

Design of Lighting System Automation for a Supermarket

¹Austris Zeltins, ²Igors Uteshevs

Riga Technical University, Latvia
Corresponding Author : ¹Austris Zeltins

ABSTRACT

The project "Designing a Lighting Automation System for a Supermarket" is designed and developed by the lighting plan, electricity distribution schemes and technical solutions for managing lighting in the sales area and personnel premises in such a way as to ensure maximum efficiency and save electricity. This project describes the needs and requirements of the customer, the devices chosen to automation the lighting system.

Keywords: Automation control systems, PLC programming, lighting systems applications.

Date of Submission: 25-11-2017

Date of acceptance: 22-12-2017

I. INTRODUCTION

Modern industrial electrical engineering has evolved to such an extent that it enables us to automate many different, seemingly everyday routines and processes. Such automation makes it possible to significantly increase the efficiency of work by reducing the time the employee would otherwise have consumed himself in the performance of the specified activity. Automation can greatly increase resource efficiency, which is especially important for large businesses where the economies of scale are the most visible.

In the spacious rooms where people work and stay on a daily basis after certain and predictable time schedule, users need simple light control. In this case, automated lighting control is the most effective solution. This can be achieved through appropriate illumination programmable logic controllers, which can be customized to fit the particular object to get the most effective result.

This work is addressed and creates a lighting system and its automated management for the supermarket. To achieve lighting automation, a programmable logic controller - PLC (programmable logic controller) in combination with magnetic contactors and three-position switches will be used. The controller should be able to turn on and off certain lighting groups in the sales area and in the personnel rooms, regardless of the program installed in the controller, depending on the time of day, alarm control and manual control.

At the moment, all large and less large industrial companies are increasingly beginning to switch to different automation of production-related processes using programmable logic controllers, since they have proven that logic controllers significantly improve work efficiency and cost-effectiveness. For these reasons, therefore, productivity increases and, whatever the purpose of the controller, it will reimburse the initial investment for its installation in a relatively short period of time.

For technical staff, the use of programmable logic controllers offers several advantages over analogue and relay equipment:

- Saved time savings, because reprogramming can be faster than wiring and changing the electrical circuit.
- Flexible operation of equipment changes by replacing only programs and settings.
- Simpler management and extra control.
- Control and management tasks that were previously not feasible - control, mathematical functions, calculations, communication, etc.
- Possibility to diagnose the equipment when connecting to the controller.
-

II. PROBLEMS FORMULATION

For the development of an electric lighting project, the supermarket has prepared a description of its requirements and a catalog on which the project should be guided and developed, taking into account both the requirements of the customer and all the rules and standards for electro technical design.

- The main illumination through the zones and the accent lighting must be separated in separate groups that can be controlled either automatically or manually.
- Each second luminary's line (for general lighting) must be taken from another phase of the system.

- Set the interior illumination unit to the e-mail section room and manual and automatic control switches installed in the security room together with BMS.
 - The light control panel must be installed in the security room, the remote control switches must work in 3 modes: automatic control, on and off. The cables between the illuminating switch and the control panel must be clearly indicated in the electrical engineering part of the project. The switchboard must provide a switch for manual emergency lighting, and a relay that will turn on emergency lighting in the event of a fire alarm, and a relay which will turn on the light when receiving a signal from the security panel.
 - For accent lighting, power is supplied through three-phase contactors controlled by the controller's time function.
 - Add basic light luminaries with 5-core cables to ensure that lighting can be switched on in various variations. Each individually controlled group of luminaries must be evenly distributed throughout the entire sales area, so that in case when one of the lighting groups is disconnected, the grass remains evenly illuminated.
 - The illuminator for internal and external store lighting, installed in the security room, the remote control switches must operate in three modes - automatic, switching on, off. Connect the power supply to the remote control from the electrical lighting circuit (A1). The switches on the control panel need to indicate the position of the switch with the signs: R - manual operation (on); A - automatic control; 0 - no position (off). The automated system is controlled by Schneider Electric's Modicon TM221CE24R programmable Lighting Controller with the TM3DQ8R expansion module, which in turn controls magnetic contactors that in turn will include certain lighting groups.
- Logic controller TM221CE24R has several powerful functions and applications that can perform several automation tasks and can handle a wide range of hardware. Configuration and programming of the controller is performed using the SoMachine Basic computer program, which supports three programming languages: IL (Instuction List), LD (Stair Diagram), Grafset (List).
 The controller is powered by an AC voltage from 100 to 240 V AC. The controller has built-in real-time clock and has 512 KB of RAM and 1.5 MB of flash memory.

