Sudan University of Science and Technology

College of Graduate Studies

Design and Implementation of Building Management System using Internet of Things

تصميم وتنفيذ نظام إدارة المباني بإستخدام إنترنت الأشياء

A Thesis Submitted In Partial fulfillment for the Requirements of the Degree of M.Sc. in Mechatronics Engineering

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الإستـهلال

بسم الله الرحمن الرحيم

قال تعالى: " وَيَسْأَلُونَكَعَنِالرُّوحِقُلِالرُّوحُمِنْأَمْرِرَبِّيوَمَاأُوتِيتُممِّن

الْعِلْمِإِلَّاقَلِيلا "

سورة الإسراء الآية (85)

و قال تعالى: " فَتَعَالَى اللَّهُ الْمَلِكُ الْحَقُّ ۗ وَلَا تَعْجَلْ بِالْقُرْآنِ مِن قَبْلِ أَن يُقْضَىٰ

إِلَيْكَ وَحْيُهُ ۖ وَقُل رَّبِّ زِدْنِي عِلْمًا "

سورة طه الآية (114)

صدق الله العظيم

DEDICATION

Each challenging work needs to self-efforts as well as Guidance of elders especially those who were very close to our heart.

My humble effort dedicate to my sweet and loving

MOTHER AND FATHER,

Whose affection, love, encouragement and pray of days and nights make me to able to get such success and honor,

Along with all hard working and respected teachers.

ACKNOWLEDGEMENT

In the accomplishment of this project successfully, many people have best owned upon me their blessing and the heart pledged support, this time I am utilizing to thank all the people who have been concerned with project.

Primarily I would thank Allah for being able to complete this project with success. Then I would like to thank my supervisor and the program supervisor Dr.Fath-Elrahman Ismael and all teachers whose valuable guidance has been the ones that helped me patch this project and make it full proof success his suggestions and his instructions has served as the major contributor towards the completion the project.

Then I would like to thank my Parents again, brothers, sisters, family, friends and partners who have helped me with their valuable suggestion and guidance has been helpful in various phases of the completion of the project.

Last and not the least I would like to thank my classmates who have helped me a lot.

المستخلص

يقدم هذا البحث نظام إدارة المباني، والذي هو الوحدة الرئيسية من أجل تنفيذ السيطرة والأتمتة. يرتكز نظام إدارة المباني هذا على التبديل والتحكم في مدخلات و مخرجات الطاقة ، بجانب هذا الأمان. نظم خدمات البناء الحديثة هي تكامل بين المكونات الميكانيكية والكهربائية والتحكم فيها. في عالم اليوم يتم تشغيل العديد من الأنظمة الفرعية في مباني كبيرة بشكل منفصل ، كل منها بهيكله الخاص لتكنولوجيا المعلومات. هذه الأنظمة التقليدية لديها العديد من العيوب مثل فقدان المزيد من الطاقة ، الوقت الضائع و صعوبة التحكم في مختلف الانظمة في المبني. هذا البحث عمل علي تصميم وتنفيذ نظام إدارة المباني باستخدام إنترنت الاشياء للتحكم ومراقبة ثلاثة أنظمة فرعية: أنظمة الإضاءة والتهوية ودرجة الحرارة باستخدام وحدة التحكم PFC 200 للمساعدة في تقليل تكاليف التشغيل في المباني وتشغيلها والتحكم فيها عن بعد. تتطلب الأنظمة في المباني صيانة أو دعمًا منظمًا لتوفير الأداء الأمثل المستمر بالإضافة إلى تعديل وتوسعة النظام لدمج المباني الجديدة وإعادة التجديد التي توفر الصيانة المستمرة المنتظمة لنظام إدارة المباني ونظام التحكم في الوصول بالكامل لضمان استمرار التحكم بالمبني في المستويات المثلى ونظام التحكم في الوصول ليعمل بسلاسة.

ABSTRACT

This research presents a building management system (BMS), which is the key module in order to perform the controlling and automation. The main area of this BMS focuses on switching and controlling of the power input/output, beside this security. Modern building services systems are an integration of mechanical, electrical and control components. In the world of today, various subsystems in a big building have been traditionally operated separately, each with their own Information Technology (IT) structure. These Conventional systems have more drops such as lost more energy, lost time under used facility. This research Design and Implement Building Management System using Internet of Thing (IoT) that controlling and monitoring three subsystems: lighting, ventilation and temperature systems using controller PFC 200 of WAGO to help reducing running cost for energy in the building energy management and operation and remote control .Hardware and software(e!COCKPIT) using from WAGO. Systems in Building require structured maintenance or support to give continued optimum performance as well as modifying and extending the system to incorporate new buildings and refurbishments provides regular ongoing maintenance of the entire BMS and Access Control Systems to ensure that plant continues to be controlling at optimum levels and the access control system operates smoothly.

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LIST OF ABBREVIATIONS

AC	Alternating Current
AHU	Air Handlers Unit
BAS	Building Automation System
BMS	Building Management System
CAV	Constant Air volume
CCTV	Closed Circuit Television
CEO	Comfortable Environment Operators
CFM	Cubic Feet per Minute
DALI	Digital Addressable Lighting Interface
DC	Direct Current
DCV	Demand Control (or Controlled) Ventilation
DSS	Data storage server
DX	Direct Expansion Air Conditioning
EDS	Energy data server
HVAC	Heating Ventilation and Air Conditioning
IAQ	Indoor air quality
I/O	Input/output System
IOT	Internet of Things
ISA	International Society Of Arboriculture
MIS	Management Integration server
MWU	Morning Warm-Up
SCS	System core server
SMS	System Management Server

SNMP	Simple Network Management Protocol
VAV	Variable Air Volume
VFD	variable Frequency drive

Chapter One

INTRODUCTION

Chapter One

Introduction

1.1 Preface

In the world of today, a major change in technology can be seen as an advantage, a number of different fields from industrial & communication to household application can be automatically controlled. This research presents a building management system (BMS), which is the key module in order to perform the controlling and automation. The main area of this BMS focuses on switching and controlling of the power input/output, beside this security and HVAC process has also kept as a main concern in this system.

In this area, where energy management is the concern of everyone, the buildings are being constructed in a manner to provide maximum comfort and ease to the people with minimum energy utilization. This whole thing is only possible with the help of controlling devices that are to be installed in a building during construction. This controlling can be of any type, from simple switching on and off of the lights, to water motor control and many more. Therefore main idea of designing this system is to automate these operations of the plant in most resourceful manner. Besides controlling, security factor has also been kept in concern with password protection. Cameras, fire alarms systems, main gate security and main gate barrier automation has been kept at priority in this system. Another features which is required in a multiple story building is elevator which can also been found in our system.

1.2 Problem Statement

The various subsystems in a building have traditionally been operated separately, each with their own IT structure. However, as the number of subsystems increased the case for integrated solutions also grew. In particular, the addition of fluctuating renewable energy generation and energy storage capacity added a new level of complexity, one which demanded a new form of management in buildings, in order to reduce rising overall costs. Conventional systems suffer from inefficient use of energy and time under used facility. This research considers three subsystems: lighting, ventilation and temperature systems. It also Studies saving energy cost before and after adding BMS to the systems.

1.3 Proposed Solution

In this thesis, modern control system with management level named Building management system (BMS) is designed to save energy, cost, time and enables comfort conditions to be easily monitored and controlled from a single point using software e!COCKPIT connecting with Internet of thing (IOT).

1.4 Aim and Objectives

The main aim is to design and implement Building Management system using Internet of thing.

The detailed objectives include:

1. Sending information about the linked system's state to the user's device via IOT.
2. Giving the user the ability to control the system's functions remotely.
3. Saving energy by limiting the user's unnecessary use of electricity.
4. Develop, operate and modern systems.

1.5 Methodology

A BMS of WAGO is a microprocessor-based system which provides the facility to control any building service it works by using intelligent standalone controllers or outstations, to accurately control plant such as boilers, pumps, fans, lights and security systems in response to changing conditions.BMS systems are "Intelligent" microprocessor based controller networks installed to monitor and control a buildings technical systems and services. In this research reviewed three systems: lighting, ventilation and temperature systems controlling and monitoring using controller PFC 200 WAGO and connecting with IOT.

Research methodology phases are:

1. Design a proposed control circuit for the system (WAGO HARDWAED).
2. Simulation of the proposed control system (WAGO SOFTWARE) using e!COCKPIT.
3. Controlling and monitoring three systems: lighting, ventilation and temperature systems from control room, WAGO phone application and manually from design.
4. Read the new performance and compare it with old performance for saving energy cost and time.

1.6 Thesis Organization

This thesis composed of five chapters, their outlines are as follows: chapter One introduces the problem and the proposed solution. Chapter Two gives an overview of the components used to implement the system and provides previous work. Chapter Three describes the system design and the process in details. Chapter Four represents testing this system and results; finally, Chapter Five represents recommendations and its discussion.

Chapter Two

LITERATURE REVIEW

Chapter Two

Literature Review

2.1 Introduction

In the world of today, a major change in technology can be seen as an advantage, a number of different fields from industrial & communication to house hold application can be automatically controlled. This research presents a building management system (BMS), which is the key module in order to perform the control and automation. The main area of this BMS focuses on switching and control of the power input/output, beside the security and HVAC process has also kept as a main concern in this system.

2.2 Background

While building management systems (BMS) have become smart in recent years, they are certainly not new. In fact they have gradually evolved over the last 50+ years and into the 21st century systems we see today. BMS has always been boosted by the technological developments of the time, but today's smart building technology is influencing BMS like nothing before.

Building Management system have been introduced to this world in 1970, initially it was started with very limited features but within time a lot of changes and modifications had been made, started with the controlling of power and lightening to heating and cooling of a building together with the alarm system as a further modification in order to provide maximum security. Intrusions can be easily monitored with the help of closed circuit television CCTV.BMS is a micro-processor based system which centralizes and simplifies:

- Controlling Monitoring
- Operation and management of heating, air-conditioning, ventilation & other building services to achieve:
    - Safe and comfortable working environment.
    - Energy saving & efficient operation.
    - Reduced time & cost.

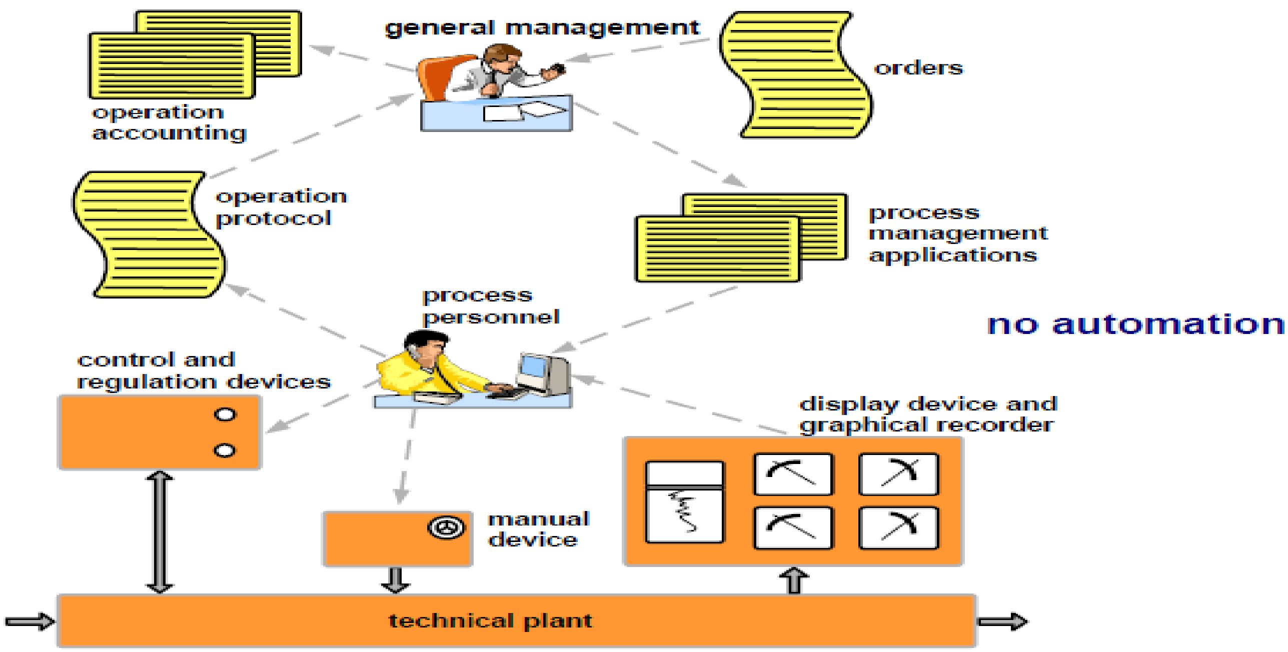

Figure (2.1): Operation without computer

BMS is essentially a computer-based control system that monitors and manages a building's mechanical and electrical equipment, including Ventilation, lighting, power, and fire and security systems. Consisting of software and hardware, a BMS is typically configured in a hierarchical manner and can be proprietary, using such protocols as C-Bus or Profibus.

If there were one word to define the development of our modern society in the past decade, it would probably be “data.” The collection, storage and analysis of data from innumerable sources for a broad variety of Purposes is shaping the world we live in, not least our buildings.BMS has evolved to be the central platform for coordination of data gathering and the subsequent use of that intelligence. [1]

The driving force of this evolution is energy efficiency. With 40% of total energy consumption coming from buildings the case for greater efficiency is strong. Modern BMS systems allow for historical trend analysis to be paired with real-time data collection to optimize subsystems such as lighting and HVAC. These mountains of ‘big data’ are continuously growing, as is our ability to analyze them, meaning the more data we have, the greater our intelligence, and the greater our ability to optimize energy use. If there were a second word to define the development of our modern society it would probably be ‘connectivity,’ not least in buildings. By constantly observing and controlling air quality, for example, a BMS can create an indoor environment that boosts employee health and productivity. Furthermore, by monitoring different machine health parameters a BMS can optimize maintenance scheduling and reduce costly downtime.Connectivity also enables remote monitoring and control of BMS. Not only does this create greater flexibility for building managers, it also increases safety and security for a building’s occupants and assets. Alarms coupled to connected HVAC, fire, security systems, as well as access control permit immediate and effective responses to a wide variety of emergency situations. [1]

All of these developments can be attributed to the emergence of the internet of things (IoT) in smart buildings in recent years. The trends promoting growth in the BMS market are now directly linked to the IoT movement. Similar and simultaneous development in the industrial internet of things (IIoT) has advanced data and connectivity for industrial purposes. This is also feeding back into BMS development in the form of lower cost of ‘things’ with embedded intelligence, advances in predictive analytics, as well as the growth of cloud based services. [1] We are even seeing tremendous changes at the construction phase of buildings through the rise of building information management (BIM). Each generation of BIM further eases the integration of complex building systems into architecture, engineering, and construction workflows. BIM allows for the incorporation of BMS solutions at the design phases of a project, this enhances BMS integration, reducing operating costs in a building.BMS and associated systems are not only cutting costs but also creating value. Enhanced safety, security and flexibility are creating a competitive advantage for advanced BMS enabled buildings. Smart building owners can attract better tenants at higher rates, largely because smarter buildings can attract smarter employees.As BMS and the IoT continue to develop we will see greater cost savings and new features, creating unprecedented value from the building. The future of buildings is data rich and connected, and more than just embracing these characteristics, BMS has risen to become the blood stream and beating heart of the smart building. A BMS system is a computerized system that analyses the specific necessities of a particular building by controlling the associated plant installed in it and helps save the energy .The devices installed outside the buildings are connected with panels which can be switch on or off over different sets of instructions.

The working of BMS is totally based on the input in a form of information by the devices such as sensors, once the information is collected it can be processed with the help of controller that will further instruct the system to perform a specific task, in this BMS, switching on and off of the plant can be controlled in the same manner, plant can be set to a respective temperature in order to provide heating and cooling with respect to the temperature outside the building.BMSs are not new technology; they have been in use for over 30 years. However, they have become increasingly popular in the last five years due to the lower cost of microprocessors and advances in computer software which make the systems much more user friendly. There is more company have BMS hardware and design such as semience, Honeywell and FMA. In this research talk about BMS of WAGO Company and review three systems: lighting, ventilation and temperature systems controlling and monitoring using controller PFC 200 WAGO and connecting with IOT. [1]

2.2.1 BMS Benefits

Improved indoor environment quality, Faster response to Occupant needs, End-user complaints and Trouble conditions, Maintenance Savings ,Runtime monitoring alerts timely maintenance of equipment and avoids expensive failures, Energy Savings, Reduced operator training, Improved management reporting, Timely and effective control, Performance Benchmarking. [2]

2.2.2 BMS Suppliers and Integrators

1-Procured as a complete system that includes engineering, supply, installation, programming and commissioning.

2-Specialist Integrators that are either directly associated with the manufacturer or are approved re-sellers.

3-All Integrators should have full factory technical support

4-Need to work closely with Mechanical Services, Mechanical Electrical and other contractors.

5-For new construction BMS is usually included within the mechanical services package.

6-‘Tier 1 Company’ only refers to a direct factory association and not to the quality of products or service. [2]

2.2.3 Building Control Applications

Building control applications include for the following Zones:

1- Temperature monitoring and control.

2-Zone Variable Air Volume (VAV) control to zones.

3-Zone CO2 monitoring and control (Air Quality).

4-Air handling unit supply air temperature control.

5-Air handling unit supply air flow / pressure control.

6-Main Plant Chiller and Boiler sequencing.

7-Toilet, car park, kitchen and general exhaust fan control.

8-After Hours Building Control.

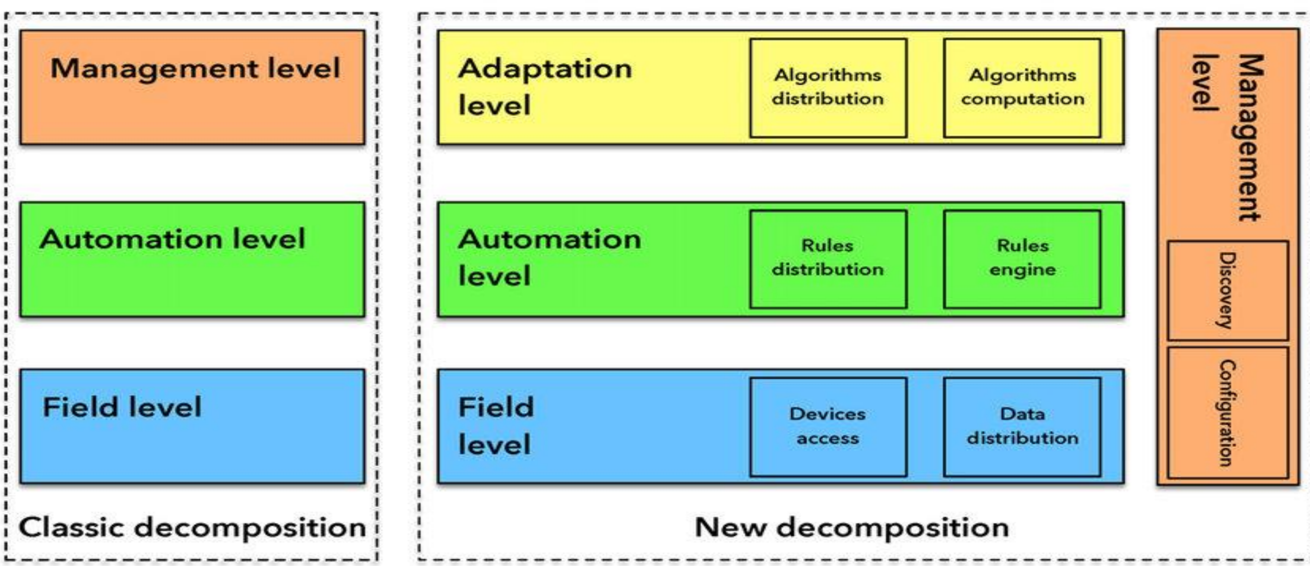

Figure (2.2): BMS Levels

2.3 Definition of BMS and BAS

2.3.1 Definition of BMS in Dictionary and in ISA

Definition of BMS in Dictionary **B** building**, M** Management**, S** system, is Building Management system.

Definition of BMS in ISA a building management system (BMS) is a control system that can be used to monitor and manage the mechanical, electrical and electromechanical services in a facility. Such services can include power, heating, ventilation, air-conditioning, and physical access control, pumping stations, elevators and lights.

Or BMS otherwise known as a building automation system (BAS) is a computer –based control system installed in buildings that controls and monitors the buildings mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems and security systems. [1]

2.3.2 Definition of (BAS) in Dictionary and ISA

Definition of BAS in Dictionary **B** building**, A** Automation, **S** system**,** is Building Automation system.

Definition of BAS in ISA Building automation is the automatic centralized control of a building's heating, ventilation and air conditioning, lighting and other systems through a building management system or building automation system (BAS). The objectives of building automation are improved occupant comfort, efficient operation of building systems, reduction in energy consumption and operating costs, and improved life cycle of utilities.

