The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM)
ISSN: 2602-3199

The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM)

Volume 1, Pages 111-115

ICONTES2017: International Conference on Technology, Engineering and Science

AUTOMATION SYSTEM DESIGN FOR FAULT DETECTION IN STREET LIGHTING

Murat Ayaz
Kocaeli University

Koray Erhan
Kocaeli University

I. Malik Kundakci
Kocaeli University

H. Metin Ertunc
Kocaeli University

Abstract: Today, with the Industrial 4.0 revolution, industrial applications are being designed with information technology. Substantial properties such as decision making, action taking and traceability for industrial applications are achieved with usage of information technology. Just as in all areas of industry, lighting applications are evaluated within this scope. In this study, a fault detection system is developed to find the location of faults in street lighting. A transformer center provides energy for many street lighting fittings. In some cases, many of the lighting columns are fed by a single distribution transformer. Detection of a faulty lamp in a large number of lighting fittings is often not possible, and the user is adversely affecting comfort. Generally, the authorities are aware of the situation by means of the complaints of the neighborhood residents. With the proposed algorithm given in this study, it is possible to predict which lighting fitting is faulty with the help of the current sensors placed in the transformer center. Current values of each lines connected to the transformer is evaluated in the proposed fault detection system. As it is known how many lighting columns are in each line, it can be determined by making calculations how many lighting fittings are defective on one line. Then, the proposed system calculates the equivalent resistor value and estimates location of the faulty lighting fitting. For example, 15 lighting columns fed by same line are divided into 3 groups such as 1-5, 5-10 and 10-15, and the location of the faulty lighting fitting can be estimated within a certain range (groups). This allows determining the location of the faulty lighting column within a 100-meter zone instead of within lighting columns located in hundreds of kilometers zone. In this regard, intervention to the fault is possible in a short time and with great certainty. This situation provides both reducing of the workforce and improving user comfort.

Keywords: Street lighting systems, industrial automation, industry 4.0, plc.

Introduction

The number of people living in cities has increased after industrial revolution. According to Ozcaglar (2016), 23% of citizens live in rural areas and 77% live in urban areas in 2012 (city and town centers). Growing cities need more comprehensive logistic infrastructure. Hence, highways and urban roads have been increased accordingly. Street lighting has also been continuously improved in this case due to provide traffic safety, maintain the order and safety of the community and aesthetic concerns.

Lighting systems have been used in cities since the 4th century. As stated in study conducted by Bourne (1996), at first, street lighting is provided by torch and gas lamps. After the invention of the electricity in the 19th century, street lighting is provided by street lighting poles. Today, various control methods are used in street

- Selection and peer-review under responsibility of the Organizing Committee of the conference
*Corresponding author: Murat Ayaz- E-mail: murat.ayaz@kocaeli.edu.tr

lighting. Leccese's (2013) system, the lamps are controlled wirelessly using ZigBee communication protocol. Denardin, Barriquello, Campos, Pinto, Dalla Costa, Do Prado (2011) proposed a network-based smart system design. In a study by Lavric, Popa, Males, Finis (2012), the performance of ZigBee protocol based street lighting control systems are compared. The lighting poles are opened and closed collectively depending on the darkening of the air. Therefore, controlling of each armature individually is often not preferred in environmental luminance systems. In general the problem that may occur in lighting systems is an armature malfunction. Detecting the faulty lighting pole by visual control is difficult. According to the statement made by the Ministry of Energy in 2012, there are about 17 million street lighting poles in Turkey. Late detection of faults can cause serious problems in terms of safety and user comfort. The faulty of the lighting system must be immediately reported to maintenance team to respond to the failure. Failure control can be done wirelessly with remote management systems in long distance systems. But wireless systems have some disadvantages as high installation cost, complex structure and hard to implement to the system. In this study, a fault detection method is proposed for environmental luminance system.

Programmable Logic Controller (PLC) is widely used in automation and control systems. These user friendly devices are in use to control the lighting systems in many transformer substations. The designed system can be added to the existing system via only one analog port for each line. Most PLCs have analogue value reading capability and many PLCs are got this feature by additional module. In this study, it is assumed that there are 15 luminaires in one lighting line. Each armature is assigned a resistance value. Equivalent resistance value is read by PLC and it try to detect the faulty lighting pole. If more than one lighting poles are fails, the first fault is taken to memory and then the new fault is tried to be estimated by calculating the equivalent resistance again.

Method

Environmental luminance and street lighting systems are designed considering energy distribution center position. Energy distribution centers are divided into zones and infrastructure is set up. Figure 1 shows the lighting power lines connected to a transformer. In this study, it is accepted that there are 15 lighting poles and armatures on each lighting line. These values are selected for simulations and calculations. There is one central PLC unit to control the lighting system in transformer center and there is an analog data input card for each lighting line.