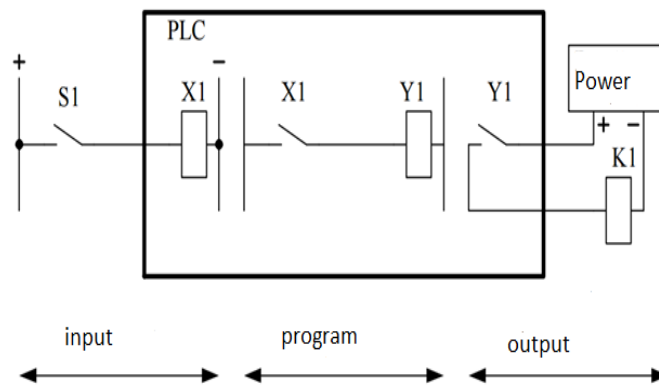


Figure 1. PLC control principle.

Table 1. List of groups controlled by switches (fragment).

| Switch Nr. | Gropes |
|------------|--|
| S1 | lighting in the trading hall |
| S2 | lighting in the trading hall |
| S3 | lighting in the trading hall |
| S4 | accent lighting in the sales area in the fish and meat weighing area |
| S5 | accent lighting in the trading hall in the confectionery area |
| S6 | accent lighting in the sales area in the bread area |
| S***n | El. **** |
| S20 | emergency lighting throughout the supermarket area |

The electrical connection to the illumination control unit A2 will be supplied from the illumination distribution A1, which in turn will receive power from the 1PGS and is protected by a 160A automatic switch. 1PGS saddle is fed from the main distribution unit 1GMS in the mall.

