Design of goniophotometer with the automated measuring system

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***Abstract*—This paper deals with the design of a goniophotometer which is a device used for measuring the light distribution of luminaire. Light distribution is measured in the way that luminaire changes its position, respectively angle towards to luxmeter which measures light intensity in defined angle. The proposed automated system is used for the control of two motors which are used for positioning the luminaire. The proposed system is used also for automated measuring of luminous intensity at defined angles which can be defined by the user. This can speed up measurement significantly because, if the luminaire is symmetrical so only half of the measurement samples are necessary. The next advantage of the proposed system is that all results of measurements are saved in EULUMDAT which except for values of luminous intensity contains parameters of luminaire and parameters of measurement. Files in this format can be processed directly in some special software for lighting design.**

Keywords—goniophotometer, automated measurement, luxmeter

I. Introduction

Goniophotometers are devices respectively laboratory instrument that serves to measure the angular distribution of luminous intensity of luminaire. This is one of the most important parameters of the luminaire which indicate the performance of the luminaire [1,2,3].

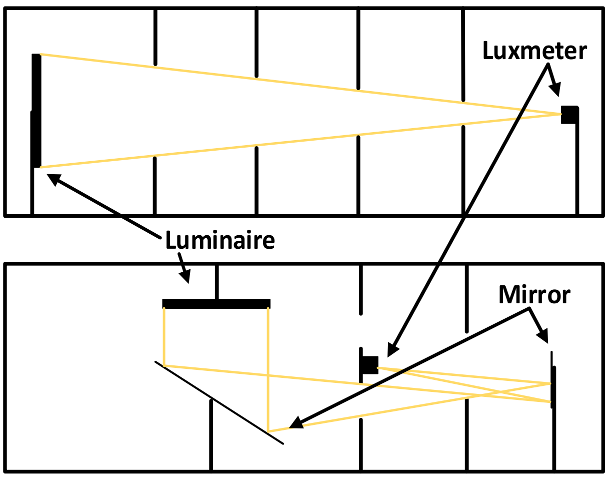

Fig. 1. The basic structure of the near-field goniophotometer on top and far-field goniophotometer on bottom

Like other devices, there are different types of goniophotometers. Goniophotometers can be divided into two main groups as we can see in figure 1. The first group of goniophotometers is near-field goniophotometers. In these goniophotometers, the measuring head of the luxmeter receives light from the luminaire directly without using any mirrors. This is the biggest advantage of this type of goniophotometer, so the complexity of construction is small. The main disadvantage of this type of goniophotometer is that the distance between the light source (luminaire) and the measuring head of the luxmeter should be minimal 15 times larger than the diameter of the light source. For example, for the measurement of a technical lamp with a length of 1.5m, the distance between this luminaire and luxmeter should be at least 22,5m. Thus, construction is simple but quite large. The second group is far-field goniophotometers using mirrors to direct the beam to the head of the luxmeter. Usually, two mirrors are used, one fixed mirror and one moving mirror. Thus, the complexity of construction is higher, but the advantage is that construction is much smaller compared to near-field goniophotometers. Next criterion of divisions of goniophotometers by moving part. The moving part can be a mirror, measuring head of the luxmeter, or luminaire (light source). Goniophotometer with moving light source can be divided based on fixed and moving axis (figure 2.). Type A goniophotometer has a fixed horizontal axis and vertical axis moving vertical axis perpendicular to the latter. This type is used mainly for the testing of automotive lighting and optical systems. The second type, type B goniophotometer has a vertical axis fixed and a moving horizontal axis perpendicular to the latter. This type of goniophotometer is mainly used for floodlights. Last, most common, type C goniophotometer is like type B goniophotometer, but construction is rotated 90° on the horizontal axis [6-11].

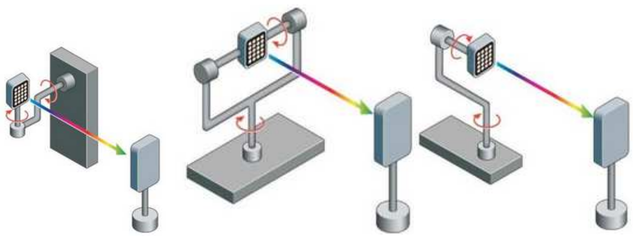

Fig. 2. Type A goniophotometer (left), Type B goniophotometer (midle) and Type C goniophotometer (right) [7].

The proposed system of goniophotometers with an automated measurement system is a near-field type goniophotometer. This type of construction was chosen because of its simplicity of construction. The proposed system is type C so the rotation part of the goniophotometer is the luminaire itself.

II. Proposed construction and used hardware

The proposed system for the position of the luminaire consists of two motors, each motor for positioning the luminaire on one axis (figure 3). Both motors are connected to worm gearboxes for increasing the torque during positioning. These motors contain their controller for easier control of motors. The first motor with a gearbox is used for the position of the platform which contains the second motor with a gearbox. This platform is square to the axis of light emission. The second motor with a gearbox is used for positioning the luminaire in the axis of light emission. At output shafts of both gearboxes are placed home switches which are used for initialization of position of the luminaire in both axes.

