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Design and simulation of a smart home using the KNX standard

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Abstract: This paper addresses the problem of high electricity consumption in public buildings, especially large buildings such as hospitals and others. By searching for the best solution to reduce electricity consumption, the KNX standard was identified.
The KNX standard was proven to be efficient in reducing electricity consumption through a previous study conducted by ABB. This standard was applied to a house and simulated on the KNX virtual program.
This paper discusses the basic structure of the KNX standard, through which we can add many things that make the building smarter and save electricity using hundreds of actuators and sensors provided by this standard.

Keywords: KNX standard, KNX virtual.

Introduction

As a result of urban development and the General Electricity Company's failure to keep up with this development and its cessation of building new stations for nearly eleven years to keep pace with this development and the increased demand for electricity, this resulted in the power being cut off for hours and sometimes days. During this period, the General Electricity Company began building new stations and maintaining old stations. In contrast, it will take a long time to achieve final stability. In parallel with the process of station construction and maintenance, electricity consumption can also be reduced, especially large public buildings such as hospitals and others that have excessive and high electricity consumption. From here, the journey of searching for the best solution to reduce electricity consumption began, which is called (smart buildings). Smart buildings are buildings equipped with smart devices that help optimize energy consumption and reduce electricity bills.

Smart buildings can reduce electricity consumption in several ways, including:

Temperature control: Smart buildings can analyze weather data and automatically adjust the temperature according to weather conditions

Lighting control: Smart buildings can analyze lighting data and automatically adjust lighting according to weather conditions and time of day.

Control of electrical appliances: Smart buildings can analyze usage data and automatically adjust electrical appliance usage based on weather conditions and time of day. It is possible to warn about fire and take necessary measures.

Review of previous research (previous studies)

The Paper is a by ABB company titled Energy Saving with KNX Case Study. March 1, 2018.

Summary: The first case study looks at student accommodation, where KNX controls were used for lighting, heating, ventilation, and energy management. The lighting controls provided up to 58% energy savings, and the heating controls resulted in around 15% savings compared to the property without controls, though this could be as high as 50-60% with more efficient heating systems. The integrated energy management and visualization features also provided benefits.

The second case study examines an office building, where a complete KNX lighting control system was installed. Compared to the previous traditional lighting system, the new KNX system provided 35% savings from presence/daylight detection and 10% savings from dimming, resulting in a total annual cost savings of over £34,000. The payback period for the KNX installation was estimated at 5-8 years.

The Paper concludes by highlighting that KNX can provide energy savings of up to 40-60% across various building systems like shading, room control, lighting, and ventilation. It emphasizes that energy efficiency is crucial for addressing economic, environmental, and social issues, and that KNX is an effective solution for optimizing building energy use

The problem

The problem lies in the high consumption of electricity in public and private buildings.

Research Objectives

Reducing electricity consumption.

What is KNX?

KNX, also known as Konnex, is an open international building control standard. It is a successor of three previous standards, European Home Systems Protocol (EHS), Bati BUS, and the European Installation Bus (EIB). The KNX standard is administered by the KNX Association which was founded in 1990. As of June 2010, the KNX Association has over 200 manufacturing members. [1]

Principle of operation

KNX is a bus-based system. Devices communicate independently without a central computer or a control system. The communication is accomplished by telegrams transmitted on the bus. With the same bus cable, the power is distributed to the bus devices. Below an illustration of a simple KNX system, the green line is the KNX bus and the red line is a 230 VAC line. (Figure 1) [2]

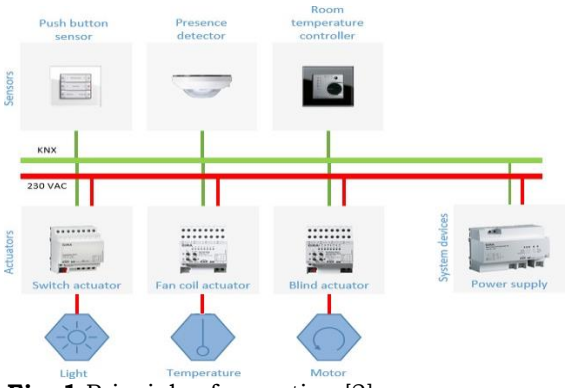


Fig. 1: Principle of operation.[2]

Data transfer media

The versatility of KNX is based not only on its protocol, but also on the broad range of available data transfer media. A bus can consist of a combination of media described in this section.