Building automation is an example of a distributed control system – the computer networking of electronic devices designed to monitor and control the mechanical, security, fire and flood safety, lighting (especially emergency lighting), HVAC and humidity control and ventilation systems in a building.BAS core functionality keeps building climate within a specified range, provides light to rooms based on an occupancy schedule (in the absence of overt switches to the contrary), monitors performance and device failures in all systems, and provides malfunction alarms to building maintenance staff. A BAS should reduce building energy and maintenance costs compared to a non-controlled building. Most commercial, institutional, and industrial buildings built after 2000 include a BAS. Many older buildings have been retrofitted with a new BAS, typically financed through energy and insurance savings, and other savings associated with pre-emptive maintenance and fault detection. [2]

2.4 Building Automation

2.4.1 Building Automation System Terms

The term building automation system, loosely used, refers to any electrical control system that is used to control a buildings heating, ventilation and air conditioning (HVAC) system. Modern BAS can also control indoor and outdoor lighting as well as security, fire alarms, and basically everything else that is electrical in the building. Old HVAC control systems, such as 24 V DC wired thermostats or pneumatic controls are forms of automation but they have a lack the modern systems flexibility and integration. [2]

2.4.2 Buses and Control

Most building automation networks consist of a primary and secondary bus which connect high-level controllers (generally specialized for building automation, but may be generic programmable logic controllers) with lower-level controllers, input/output devices and a user interface (also known as a human interface device). ASHRAE's open protocol BACnet or the open protocol LonTalk specify how most such devices interoperate. Modern systems use SNMP to track events, building on decades of history with SNMP-based protocols in the computer networking world.Physical connectivity between devices was historically provided by dedicated optical fiber, Ethernet, ARCNET, RS-232, RS-485 or a low-bandwidth special purpose wireless network. Modern systems rely on standards-based multi-protocol heterogeneous networking such as that specified in the IEEE 1905.1 standard and verified by the nVoy auditing mark. These accommodate typically only IP-based networking but can make use of any existing wiring, and also integrate power line networking over AC circuits, power over Ethernet low-power DC circuits, high-bandwidth wireless networks such as LTE and IEEE 802.11n and IEEE 802.11ac and often integrate these using the building-specific wireless mesh open standard ZigBee).Proprietary hardware dominates the controller market. Each company has controllers for specific applications. Some are designed with limited controls and no interoperability, such as simple packaged roof top units for HVAC. Software will typically not integrate well with packages from other vendors. Cooperation is at the Zigbee/BACnet/LonTalk level only.Current systems provide interoperability at the application level, allowing users to mix-and-match devices from different manufacturers, and to provide integration with other compatible building control systems. These typically rely on SNMP, long used for this same purpose to integrate diverse computer networking devices into one coherent network. [2]

2.4.3 Types of Inputs and Outputs

2.4.3.1 Sensors

Analog inputs are used to read a variable measurement. Examples are temperature, humidity and pressure sensors which could be thermistor, 4–20mA, 0–10 volt or platinum resistance thermometer (resistance temperature detector), or wireless sensors.

A digital input indicates if a device is turned on or not - however it was detected. Some examples of an inherently digital input would be a 24 V DC/AC signal, current switch, an air flow switch, or a Volta-free relay contact (dry contact). Digital inputs could also be pulse type inputs counting the frequency of pulses over a given period of time. An example is a turbine flow meter transmitting rotation data as a frequency of pulses to an input.Nonintrusive load monitoring is software relying on digital sensors and algorithms to discover appliance or other loads from electrical or magnetic characteristics of the circuit. It is however detecting the event by an analog means. These are extremely cost-effective in operation and useful not only for identification but to detect start-up transients, line or equipment faults, etc. [3]

2.4.3.2 Controls

Analog outputs control the speed or position of a device, such as a variable frequency drive, an I-P (current to pneumatics) transducer, or a valve or damper actuator. An example is a hot water valve opening up 25% to maintain a set point. Another example is a variable frequency drive ramping up a motor slowly to avoid a hard start.Digital outputs are used to open and close relays and switches as well as drive a load upon command. An example would be to turn on the parking lot lights when a photocell indicates it is dark outside. Another example would be to open a valve by allowing 24VDC/AC to pass through the output powering the valve. Digital outputs could also be pulse type outputs emitting a frequency of pulses over a given period of time. An example is an energy meter calculating kWh and emitting a frequency of pulses accordingly. [3]

2.4.4 Infrastructure

2.4.4.1 Controller

Controllers are essentially small, purpose-built computers with input and output capabilities. These controllers come in a range of sizes and capabilities to control devices commonly found in buildings, and to control sub-networks of controllers.Inputs allow a controller to read temperature, humidity, pressure, current flow, air flow, and other essential factors. The outputs allow the controller to send command and control signals to slave devices, and to other parts of the system. Inputs and outputs can be either digital or analog. Digital outputs are also sometimes called discrete depending on manufacturer.

Controllers used for building automation can be grouped in three categories: programmable logic controllers (PLCs), system/network controllers, and terminal unit controllers. However an additional device can also exist in order to integrate third-party systems (e.g. a stand-alone AC system) into a central building automation system.Terminal unit controllers usually are suited for control of lighting and/or simpler devices such as a package rooftop unit, heat pump, VAV box, fan coil, etc. The installer typically selects one of the available pre-programmed personalities best suited to the device to be controlled, and does not have to create new control logic. [3]

2.4.4.2 Occupancy

Occupancy is one of two or more operating modes for a building automation system. Unoccupied, Morning Warm-up, and Night-time Setback are other common modes.Occupancy is usually based on time of day schedules. In Occupancy mode, the BAS aims to provides a comfortable climate and adequate lighting, often with zone-based control so that users on one side of a building have a different thermostat (or a different system, or sub system) than users on the opposite side. A temperature sensor in the zone provides feedback to the controller, so it can deliver heating or cooling as needed. If enabled, morning warm-up (MWU) mode occurs prior to occupancy. During Morning Warm-up the BAS tries to bring the building to set point just in time for Occupancy. The BAS often factors in outdoor conditions and historical experience to optimize MWU. This is also referred to as optimized start.An override is a manually initiated command to the BAS. For example, many wall-mounted temperature sensors will have a push-button that forces the system into

Occupancy mode for a set number of minutes. Where present, web interfaces allow users to remotely initiate an override on the BAS.Some buildings rely on occupancy sensors to activate lighting or climate conditioning. Given the potential for long lead times before a space becomes sufficiently cool or warm, climate conditioning is not often initiated directly by an occupancy sensor. [3]

2.4.4.3 Lighting

Lighting can be turned on, off, or dimmed with a building automation or lighting control system based on time of day, or on occupancy sensor, photo sensors and timers.[8] One typical example is to turn the lights in a space on for a half-hour since the last motion was sensed. A photocell placed outside a building can sense darkness, and the time of day, and modulate lights in outer offices and the parking lot.Lighting is also a good candidate for demand response, with many control systems providing the ability to dim (or turn off) lights to take advantage of DR incentives and savings.In newer buildings, the lighting control can be based on the field bus Digital Addressable Lighting Interface (DALI). Lamps with DALI ballasts are fully dimmable. DALI can also detect lamp and ballast failures on DALI luminaries and signals failures. [3]

2.4.4.4 Air Handlers

Most air handlers mix return and outside air so less temperature/humidity conditioning is needed. This can save money by using less chilled or heated water (not all AHUs use chilled or hot water circuits). Some external air is needed to keep the building's air healthy. To optimize energy efficiency while maintaining healthy indoor air quality (IAQ), demand control (or controlled) ventilation (DCV) adjusts the amount of outside air based on measured levels of occupancy.Analog or digital temperature sensors may be placed in the space or room, the return and supply air ducts, and sometimes the external air. Actuators are placed on the hot and chilled water valves, the outside air and return air dampers. The supply fan (and return if applicable) is started and stopped based on either time of day, temperatures, building pressures or a combination. [3]

2.4.4.5 Constant Volume Air Handling Units

The less efficient type of air-handler is a "constant volume air handling unit," or CAV. The fans in CAVs do not have variable-speed controls. Instead, CAVs open and close dampers and water-supply valves to maintain temperatures in the building's spaces. They heat or cool the spaces by opening or closing chilled or hot water valves that feed their internal heat exchangers. Generally one CAV serves several spaces. [3]

Other Infrastructure:

- Variable volume air-handling units, VAV hybrid systems, Central plant, Chilled water system, Condenser water system, Hot water system, Alarms and security.

2.4.5 Protocols and Industry Standards

A protocol is basically the communication language used by all the components in the system to transmit signals to each other and to the central processor. Typical building automation systems will have thousands of such components which need to communicate each other. Prominent protocols are BACnet, Modbus, KNX, Lonworks etc. Different manufacturers of components use different protocols for their components. For any addition of systems at a later stage, components of same protocol need to be used. However interface components are available to use components of other protocols. KNX is an open protocol for which any manufacturer can develop new components. [4]

- ASHRAE(American Society of Heating, Refrigerating and Air Conditioning Engineers), international organization for people involved in heating, ventilation or air conditioning.
- BACnet, network communications protocol for building automation and control systems that has been adopted worldwide as ISO 16484-5:2003
- Bluetooth, short range point-to-point and mesh, low-power wireless communication standard enabling building automation solutions
- DALI, network-based systems that control lighting in buildings
- Dynet, a Dynalite network and protocol
- EnOcean (battery less, interoperable, wireless standard)
- KNX, system for Home and Building Controls
- LonTalk, protocol created by Echelon Corporation for networking devices. The official ISO standard numbers for building automation worldwide are: ISO/IEC 14908-1, ISO/IEC 14908-2, ISO/IEC 14908-3, and ISO/IEC 14908-4
- OPC, industry standard used widely in manufacturing, process control, and building automation. The open standard transfers, values, historical data, and alarms and events.

- S-Bus (Smart-BUS, SBUS), open protocol, open source
- ZigBee,short range, low-powered wireless communication standard targeted at building automation.

2.5 WAGO History

Due to falling prices for semiconductors, decentralized designs are affordable. Several logic units control the process and communicate with each other via a network. There is no longer a large controller that controls everything; instead, multiple, small controllers exchange process values with each other. If one controller fails, then the entire system is not idled, because the other controllers continue to function. The controllers communicate with each other via a bus system, to which the operating and observation stations can also be connected. The hardware for Process Control Systems is moving away from specialized systems and toward widespread and inexpensive IT components. n addition, a further decentralization is occurring: Intelligence is available in increasingly smaller and mobile units that are closer to the field level. Through the use of prescribed engineering elements and configuration aids, the engineering costs are further reduced.

Machine modularization has become the current state of technology. The reason behind this is decentralized system intelligence. In conjunction with the WAGO-I/O-SYSTEM, the ETHERNET controller can be used as a user-programmable controller within ETHERNET networks. As a system partner, WAGO solves all automation tasks using centralized and decentralized control architecture in all sectors of industrial, process, and building automation. Integrated Web pages and Web-based visualization provide IT applications with real-time process data. Both large memory and an integrated multitasking system readily meet stringent automation requirements. A large number of library functions support both software/hardware interfaces and integrated file system. [9]

2.5.1 WAGO Building Automation

2.5.1.1 Management Level

At the management level, building automation is an integral part of both cost and facility management; it’s also a key component in overall building control. Open protocols link higher-level functions to building automation. To make the most of these protocols, WAGO offers software tools for commissioning and diagnostics to optimally support both system engineering and monitoring. Access to the Web visualization of each individual control unit is also performed at this management level.

2.5.1.2 Automation Level

ETHERNET has long established itself as the dominant medium at the automation level. As such, WAGO’s control units can be easily and efficiently interlinked using open, standardized bus protocols for building automation (e.g., BACnet IP, KNX IP or Modbus/TCP). Standardized protocols provide interoperable and future-ready interfaces between individual building technologies and levels.

2.5.1.3 Field Level

Depending on the application, building automation systems can vary greatly from one building level to the next, requiring different transmission media (wired or wireless) and interfaces. Thus, flexible and easy-to-install media are required on the field level (room level). This is why WAGO offers a wide variety of solutions

Ranging from the direct control of standard sensors and actuators via interfaces to two-wire subsystems (e.g., DALI, BACnet MS/

TP, KNX TP1 or Lon Works), on through to radio-based solutions such as EnOcean or Bluetooth. [10]

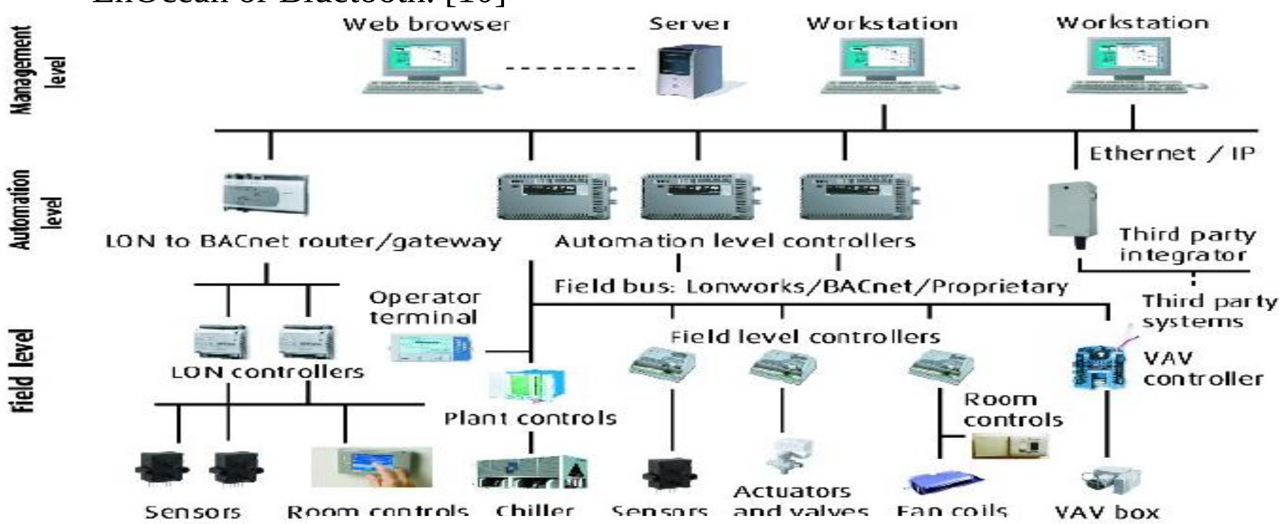

Figure (2.3): BMS Levels network

2.5.2 Components of an industrial automation system

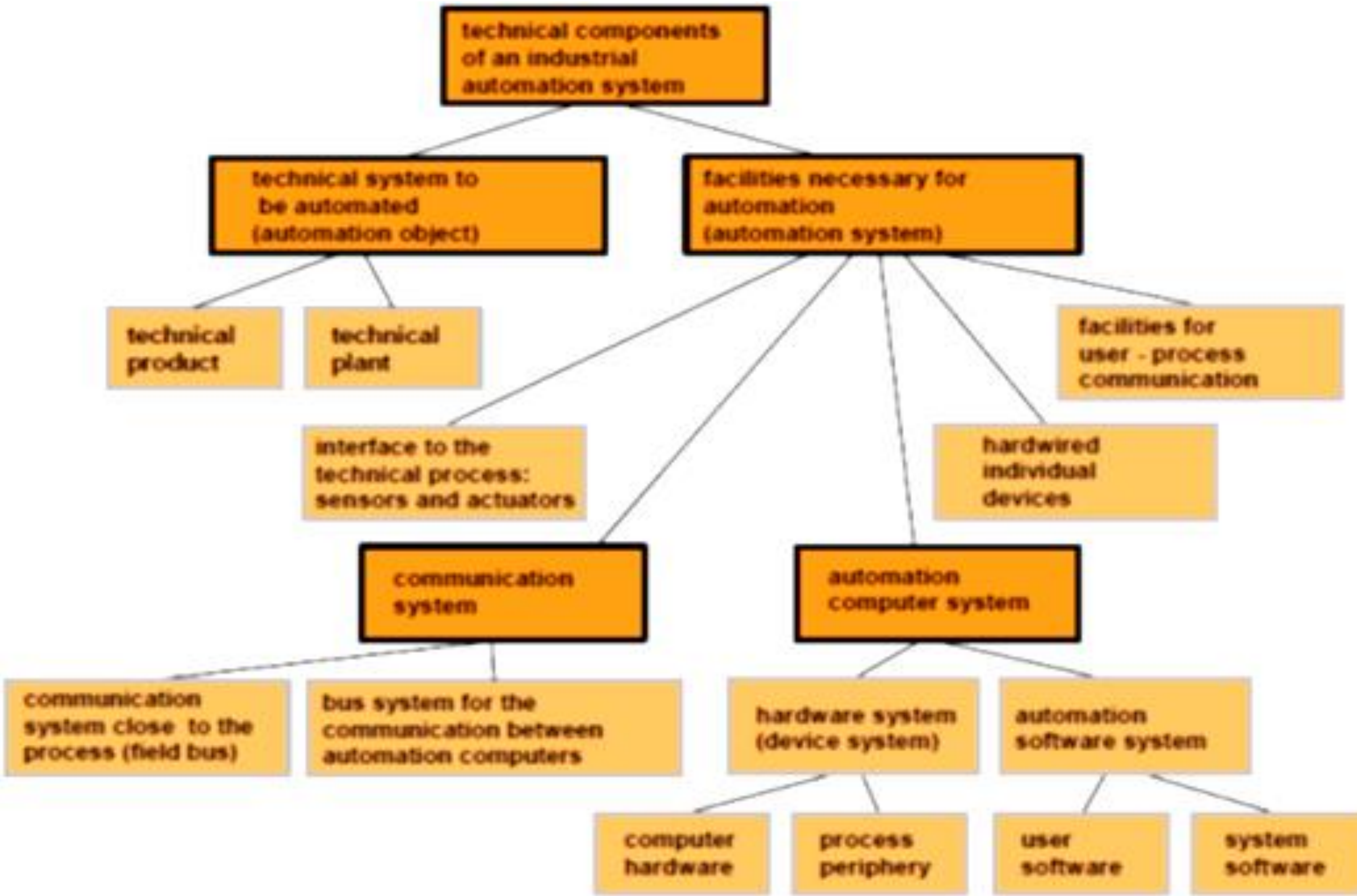

Figure (2.4): Industrial Automation System

2.5.2.1 Industrial Automation System Contents

Sensors, Actuators, Simple Products, Complex Products and Different Forms of Automation Computers. [5]

2.5.2.2 Components of Levels in BMS

1. **Upper Level (Management Level)**

It's the level which Dispatching and administration as well as work with databases and statistical functions. At this level cooperation between personnel (operators, dispatchers etc.) and system is performed, which is implemented by means of computer devices and SCADA-systems. Have types of server to do optimal decentralized System its: [5]

System Management Server (SMS) Used for checking operational state of the System Core Server and DDCs (Direct Digital Controllers), **Data Storage Server (DSS)** Used for data management for Data Point records and daily/monthly/annual reports, **Management Integration Server (MIS)** Integrated SMS and DSS into one unit for the system of 5,000 or less objects**, System Core Server (SCS)** Used for controlling DDCs and delivering Data Point information to SMS and DSS and **Energy Data Server (EDS)** Used for building energy management.[5]

2. **Middle Level (Automation Level):**

The main level in automation system. Automated management of functional processes. Basic components of this level are: main controllers, signal input-output units, and various switching equipment. Latest controllers ensuring smarter facility control:

3. Low Level (Field Level):

Level of terminals with input/output functions. This level includes sensors, actuating mechanisms, cabling between devices and low-middle levels. [5]handy control panels for building users:

- **Neopanel, Neoplate, Operator Panel**

These simple and sophisticated control panels enable building users easy to control on/off, set temperature/humidity, and extend operating hours of Heating, Ventilation, and Air Conditioning (HVAC) system.

We have two types of AC controllers: Neopanel (digital) and Neoplate (analog). You can select ones fitting to users and room furnishings. We also have optional line-ups for direct control of the control units to meet users' needs.

- **Active and High Precision Sensors**

Responding to signals from temperature/humidity sensors, valves control water and air flows with high accuracy. Building Management System includes subsystems for managing its various components, including:

- System for commercial accounting of heat consumption.
- Automatic equipment of Central Heat Supply Station, boiler systems and heating systems.
- Cooling stations and refrigeration supply systems.
- Water supply and plumbing system.

