Smart lighting for corridors of an educational institution building

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Abstract – In summer 2017 the law of Ukraine «On Energy Efficiency of Buildings» came into force. The law demands obligatory certification of energy efficiency of state-owned buildings. Therefore it is necessary to increase energy efficiency that includes the implementation of a number of organizational and technical measures. The main organizational measure is the introduction of a system of energy management in an educational institution. Technical measures mean the introduction of modern energy-use technologies, in particular, smart technologies. The basis of smart technologies is a mini computer like Raspberry Pi or microcontroller Arduino. The advantage of smart power management systems is their scalability and the ability to integrate with other systems (security, fire safety). In the article is shown an example of using the smart system in a lighting of educational institution building.

Keywords – energy efficiency, smart technology, microcontroller, lighting.

I. Introduction

On July 23, 2017, the Law of Ukraine «On Energy Efficiency of Buildings» came into force.[1]. This law, in particular, provides for mandatory certification of energy efficiency of state-owned buildings. The purpose of certification is to determine the actual energy performance of buildings and assess their compliance with minimum energy efficiency requirements.

Energy expenditures of budgetary institutions, in particular educational institutions, are quite significant and amount to 13-15% of all current expenditures [2]. So it is necessity to increase the efficiency of energy use, which includes the implementation of a number of organizational and technical measures.

An important component of organizational measures is the introduction of an energy management system. The system of technical measures involves the modernization of power consumption systems, the replacement of inefficient equipment and optimization of operating modes. It also demands the using of smart technologies as it enables the implementation of optimal power management algorithms.

II. Selected smart platform

Today, the industry offers many technical solutions, such as, mini computers Raspberry Pi, Latte Panda, Beagle Bone, Intel Edison, controllers Arduino etc. The analysis showed that Raspberry Pi is most often used to build start-up systems. The scope of Raspberry Pi application is quite large: from simple tasks to multi structural start-system [3].

The Raspberry Pi is a series of small single-board computers developed in the United Kingdom by the Raspberry Pi Foundation. The Raspberry Pi hardware has evolved through several versions (from version 1 to version 3 with different modifications A, A+, B, B+) that feature variations in memory capacity and peripheral-device support. The block diagram of Raspberry Pi is given on Fig. 1.

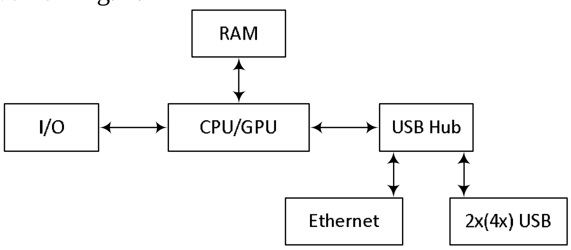

Fig.1. Block diagram of Raspberry Pi.

In the first generation Raspberry Pi was used the Broadcom BCM2835 SoC Processor. Later it was upgraded to a Broadcom BCM2837 SoC with a 1.2 GHz 64-bit quad-core ARM Cortex-A53 processor.

We can use Raspberry Pi with different operational systems like Debian, Fedora, Arch Linux, Gentoo, RISC OS, Android, NetBSD, FreeBSD, Windows 10 IOT etc.

Also Raspberry Pi 1 Models A+ and B+, Pi 2 Model B, Pi 3 Model B and Pi Zero (and Zero W) GPIO J8 have a 40-pin pinout (Raspberry Pi 1 Models A and B have only the first 26 pins). These pins are named GPIO (general purpose input-output).

When programming the GPIO pins there are two different ways to refer to them: GPIO numbering and physical numbering. Both numberings for Raspberry Pi 3 are given on Fig. 2.

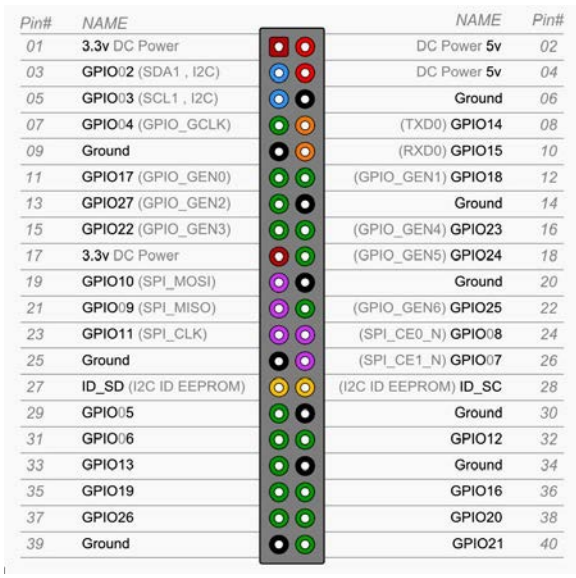

Fig.2. GPIO and physical numbering of connectors for Raspberry Pi 3.