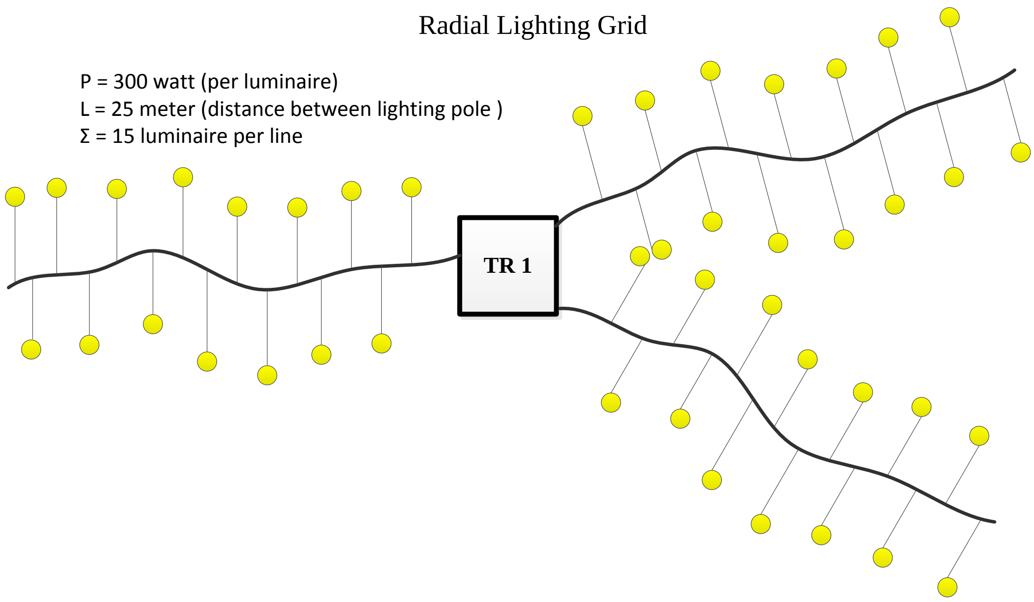

Figure 1. Lighting power lines connected to a transformer

A modular card is designed for each armature in the system as shown in Fig. 2. There is a relay set that connected to current sensor on the card. The current sensor controls the armature current. The system has a specific resistance module which is numbered for each armature. The values of these resistances are prime numbers. The system calculates the equivalent resistance value and determines the faulty armature. Electric circuit which includes the relays is controlled at 24 V. Table 1 shows the specific resistance values for each lighting armatures. These values can be increased or grouped depending on the number of armatures.

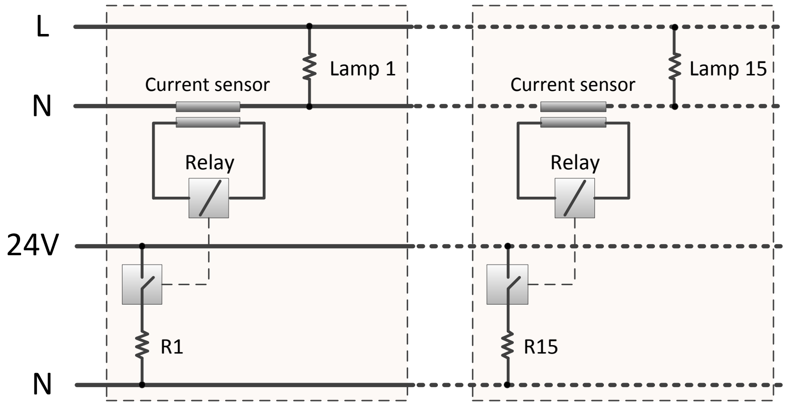

Figure 2. The modular resistor and relay unit

Table 1. The parameters of the proposed system

Address Number	Resistor Value (Ω)	Faulty Lamp	Equivalent Resistor Value (mΩ)
R1	11	Lamp 1	2423
R2	13	Lamp 2	2344
R3	15	Lamp 3	2289
R4	17	Lamp 4	2248
R5	23	Lamp 5	2173
R6	29	Lamp 6	2132
R7	37	Lamp 7	2098
R8	43	Lamp 8	2082
R9	59	Lamp 9	2055
R10	67	Lamp 10	2046
R11	79	Lamp 11	2037
R12	91	Lamp 12	2030
R13	101	Lamp 13	2026
R14	113	Lamp 14	2021
R15	131	Lamp 15	2016
		Non Faulty Lamp	**1986**

Each armature has different resistance values. Therefore, it is possible to determine which armature is faulty according to the equivalent resistance value. The equivalent resistance varies according to resistance value of the faulty armature. For instance, if armature 3 fails, the current sensor connected to the armature will cut off the power supply of the relay circuit. And 15 ohm resistance belongs to 3rd armature will be removed from the control circuit. The equivalent circuit resistance calculated by Equation 1 will increase from 1986 ohms to 2289 ohms. It can be determined that the equivalent resistance value pairs with the faulty armature. Table 1 shows the equivalent circuit resistance values calculated considering only one armature faulty case. These values are expanded by considering other cases.