- Lightning, electric power supply and uninterrupted power supply system.
- Smoke removal, firefighting, etc.
- Fire alarm system, fire and other emergency warning systems.
- Security-burglar signaling system.
- Access monitoring and control system.
- Closed-circuit, terrestrial and satellite television.
- Structured cable system (SCS).
- Telephone and long-distance communication.
- Automated parking.
- Other low current systems. [6]

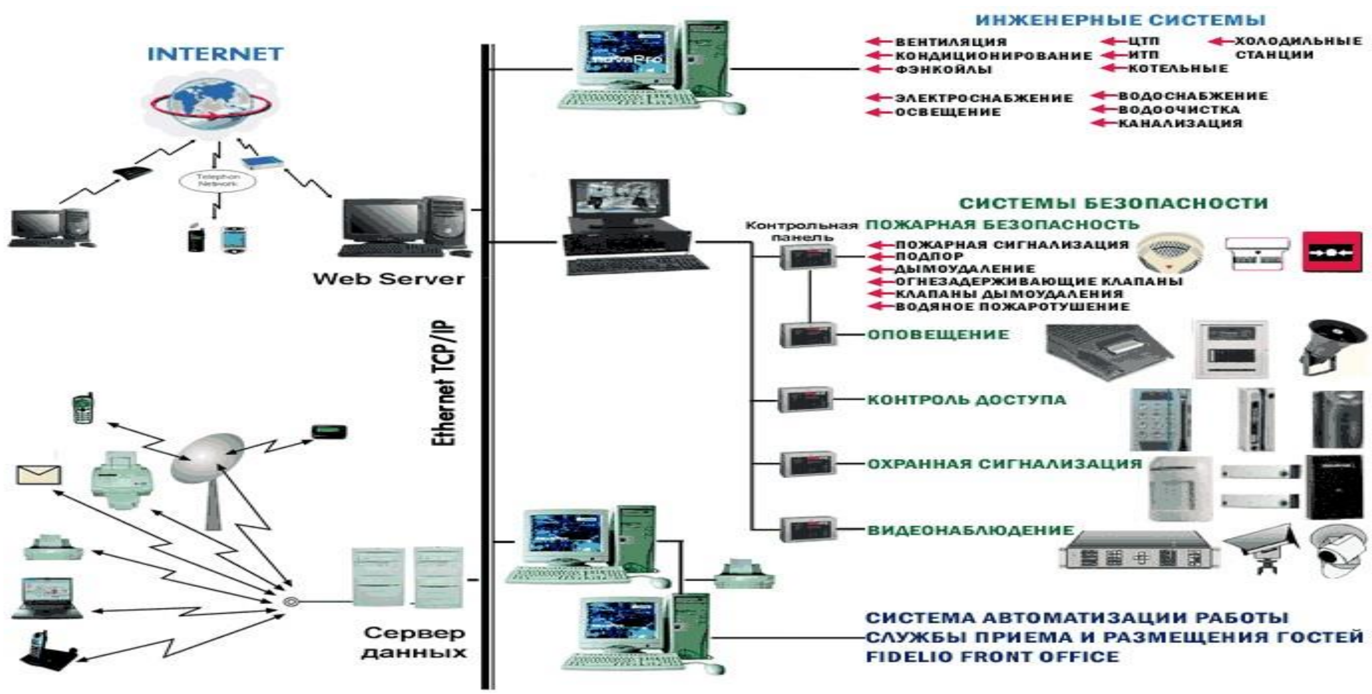

Figure (2.5): BMS System

2.5.3 Hardware Design

The Hardware of this Building Management System has been designed in such a manner that can carry out all the operations and instructions it's include:

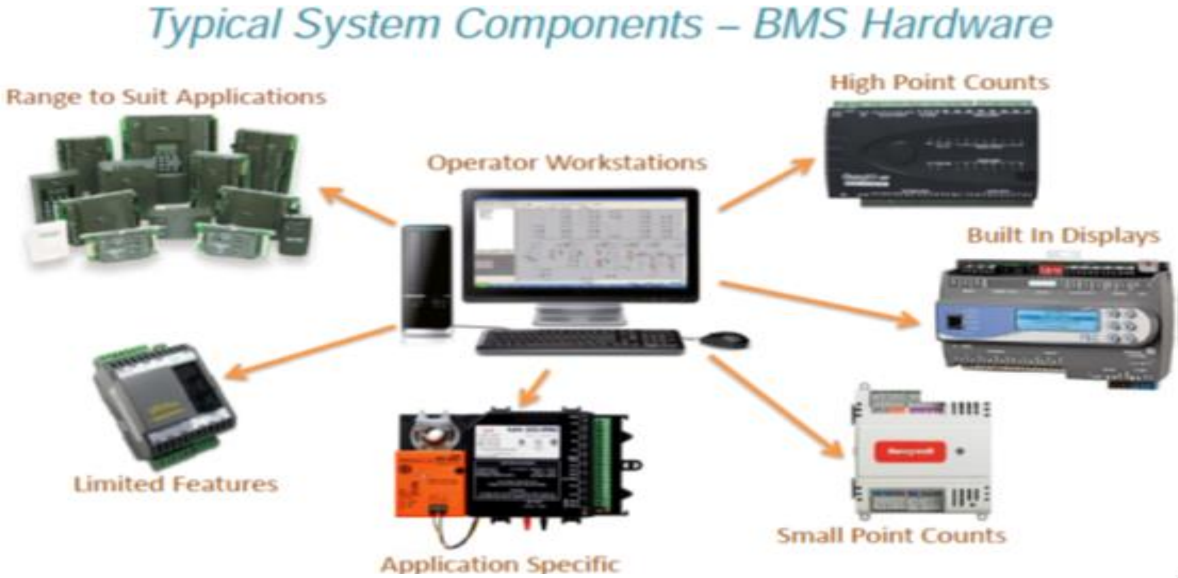

Figure (2.6): BMS Hardware

1- Structural Design

The structure of the building is separated into different groups which are based on the requirements, the base, is made up of strong and heavy metal in order to support to the structure of the heavy metallic building.

The DC motor installed should be capable enough to produce power with the aim of carrying the entire weight of Elevators. [5]

2- Mechanical Consideration

Mechanics is one of the important aspects to be considered as majority of the system has components completely based on mechanical implementations. [5]

2.6 Building Automation with WAGO

Since its founding in 1951, WAGO has pioneered innovative electrical interconnect and electronic interface systems. That same year, the idea for a screw less termination system was born and the first spring pressure terminal blocks were introduced.

WAGO's ELECTRICAL INTERCONNECTIONS division has undergone rapid development over the years, paving the way for more industry-leading innovations. In 1995, WAGO reached another milestone by launching the WAGO-I/O-SYSTEM, the world's first fieldbus-independent and finely modular I/O system. The introduction of industrial field bus systems has significantly impacted automation. Modern, decentralized topologies with distributed "intelligence "have replaced traditional, centralized automation structures.

Now, WAGO is meeting virtually all of the industry's needs as both the leader in Spring Pressure Connection Technology and a pioneer in automation technology. For more than a decade, WAGO has offered a wide range of advanced building automation components based on the WAGOI/O-SYSTEM 750. [9]

The I/O system's modular design enables solutions for pressing projects to be easily, and efficiently, implemented. A wide range of controllers with open fieldbus protocols (e.g., BACnet, KNX or MODBUS) in combination with standard inputs/outputs or subsystems (e.g., DALI, EnOcean or LonWorks) cover the entire building automation market. [9]

2.6.1 WAGO-I/O-SYSTEM

2.6.1.1 Fieldbus Controllers and I/O Modules

Figure (2.7): WAGO Building Automation

Fieldbus Controllers:

WAGO's comprehensive range of field bus controllers supports established protocol standards. Configuration, programming and visualization are

Figure (2.8): Fieldbus Controllers

Easily performed using the IEC 61131-3-compliant WAGO-I/O-*PRO* or *eCockpit* software package [10]

2.6.1.2 Communication Protocol

1-BACnet Controllers

For BACnet communication, WAGO offers two different controllers equipped with BACnet/IP (ETHERNET) or BACnet MS/TP (RS-485) interfaces. Both high-performance controllers support the BACnet Building Controller (B-BC) profile and are freely programmable. The controllers can be easily commissioned with WAGO's user-friendly BACnet Configurator. [10]

2-KNX IP Controller

The KNX IP fieldbus controller is freely programmable and communicates via standard 10/100 Mbit ETHERNET network. Commissioning the KNX interface is performed using the ETS Network Management Tool. A product database from WAGO is available for commissioning the controller.

3-ETHERNET Controllers

WAGO provides a wide range of ETHERNET controllers in different performance classes and with various interface combinations. The ETHERNET fieldbus controllers support Modbus TCP. A wide variety of standard ETHERNET protocols is also supported for easy integration into IT environments (e.g., HTTP, BootP, DHCP, DNS, SNTP, SNMP, and FTP), this using in this research.

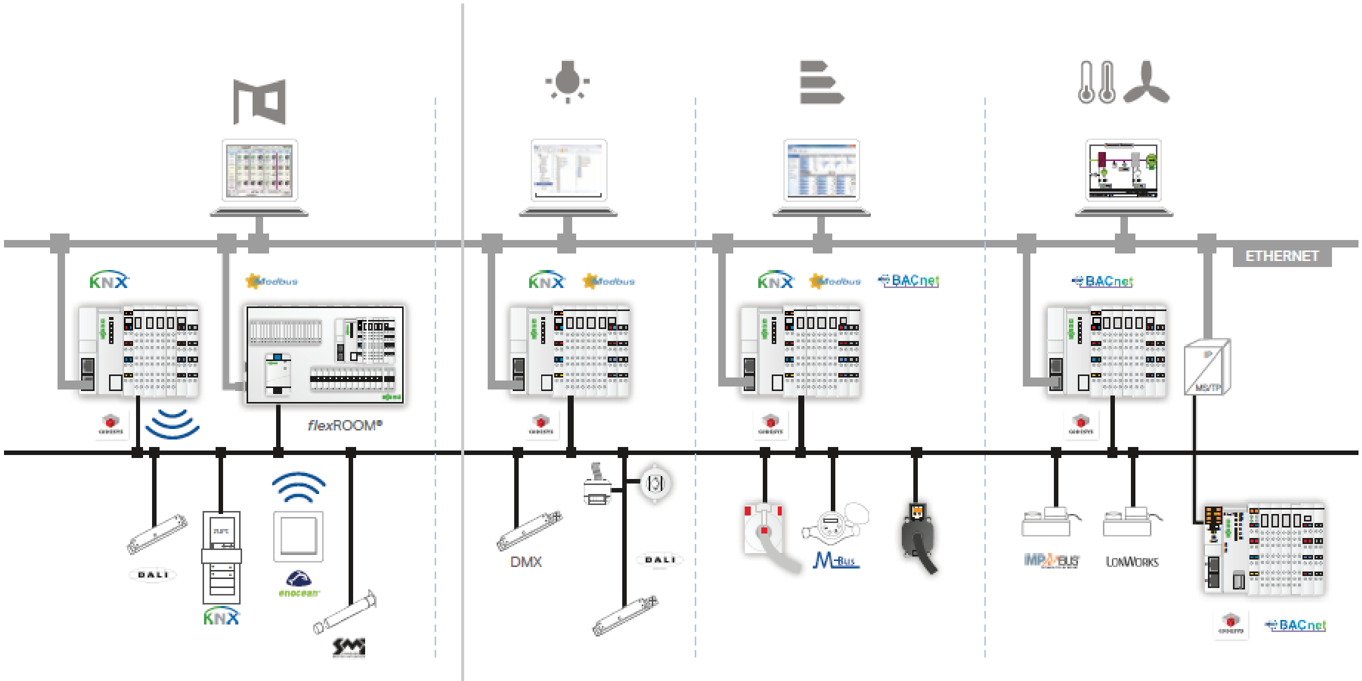

Figure (2.9): BMS protocols

For other protocols show Appendices no.6

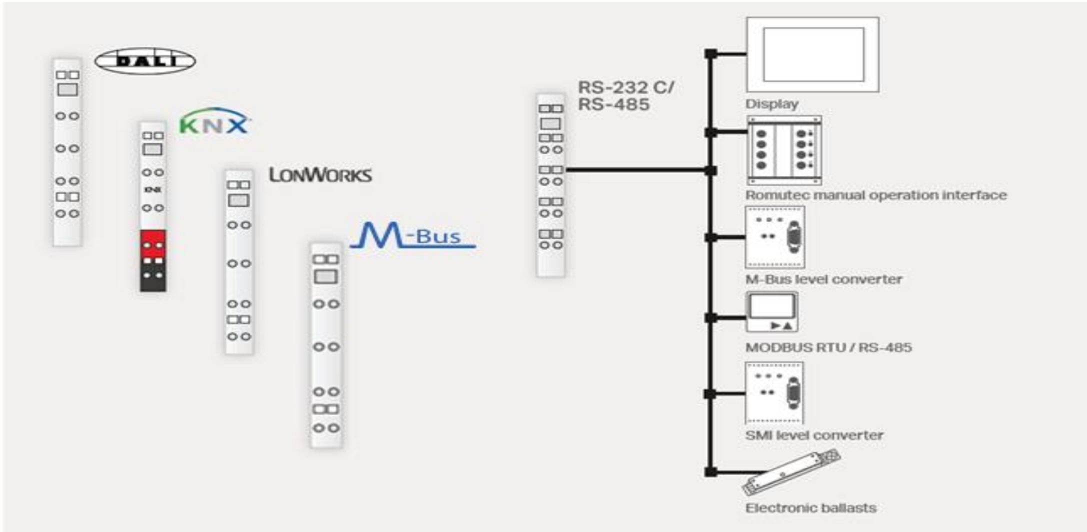

Figure (2.10): Communication Module

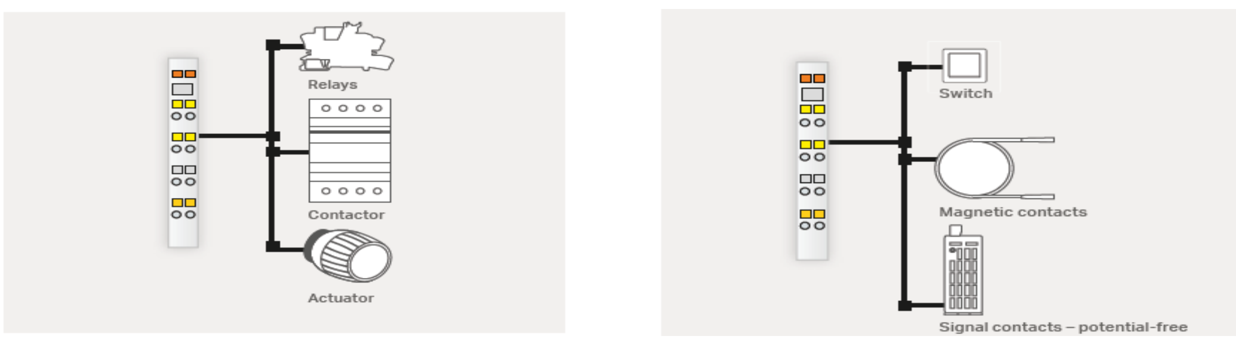

Figure (2.11): Digital Input/output

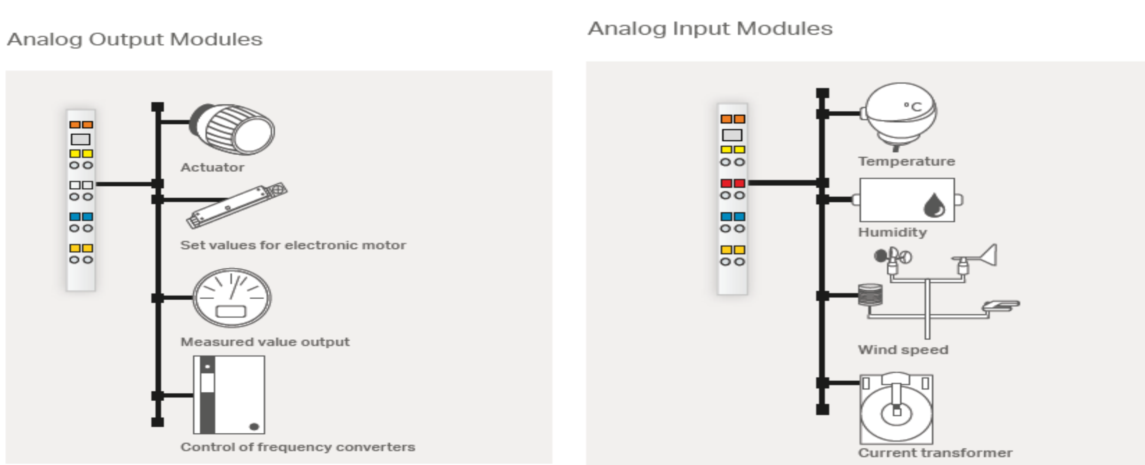

Figure (2.12): Analog Input/output

2.7 WAGO Energy Management

- Why WAGO

Features

- Measurement of energy consumption, Harmonic analysis and Tamper detect.

Advantages

- Measuring and processing all relevant measured variables with one module, Comprehensive network analysis and easily integrated with any 3rd Party billing or Energy Software's. [11]

Customer benefit

- Measuring energy consumption and network impurities, Increasing transparency and Reducing Energy Cost.

2.8 Modules for Distribution Boxes

The products and solutions outlined in this brochure form a solid foundation for building automation. However, additional peripheral systems, control modules and components are required for complete automation solutions.

WAGO not only provides a wide range of products, but can also furnish tailor-made solutions consisting of fully equipped system distribution boxes. Users not only benefit from shortened assembly times and error-free installation, but also from easier commissioning. [11]

2.9 Key BMS Components

- **Power Supplies**

The EPSITRON Series provides 24 V to power WAGO controllers and IPCs.

- **Network Infrastructure Components**

From a simple switch to configurable communication capabilities with a fiber optic connection [4]

- **Customizable ETHERNET**

User-configurable RJ-45 ETHERNET connectors

- **Transfer Modules**

For RJ-45 patch cables and universal connections, such as a 9-pole Sub-D RS-232 connection

- **Relays**

Control consumers, such as lights, shutter drives and much more.

- **WINSTA Pluggable Connectors**

Innovative connectors from the WAGO WINSTA system for preassembled components that provide fast and safe on-site installation; accommodate conductor cross-sections up to4 mm2 (12 AWG) and nominal currents up to 25 A.

- **Screw Less DIN-Rail Terminal Blocks**

WAGO TOPJOBS is a range of screw less DIN rail terminal blocks for building installations with conductor cross-sections of 1.5 mm2 to 16 mm2 (16–6 AWG).

- **Current Measurement**

Coupled with Electronic Interface devices and the WAGO-I/O-SYSTEM 750, WAGO offers a comprehensive range of perfectly tuned energy efficiency solutions. [11]

- **WAGO-I/O-SYSTEM**

Advantages of WAGO's successful fieldbus system: solution with scalable performance, high integration density and an unbeatable price/ performance ratio.

- **Custom, Ready-Made Solutions**

WAGO product specialists have the experience and efficient solutions to assist you from initial specs to final installation.

Figure (2.13): WAGO board

2.10 Basic WAGO Software

1- WAGO I/O Check

WAGO-I/O-*CHECK* is an easy-to-use Windows application for checking inputs and outputs, as well as displaying a WAGO-I/O-SYSTEM 750 node. The node does not have to be connected to a fieldbus system. In addition to checking the actuators/sensors connected on the field-side and module-specific configurations, the application can also document node configuration. [11]

2- WAGO-I/O-PRO

WAGO-I/O-*PRO* is a basic tool for creating control programs. The software contains six major, IEC 61131-3 graphic/text-based programming languages (FBD, LD, IL, ST, CFC and SFC), providing users with flexibility. Using WAGO-I/O-*PRO*, programs can be individually created. In addition, pre-designed function blocks can also be accessed from software libraries. Graphically structured programs, such as those created with the Function Block Diagram (FBD) programming language, are very easy to create. [11]

3- Web Visualization

Project-specific visualizations are generated in a graphic editor in the WAGO-I/O-*PRO* software. Ready-made macros with a graphical configuration interface are available for certain functions or function blocks, which can be easily integrated into a project.

Visualization is performed on a Web server, which is locally contained in the ETHERNET controller. This allows the visualization to be displayed in a Web browser on any computer connected to the Internet (e.g., for remote maintenance). The Web visualization can also be accessed on a tablet or smart phone using an app. [11]

4- Specific Software Tools

In addition to the previously described general software tools, WAGO also offers a selection of other tools specifically designed for a certain technology, application or product. WAGO therefore offers both DALI and BACnet Configurators, allowing devices connected to a specific network to be easily and efficiently addressed and parameterized. The individual tools and their functions are described on their respective product or technology pages. [11]

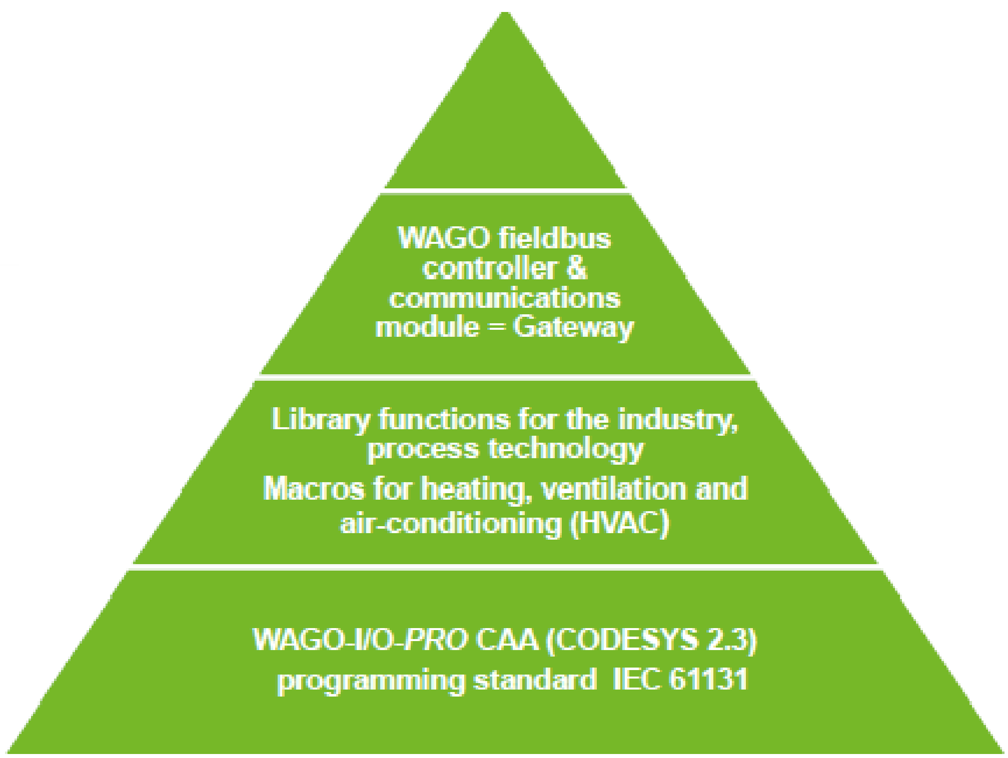

Figure (2.14): WAGO Levels

2.11 HARDWARE WAGO

1- Fieldbus Nodes

-Fieldbus independence, Modularity, Future-proof and Operating reliability and robustness. [11]

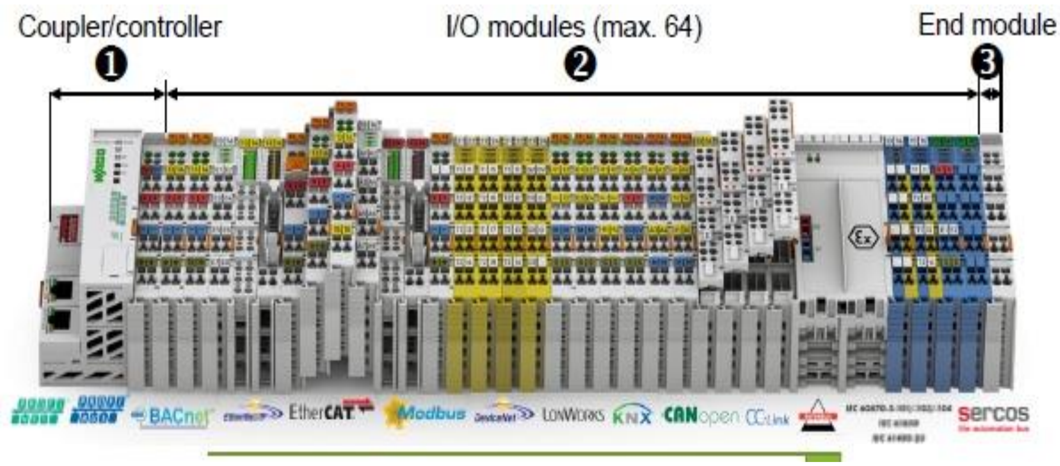

Figure (2.15): Fieldbus Nodes

2- WAGO-I/O-SYSTEM 750, 753, for scalable Automation Solutions

Fine modularity and fieldbus-independence are hallmarks of the WAGO-I/O-SYSTEM, which boasts worldwide approvals for a diverse range of applications. During development, great care was taken to ensure the system could account for all the requirements placed on decentralized fieldbus systems.