1) Twisted Pair Cabling

KNX TP is the term used when twisted pair (TP) cables are utilized as a KNX-medium. Twisted pair cabling is considered to be the best data transfer medium for KNX as it offers free topology. It is moderately low-cost and easy to install as the devices can be connected to each other without any hubs or switches. [3; 4]

2) Internet Protocol

KNX IP is the term used when the Internet Protocol (IP) is utilized as a KNX-medium. The benefits of Ethernet as a data transfer medium are: high bandwidth (100 Mbit/s), more or less cheap components, and widespread use. [5; 4]

3) Wireless Network System (WNS)

KNX RF is the term used when the Radio Frequency (RF) is utilized as a KNX-medium. A radio network is a suitable option when a twisted pair cable cannot be used as a communication medium. [3]

Topology

In this paper, only topology for twisted pair cabling is reviewed.

1) Line

A line consists of up to 4-line segments, and each segment of up to 64 connected devices. Each segment requires its own power supply. The maximum length for a line segment is 1000 m, and the maximum distance between a power supply and a bus device is 350 m. [2]

2) Area

If the capacity of the line is exceeded by the number of the devices connected to it or if it's practical to divide the automation system into smaller sections, areas can be utilized. It is possible to connect up to 15 lines to a main line with line couplers (LC). [3; 6; 2]

3) Multiple areas

Several areas can be connected to a backbone line with a backbone coupler (BC). With a maximum of 15 areas, more than 58,000 devices can be connected to the bus. By dividing the bus installation into lines and areas, the functional reliability is increased considerably as every line has its own power supply, and the lines are galvanically isolated. [3; 6; 2]

Line Topology

1) Length Limitations

The maximum length for a line segment is 1000 m, and the maximum distance between two bus devices is 700 m. [5]

2) Power Supply

Each segment requires its own power supply, and the maximum distance between a power supply and a bus device is 350 m. [3]

3) Line Repeater

If a line needs to be continued with a line repeater (LR) to a line segment, the maximum total length of the line segment is 1000 m. [3]

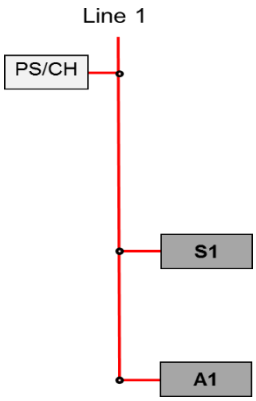


Fig. 2: Hierarchy, a line. [2]

Area Topology

1) Line Couplers

It is possible to connect up to 15 lines to a main line with line couplers (LC). [3; 6; 2]

2) Device Limitation

The maximum number of 64 devices connected to a main line is reduced by the number of line couplers connected to it as they are counted as devices. [3; 6; 2]

3) Timing Importance

If timing is critical for the automation system, the main line should be implemented with IP technology to provide a data highway. [3; 6; 2]

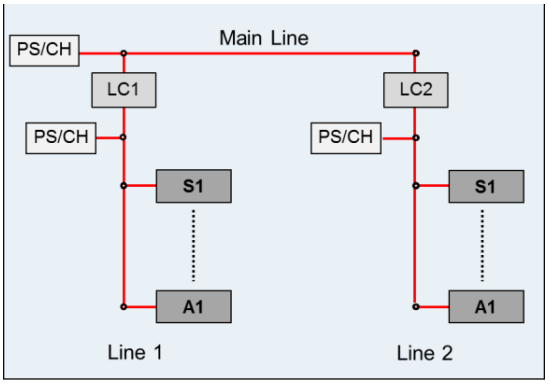


Fig. 3: Hierarchy, an area. [2]

Multiple Areas Topology

1) Backbone Coupler

Several areas can be connected to a backbone line with a backbone coupler (BC). [3; 6; 2]

2) Device Limitation

The maximum number of devices connected to a backbone line is reduced by the number of backbone couplers connected to it as they are counted as devices. [3; 6; 2]

3) Data Highways

If the automation system is extensive, the main lines and backbone should be implemented with IP technology to provide data highways. [3; 6; 2]