$$\frac{1}{Req} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3} + \cdots + \frac{1}{Rn} \tag{1}$$

A curve fitting method is performed with the Matlab Curve Fitting Tool considering the equivalent resistance values are given Table 1. This curve is shown in Fig. 3. and can be expressed by Equation 2. When the curve fitting is done proportionally, it is seen that the obtained curve is very close to the real result. Similar curves need to be created to detect multiple armature faulty cases.

$$f(x) = (p1) / (x + q1) \tag{2}$$

In the electric circuit based fault detection system, as the number of the armatures increases, faulty variations also increase. In this context, equivalent circuit resistance values are very close to each other. This makes it difficult to determine which armature is faulty. However, this disadvantage can be eliminated by using a high resolution analog data card.

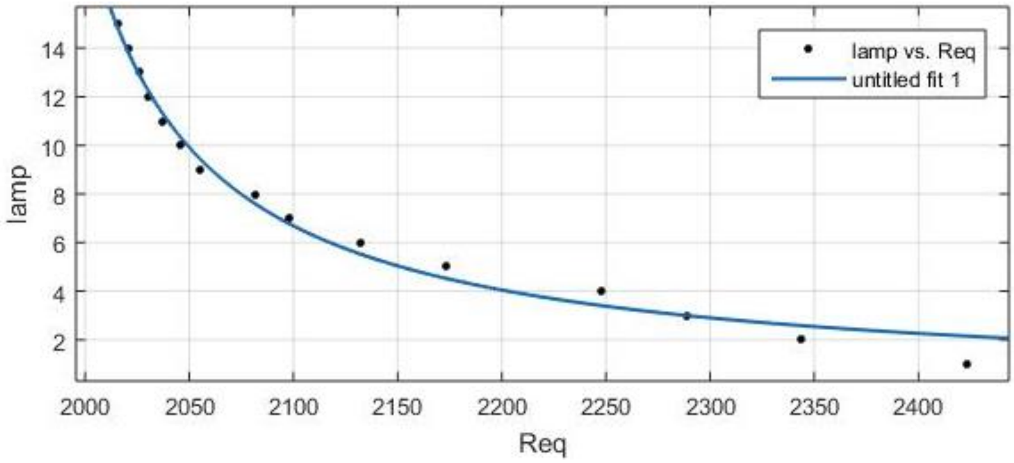

Figure 3. The waveform of the equivalent resistor values

A block diagram of the electric circuit based fault detection system is shown in Fig. 4. A PLC module and a HMI module are located in the control system. There is an analog input card is for each lighting line in the system. The current, voltage and equivalent resistance data are collected with analog input card to control. The obtained power and the lighting power supply values are compared momentarily. In addition, it is checked that there is any faulty armature and if there is a faulty armature, it is determined which armature is faulty and the operator is notified.

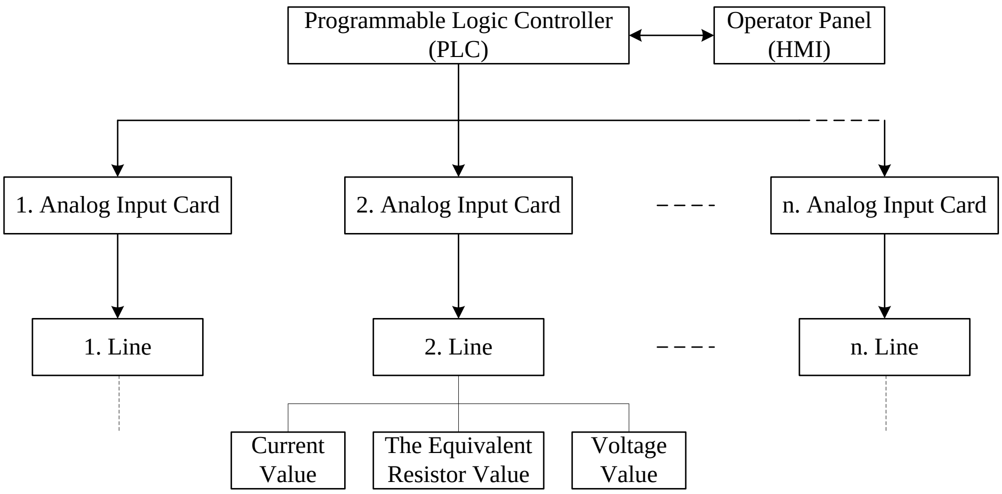

Figure 4. Bloc diagram of the control system

Operator panel (HMI) screens can be designed to be as simple and easily understandable as possible, and in a structure which more data can be viewed and controlled. In this study, simple screen design is preferred in order to simulate the system and it can be further enriched. In the designed system, the lighting lines connected to the transformer on failure screen of the operator panel are shown in Fig 5. "Fault" written in red color appears next to the fault line in case of fault. The yellow circle on the screen indicates that the fault is seen by the operator, but the fault has not yet been repaired. When the screen of the faulty line is opened, which armature is fault is shown with remark and figure. There is also a button indicating that the malfunction is seen. If the fault is solved and the equivalent resistor values are within the normal range, the yellow circle on the main page will turn green. In Figure 5, the fault screen designed for Line 3 can be seen.