3- Total Extension

The length of the module assembly that can be connected to the coupler/controller is 780 mm. The width of the end module is 12mm.

When assembled, the I/O modules have a maximum length of 768mm. [11]

- **Examples:**

64 I/O modules of 12 mm width can be connected to a coupler/controller.

32 I/O modules of 24 mm width can be connected to a coupler/controller.

4- Exception

The number of connected I/O modules also depends on the process image (PII/PIO) of the respective coupler/controller that is used to drive them.

For example, the maximum number of I/O modules, that can be connected to a PROFIBUS-coupler/controller is 63 without end module.

With regard to 32 bit ETHERNET controllers, it is possible to connect 250 I/O modules using an extension terminal. The maximum extension is then 70 meters. [11]

5- Handling the I/O Modules

- Assembly/ Removal:

• Assembly: Insert until the module engages noticeably

• Removal: Pull on the orange actuating element

• Mount terminals, if free of voltage

• Without tools

- Practical Tips:

• Be careful with the blade contacts, when removing the terminal (risk of injury)

• Keep gold contacts clean and do not touch with fingers

• Deposit terminal with the printed side up [11]

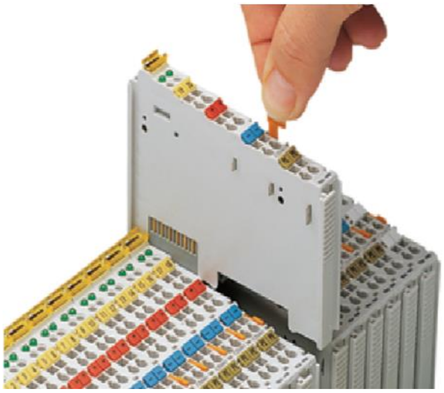

Figure (2.16): Handling I/O Modules

6- Wiring the I/O Modules

- One conductor per clamping unit
- Clamping of the wire without damage through unique design
- Gastight contact area between conductor and current bar
- Vibration and shock resistant
- Simple, easy-to-use design fast and maintenance free [11]

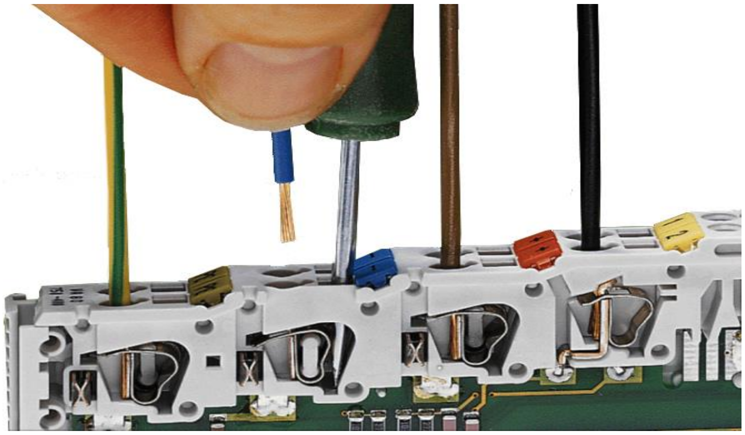

Figure (2.17): Wiring I/O Modules

7- Power Supply

The potential Levels Power supply is gavanically isolated.

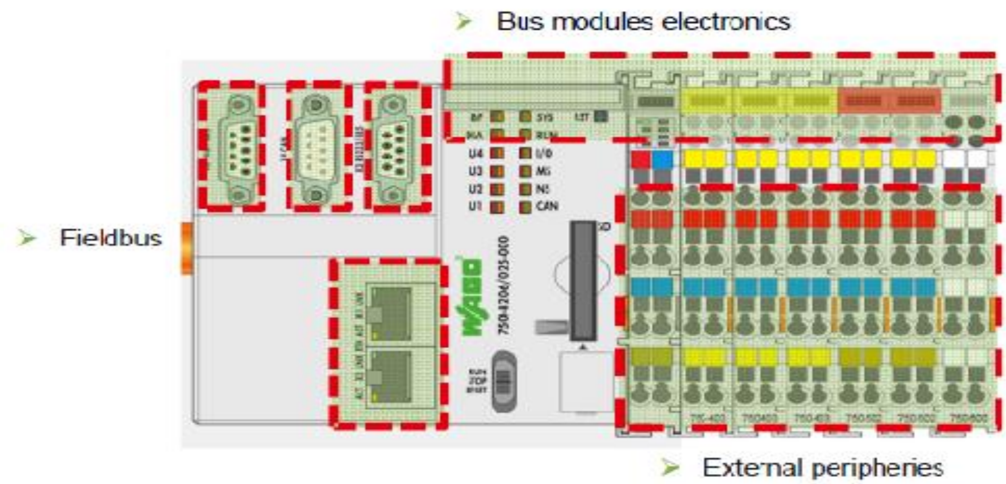

Figure (2.18): Power Supply

- **Power Supply**

Supply with electrical Isolation

Bus coupler and bus modules electronics:

• External: 24 V DC

• Internal: 5 V DC, 2000 Ma

External peripheries:

• 24 V DC, max. 10 A

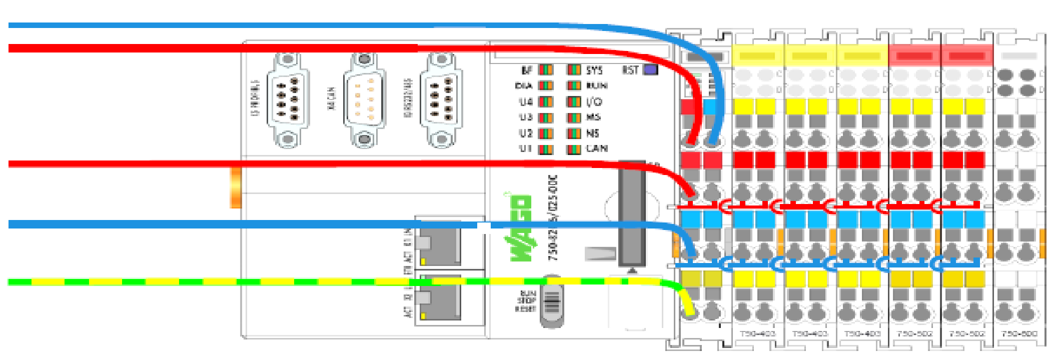

Figure (2.19): Supply with electrical

- **Power Supply**

Supply without electrical Isolation

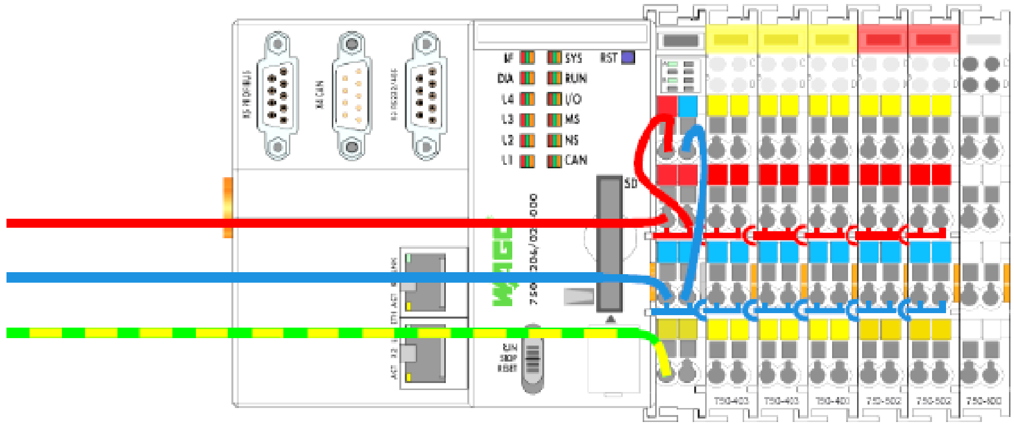

Figure (2.20): Supply without electrical

- **Power Supply**

The power supply of the internal electronics and field supply is electrically isolated at the Bus Coupler and Controller. The separation allows the separate supply of the actuators and sensors. The connection of the bus modules automatically leads to the forwarding of the supply voltages. The supply module with diagnostics also enable supply monitoring. Thus, a flexible, user-specific supply configuration of a station is ensured. The power supply of the electronics is limited to a maximum value. This value is dependent on the coupler/controller used. the sum of the internal current consumption of all us modules exceeds this value, an additional bus supply terminal is necessary. The power supply of the field supply for the external I/O (via power contacts) must not exceed 10 A. The 24 V direct current feed in supplies all system-internal components, e.g. the electronics for the fieldbus couplers/controllers, the fieldbus interface, and the I/O modules, via the internal bus (5 V system voltage). [11]

8- Communication

Connection between PC and Controller

- Serial Communication Interface
- Operating Mode Switch 8xx
- Operating Mode Switch PFC
- Reset Possibilities (Stand FW 06)
- Coupler
- Controller CODESYS 2.3
- Controller *e!COCKPIT*

- Sensors**:**

1-Active Sensors

• Supplied with active electronics

• Have external power supply

2-Passive Sensors

• Supplied by the module

• Do not have external power supply

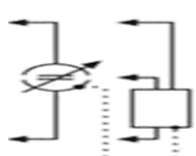

Figure (2.21): Active Sensor

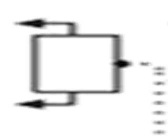

Figure (2.22): Passive Sensor

- Single-Ended**:**

• Measurement against mass

• Can connect all sensor types 24V/0V

- Differential Input:

• The module measures the difference between +Ai and –Ai

• There is no 24 V output

• Suitable for 2-wire sensor technology

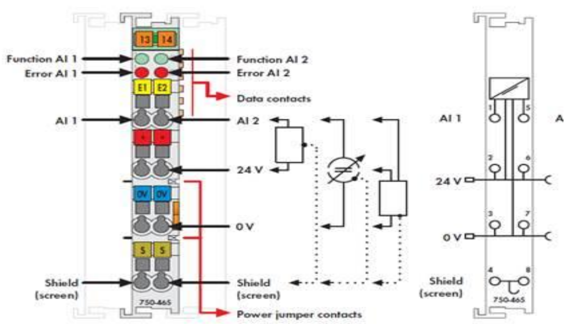

Figure (2.23): Single Ended

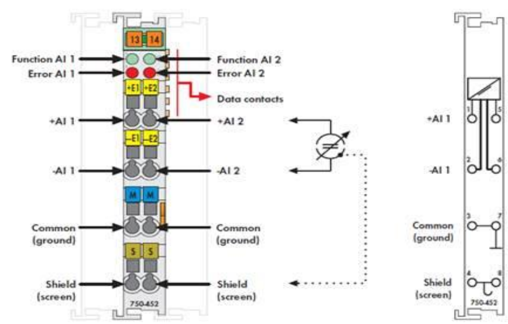

Figure (2.24): Differential Input

2.12 WAGO Services

1- Technical Support

WAGO's technical support staff is ready to assist all customers with advice and guidance: from selecting the right product, through telephone support during commissioning, all the way up to on-site troubleshooting. Customers directly benefit from knowledgeable WAGO experts who help customers implement their projects faster.

2- WAGO Provides Advice and Support

• Product selection, Product commissioning, troubleshooting and Technical advice on WAGO's wide product range.

3- Project Support

WAGO offers consulting and project planning services to help devices to get the best possible solutions for your customer and installation projects. Our experienced team of professionals will gladly help you implement your projects with WAGO products.

4- Large-Scale Applications Include

• Production facilities and warehouses, Office buildings, Shops and display areas, Schools, Hospitals and Airports

5- Planning and Project Design

• Conceptual design, Network planning, Application design, Component selection and Quote generation. [11]

6- WAGO Helps Customers With

• Advice while planning construction projects from experts with years of project experience.

• Customizing solutions to ensure the technical and financial success of large projects.

• Technical support for implementing building projects. [11]

2.13 Previous work

In the source paper [13] the authors have analyzed the hardware infrastructure, intended as the network of sensors, actuators, appliances and accumulators, of this kind of buildings. Moreover, they have discussed which kind of networking infrastructures is needed in order to cope with the particularities of complex residential buildings. Finally, they have envisioned a layered architecture, from the aforementioned hardware layer to an envisioned application layer, providing also examples of what could be done, in the near future, to increase the capabilities of our living spaces.

In [14] the author proposed that the building energy management systems its control and automation in buildings has significant role. These systems can play an important role in regular energy monitoring and management and therefore to save the possible energy and cost. The key point of the building automation market is focused upon better facilitation to the user in terms of comfort at reduced operation cost. Energy efficiency improvement will also contribute to environmental protection. Therefore there have been regulations and rating systems made that mandates the requirement of energy monitoring and control in a building. For example, the above mentioned building utilities and equipment control and automation plays an integral role in achieving the green building rating points from certifying authorities such as GRIHA and IGBC. The proposed system is to control the active systems such as lighting including artificial lighting (on/off & dimming control), air conditioners and safety features like fire alarm & gas alarm. In future the existing idea can be implemented for the whole building, i.e. various rooms or areas and then all of them can be integrated on a common platform for monitoring and control of different equipment.

In [15] the authors say that the world of today, a major change in technology can be seen as an advantage, a number of different fields from industrial & communication to household application can be automatically controlled. This paper presents a building management system (BMS) that has been designed for Iqra University using AT89C52, which is the key module in order to perform the controlling and automation. The main area of this BMS focuses on switching and controlling of the power input/output, beside this security and HVAC process has also kept as a main concern in this system. Index Terms—AT89C52, BMS, and HVAC.

Chapter Three

SIMULATION, IMPLEMENTATIONAND DISCUSSION

Chapter Three

Simulation, Implementation and Discussion

3.1 Introduction

Figure 3.1 the BMS system plan proposed in this research is composed of four sub systems: a Power supply system, a Fieldbus coupler system, Industrial switch and field device system. The design is based on linking these four systems together accurately by using a specific design and the soft logic program.

System will also be designed. In the control system which is the most important system a PFC 200 controller will be used. The design of the hardware part will be used from WAGO hardware. The design of the software part will be done by writing the soft logic program used *e!COCKPIT*. This system controlling and monitoring lighting system, ventilation system and temperature system.

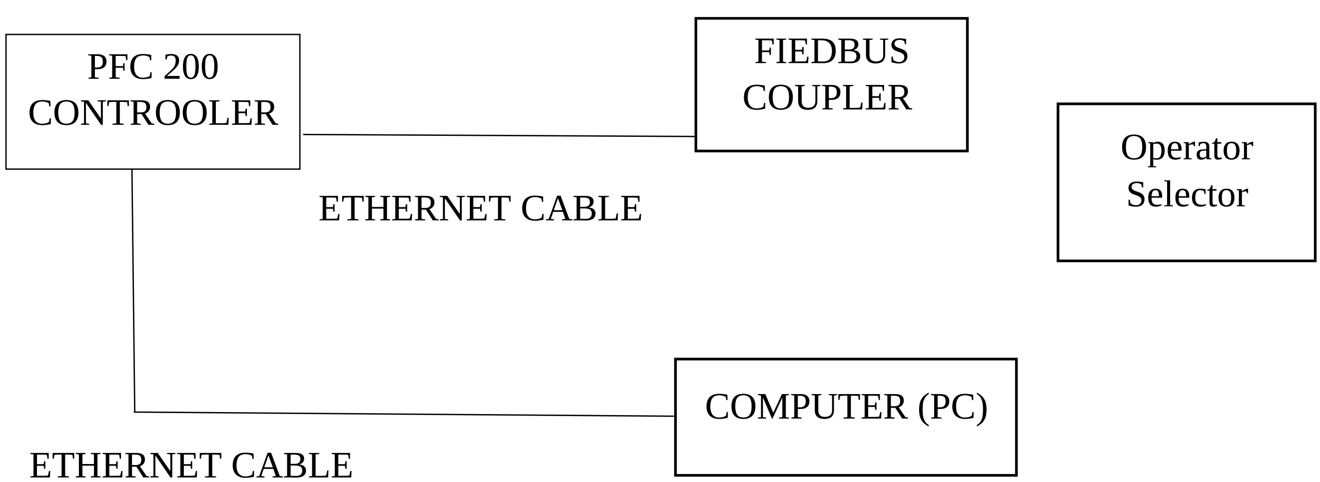

Figure (3.1): Network layout

3.2 BMS Subsystem

3.2.1 Unit One: Power Supply Unit

1/Controller PFC200:750-8202:

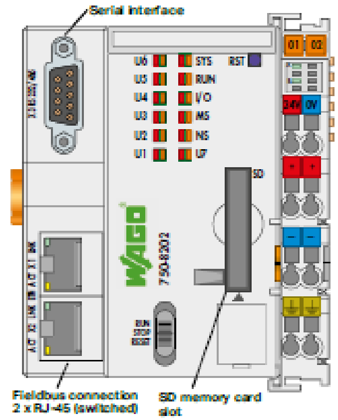

Figure (3.2): PFC 200

- **PFC100/PFC200 Controller:**

Maximum Performance in a Minimum Space As a member of the WAGO control family, the PFC100 and PFC200 Controllers with e!RUNTIME excel with high processing speed and multiple interfaces for parallel communication. All versions feature two ETHERNET ports and — depending on the model — additional interfaces. The CAN open, PROFIBUS DP and MODBUS TCP/UDP/RTU protocols provide a flexible connection to fieldbus systems and external input/output devices. These fieldbus systems can be easily configured directly in WAGO's easy-to-use *e!COCKPIT* development environment. The ETHERNET interfaces with an integrated switch also support all major IT protocols. In addition to multiple interfaces, the PFC100/PFC200 offers ample memory for your applications thanks to the internal flash memory and an integrated interface for memory cards. [3] For other information show Appendices no.2

- **Telecontrol Technology:**

Standardized telecontrol protocols according to IEC 60870-5, IEC 61850, IEC 61400-25 or DNP3 ensure use of the PFC Controllers in telecontrol technology. Link between Process Data and IT Application the PFC100/PFC200 ideally combines real-time requirements with IT functionality. It supports both MODBUS/TCP and ETHERNET/IP for use in industrial environments. HTTP, SNTP, SNMP, FTP, BootP, DHCP, DNS, telnet, SSH and other protocols simplify integration into IT environments. [3]

Integrated Web pages and Web-based visualization provide IT applications with real-time process data. Furthermore, the PLC incorporates library functions for email, SOAP, ASP, IP configuration, ETHERNET sockets and file system. [3]

- **Modular Expandability:**

With the WAGO 750 I/O-SYSTEM, the PFC100/PFC200 can be expanded to almost any input/output interface. A modular, DIN-rail-mount design permits easy installation, expansion and modification of the I/O module without tools. The straightforward design prevents installation errors. In addition, proven CAGE CLAMP technology offers fast, vibration-proof and maintenance-free connections that are independent of operator skill. Depending on the I/O module's granularity, field peripherals can be directly wired using 1-, 2-, 3- or 4-wire technology. [3]

- **Maximum Reliability and Ruggedness:**

The PFC100/PFC200 is engineered and tested for use in the most demanding environments (e.g., temperature cycling, Shock/vibration loading and ESD, etc.) according to the highest standards. Spring pressure connection technology guarantees continuous operation. Integrated QA measures in the production process and 100 % function testing ensure consistent quality. [3]

- **Open-Source Software:**

The firmware used in the controllers was created based on open-source software. The software packages used and their licenses are available from the download area under www.wago.com; please observe the rules stated there. The controller firmware itself is available as a Board Support Package (BSP).If you are interested, simply contact our Technical Support AUTOMATION unit. [3]

- **Advantages:**

Programming per IEC 61131-3,Applications with higher-level languages, Linux real-time operating system, Robust and maintenance-free and Integrated Cyber-Security Packages. [3]

- **Supply Modules:**

Power is always channeled to the internal electronics power supply via the controller. The power supply to the field-side supply is electrically isolated. The division enables a separate supply for sensors and actuators. The I/O modules 'connections automatically lead to transferring the supply voltages. Bus supply modules with diagnostics enable additional monitoring of the power supply.This ensures a flexible, user-specific supply design for a station. The current supply to the electronics is limited by a maximum value. If the sum of the internal current demand of all the I/O modules should exceed this value, an additional bus supply module is necessary. Even in this case, power supply to the field-side supply of 10 A may not be exceeded. However, different bus supply modules allow a new power supply, formation of potential groups and the implem Additional steps must be implemented specifically for the location the I/O-System is installed:

• Specific power and field-side power supply filters (750-624 or 750-626) are required for marine and onshore/offshore applications.