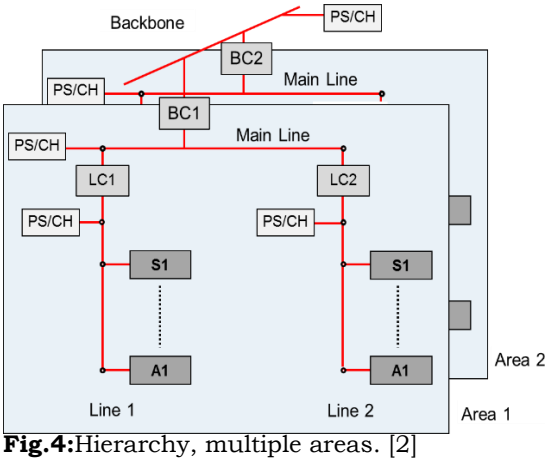


Fig.4: Hierarchy, multiple areas. [2]

THE DESIGN

1. Locators

The first step is to make site previews and identify public functions in each room, and this is where the home map is used, and all the job is located on the map. Each job is equipped with a specific code that occupies the function, its type, its place, sensors, push button and the home equipment included in the project, and compiles those functions on the excel paper so that it can be easily sought at a later date.

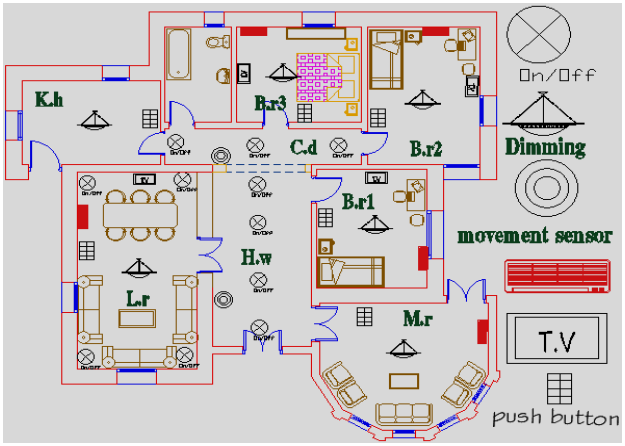


Fig. 5: The home map.

	B.r1	B.r2	B.r3	C.d	H.w	K.h	L. r	M. r	Total
Lighting Circuits				2	2		1		5
Dimming Circuits	3	3	3			2	2	2	15
Shutters	1	1	1			2	2	4	11
Air-Conditioning	1	1	1				1	1	5
Presence Sensor				1	1				2
heat alarm detector	1	1	1	1	1	1	1		7
smok detector						1			1
push button	1	1	1	1	1	1	1	1	8
TV	1	1	1				1		4

Table. 1: The functions.

2. Hardware

In this research, I used KNX devices from ABB for the target building, some of which are necessary in each project, such as power supply, line pairing and the Internet interface, and others according to the functions and loads required in the target building.

Programming

This research was programmed by ETS software and is an abbreviation for engineering tool software, it is a specialized program used in designing and configuring control facilities for smart homes and buildings. It operates within the KNX system, a standard for home and building automation. Catering to different project sizes, ETS offers different editions: ETS Professional for comprehensive solutions, ETS Lite for smaller projects, and ETS Demo for basic needs.[7]

Fig. 6:ETS6.

1. building structure

After entering the program and setting up a new project, we add the structure of the building used in the project, the number of floors and rooms in the target building.

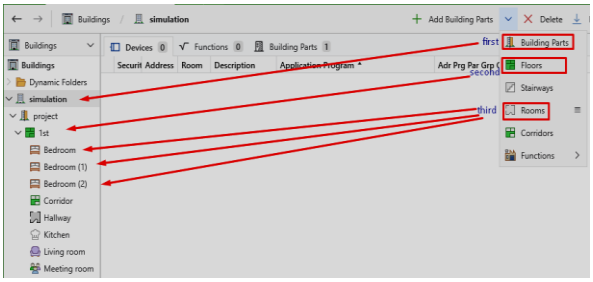
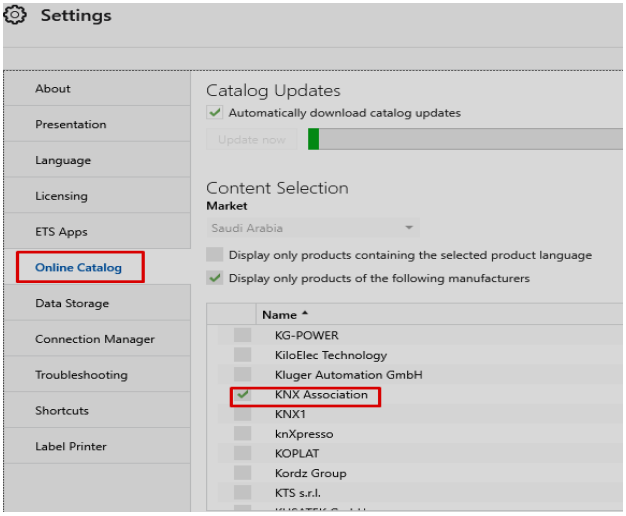


Fig. 7: Step 1 of building structure.