So, the 40-pin pinout is the base of smart system for control of energy consumption.

For this purpose there need to connect them in electrical circuits. The total output current of all pins should not exceed 50 mA. 5-volt pins can give up to 500 mA.

III. Lighting control system of corridors of buildings

The effectiveness of smart technologies is illustrated on the example of modernization of the lighting system for the corridors of educational institution building. Building contains nine floors and typical floor plan of the building is shown on Fig. 3.

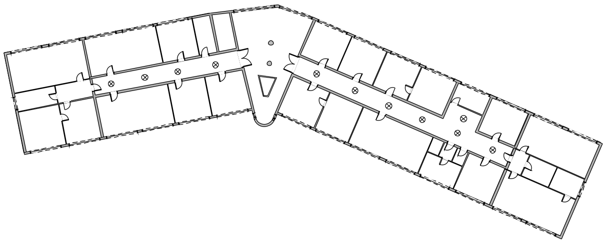

Fig.3. Typical floor plan of the building.

Building is characterized by long corridors that do not have access to natural lighting. Therefore, the system of artificial lighting (there are 4 luminaires in the left corridor and there are 7 luminaires in the right corridor) works every day for 10-12 hours except Sunday. Each luminaire contains two lamps with a nominal power 18 W. As a result monthly energy consumption is 51.5 kWh and annual energy consumption is 500 kWh. The annual cost of lighting only two corridors is more than 1150UAH.

Traditional approaches (like motion sensors in combination with the sensors of illumination) that are used to optimize the work of such illumination are ineffective. Instead, we propose to use of lighting control based on the educational process schedule. For example turning on all luminaires during breaks and reducing their number to quarter during training time.

Implementation smart control system will allow us to reduce energy consumption by 50-60%.

With this purpose it is necessary to divide all luminaires into four groups. First and third groups are permanent illumination of the right and left corridors (totally 3 luminaires); second and fourth groups are main illumination of the right and left corridors (totally 8 luminaires).

For switching power circuits, we could use 4-channel relay module (Fig.4a) or two 2-channel relay module (Fig.4b). 2-channel relay module (Fig.4b) contains 2 relays with parameters 10 A/220 V. Voltage supply is 5 V DC, control current 20 mA, speed 10 ms. The relay module owns 4 pins – Ground, DC Power 5 V and two control pins (Fig. 4.)

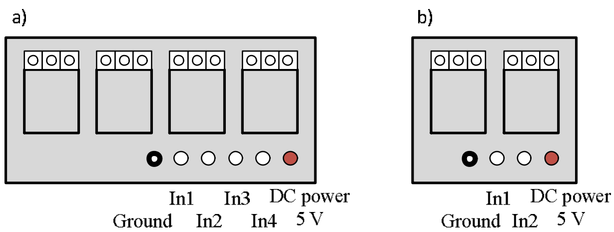

Fig.4. The pins and terminals of the relay module.

Each relay has three terminals allowing us to connect two devices that work at opposite time.

Lighting control system for building of educational institution is given on Fig. 5.

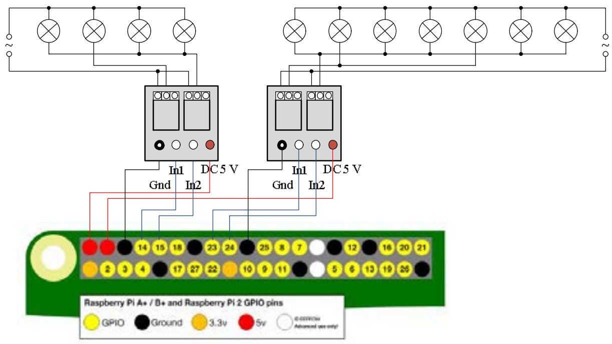

Fig.5. Smart lighting control system for building.

After the introduction of smart lighting control system monthly energy consumption will be equal 51.5 kWh and annual energy consumption will be equal 500 kWh. It is less than 50% of current energy consumption.

Annual expenses for electric energy will amount to UAH 565 and the expected annual savings of UAH 585. The simple payback period of the system is 4-5 years.

The advantage of the smart lighting control system is its scalability. In particular, it is easy to expand on lighting control of other floors. This will increase the attractiveness of the implementation of such systems.

The lighting control system (smart power management system in general) can be integrated with other systems like security system, fire safety system, etc. As a result we can easy transform it into «smart house system».

Conclusion

The introduction of obligatory energy certification of budget buildings leads to the need to increase their energy efficiency.

Increasing energy efficiency in particular involves using of the smart power management systems.

Efficiency of application of smart technologies is shown on the example of the lighting system for the corridors of educational institution building.

The smart power management system can be transformed it into «smart house system».

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