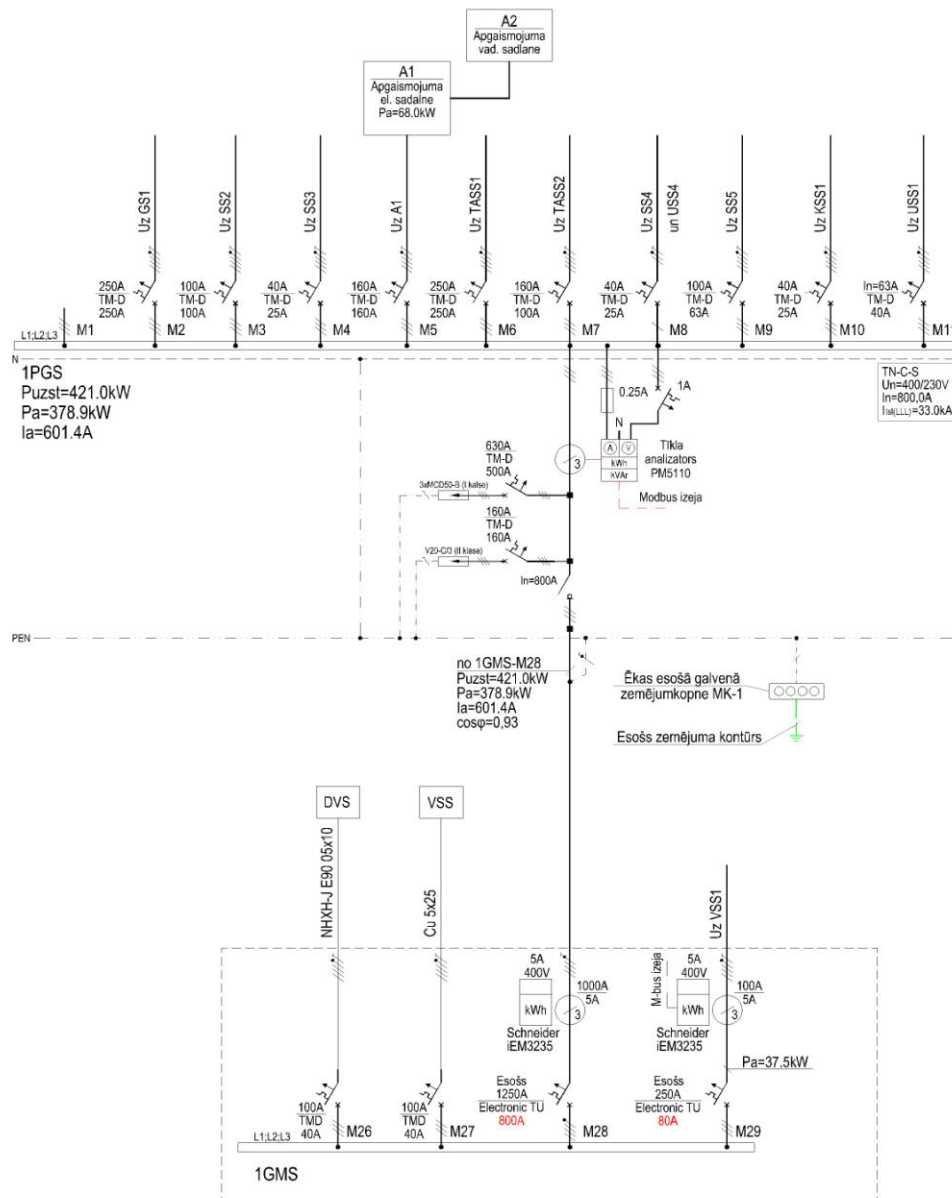


Figure 2. Supermarket electrical circuit diagram from the shopping center division

The controller and its control chains are fed from the lighting circuit A1 through the 6A automatic switch. The controller is designed to connect 230V power through the 2A automatic switch, and each of the relay group inputs has its own 2A automatic switch. From the controller inputs, only one of which is supplied with a 24V signal through the AS system relay 2 of the security system, and the signal input is protected by a 0.15A fuse. From the controller relay outputs, the signals are further subjected to 3 position switches, from which, in anticipation of the position of the switch, the signal is fed further to the magnetic contactors of the A1 terminal and a certain group of lights is switched on.

As a control signal, 230V AC voltage is used, so no voltage converters are required in the system. The lighting automation system is installed in accordance with the design of the illuminated distribution assembly monolithic circuitry and the illumination control panel extended circuits.

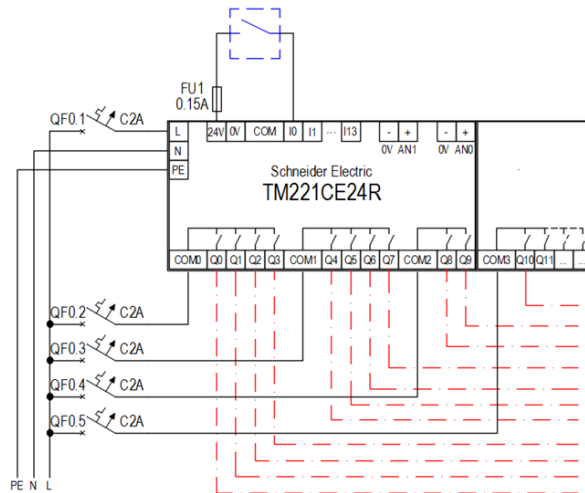


Figure 3. Controller Mounting Scheme

III. CREATE A PROGRAMMABLE LOGIC CONTROLLER PROGRAM

Schneider Electric has designed and developed its own SOMachine Basic software program for its logic controller group TM221, which was included in this project for both program development and uploading to the controller itself.

The controller program code was developed in the Ladder programming language, and control of output groups according to the time of day setting is achieved through the SCHEDULE (graph) block provided by the SoMachine Basic computer program.