2. Add devices

In this step, we import the devices used in the project, here I will import the devices used in the project from KNX association so that I can simulate later which is the same way in all companies and the only difference is the parameters I will explain later.

Fig. 8:download the catalogue.



3. individual address

After adding devices, we note that each KNX device has a unique address. The address that identifies this device in the KNX network. This unique address is called physical address or individual address. The way that the Physical addresses of the KNX devices are organized define the topology of the KNX network. 16 bits that represent Physical address are divided into 3 parts:

- 4 bits that represent Area number
- 4 bits that represent Line number
- 1 byte that represent device number [8].

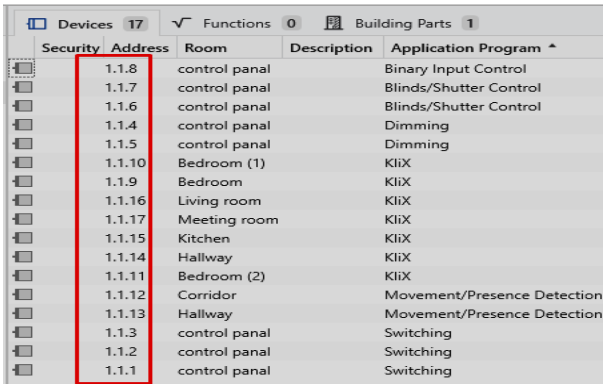


Fig. 9:individual address for my project.

4. Adjust the parameters

When adjust the parameters it identifies the "Group Objects" available to the device on the KNX network, and also allows to adjust the behavior of the device on the network. For example, if you have one push button that supports three functions for buildings: switching, dimming and shutter, the button function is determined by a parameter called 'function', and this parameter is adjusted via the device parameters dialogue in ETS [9].

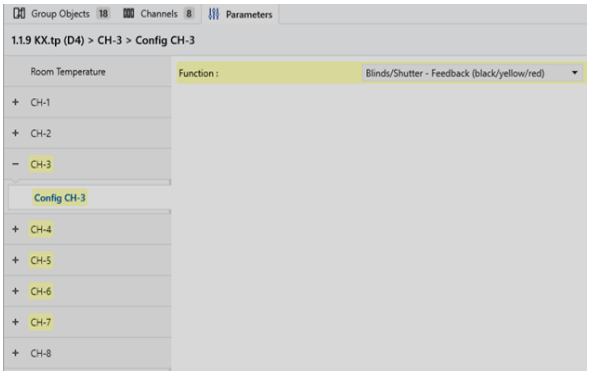


Fig. 10:when adjust the parameters for push button are four cases: switching, dimming, shutter, scenario.

5. Group Object

After setting the parameters you will notice a change in Group Object which is a data point representing a specific function of the device, such as the relay of switch operator. It is part of KNX standard automation of commercial and residential buildings. The device can contain multiple mass objects, and each group object has a unique group address that connects it to other devices on KNX buses. The Group Object's properties include its name, description, priority, flags, data type, function, length, and group addresses. The Group Object can be linked to at least two group addresses, one for sending telegrams to the bus and the other for receiving from the bus [10].

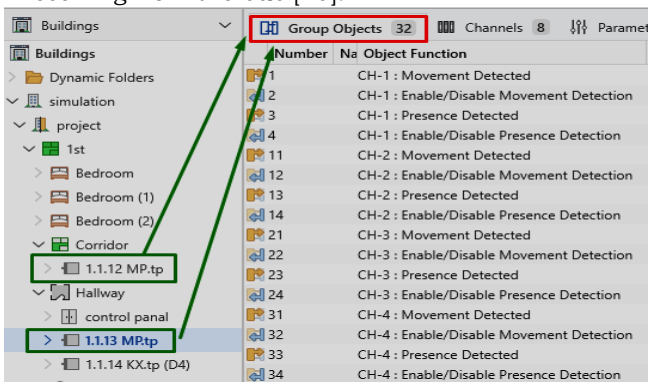


Fig. 11: Group Object for movement sensor.