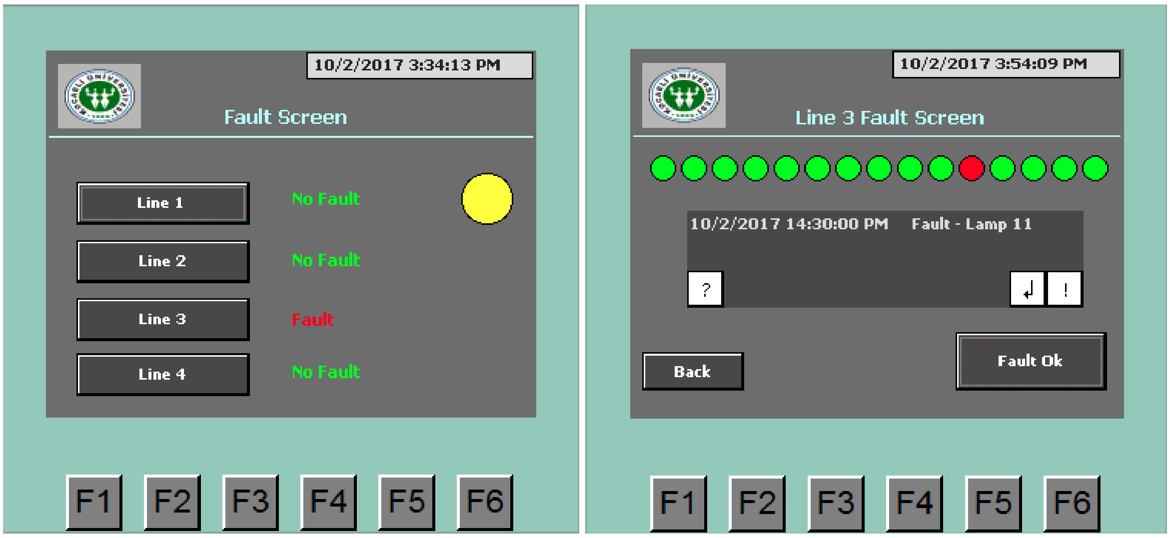

Figure 5. Main fault screen and fault screen of line 3

Conclusion

In cities, environmental and street lighting is of great importance both in terms of aesthetics and security aspects. In this context, new design and control studies on environment and street lighting are increasing day by day. In addition to preferring more aesthetic lighting systems that consume less energy, it is also important to solve the faults by making a diagnosis. In recent years, with the increasing use of wireless data network in particular, each system is designed with wireless communication modules and fault detection is provided by this method. However, high investment costs are a big disadvantage of these systems. In this study, a fault detection system with an electric circuit base is proposed. The proposed system has a modular structure consisting of a resistor and relay set for each armature. It is predicted that the proposed system will be cheaper than other control systems in terms of cost. However, the limited number of armatures can be controlled with the proposed system and high resolution data cards are required for acquisition of the equivalent circuit resistance value. These are main drawbacks of the proposed systems.

References

Bourne R., (1996). The Beginnings of Electric Street Lighting in the City of London., *Engineering Science and Education Journal*, pp. 81-88.

Denardin G. W., Barriquello C.H., Campos A., Pinto R. A., Dalla Costa M. A., & Do Prado R. N (2011), Control Network for Modern Street Lighting Systems., *IEEE International Symposium on Industrial Electronic*, pp. 1282-1289.

Lavric A., Popa V., Males C., & Finis I. (2012). A Performance Study of ZigBee Wireless Sensors Network Topologies for Street Lighting Control Systems . *International Workshop on Mobile Ad-Hoc Wireless Networks*, pp. 130-133.

Leccese F., (2013). Remote Control System of High Efficiency and Inteligent Street Lighting Using a ZigBee Network of Devices and Sensors., *IEEE TRANSACTIONS ON POWER DELIVERY*, 28(1), 21-28.

Ozcaglar A. (2016)., Büyükşehir Belediyeli İllerde Kır ve Kent Nüfusunun Tespiti Mümkün Mü?, *International Geography Symposium*, pp. 271-291.