The program itself is relatively simple and easy to configure. Each controller output has its own "SCHEDULE" block, which is configured accordingly to give a signal to the controller relay output depending on the timing setting.

| Used | Address | Configured | Output bit | Start Day | Start Month | End Day | End Month | Start Time | End Time | Mon | Tue | Wed | Thu | Fri | Sat | Sun | Comment |
|-------------------------------------|---------|-------------------------------------|------------|-----------|-------------|---------|-----------|------------|----------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|------------------|
| <input checked="" type="checkbox"/> | %SCH0 | <input checked="" type="checkbox"/> | %M0 | 1 | January | 31 | December | 06:00 | 00:00 | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | Tirdznieciba zāl |
| <input checked="" type="checkbox"/> | %SCH1 | <input checked="" type="checkbox"/> | %M1 | 1 | January | 31 | December | 07:00 | 23:00 | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | Tirdznieciba zāl |
| <input checked="" type="checkbox"/> | %SCH2 | <input checked="" type="checkbox"/> | %M2 | 1 | January | 31 | December | 08:00 | 22:30 | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | Akcenta apgais |
| <input checked="" type="checkbox"/> | %SCH3 | <input checked="" type="checkbox"/> | %M3 | 1 | January | 31 | December | 08:00 | 22:30 | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | Kasu zonas apg |
| <input checked="" type="checkbox"/> | %SCH4 | <input checked="" type="checkbox"/> | %M4 | 1 | January | 31 | December | 08:00 | 22:00 | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | Tirdzniecibas zā |
| <input checked="" type="checkbox"/> | %SCH5 | <input checked="" type="checkbox"/> | %M5 | 1 | January | 31 | December | 07:30 | 23:00 | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | Apgaismojums |
| <input checked="" type="checkbox"/> | %SCH6 | <input checked="" type="checkbox"/> | %M6 | 1 | January | 31 | December | 08:00 | 22:30 | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | Kulinārijas ceħa |
| <input checked="" type="checkbox"/> | %SCH7 | <input checked="" type="checkbox"/> | %M7 | 1 | January | 31 | December | 05:00 | 00:00 | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | |
| <input checked="" type="checkbox"/> | %SCH8 | <input checked="" type="checkbox"/> | %M8 | 1 | January | 31 | December | 05:00 | 23:00 | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | |

Figure 4. Screenshots from the Controller Program Code

The illumination level is calculated using the computer program "DIALux".

