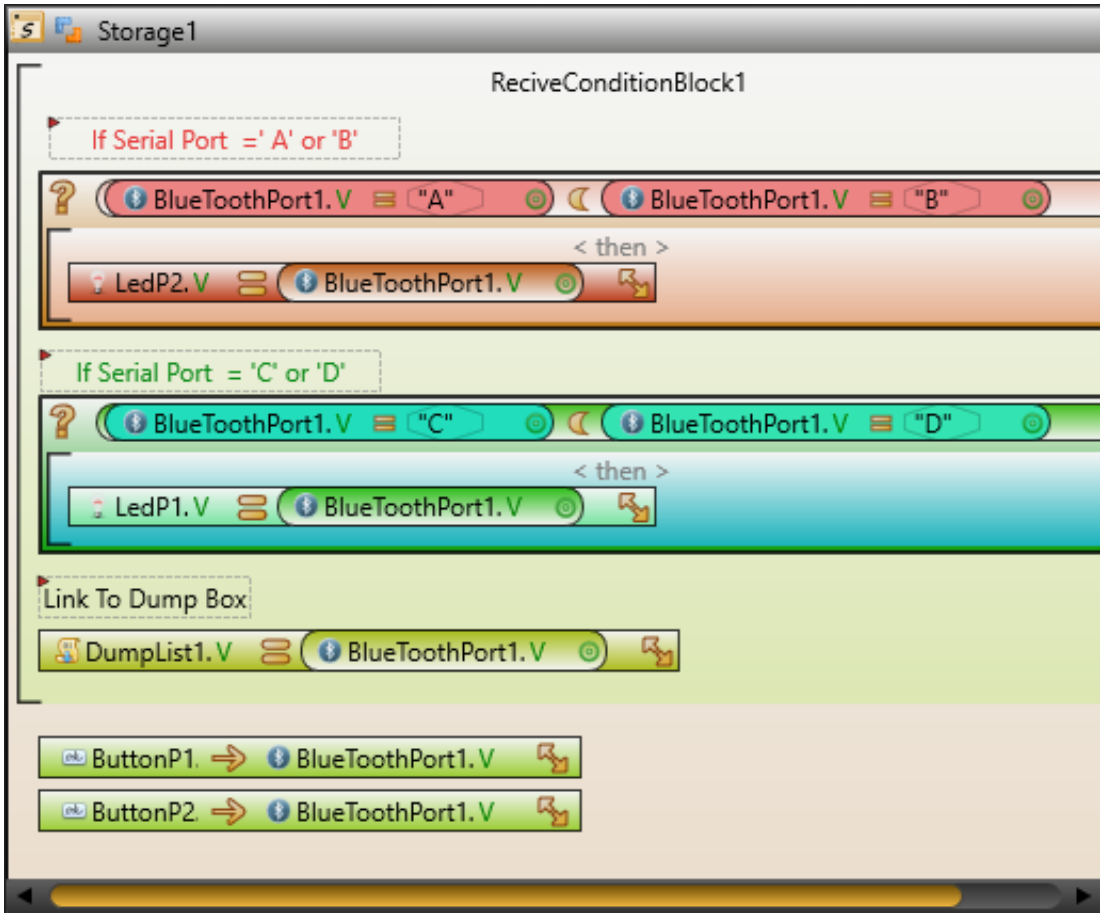


Figure II.21: Selecting the Bluetooth port as referange.

Note: We will obtain the same result in the Serial-port Communication test above.

II.5 Conclusion

The goal of this chapter is to elaborate our PLC's hardware architecture and software environment and find connectivity solutions to the latter in which it would accord with the requirements of the industry 4.0.

Master/Slave communication is an important factor in the industry 4.0 especially for the big automation processes who need several PLCs.

Micset SCADA software is a great addition to our project in which any automation process can be controlled and monitored using a Human-Machine Interface (HMI).