6. Group Addresses

Group addresses and their role in the KNX network are critical to the logical and semantic performance of the devices. Physical addresses, unique to each KNX device, are fundamentally different from group addresses. Group addresses provide logic and meaning in the KNX network, enabling devices to interact and communicate efficiently. It is important to understand the different structures of group titles, such as level 3 structure, level 2 structure, and freely defined structure.

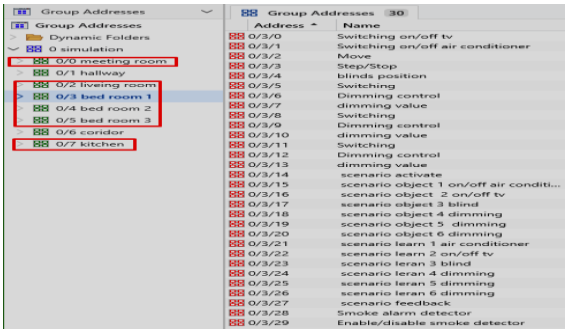


Fig. 12:when add group addresses for bed room 1 it differs from the rest of the rooms in number only.

7. Connect the group objects with their group address

Can link a Group Object to a Group Address by dragging and dropping the object onto the address or vice versa.

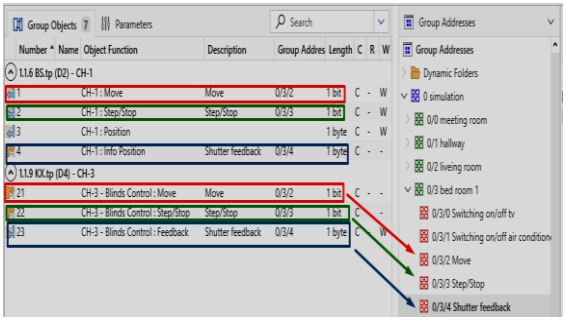


Fig. 13: example for link a Group Object to a Group Address for bedroom1 ،link shutter control with push button.

THE SIMULATION

KNX Virtual

The simulation process is done using KNX Virtual is a Windows-based application that simulates a KNX installation. It is designed to help users get acquainted with the KNX technology by setting up a simulated KNX installation, for free. The application represents more than 10 different types of KNX devices, all connected to one TP line. These KNX devices operate upon a number of 'building loads' like lamps, dimmable lamps, blinds, heating & cooling valves. KNX Virtual also makes it possible to experiment (rehearsal) with more advanced building features like weather modules, alarms, scenes and even logic operations.

KNX Virtual doesn't require any investment in hardware (such as power supply, USB or IP interface, KNX devices) as you will work with virtual devices, commissioned by ETS. [11]

- Step 1

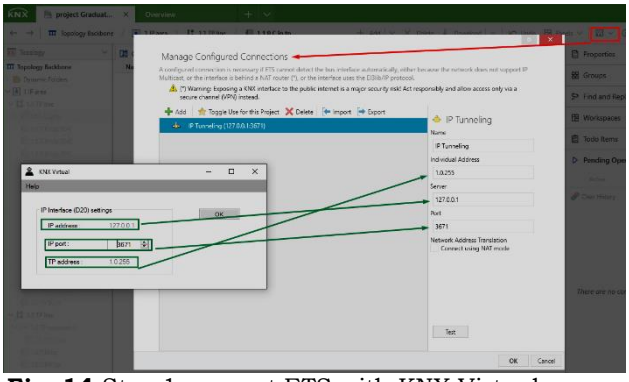


Fig. 14: Step 1 connect ETS with KNX Virtual.

- Step 2: we download the device we want to emulate by choosing from the download list download all.

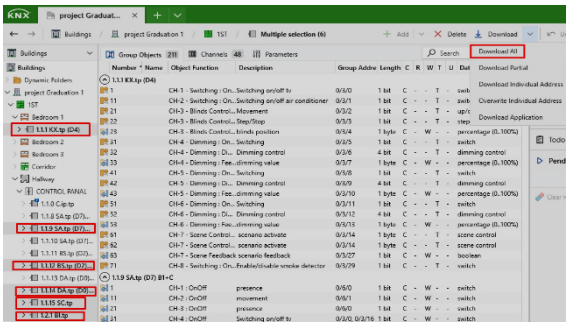


Fig. 15: Step 2 devices download from ETS to KNX virtual.