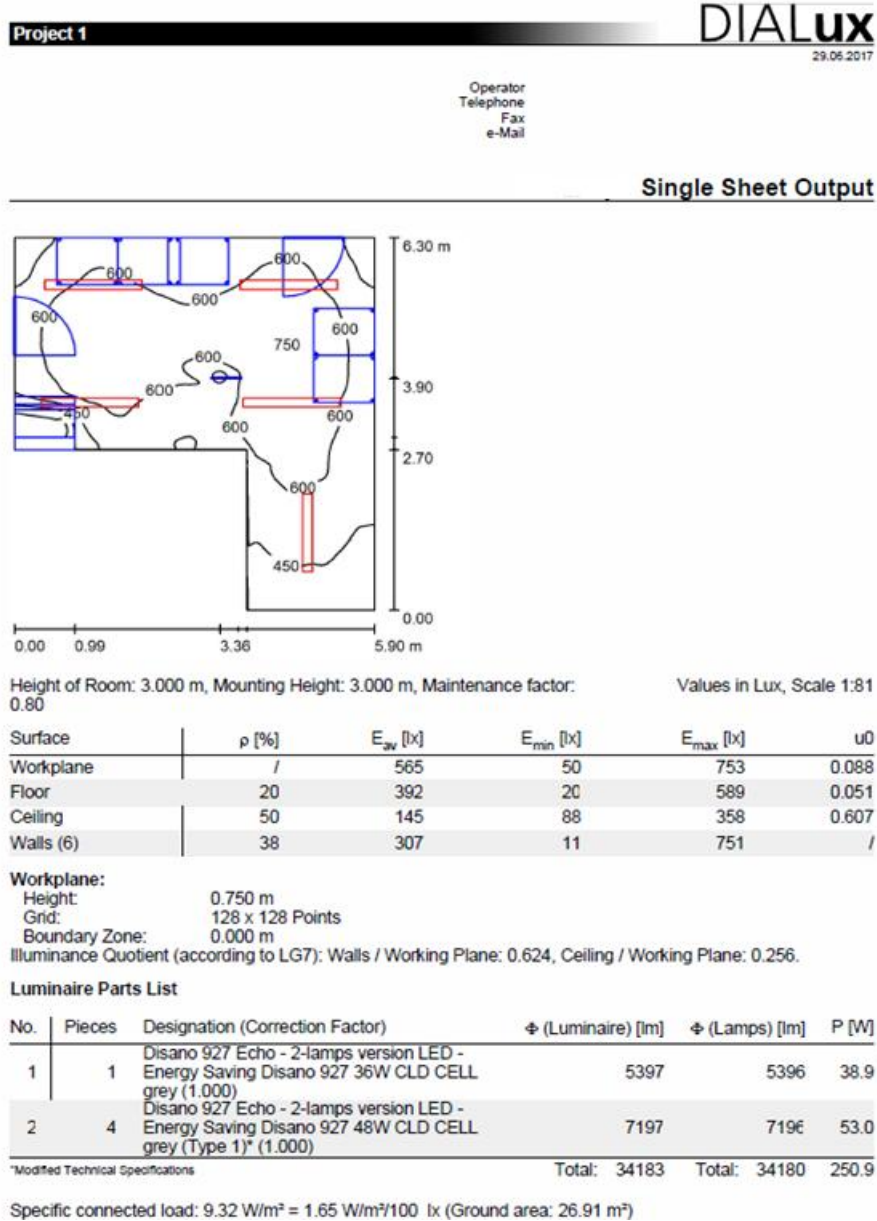


Figure 5. DIALux informational lighting levels for the culinary space

IV. CALCULATION OF LIGHTING POWER AND ENERGY CONSUMPTION

The power consumed by each lighting group is calculated according to formula 1 which takes into account the number of individual luminaires in the group and the nominal power of the luminaire. Calculation of power for the lighting group QF1.1:

$$P_{gr1.1} = \sum P_{ni} * n_i = 46 * 98 = 4500W \quad (1)$$

Where: $P_{gr1.1}$ – the power of the lighting group QF1.1;

P_{ni} – rated lamp rated luminary;

n_i – number of luminaires;

In turn, the total amount of power consumed by the entire lighting system depends on the time of day and is calculated as the sum of the power of all the illumination groups turned on.

Total installed power (P_u) calculation for all lighting:

$$P_u = \sum P_{gr,i} = 70.2kW \quad (2)$$

where $P_{gr,i}$ - is the power of a separate lighting group.

The graph below shows the total daily power consumption of automatically controlled luminaries in a supermarket.

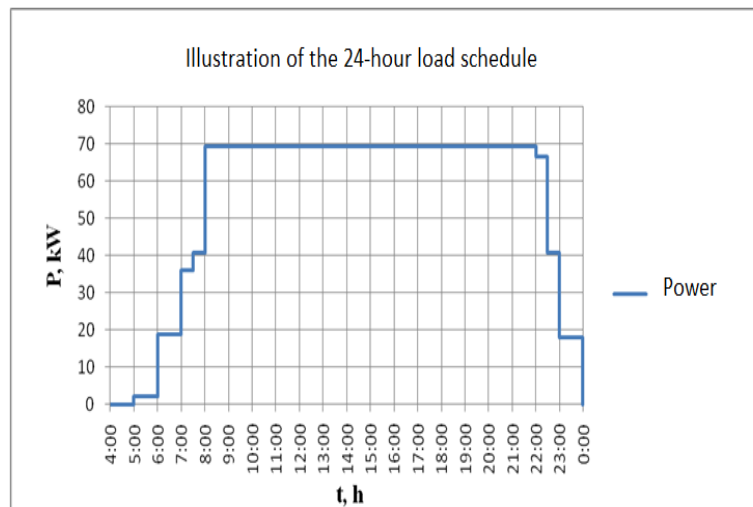


Figure 6. Illustration of the 24-hour load schedule

After that, when the power of each light group is known and the time it is kept on, it is possible to calculate the energy consumption according to formula 3:

$$E = P_{gr.i} * t_i \quad (3)$$

where E - amount of electricity consumed [kW*h]