• A specific supply module (750-606) is required to operate intrinsically safe Ex modules.

• Additionally, both a bus supply module and a field-side power supply filter are recommended when operating intrinsically safe Ex i modules for marine and onshore/offshore applications.

• As part of operating safety-related I/O modules, PELV/SELV power supply units must be used for 24 VDC supply of electronics and field.

In addition, specific power and field-side power supply filters must be provided (750-626). [3]

2/ Input Module 750-400:

- This digital input module receives control signals from digital field devices, Each input module has a noise-rejection filter and Field and system levels are electrically isolated. [3]

Figure (3.3): Input Module 750-400

Table (3.1): Input Modules

Signal voltage	Number of channels	**Input filter**	**Special feature**
5 V DC	4	0,2 ms	
24 V DC	2, 4, 8, 16	3,0 ms	optional: ribbon cable (16-Channel)
24 V DC	2, 4, 8, 16	0,2 ms	
24 V AC/DC	4	20 ms	
24 V AC/DC	4	50 ms	with power contacts
42 V AC/DC	4	20 ms	
48 V DC	2	3,0 ms	
110 V DC	2	3,0 ms	
220 V DC	2	3,0 ms	
120 V AC	2	10 ms	
230 V AC	2	10 ms	
NAMUR	2	3,0 ms	proximity sensor
NAMUR Ex-i	1, 2, 8		proximity sensor
24 V DC	2		break-in alarm
PTC	8		PTC thermistor

3/Output Module 750-501:

- This digital output module transmits control signals from the automation device to the connected actuators.
- All outputs are short-circuit-protected.
- Field and system levels are electrically isolated [3]

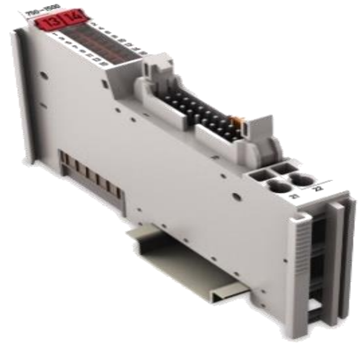

Figure (3.4): Output Module 750-501

Table (3.2): Output Modules

Signal voltage	Number of channels	Input filter	Special feature
5 V DC	4	20 mA	
5-14 V DC	8	1,0 A	
24 V DC	2, 4, 8, 16	0,5 A	optional: with diagnosis
24 V DC	2	2,0 A	optional: with diagnosis
24 V DC	16	0,5 A	ribbon cable
24 V DC Ex-i	2	50VA/30W	
230 V AC/DC	2	300 mA	SSR
230 V AC/DC	2	500 mA, 3 A (<30 S)	SSR
125 V AC/30 V DC	2	AC: 0,5 A; DC: 1 A	relay, changeover
100 V AC/30 V DC	2	AC: 0,5 A; DC: 1 A	relay, changeover, Ex-i
230 V AC	2	1,0 A	relay, changeover
230 V AC/30 V DC	2	2,0 A	relay, closer
230 V AC	1	16 A	relay, closer

4/End Module 750-600:

After the fieldbus node is assembled with the correct bus coupler and I/O modules, the end module is snapped onto the assembly.

It completes the internal data circuit and ensures correct data flow. [3]

Figure (3.5): End Module 750-600

3.2.2 Unit Two: Fildbus System

1/Fieldbus Coupler 750-352:

The 750-352 ETHERNET Fieldbus Coupler connects ETHERNET to the modular WAGO-I/O-SYSTEM. The fieldbus coupler detects all connected I/O modules and creates a local process image. This process image may include a mixed arrangement of analog (word-by-word data transfer) and digital (bit-by-bit data Two ETHERNET interfaces and an integrated switch allow the fieldbus to be wired in a line topology. This eliminates additional network devices, such as switches or hubs. Both interfaces support Auto-Negotiation and Auto-MDI(X).The DIP switch configures the last byte of the IP address and may be used for IP address assignment (DHCP, BootP, static).The coupler is designed for fieldbus communication in both Ethernet/IP and MODBUS networks. It also supports a wide variety of standard ETHERNET protocols (e.g., HTTP, BootP, DHCP, DNS, SNMP, and FTP). An integrated Web server provides user configuration options, while displaying coupler's status information. The coupler has an integrated supply terminal for the system voltage. The field power jumper contacts are supplied via a separate supply module. [7] For Other information show Appendices no.4

Figure (3.6): Fieldbus Coupler 750-352

2/Power Supply 787-602: For other information show Appendices no.3

The supply module provides the I/O modules with the corresponding supply potential. Series I/O-System Power Supply 24 VDC. The maximum current at the supply module is 10A. When configuring the system, it must be ensured that this total current is not exceeded. Should higher currents be necessary, intermediate supply modules must be added in the assembly. [7]

Figure (3.7): Power Supply

3/Analog Input 750-455:

-The analog input module processes signals of a standard magnitude 4–20mA.

-The input signal is electrically isolated and is transmitted with a resolution of 12 bits.

-The internal system supply powers the module.

-The input channels of the module have one common ground potential. [7]

Figure (3.8): Analog Input 750-455

Table (3.3): Analog Inputs Range

Signal voltage	Number of channels	Special feature
0-20 mA	2	optional: Ex-i
0-20 mA	2, 4	
4-20 mA	2, 4	
0-10 V DC	2, 4, 8	optional: 10 bit; ±10 V
± 10 V DC	2, 4	

4/End Module 750-600:

After the fieldbus node is assembled with the correct bus coupler and I/O modules, the end module is snapped onto the assembly. It completes the internal data circuit and ensures correct data flow. [7]

Figure (3.9): End Module 750-600

3.2.3 Unit Three: Industrial Switch 852-111

The 852-111 is a 5-port 10/100Base-TX industrial ETHERNET switch supporting Auto-Negotiation and Auto-MDI-/MDI-X detection for each port. Using the switch's 5 ports, several segments can be created to reduce the network load, while providing a dedicated bandwidth to each user node. The 852-111 switch is a cost-effect solution to keep up with the constant demands of IP-based, industrial communication needs.

The switch is easy to configure and install and is best suited for small to medium-sized networks. [7]

Figure (3.10): Industrial Switch 852-

- **Features:**

5 ETHERNET ports, 10/100 Mbps auto negotiation, Front-panel diagnostic LEDs, Supports Auto-MDI/MDI-X functions, Store-and-forward switching method, Integrated address look-up table, supports 2000 absolute MAC addresses, Overvoltage protection, IEEE 802.3x flow control in full-duplex mode and DIN-35 rail mounting. [7]

3.2.4 Unit Four: Filed Device

1/Switch One Gane 3/Fan 5/Relays

2/Temperature Sensor (Show Appendices no.5) 4/Light

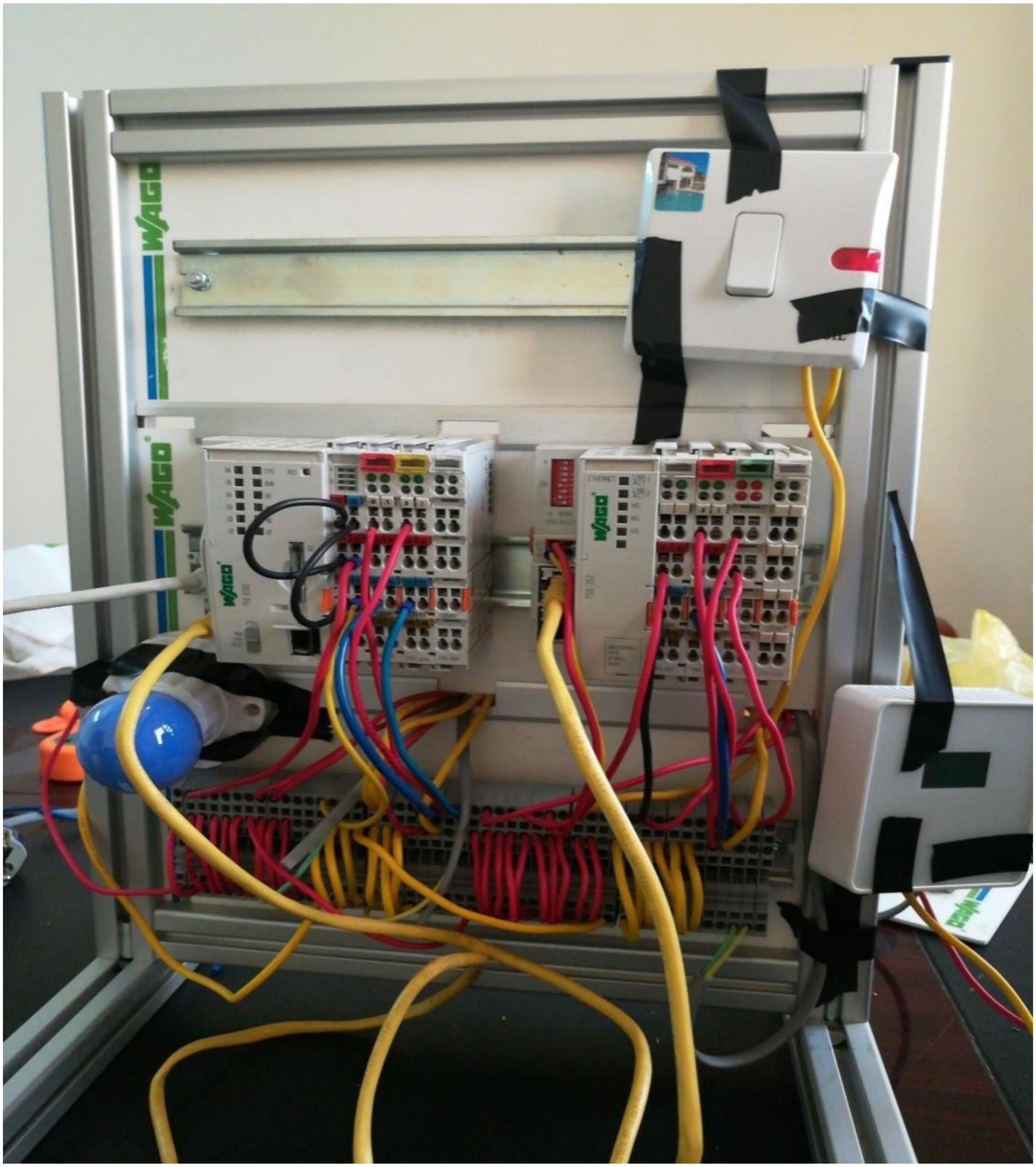

Figure (3.11): Wireless layout

3.3 System Structure:

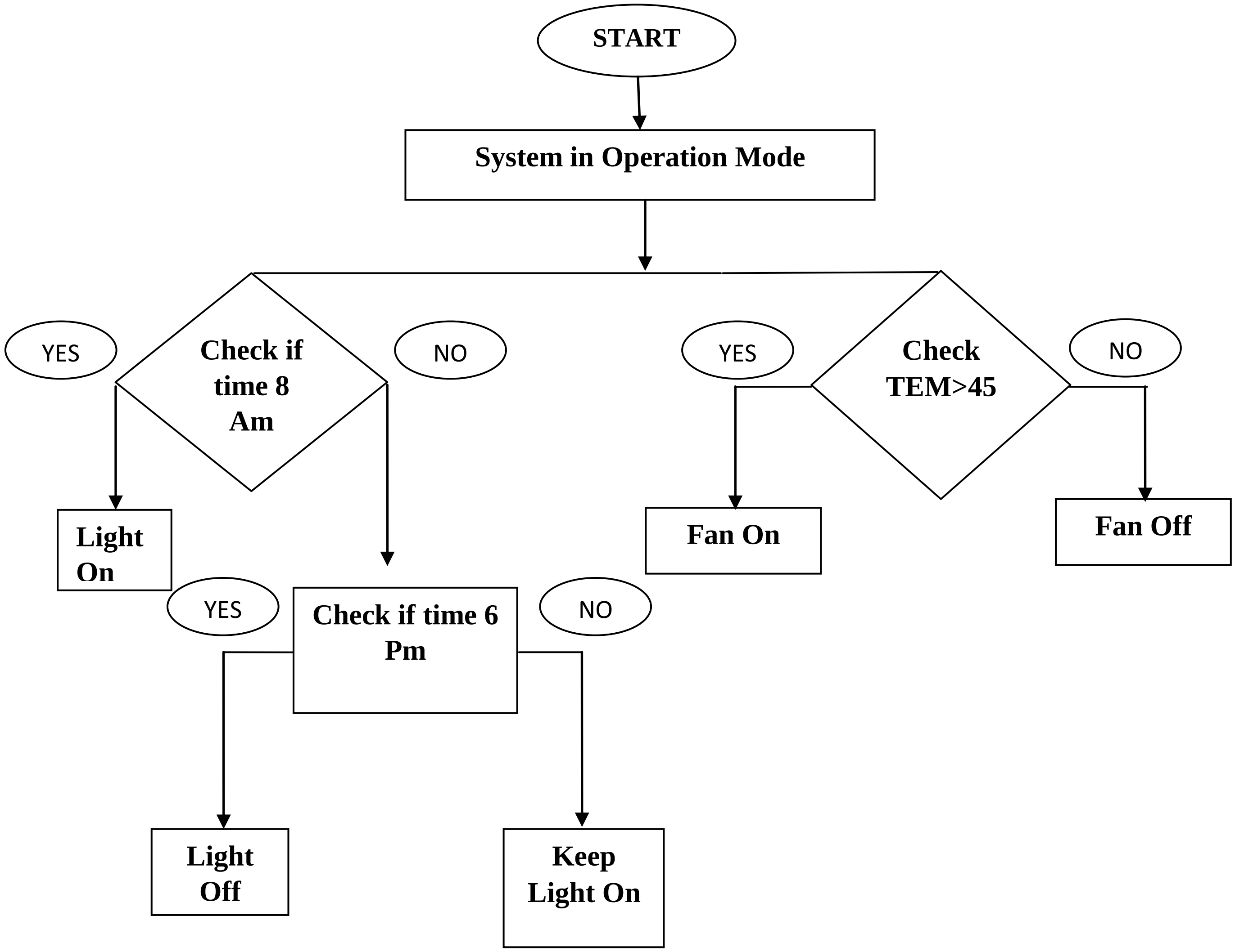

Figure (3.12): Proposal System

3.3.1 Why WAGO Component???

The main reason to select WAGO Hardware it is easy in wiring, Open-Source Software, Telecontrol Technology, Maximum Reliability and Ruggedness, Security on Board and Supply Modules.

The main Advantage for controller PFC200 WAGO with using Modules can keeping each system in other place not all in control room such as lighting system in first floor or ventilation system in fifth floor. This advantage only in WAGO Controller. Also main customer advantage Measuring energy consumption and network impurities, Increasing transparency and Reducing Energy Cost.

3.4 Software

As mentioned before the program software which is used for the system called **e!COCKPIT**. Is the software for WAGOPFC200 controller. The programming executed by LADDER DIAGRAM. [6]

3.4.1 Software for Mechanical Engineering

Software is used in every phase of machine and system automation - from design to successful machine operation.

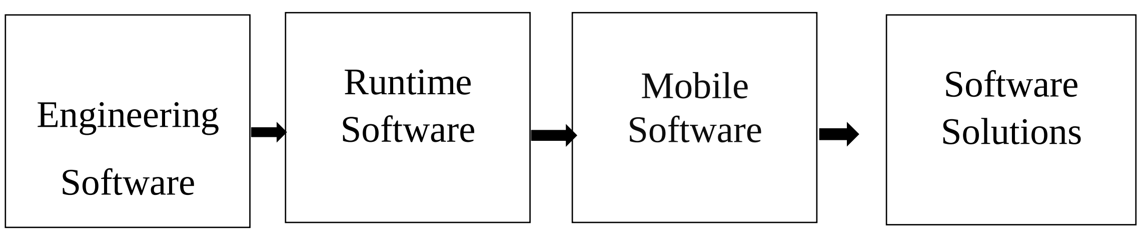

Figure (3.13): Software for Mechanical Engineering

1-Engineering Software:

Quickly implementing complex machine functions is critical in modern mechanical engineering applications. PC-based engineering software supports all development activities. The focus is on simple configuration, timely programming and efficient commissioning of automation network components. Engineering tools are typically not permanently linked to the machine they only communicate with the machine during startup and maintenance. [6]

2-Runtime Software:

The machine is controlled by runtime software that determines behavior, while enabling both operation and current status monitoring for the user. It also transmits operating data to higher-level systems. With comprehensive, tried-and-tested software function blocks (IEC libraries), development goals are reached more quickly. Unlike engineering software, runtime software operates continuously — it is a part of the machine and ensures correct operation. [6]

3-Mobile Software (Apps):

Software on mobile devices can also be productive in the industrial environment. The software allows users, for example, to quickly and easily operate and monitor automation processes from a Smartphone or tablet — from anywhere. Mobile software typically communicates only with the machine’s controller for a specific application. [6]

3.4.2 e!COCKPIT

Engineering Software, based on CODESYS 3 Preparing machines and systems for faster startup: *e!COCKPI* the new engineering software shortens development time for automation projects while impressing with a modern and clearly laid out user interface. At the software’s core is CODESYS 3, which provides the simple and versatile creation of applications. [3]

Ensuring a project’s long-term viability through sustainable cost savings hinges on a user’s ability to quickly adapt to new software that offers a high degree of reusability. This sharpens your competitive edge by reducing your time to market. WAGO set out to fulfill these exact requirements by developing its own engineering software: *e!COCKPIT*. This integrated development environment supports every automation task from hardware configuration, programming, simulation and visualization up to commissioning - all in one software package. Use the programming tool to cover all important automation bases while simultaneously engineering particularly complex projects quickly and easily. [3]

- **Advantages:**

• Measure both machine code's runtime behavior and code coverage right at the beginning of the development phase

• Detect runtime problems at an early stage

• Identify both time-consuming program parts and unused programming blocks

• Overall and individual measurement of all application blocks

• Identify the code efficiency by comparing historical and actual measurements

• Increase the software quality Main functions:

• Implicit binary code extension during translation, without changing the program code of a project

• Dynamic measurement via code instrumentation at each function entry and exit

• Only during measurement: temporary code enlargement and runtime extension of 10 to 50%

• Measurement start by a variable or by command

• Overview of the measurement results in the development environment. [3]

- **Functions:**

• Control the runtime measurement via freely selectable Boolean variable, Measure the runtime of individual programming blocks and function block instances within the “profiler watch list”,Measure the percentage of missed instructions per block via code coverage and Measurement results show the time-critical path. [3]

- **Setting Options:**

• Select the task to be measured

• Select the unit base (tick, milliseconds or microseconds)

• Define the memory size required for the measurement

• Adjust the measurement behavior (next or maximum cycle)

• Select the calls to be measured in the monitoring list

• Select the program blocks to be measured to determine the code coverage

- **The Results in Detail:**

• Percentage of time spent in the call

• Total time spent in call

• Average time of all POU calls in a single cycle

• Minimum and maximum processing time over multiple cycles

• Number of calls

• Time spent for each call

• Standard deviation of average measured time

- **Display The Results As:**

Summary table, Call tree (time- or process-oriented),Tables or Watch list.

- **Workstation License:**

Can be installed on up to two PCs (e.g., notebook & desktop).

- **Multi-user License:**

Can be installed up to the number specified.

- **Site License:**

Allows the installation of an unlimited number of licenses at one location

Buy-out license:

Allows the installation of an unlimited number of licenses in one company at all company sites in that country. In addition the software may be used in all products produces by the company that contain WAGO automation technology and therefore form a functional unit. [3]

3.4.3 Configuration and Parameterization

The integrated *e!COCKPIT* configurators figure 3.13 provide modern operating tools and workspaces, such as:

• Graphical network topology: Complex dependencies between network participants and their current states are easily and intuitively accessed.

• Drag & Drop: Simplifies interaction with devices.

• Copy & Paste: Individual devices or whole network branches can be duplicated quickly.