After pressing download all, the program will ask me to press the programming button for the device in the KNX virtual, and it will ask me every time I get up download press the programming button.

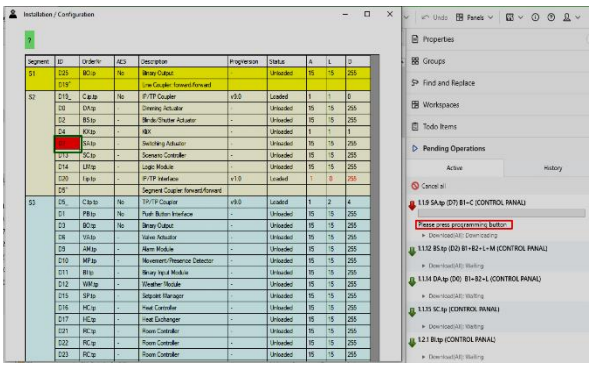


Fig. 16:pressed the programming button for the device in the KNX virtual.

Fig. 17:bedroom1 simulation for each of the: switch actuator, dimming control, blind/shutter control.

Fig. 18:bedroom1 simulation for each of the: scenario control, binary input control (there is a fire).

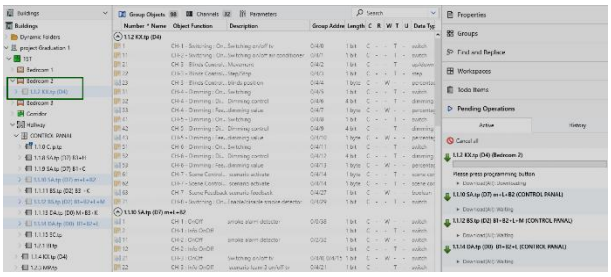


Fig. 19:devices download for bedroom 2.

Fig. 20:bedroom 2 simulation for each of the: scenario control, binary input control (there is a fire).

Fig. 21:bedroom 2 simulation for each of the: scenario control, binary input control (there is a fire).

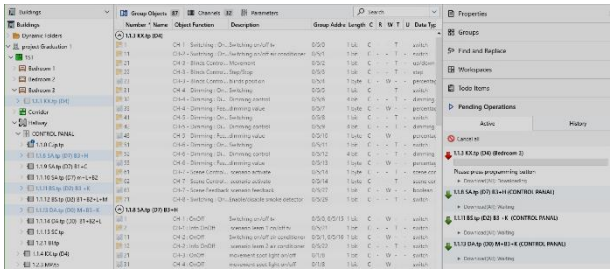


Fig. 22:devices download for bedroom 3.

Fig. 23:bedroom 3 simulation for each of the: switch actuator, dimming control blind/shutter control.

Fig. 24:bedroom 3 simulation for scenario control.

Fig. 25:devices download for kitchen.

Fig .26:kitchen simulation for each of the: dimming control, blind/shutter control.

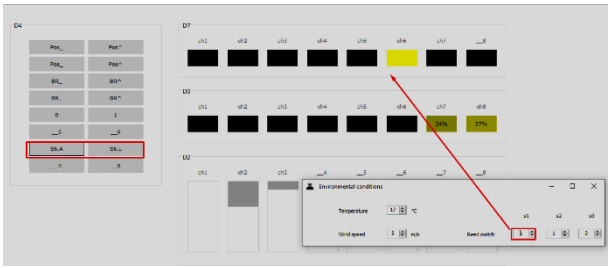


Fig. 27:kitchen simulation for each of the: scenario control, binary input control (there is a fire).

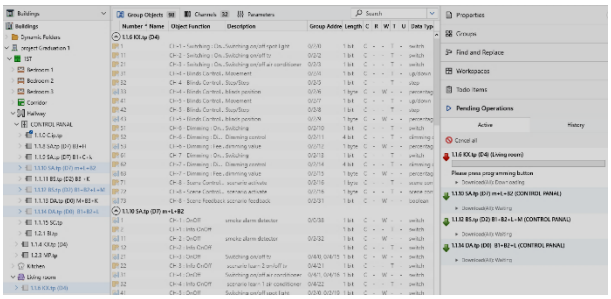


Fig. 28:devices download for living room.

Fig. 29:living room simulation for each of the:1-switch actuator 2-dimming control 3-blind/shutter control.

Fig. 30:living room simulation for each of the: scenario control, binary input control (there is a fire).