P_{gr.i} - power of the particular lighting group [kW]

t_i - time of the set state of the particular group [h]

When calculating the electricity consumption, 1102.18 kW* h is consumed per day for lighting. If there was no such automated system and all lighting would be switched on from the very first morning starting from the first works and turned off only on the evening after all employees had already left, then electricity consumption would be 1318.41 kW*h overnight. From these results by the formula 4:

$$\Delta E = \frac{E_2 - E_1}{E_1} * 100\% \quad (4)$$

where E₁ – amount of electricity consumed for the automated system [kW*h]

E₂ – amount of electricity consumed for the automated system [kW*h]

It turns out that in the case of a manual system, when all lights are switched on in the morning and turned off only in the evening, the power consumption is by 20% more than the use of an automated system, with which the programmable logic controller can set daily clock timetables that lead to timely lighting turning “on” and “off”.

The amount of electricity saved during the year is very significant at 78 924 kW/h, which in turn translates into € 10 809 per year.

V. CONCLUSION

In the work, analyzing the tasks performed and following the requirements of the client, the most suitable lighting control equipment and control system were found and selected.

- The work was devised and developed a layout plan for luminaries, which was tested with compliance with labor safety standards by means of the program "DIALux" to ensure that all rooms provide optimum lighting;
- A lighting and control scheme for illumination has been established in accordance with all requirements and the chosen control and protection equipment;
- After the development of a complete illumination assembly scheme and a plan, a programmed logic controller work program was developed for controlling lighting according to the customer's instructions;
- After the project was completed, the developed system was constructed and all necessary measurements and tests were carried out to put it into operation;
- After the illumination system has been developed under the operating voltage, the customer has verified that all tasks assigned to him are fulfilled and the system works as intended.

REFERENCES

- [1]. Ainārs Galiņš, Pēteris Leščevics. Programmējamie Loģiskie kontrolleři: mācību līdzeklis. Jelgava: LLU, 2008-135lpp. Pieejams: <https://estudijas.llu.lv/mod/resource/view.php?id=51393>
- [2]. MELNIKOVS ELEKTROAPGĀDE. MĀCĪBU LĪDZEKLIS RĪGA 2012-444LPP.
- [3]. J.Barkāns Elektrisko sistēmu projektēšana Rīga: RTU izdev., 36 lpp.
- [4]. U.Grunte, O.Makreckis, V.Zacmanis Lietotāju un speciālo elektroiekārtu ekpluatācija. mācību līdzeklis Rīga 2012-106lpp.
- [5]. Latvijas Elektrotehniskā komisija. Latvijas Energostandarts LEK 048, Rīga 2005-45lpp.
- [6]. Ministru kabinets. Darba aizsardzības prasības darba vietās. Ministru kabineta noteikumi Nr.359 Rīga 2009
- [7]. International Electrotechnical Commission. IEC 61131-3: standarts industriālajiem programmējamiem loģiskajiem kontrolleřiem.
- [8]. Schneider Electric. Modicon M221 logic controler: katalogs 2016-35lpp.
- [9]. Schneider Electric. TM3DQ8R mudele: datu lapa. 2014-5lpp.
- [10]. Schneider Electric. LC1D25M7 TeSys D contactor: datu lapa. 2012-3lpp.
- [11]. Schneider Electric. Getting Started With SoMachine. Mācību līdzeklis, pieejams: http://www2.schneider-electric.com/resources/sites/SCHNEIDER_ELECTRIC/content/live/FAQS/288000/FA288633/en_US/Training%20Manual%20EN.pdf
- [12]. Ezzat Baoudi. DIALux evo Tutorial. mācību līdzeklis, pieejams: <https://ezzatbaroudi.files.wordpress.com/2013/01/dialux-evo-tutorial-5-pdf-file-creating-a-complete-interior-and-exterior-project.pdf>
- [13]. Mail the Camera Ready paper in MS-Word format to theijes@submitmails.com

Austris Zeltins. "Design of Lighting System Automation for a Supermarket." The International Journal of Engineering and Science (IJES), vol. 06, no. 12, 2017, pp. 66-72.