General conclusion

General conclusion

The Internet of Things has emerged as a sensation for development in more than one area. It is including a price automated capability and superior functioning. The use of sensor gadgets to make the belongings become automated machines/device is bringing a brand-new transformation with-inside the industries in phrases of earnings and pleasant production.

Continuous improvement means renewing technologies that are successfully established in the industry through a method that updates them to the new perspective of current technological realities. Every machine is getting smarter, from device to device, it is more important than ever to allow communication between control devices, especially in a decentralized way, from now on the natural direction of technological evolution, given the enormous benefits of greater flexibility, reconfiguration and low-cost new reality that Industry 4.0 established.

The goal of this work was to elaborate a connectivity solution for our PLC prototyping platform. We begin by introducing the main pillars of industry 4.0 with the role of internet of things (IOT) and industrial internet of things (IIOT) plus the road of industries to smart manufacturing.

In order to keep the consistency of our project, and to maintain the process to have a complete solution for our PLC connectivity with the consistence for the architecture of our PLC introduced in our work, MICSET software application played the principal role to act as a communicable interface providing several connectivity solutions with several communication methods such as Serial port, Bluetooth communication and much more.

Some of the difficulties we encountered in our work are the non-full control over STM32F407 card and its complexity using both the LDmicro software and MICSET software and the indispensability of the our card in Proteus software, that made us kill two bird with one stone by inserting a new card **STM32F401VE** to the LDmicro software, test it and approve its functionality and also approve the Serial port communication in MICSET software.

The Solution elaborated in this work confirmed to be effective and fantastically appropriate alternative in terms of low-cost compatibility with our Programmable Logic Controllers software used in the final project part and its adequate behaviour under the monitoring control requirements.

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Appendix

.1 Micset IDE

Micset Vulkan 8.0 is a program for visual design simulation and test multi-platform projects.