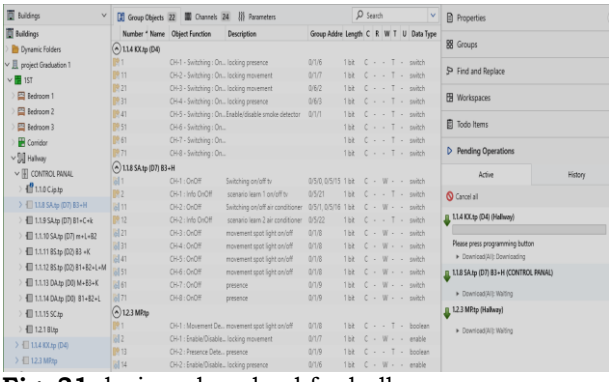


Fig. 31:devices download for hallway.

Fig. 32:when there is movement and presence in hallway and there is a fire.

Fig. 36:when there is presence only.

Fig. 33:when there is movement only.

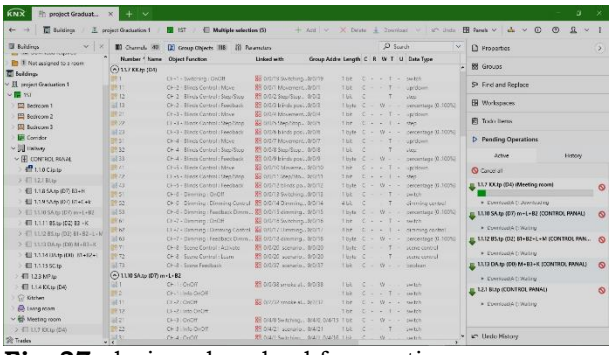


Fig. 37: devices download for meeting rom.

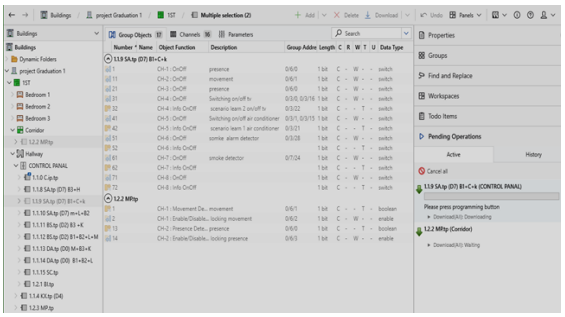


Fig. 34:devices download for corridor

Fig. 38:meeting room simulation for each of the:1- switch actuator 2-dimming control 3-blind/shutter control.

Fig. 35:when there is movement and presence in corridor and there is a fire.

Fig. 39:meeting room simulation for scenario control.

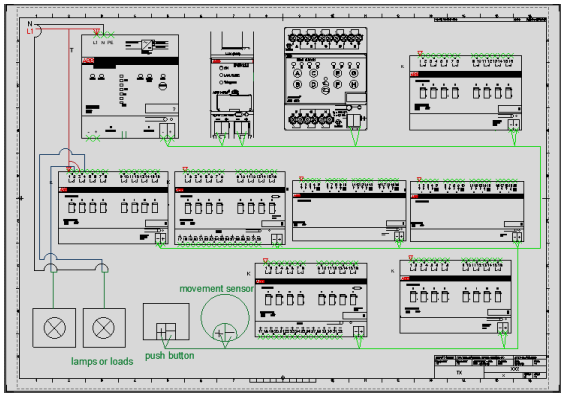


Fig. 40:control panel

Conclusions

Automation can provide useful functions for buildings. The most important functions are those that can save energy and provide security, as a building automation system, KNX has proven to be a very excellent choice.

KNX has been around since a long time and they have become a standard. There is a wide range of products offered by more than 500 factories. Minor modifications can be easy to do because they may not need any wiring just reprogramming.

This search was implemented on an apartment that includes all the devices in it. Those functions were programmed on the ETS6 program, a simulation of the functions was performed to ensure that the programming was done correctly and the results were satisfactory. A design was made for the control panel with some connections for explanation using AutoCAD. I had a lot of difficulty, including the lack of information, especially in matters of programming and linking to the simulator. I hope that the project is simple and helps to understand this system.

Recommendations

We strongly recommend that state institutions adopt this standard in all government buildings because it has many advantages that state institutions lack, the most important of which is the provision of electricity and that special laboratories be provided for this standard in colleges so that it can be studied in practice.

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