• Batch processing: Parameter values are set simultaneously for several devices. [3]

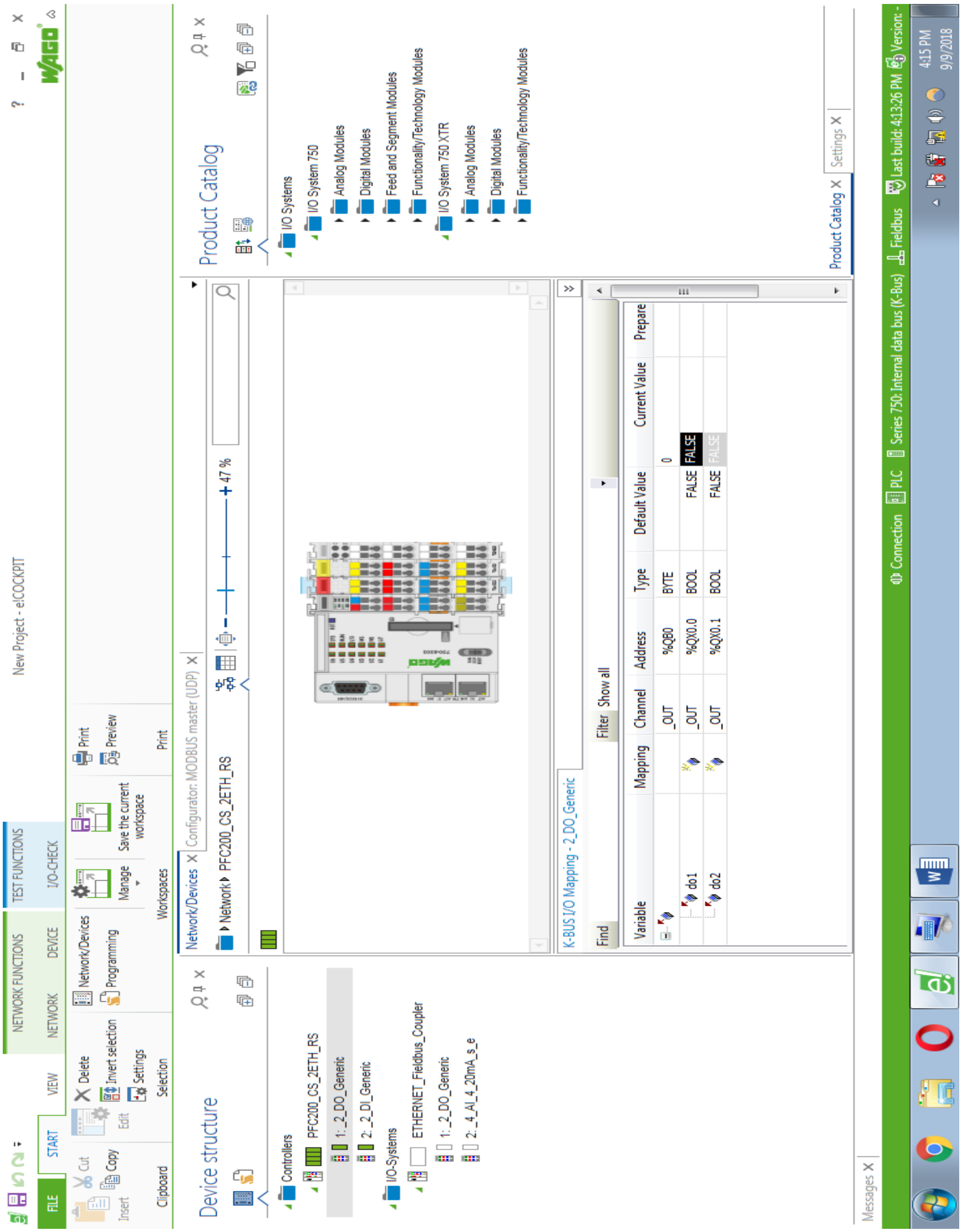

Figure (3.14): *e!COCKPIT* Configuration

3.4.4 Programming

e!COCKPIT offers multiple software development options:

• IEC 61131-3 PLC programming languages: Structured Text (ST), Ladder Diagram (LD), Function Block Diagram (FBD), Instruction List (IL), Sequential Function Chart (SFC), Continuous Function Chart (CFC).

• For flexibility, all programming languages can be combined with one another.

• Created programs can be easily debugged on the engineering PC via simulation.

• New paradigms such as object-oriented programming are included.

• In this project will use Ladder Diagram Language as you show in figure (3.15). [9]

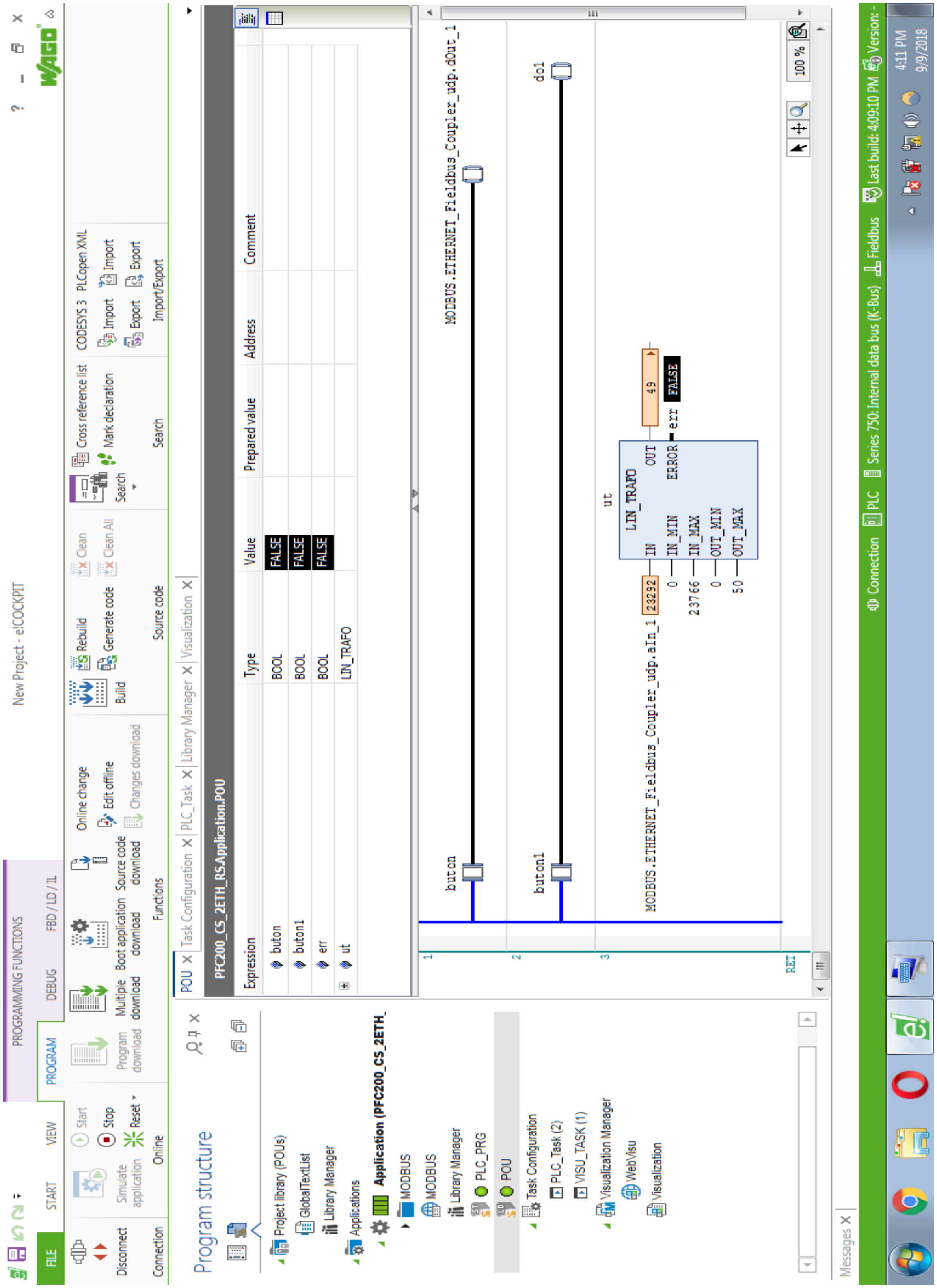

Figure (3.15): *e!COCKPIT* Programming

3.4.5 Visualization

Advanced user interfaces for operating and monitoring machines are standard. Today, HMI-based design is a critical factor that influences the purchase of an entire automation line. e!COCKPIT employs Drag & Drop to streamline the design of modern user interfaces. The integrated visualization editor provides:

• Access to IEC program variables.

• Closed simulation of HMI and PLC program on the engineering PC.

• Guaranteed language independence via Unicode character set.

• Current standards such as HTML 5 or CSS.

• In this research you can show three systems: lighting, ventilation and temperature system as show in figure (3.16). [9]

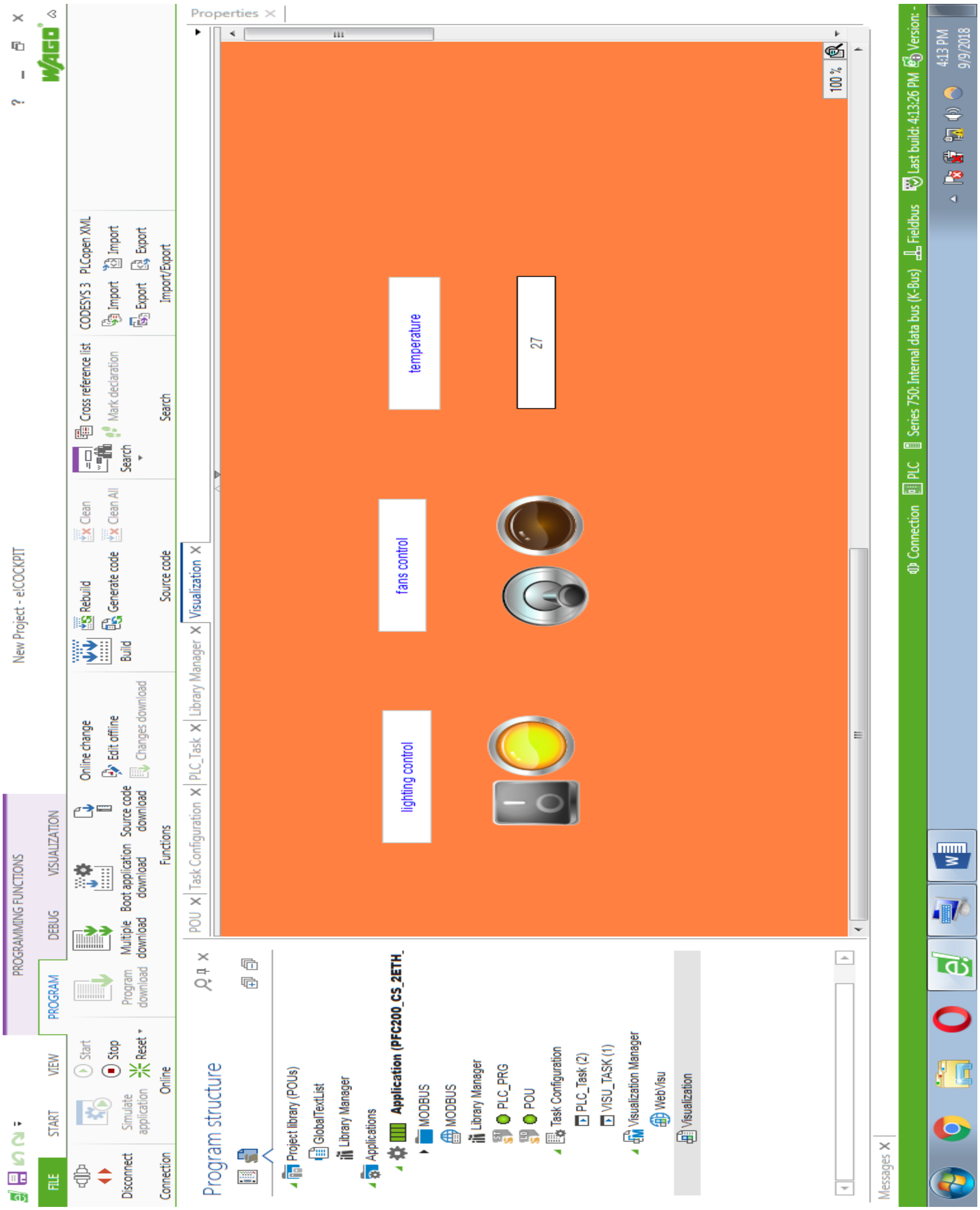

Figure (3.16): *e!COCKPIT* Visualization

3.4.6 Diagnostics

Being acutely aware of the automation network's current status is an absolute must for the rapid detection and elimination of errors — be it during development in the office or directly on the machine during commissioning. e!COCKPIT provides comprehensive diagnostic capabilities:

• Individual views always display the controllers' status information, for example, both graphically and in tabular form.

• To keep project on time, error messages are transmitted directly and clearly.

• The structured wiring test function systematically identifies wiring errors. [9]

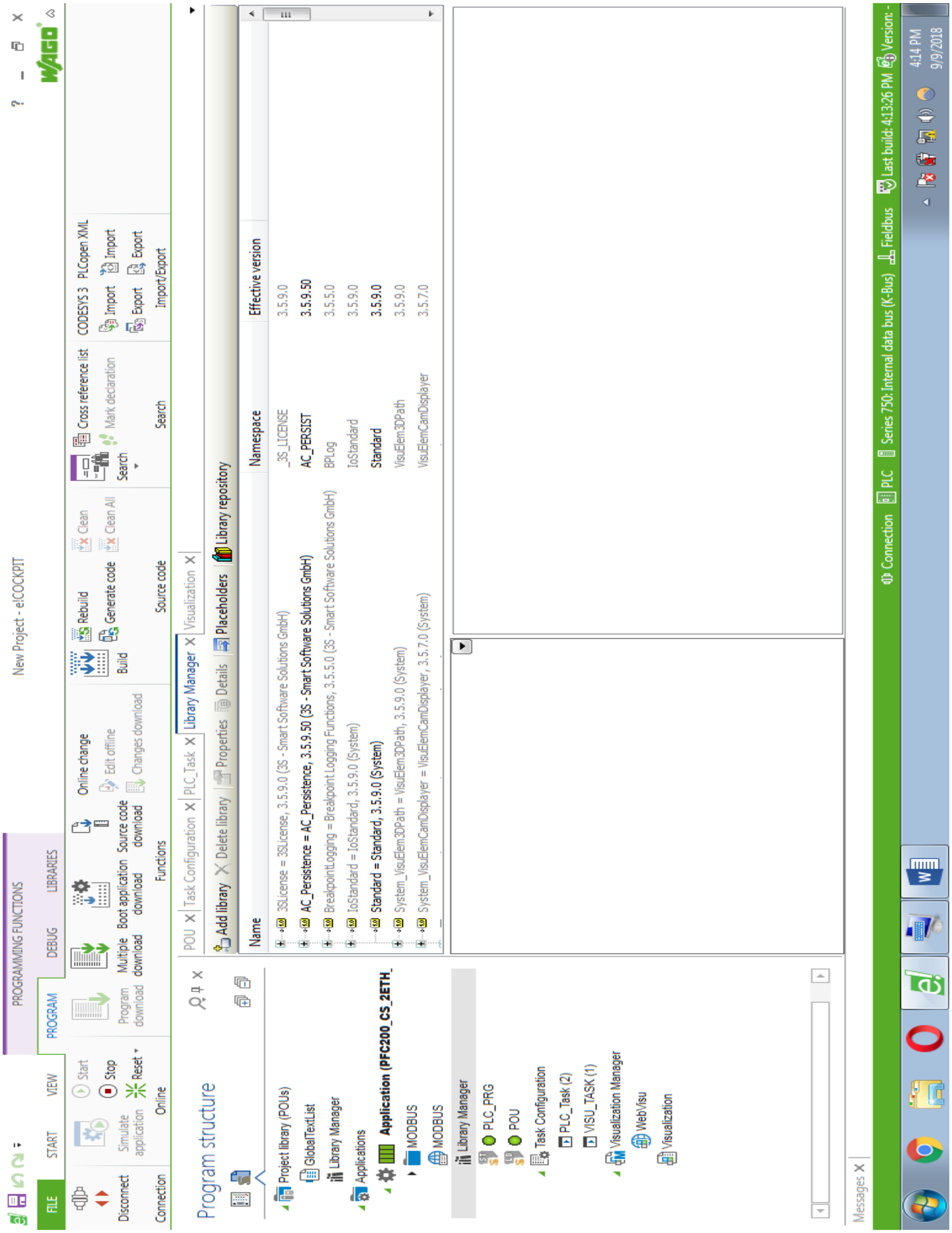

Figure (3.17): *e!COCKPIT* Diagnostics

3.4.7 WAGO WebVisu App

For mobile system operation/monitoring using the WAGO WebVisu App, you can access CODESYS 2 WebVisu websites on mobile devices. The desired system or machine can then be operated and monitored at any time. Up to 100 controllers can be predefined for direct and quick access via the URL.

WAGO WebVisu App is available for free as an iOS version for iPhones and iPads in the Apple "App Store", and as an Android version for smartphones and tablets in the "Google Play" store. AppFeatures is Supports iPhone & iPad (iOS),Supports Smartphone & Tablet (Android),Supports Laptops/ PC, HMI and Supports common WAGO controllers with WebVisu. APP have advantages such as calling of CODESYS WebVisu websites andIntuitive operation (self-explanatory).also have benefits formobile plant and facility control/monitoring (operating &monitoring) and For monitoring different parts of plants and applications with only one mobile device. [10]

Note: An overview of the supported WAGO controllers, operating manuals and application notes can be found on our website or at www.wago.com/webvisu ,In this research used ZAIN WI-FI router as a network connected with all components in one network, to help us to control and monitoring system from mobile using WAGO WebVisu figure 3.18.[10]

Figure (3.18): WAGO Mobile Application

CHAPTER FOUR

Testing and Results

CHAPTER FOUR

Testing and Results

4.1Testing Using WAGO Energy Data Management

4.1.1 Measurement System with Added Value:

This user-friendly solution, consisting of software combined with a modular control system, records measurement data from different media and influential factors for energy monitoring and processes them for further analyses, archiving and reporting.

With application controllers from the high-powered PFC200 family, data from meters and sensors can be easily collected by one convenient input module and parameterized through the available software application.

- **Components For Electrical Energy Measurement**

  1-Current transformers for connecting electrical installations of different rated currents.

  2-Voltage taps for voltage measurement.

  3-Ready to easily retrofit into existing systems.

  In this research will used current transformer 855 SERIES.

Figure (4.1): Electrical Energy Measurement Components

- **Four Easy Steps**:

1. Select the hardware needed; information about the I/O modules and current transformers to be used.

   Adding to research circuit:

   1-**POWER MESURMENT MODULE 750-495**

   750-495 3-phase power measurement, 690 V, 1 A

   2- **PLUG-IN CURRENT TRANSFORMER 855 -305/100-201**

   Primary rated current: 100 A; Secondary rated current: 1 A; Rated power: 2.5 VA and Low-voltage current transformer for operating voltages up to max. 1.2 kV. For other information show Appendices no.1

   3- **Current terminal.**

2. Install hardware.
3. Set the energy data management parameters.
4. Direct connection via MODBUS TPC/UDP; send CSV files via FTP or FTPS.

- **Advantages of Energy Data Management:**

-Modular energy and process data collection, management and visualization.

-User-friendly energy data evaluation and derivation of efficiency plans.

-Easy input parameterization via Web visualization.

-No programming experience required.

-Connect existing sensors to the WAGO-I/O-SYSTEM.

-Integration into existing systems for flexibility and maximum return on investment.

-Scalable, modular I/O system Hassle-free expansions at any time.

- **Visualization**

Visualize configured data points as line or bar charts via data plotter also visualize several data points over the same time interval for an initial benchmark.

Figure (4.2): Visualization of Energy

4.2 Test Study:

In my test will review system before and after operation BMS in visualization screen using Electrical Energy measurement technology.

4.2.1 System before add BMS:

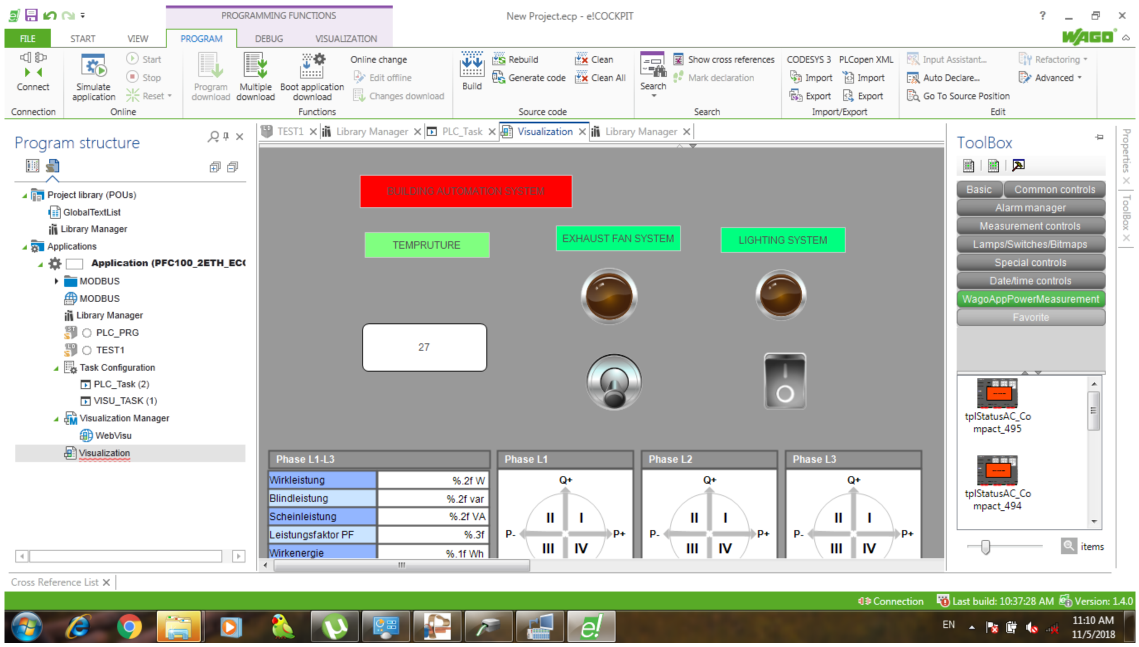

Figure (4.3): Visualization before Operation BMS

-In Figure (4.3) showing three systems: lighting, ventilation and temperature system before operation BMS.