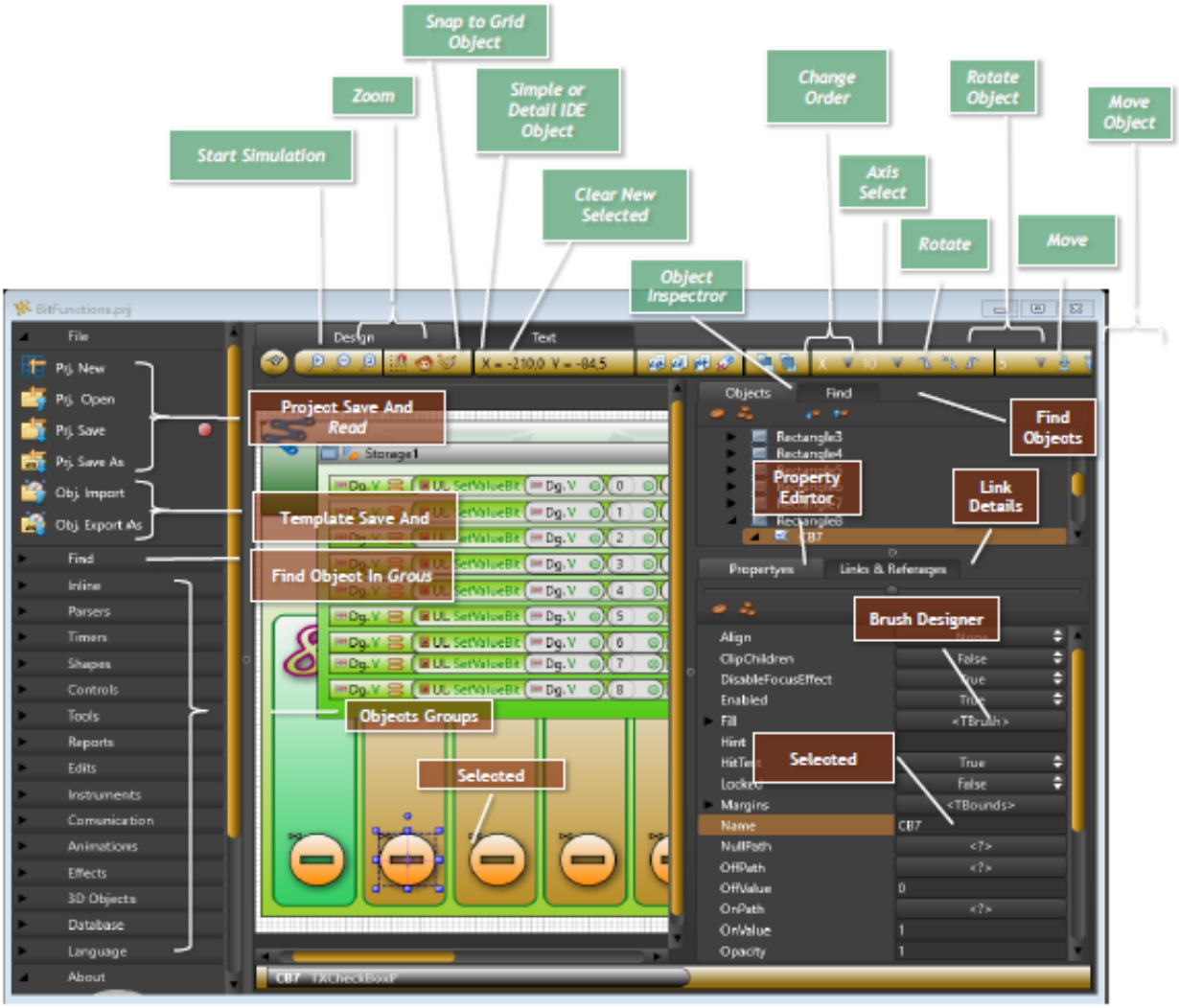


Figure 22: MICSET App presentation

.1.1 New object

- Select object from object group boxes.
- Move mouse to new object position.
- Click for create new object