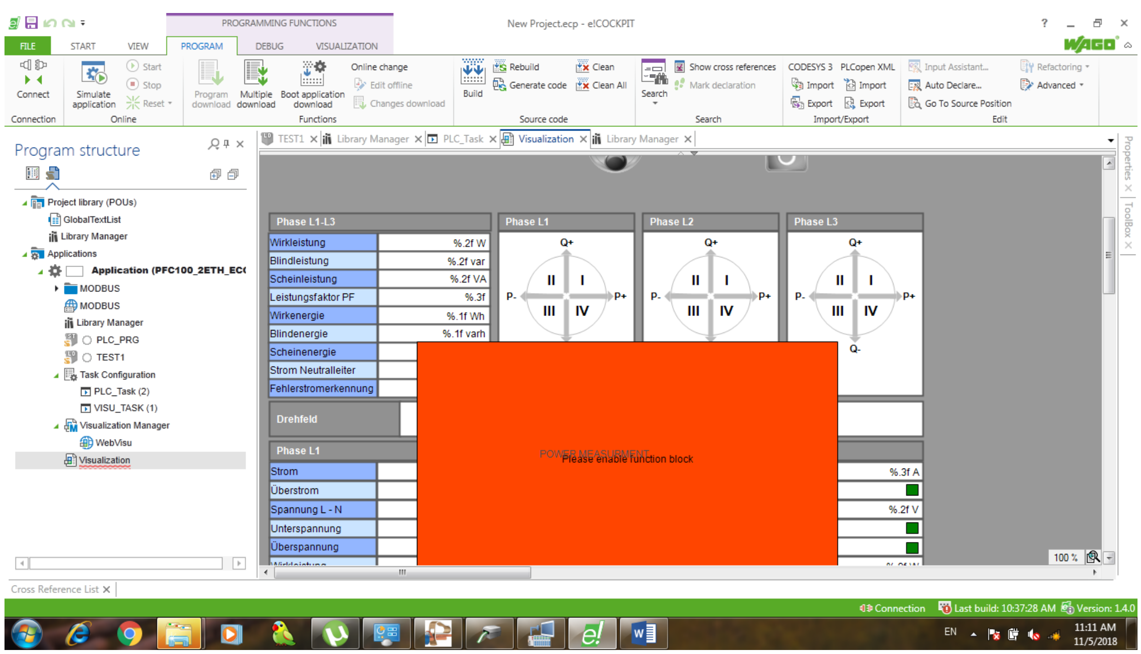

Figure (4.4): VisualizationL1, L2, L3

- LI, L2, L3 Give you readings voltage and current for any system alone, show Figure 4.4.

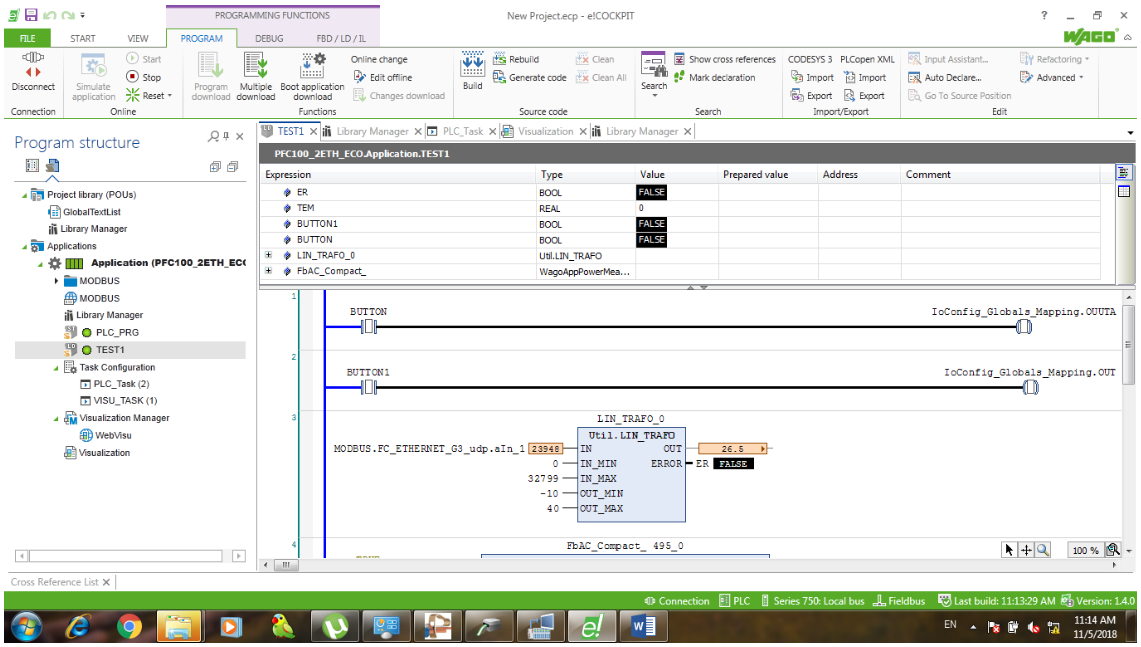

Figure (4.5): Full Program Using Ladder Diagram

-Programming with ladder Diagram showing in Figure (4.5) for three systems.

4.2.2 System after add BMS:

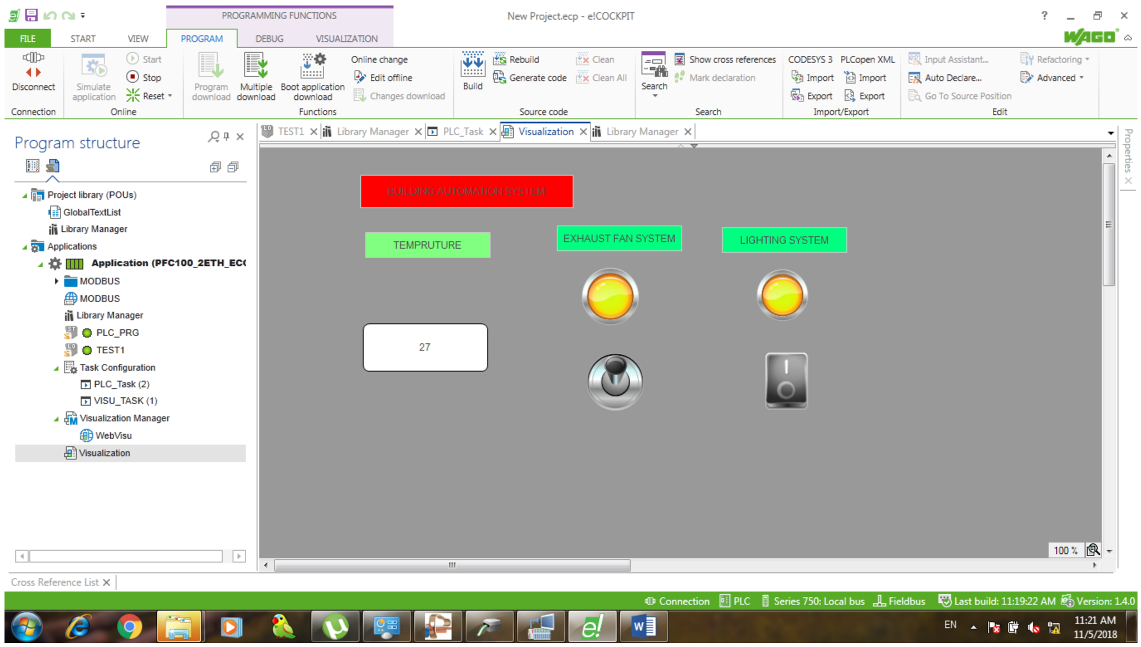

Figure (4.6): Visualization after Operation BMS

In Figure (4.6) you are showing system in operation mode in visualization screen.

Now will add to my circuit:

1-POWER MODULE 750- 495.

2- PLUG-IN CURRENT TRANSFORMER 855 -305/100-201.

Using Electrical Energy measurement technology to compare between Total Apparent Power before and after add BMS for the system showing in test application screen.

**Total Apparent Power: It's the internal consumption power in the system.

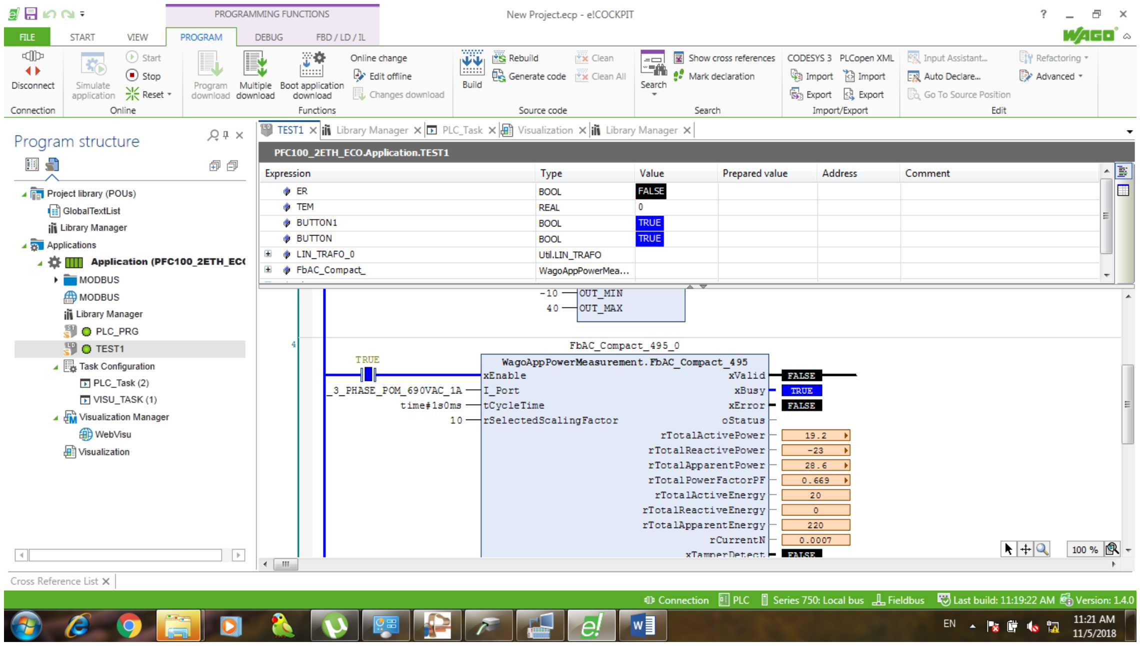

Figure (4.7): Test before Operation BMS

- Total Apparent Power read by Plug-In Current Transformer before operation BMS as showing in figure (4.7).

Total Apparent Power =28.6 **w**

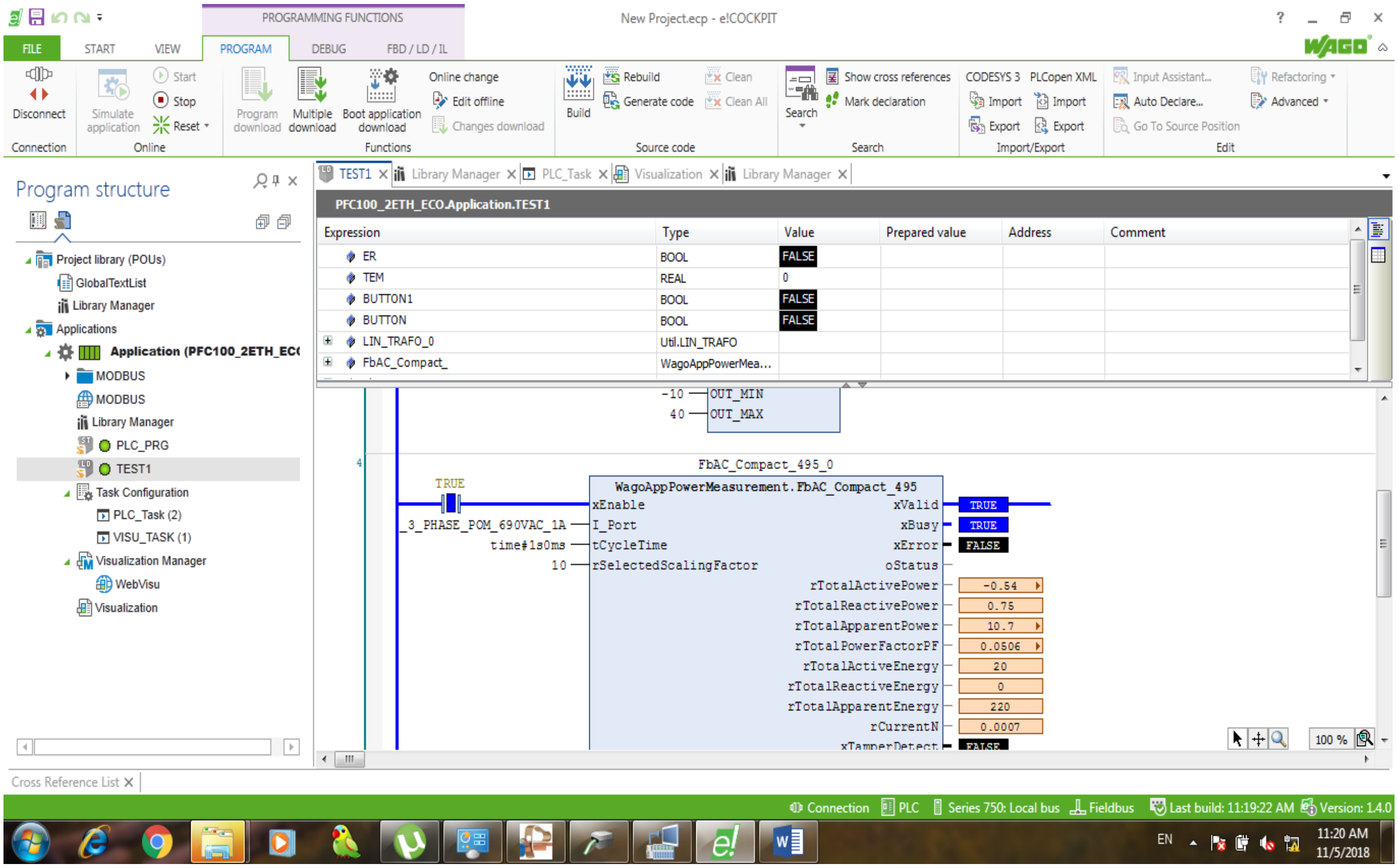

Figure (4.8): Test after Operation BMS

- Total Apparent Power read by Plug-In Current Transformer after operation BMS as showing in figure (4.8).

Total Apparent Power =10.7 w

-The value of Total Apparent Power in operation BMS decreases to much comparison before operation BMS, this meaning with using BMS this system saving more energy than before. Because the system is work only when you need it not like before system is work all time without stop.

4.3 Research Result

The main result in this research is made example design for smart home or smart building controlling and monitoring by BMS and example programming for three subsystems: Lighting, ventilation and temperature systems and approve saving energy for the all system.

Future you can add many systems for same design and operation it in big buildings in the country.

4.4 Benefit Result for Building Management System

4.4.1 Energy Savings

The introduction of state-of-the-art controls and communications provide savings by ensuring that the plant is operating at its peak efficiency whenever it is used and that it only operates when needed.

4.4.2 Flexibility of Use

This benefit is particularly appropriate to universities and colleges, many of which now offer services such as:

• hosting conferences

• renting residences during holiday periods

• leasing individual rooms for specialist lectures

• running student union activities such as night clubs.

Each activity will have a different service requirement and will mean that the general patterns for heating, lighting, etc. will frequently be changing. A BMS provides flexibility, allowing the specific needs to be programmed, providing comfort conditions when and where necessary. Changes to programmers can be made through the supervisor either at the main console or other PCs on which the appropriate software is installed. This enables system changes to be made from remote sites or even from the operator's home. Certain changes can also be made locally at the appropriate outstation

4.4.3 Monitoring and Targeting

The data stored by the BMS can be readily transferred into standard monitoring and targeting (M&T) applications. This will encourage energy savings through comparison against targets and also allow resources to be targeted to improve efficiency in the poorer performing areas.The information can also be fed into energy efficiency promotion campaigns in which students and staff are encouraged to adopt good housekeeping practices.

4.4.4 Improved Reliability

A BMS can improve the operating reliability of plant by enabling the operator to carry out routine checks and adjustments from the supervisory control point. The system can be set to indicate problems and provide alarms which will allow the maintenance staff to respond rapidly and rectify any situation before it gets critical. The system can also be used to auto-dial appropriate staff, including external contractors, to deal with specific problems as they occur.A BMS will also enable the operating hours of various items of plant to be accurately recorded. This information can then be used within a planned preventative maintenance programmer to avoid sudden and unforeseen breakdown of plant, thereby eliminating costly repairs and inconvenience due to plant failure.

4.4.5 Manpower Cost Savings

Manpower costs are often a major proportion of any building services budget. The use of a BMS will enable significant savings to be achieved through:

- providing control adjustments from a central point
- Automatically taking meter readings
- improving planned preventative maintenance regimes
- extending the operating life of plant
- improving the environment within buildings which can delay the need for redecoration, repair and maintenance.

4.4.6 Improved Comfort Conditions

The improved control available through a BMS will provide managers with a tighter hold over environment and comfort conditions and achieve greater occupant satisfaction. By preventing overheating or overcooling, energy savings can also be achieved. Furthermore, close control and monitoring of conditions will often enable the BMS operator to identify problem areas and to make appropriate changes to the comfort conditions before the occupant has noticed any discomfort.

4.4.7 Security, Fire Detection and Alarm

With the high level of computers and other information technology (IT) and specialist equipment, the matter of on-site security is a major concern.

In addition to loss of property, the role of security extends to personal safety, which is of particular importance in residential sites where students are often vulnerable. A BMS can be used to provide security. Once the basic communications network has been installed,the BMS can readily be extended to incorporate all standard security, fire detection and alarm systems, such as closed circuit television (CCTV), occupancy sensors, door and window release switches, smoke detectors, etc. The BMS can even be used to contact the emergency services directly via a modem link.

Chapter Five

Conclusion and Recommendations

Chapter Five

Conclusion and Recommendations

5.1 Conclusions

The main conclusion of this design is to propose a solution for smart home system. Controlling and monitoring three subsystems: lighting system, ventilation system and temperature system. The working of BMS is totally based on the input in a form of information by the devices such as sensors, once the information is collected it can be processed with the help of controller that will further instruct the system to perform a pacific task, in this BMS, switching on and off of the plant can be controlled in the same manner, plant can be set to a respective in order to measure temperature by sensor and operation ventilation and lighting system.

The design is based on a controlling and monitoring device that is to be installed in a building during construction. In this design, three subsystems are studied: ventilation, lighting and temperature system. The design is being constructed in a manner to provide maximum comfort and ease to the people with minimum energy utilization. Intrusions can be easily monitored with the help of control system or manual from the switch.

The achieved Results are be easily to controlling and monitoring the system local or remotely and reducing running cost for the building by saving energy.

The Conclusion of This Study is as Following

1. The study has made use of different types of technology and scientific advancements in order to solve a problem of modern communities. This is established through using the PFC 200 controller to controlling system and help save the energy.

2. The study has made use of e!COCKPIT software . At the software's core is CODESYS 3.advantage of using this software its Detect runtime problems at an early stage, Measurement start by a variable or by command and Dynamic measurement via code instrumentation at each function entry and exit. Also presentation system in 3 way: Programming, Visualization and Diagnostics.

3. A number of different types of power and switches are used in the control process as shown in the system design to benefit from them in writing the program and using the relays for the actions required.

4. The PFC200 is programmed using a ladder diagram. This has been done because of the easiness of writing logical operations and following up with them using the program as is modifying them if needed in the future.

5. PFC200 controllers are used to control the system. These controllers are highly accurate, efficient and reliable. It shows that they are the most appropriate for this system because of their high efficiency, there adaptability to environmental conditions and the ease of their replacement and modification in the future if needed.

5.2 Recommendations

Use different protocols and compare between the new system and the system which is applied in this research and find which one better efficient and better performance, Use other controller from different companies such as Siemens and Schneider and Increase more of systems to represent this study future.

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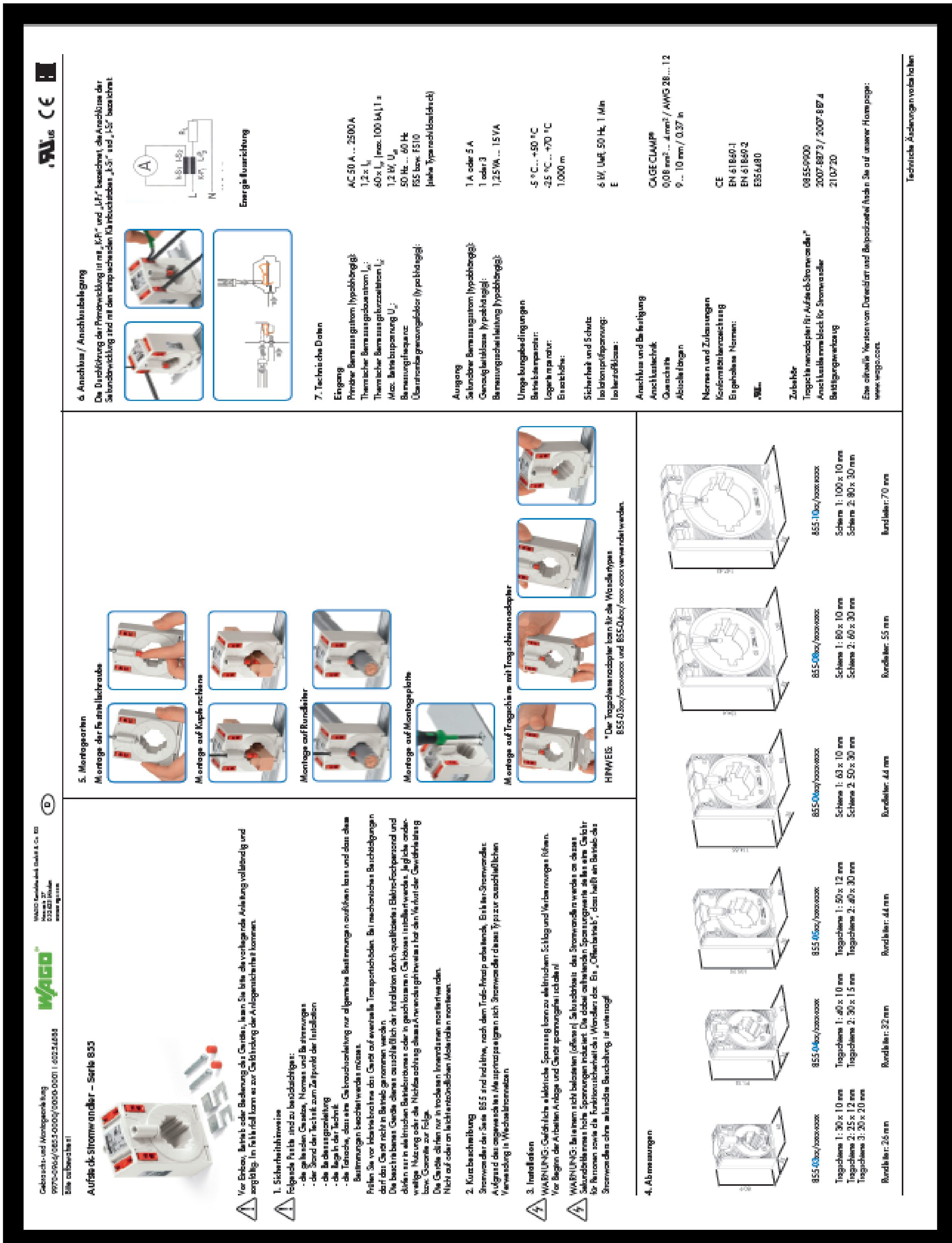
Appendices



Appendices no.1: Current Transformer

PFC100/PFC200 Controller
Versions

Extended Temperature Range

Industrial automation technology is typically operated in temperatures ranging from 0 ... 55 °C. However, there are applications like telecontrol technology that require an extended temperature range. These version are available in an extended temperature range of −20 ... +60 °C.

ECO

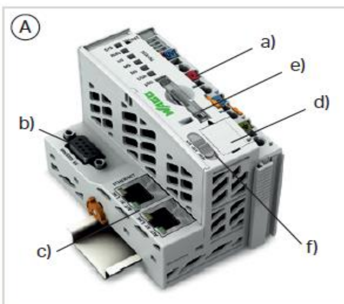
The ECO version of the PFC200 limits the number of stackable I/O modules to four.

Telecontrol Technology

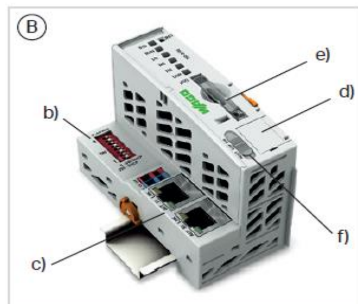
The telecontrol technology versions of the PFC200 are distinguished by the integrated, standardized telecontrol technology:

- IEC 60870-5
- IEC 61850
- IEC 61400-25
- DNP3

Interfaces and Types

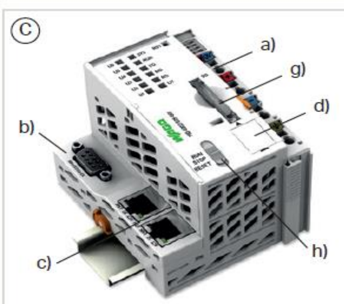


- Includes supply module (a)
- Technical differences on the connection level (b)
- ETHERNET 2 x RJ-45 (c)
- Service interface (d)



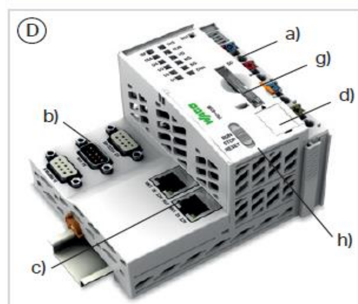
Housing Design (A)

- microSD card slot for external storage media (e)
- Stop/start switch (f)
- W x H x D (mm) 61.5 x 71.9 x 100



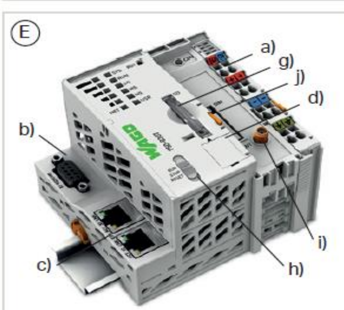
Housing Design (B)

- microSD card slot for external storage media (e)
- Stop/start switch (f)
- W x H x D (mm) 49.5 x 71.9 x 96.8



Housing Design (C)

- SD card slot for external storage media (g)
- Stop/start switch (h)
- W x H x D (mm) 78.6 x 71.9 x 100



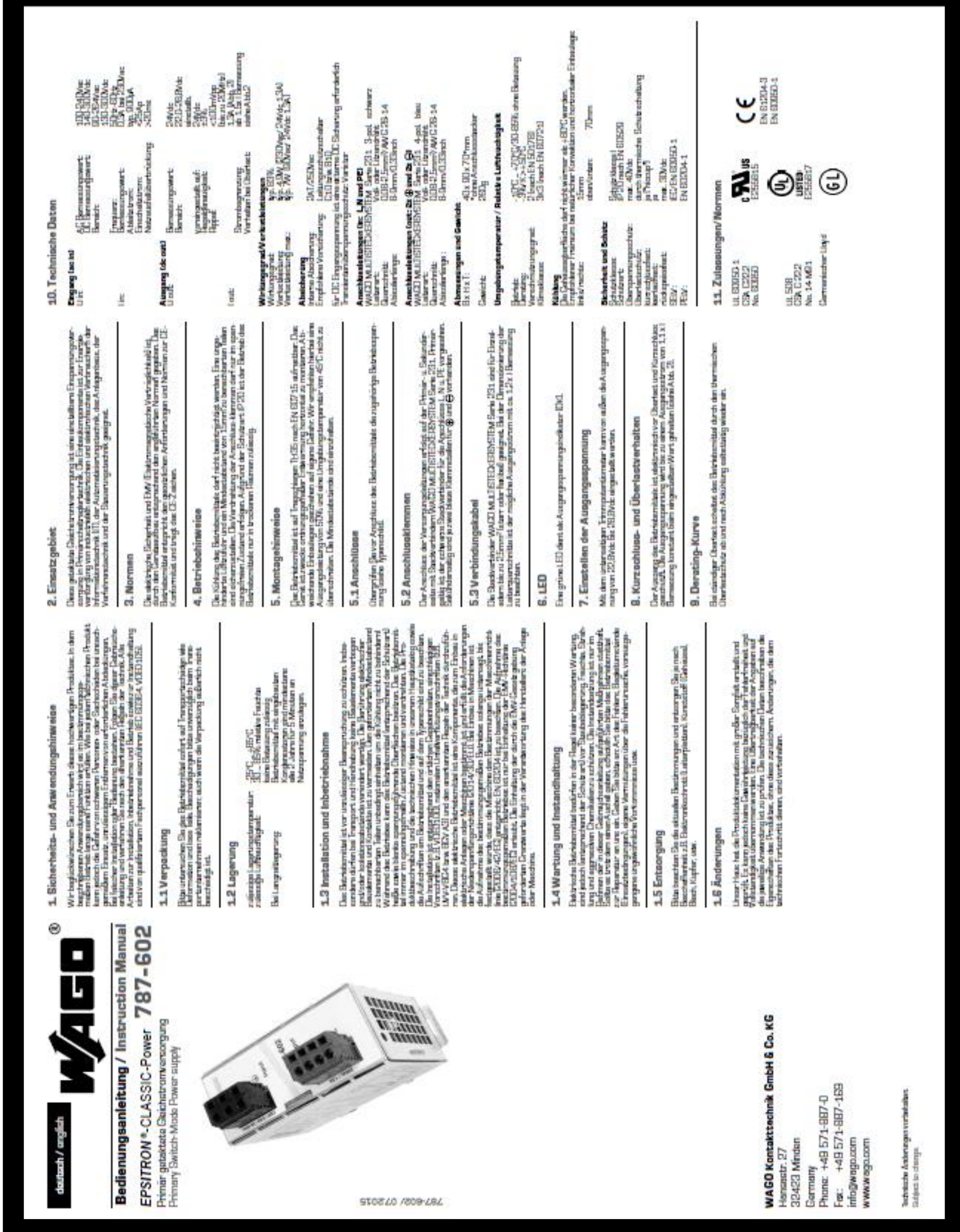
Housing Design (D)

- SD card slot for external storage media (g)
- Stop/start switch (h)
- W x H x D (mm) 112 x 71.9 x 100

Housing Design (E)

- SD card slot for external storage media (g)
- Stop/start switch (h)
- GSM antenna connection (i)
- SIM card slot (j)
- W x H x D (mm) 102.5 x 71.9 x 100

Appendices no.2: PFC 200 Controller



Appendices no.3: Power Supply 787-602

4.1 View

The view below shows the different parts of the device:

- The fieldbus connection is within the lower range on the left side.
- Over the fieldbus connection is a power supply unit for the system supply.
- LEDs for bus communication, error messages and diagnostics are within the upper range on the right side.
- Down right the service interface is to be found.

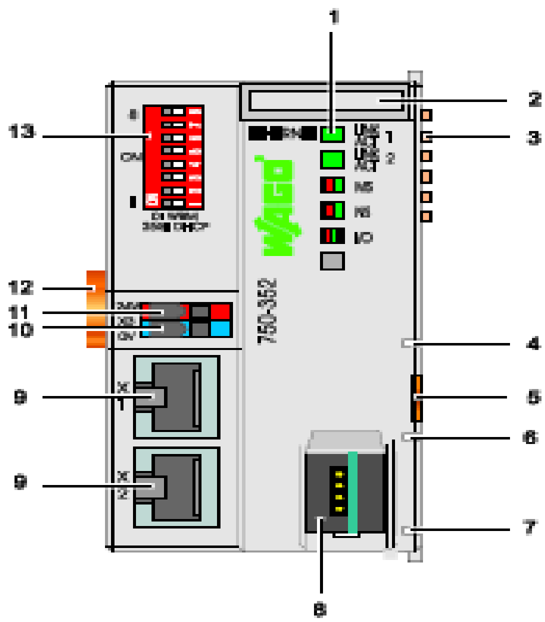


Figure 23: View ETHERNET TCP/IP Fieldbus Coupler

Appendices no.4: Fieldbus Coupler 750-352

Table 11: Legend for Figure "View ETHERNET TCP/IP Fieldbus Coupler"

Pos.	Desig-nation	Meaning	Details see Section
1	LINK ACT 1, 2, MS, NS, I/O	Status LEDs Fieldbus	„Device Description" > „Display Elements"
2	—	Marking possibility on four miniature WSB markers	—
3	—	Data contacts	"Connect Devices" > "Data Contacts/Local Bus"
4	—	Unlocking lug	"Mounting" > "Inserting and Removing Devices"
5	—	Service interface (open flap)	"Device Description" > "Operating Elements"
6	X1, X2	Fieldbus connection 2 x RJ-45 as 2-Port ETHERNET Switch	„Device Description" > „Connectors"
7	-	CAGE CLAMP® Connections System Supply DC 0 V	"System Description" >"Voltage Supply"
8	+	CAGE CLAMP® Connections System Supply 24 V DC	"System Description" >"Voltage Supply"
9	—	Locking Disc	„Mounting" > „Plugging and Removal of the Device"
10	—	Address Selection Switch	"Device Description" > "Operating Elements"

Appendices no.4: Fieldbus Coupler 750-352

AX-RHT-S

Room RH & T Transmitter

AXIO

Product overview

The AX-RHT-S25 is a range of Room Relative Humidity & Temperature transmitters. An integrated LCD display is available as an option. The analogue outputs are selectable for current or voltage. Wiring is simplified with connections all made on the back-plate, and a plug-in electronics housing.

Options for this range of sensors include the addition of various passive temperature sensors for most BMS systems.

Features

- 2.5% Accuracy standard
- Optional 2-Line LCD display
- 0-5/10Vdc and 4-20mA selectable output
- Optional thermistor output for temperature

Product specifications

RH Accuracy	±2.5% typical (20 to 80% RH at 25°C), ±2.0% option
Temperature Accuracy	±0.3°C typical
Sensor Type / Protection	Capacitive / PTFE filter
Long Term Stability	±1% RH at 50% RH in 5 years
Repeatability / Hysteresis	±0.5% RH / ±1% of span max
Response Time	15 seconds @ 25°C, but dependant on airflow
Supply Voltage	24Vac/dc (±15%) (24Vdc only with 4-20mA output selected)
Output (Voltage)	0-10Vdc, 0-5Vdc at 10mA maximum load
Output (Current)	4-20mA at 500 Ohms maximum load (use on 24Vdc supply only)
Output Range - RH	0 to 100% RH
Output Range - Temperature	-10°C to +40°C
Display option	3 digit, 2 line, 6mm character height LCD display of RH and Temperature
Terminals	Rising clamp 0.5-1.5mm² cable
Ambient Temperature Range	-10°C to 50°C, 0-95% RH
Dimensions, Weight & Ingress	87 x 82 x 27mm, 75g, IP20
Country of Origin	United Kingdom

Order codes

AX-RHT-S	Room RH & T Transmitter - 2 x analogue outputs, 2.5% accuracy
AX-RHT-SD	Room RH & T Transmitter with Display - 2 x analogue outputs, 2.5% accuracy
AX-RHT-S2	Room RH & T Transmitter - 2 x analogue outputs, 2.0% accuracy
AX-RHT-S2D	Room RH & T Transmitter with Display - 2 x analogue outputs, 2.0% accuracy
-x	Additional passive thermistor output. See Page 2 for options

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Appendices no.5: Temperature Sensor

Appendices no.6: Protocols**:**

- **BACnet:**

- **BACnet Controllers Features**
- Freely programmable control
- B-BC device profile (BACnet-Building-Controller)
- Modular design at the I/O level
- SD card slot in BACnet IP controller
- Integrated 2-port switch
- Easy startup using the WAGO BACnet Configurator
- Webserver ,MODBUS/TCP (UDP), HTTP, BootP, DHCP, DNS, SNTP, FTP, SNMP
- Certified BTL, WSPCert / AMEV-Testat AS-A
- Easily integrate sub-bus systems like DALI, Mbus, LON, KNX, and Modbus RS232/485.
- Acquisition of I/O signals in BACnet MSTP or IP networks [9]
- **Advantage**

- Reduce total project hardware costs by using the inexpensive coupler under any automation stations.
- Easy commissioning with no-cost BACnet Configuration [9]

- **KNX:**

- **Maximum Flexibility and Powerful Performance:**

KNX is a uniform, manufacturer-independent communication protocol for intelligently networking various building automation functions. KNX is used to plan and implement energy-efficient solutions, while incorporating greater functionality and convenience into buildings.

Global communication standards paired with maximum data speeds make ETHERNET an indispensable building automation technology. With its KNX IP Controller, WAGO offers a product that links the KNX world with ETHERNET, and makes it freely programmable. Using this controller, you can link, control, regulate and monitor all types of KNX devices from a variety of sectors. When paired with the WAGO-I/O-SYSTEM 750 I/O modules, other sensors, actuators and sub-buses (e.g., DALI and EnOcean) can be easily integrated into the controller. [12]

- **WAGO KNX Concept Consisting Of:**

- KNX IP freely programmable controller
- KNX TP1 Module
- KNX IP router (controller + I/O module)

- **KNX – Why WAGO?**

- **Free Programmable Controller** – no limits regarding the functionality and future security for later adjustments

- Handling by using the ETS software and the WAGO KNX plug-in - As the installer is used to do it
- Router and application controller in one concept
- Standard sensors and actuators can be used wired to the IO modules. All this IO points can be converted to KNX Variables. Also reflects in cheap building automation functions and reduction of KNX bus load by using Standard IO modules.
- One controller for many applications – no longer special KNX components requested / can replace many single KNX devices.
- WEB server and RTC on board without additional hardware. [13]

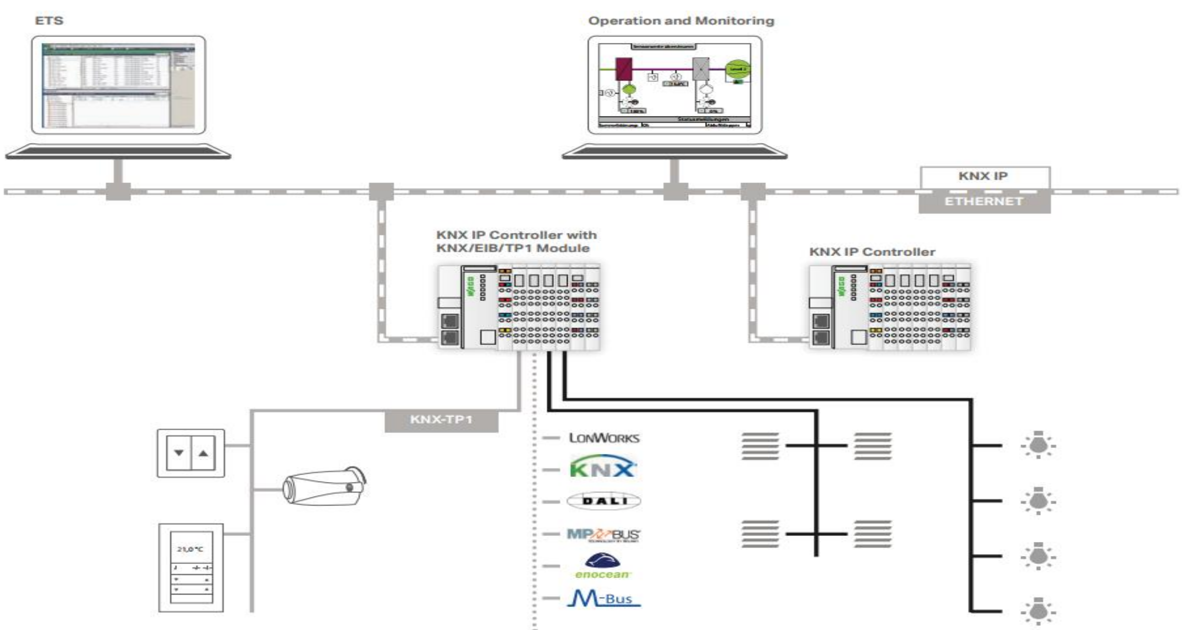

Figure :KNX System

- **DALI**

DALI stands for “Digital Addressable Lighting Interface” and is a protocol that adheres to the IEC Standard 62386. The DALI standard, a protocol common to all manufacturers, substitutes for the 1–10V dimmer interface and ensures the interoperability of DALI devices (e.g., electronic Ballasts in lighting applications). A DALI master can control a line with up to 64 devices. In addition, sensors (e.g., brightness measurement and presence detection) can be integrated into a DALI network. [14]

- **DALI System**

- Control of individual lights or light groups.
- No parallel wiring of the control groups necessary.
- It is possible to assign individual lights to operating elements and to group lights after installation without re-wiring. [14]

- **DALI Benefits**

- Two pole cable, no potential for the control wire.
- No need for special cable/bus.
- No wiring according to groups (and/or channels).
- Free addressing of the DALI devices: together, by groups or individual.
- Scene memory in the DALI devices (max. 16).
- Individual status messages from the DALI devices (e.g. lamp errors).

- No external relay or dimmer, DALI devices switch on, off and Dim by themselves. [14]

- **Compar Between DALI And KNX**

Table Compare DALI and KNX

Features	DALI	KNX
Power Supply	Yes	Yes (160, 320 640mA)
Cable and Polarity	Standard cables, no polarity	Special KNX cable required, Polarity
Actuators	No	Yes
Ballast	Yes	No
Products	Limited to Lighting control only	Complete Building control system. Controllers , displays , sensors, actuators, switches etc.
Configuration topl	Cost Free Wago Dali Configurator (from Website)	Need Expensive ETS software to commission (KNX certified professional required)
Control Philosophy	Control of individual lights, groups and lines.	Control per Actuator, not per Light.
Topology	64 ECGs , 16 multi sensors	64 Devices per Line Coupler

- **Additional Technologies:**

The WAGO-I/O-SYSTEM provides the user with a wide range of interface solutions for bus systems and subsystems for building automation. Beyond the previously mentioned protocols, WAGO also supports:

The STANDARD MOTOR INTERFACE has the abbreviation SMI and is the standardized electrical interface for electrical drives. SMI was developed for connecting drives with integrated electronic circuits for applications in roller shutters and sun protection systems. The products of different manufacturers can be combined. The interface is highly robust and economical. [11]

The MP-Bus controls HVAC actuators for dampers, regulator valves or VAV air volume controls. The actuators have connections for sensors (temperature, humidity, ON/OFF switches), which are also accessible via MP-Bus. [11]

LONWORKS®

LonWorks technology is standardized per ISO/IEC 14908. In addition to BACnet and KNX, LonWorks is one of the most important protocols in building automation worldwide. A large number of manufacturers use LonWorks as a communication protocol, allowing interoperable communication between intelligent devices. [11]