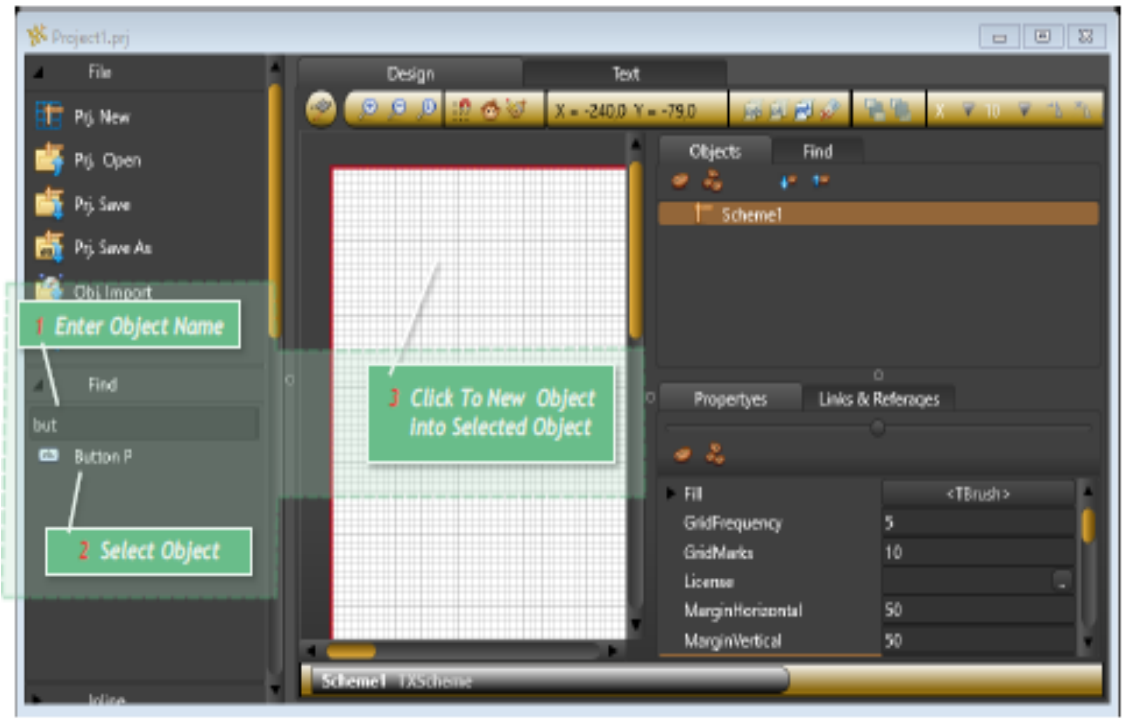


Figure 23: Creating new object

.1.2 Property editor

Used for change object property values

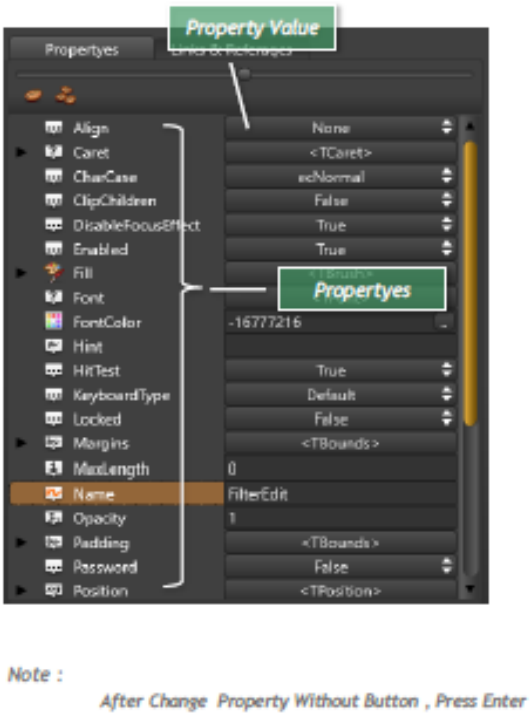


Figure 24: Property editor

.2 Global properties

Align	Position Children Into Parent.
Enabled	If False Do Not Select Component.
Fill	Change Fill Color or Gradient .
Hint	Show Short Message. Work Only Windows.
Name	Name For referange. After Create IDE Make new Name With Number Suffics. No Dupplicate Name
Opacity	1 is %100 0.5 is %50
Margins	Work If ComponentName . Align Property Is Diffenrent By None Distance From Parent Object
Padding	Work If ComponentName . Align Property Is Diffenrent By None Distance Child Object From Parent
Corners	Wirk If ComponentName .XRadius or ComponentName . YRadius > 0 Make Radius By X or Y Axis
Stoke	Change Stoke Color or Gradient
Visible	Component Visible State
Size	Have Two Sub Property Size . Width Componen Width Size . Height Component Height
Position	Have Two Sub Property Position .X Componen Position X Axis Position .Y Componen Position Y Axis
HitTest	If ComponentName .HitTest = True Then Runtime Mouse Events Not Work
Locked	Lock Position Component Design Time
RotationAngle	Rotation Angle Component
RotationCenter	Have Two Sub Property RotationCenter X 0.5 is %50 Of Width RotationCenter Y 0.5 is %50 Of Height
Sides	Select Visible Sides
RunVisible	Visible After Run
Remark	Stop Calculation
DisplayFprmat	

Figure 25: Global properties

.3 Button Component

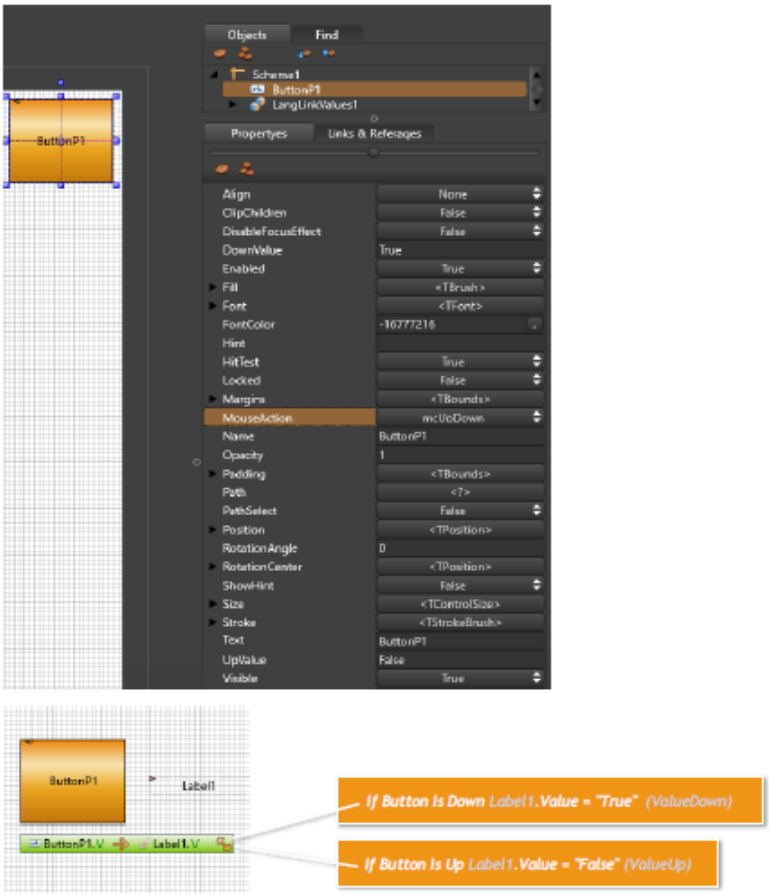


Figure 26: Events.

Events :

OnMouseDown	If Turn Mouse Down
OnMouseUp	If Turn Mouse Up
OnMouseChange	If Change Mouse Button

Propertyes :

DownValue	Value For Turn Down Default = "True"
UpValue	Value For Turn Up Default = "False"
Path	Path Button Skin
Text	Text
MouseAction	Event Actions mcUp mcDown mcUpDown
Value	Current Value
PathSelect	If False Mouse Click Region Is Rectangle Otherwise Only Path Area

Figure 27: Button component.

.4 Bluetooth port

for full duplex serial communication

Events : OnReceiveValue : Receive events

Commands : Connect port

Properties AlarmError & AlarmInfo

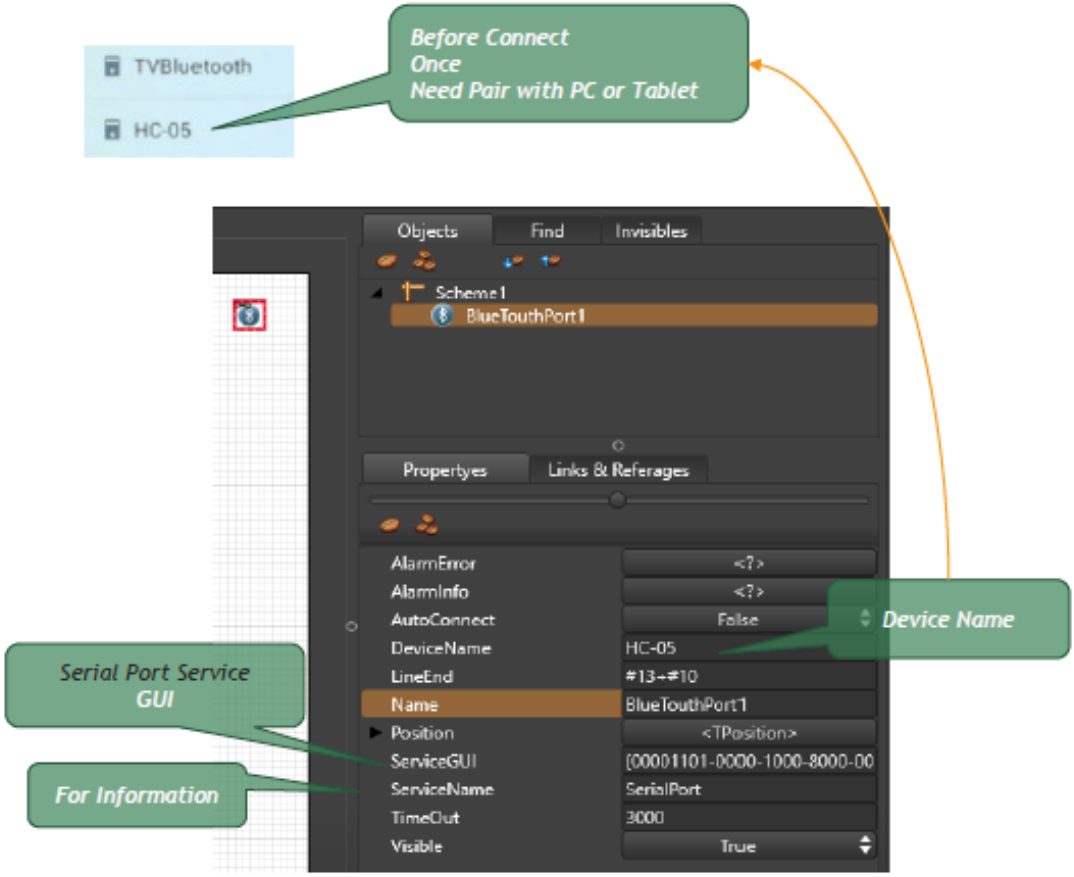


Figure 28: Bluetooth port component

.5 Alarm

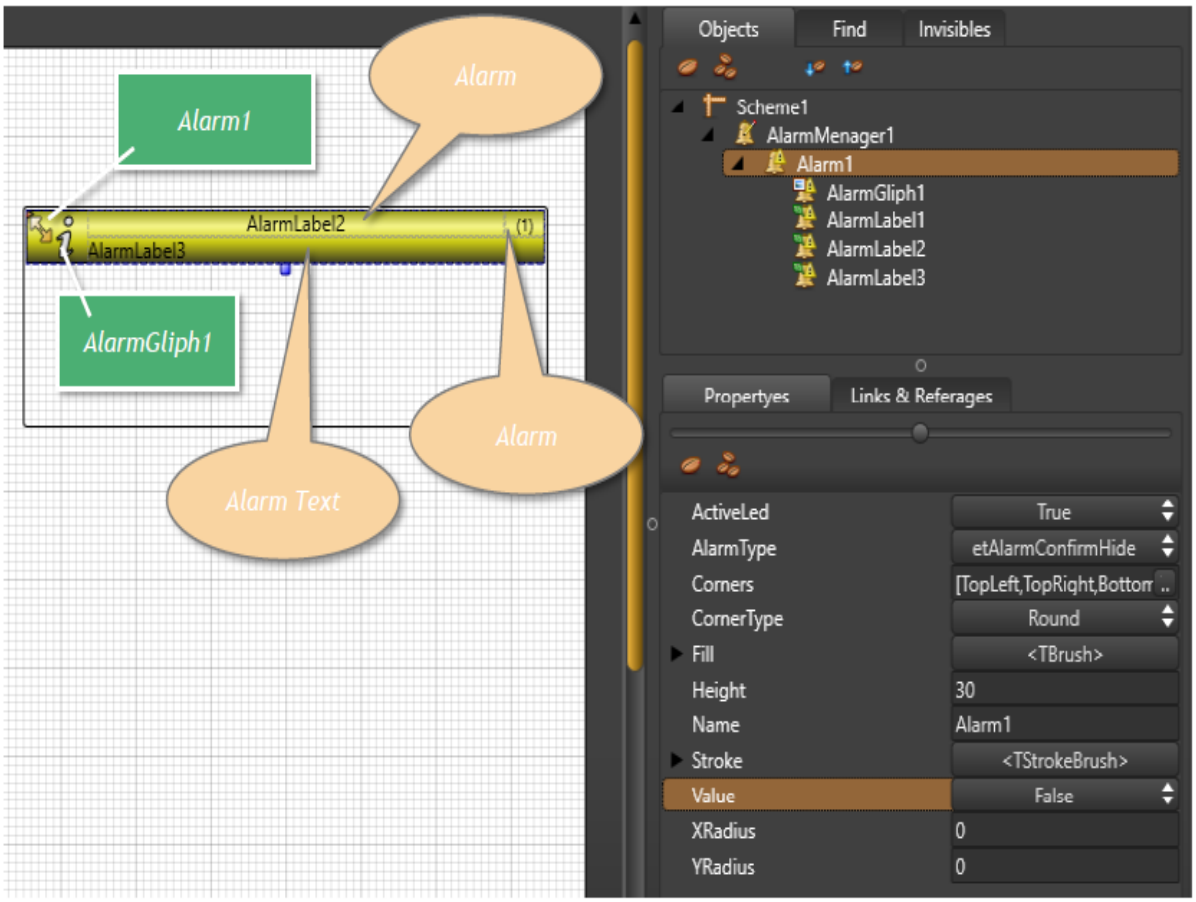


Figure 29: Alarm Component

For more information & documentations please consult the Micset help file

ملخص

إنترنت الأشياء,تمديد من آلة إلى آلة هو لبنة أساسية للثورة الصناعية الجديدة يتمثل جانب إنترنت الأشياء في الثورة الصناعية الجديدة في استخدام هذه الكائنات المتصلة في عمليات التصنيع.
الهدف هو تقديم حالة من الفن على التقنيات المختلفة المستخدمة في العالم الصناعي لدمجها في منصة النماذج الأولية من أجل اقتراح حل كامل يلامس جميع الجوانب التي يجب الاهتمام بها أثناء المنتج النهائي.
نبدأ بتحديد بيئة الأجهزة والبرامج الخاصة بنا لوحدة التحكم المنطقية القابلة للبرمجة PLC، ثم نطور حلول الاتصال مع الأجهزة الطرفية المختلفة في الصناعة والإشراف على كل شيء من خلال واجهة بين الإنسان والآلة HMI.

كلمات مفتاحية:
وحدة التحكم المنطقية القابلة للبرمجة ، واجهة الإ نسان والآلة ، إنترنت الأشياء ، الصناعة 0.4.

Abstract

The Internet of Things (IoT), an extension of machine-to-machine, is a fundamental building block of the new industrial revolution4.0. The aspect of IoT in the new industrial revolution is the use of these connected objects in manufacturing processes.
The objective is to present a state of the art on the different technologies used in the industrial world to integrate them into the prototyping platform in order to propose a complete solution touching all the aspects to be supported during the final product.
We start by defining our hardware and software environment of our PLC, then elaborate connectivity solutions with the different peripherals in the industry and supervise the whole by human-machine interface HMI.

Keywords :
Programmable Logic Controller, Human-Machine Interface , IOT,Industry 4.0.

Résumé

L'Internet des objets (IoT: Internet of Things), prolongement du machine-to-machine, est une brique fondamentale de la nouvelle révolution indistrielle4.0. L'aspect de l'IoT dans la nouvelle révolution industrielle est l'utilisation de ces objets connectés dans les processus de fabrication.
L'objectif est de présenter un état de l'art sur les différentes technologies utilisées dans le monde industriel pour les intégrer dans la plateforme de prototypage en vue de proposer une solution complète touchant à tous les aspects devant être pris en charge durant le produit final.
On commence par définir notre environnement matériel et logiciel de notre automate programmable ensuite élaborer des solutions de connectivité avec les différent péripheriques dans l'industrie et superviser le tout par une interface homme-machine IHM.

Mots clés :
Automate Programmable, Interface Homme-Machine, IOT, Industrie 4.0.