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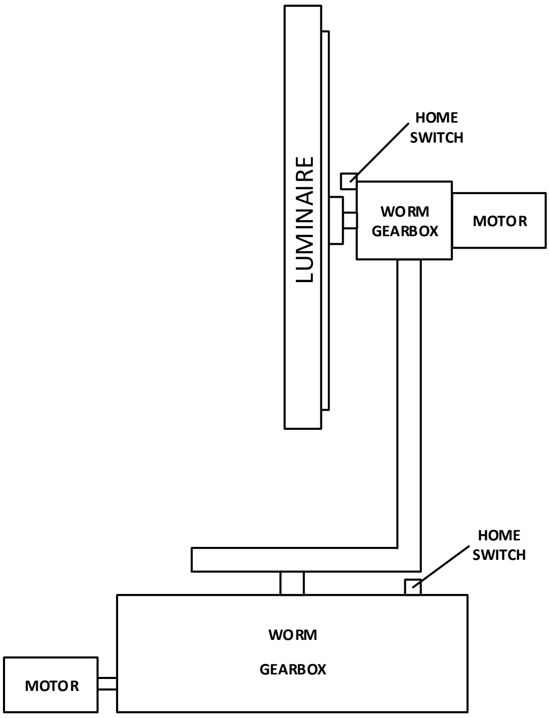


Fig. 3. Construction for positioning of luminaire

For communication with motor, controllers CAN BUS is used. For connection, CAN-BUS to PC with control system USB to CAN-BUS interface was used. For measurement of light intensity, a luxmeter that supports a connection to a PC via USB was used (figure 4).

Fig. 4. Block diagram of the communication

A. Motor with integrated controller

To simplify the complexity of control of the positioning of the luminaire motor with the integrated controller was chosen. Stepper motor Nanotec PD6-C8918M9504-E-09 was used. Parameters of the motor can be seen in table 1, below. The integrated controller can communicate with the control system with USB or CAN BUS. The proposed system is near field type of goniophotometer so the distance between motors (luminaire) and control system is quite high, CAN BUS was chosen as the communication interface. The integrated controller contains two rotaries switched which are used for the selection of node ID, in our case 1A and 1B. Node ID is used during communication as the identifier in the way that node ID is added to the constant based on the type of message. Motor, respectively motor controller, contains 6 digital inputs and 2 analog inputs, where one analog input is used for the home switch. Analog input is used because the controller also contains a 10V auxiliary power supply, so the home switch is connected between the power supply and analog input [12].

TABLE I. MOTOR PARAMETERS

Size	86 mm - NEMA 34
Interface	CANopen, USB, IO (clock direction; analog)
Operating Voltage	12 VDC - 48 VDC
Peak Current (RMS)	9.7 A
Type of Digital	Inputs 5/24 V switchable
Type of Analog Input	0 - 10 V, 0 - 20 mA / 0 - 10 V switchable
Type of Digital	Output open-drain (max. 24 V/100 mA)
Encoder Type	single-turn absolute
Holding Torque	594 Ncm
Rated Current (RMS)	9.5 A
Number of Digital Inputs	6
Number of Analog Inputs	2
Number of Digital Outputs	2
Encoder Resolution	1024 CPR
Weight	4.1 kg

B. Worm gearboxes

Because of the weight of the luminaire itself and the weight of construction where is the motor with luminaire mounted, two worn gearboxes are used. The first smaller gearbox connects the luminaire with the motor. The ratio of this smaller gearbox is 10:1, which means that the spin of the luminaire for 5-degree, which is the standard step, the motor must spin 50-degrees (500 steps of the motor). The second gearbox is much more robust because the carry weight of construction with motor and luminaire has a ratio of 108:1. That means for 5-degree, the motor must spin 540-degrees.

C. USB to CAN-BUS interface

For communication between motors and control system (PC) was chosen CAN-BUS so an interface between CAN BUS and some standard computer interface was needed. Interface between USB and CAN BUS, Kvaser Leaf Light was chosen. This interface has a standard 9-pin D-sub connector and a maximum speed of up to 1Mbit/s, which is used in the proposed system. This interface can handle up to 8000 messages per second, time-stamped with an accuracy of 100 microseconds. The proposed system uses a standard 11bit identifier, but this interface also supports a 29bit, extended identifier. The benefit of this interface is galvanic isolation, so power surges or electric shock is ensured [13].

D. Luxmeter

Luxmeter Krochmann RadioLux 111, which is a precision device for photometric measurement, was chosen for the measurement of luminous intensity. Many different measuring heads can be used with this luxmeter based on the wavelength of the measured light. The photometric head class A according to DIN 5032-7 was used. This luxmeter has a range from 0,001lx to 360klx, in three measuring ranges or auto range can be used. Luxmeter is connected to the control system (PC) via USB. Through serial communication besides measuring the actual sample is possible to set up a measuring range, store the measurement sample in the memory of the luxmeter, and shut down the luxmeter after the end of the measurement of the goniophotometer [14].

III. Control of Automated Measurement

The control algorithm was implemented in the graphical programing language LabVIEW. This graphical language was chosen because of its visualization capabilities during the run of the program and help during debugging. In figure 5, we can see the front panel of the LabVIEW application where users set parameters of measurement. Users choose an angle step in each axis of the luminaire a range of movement. Next, user fill all parameters of the luminaire which will be saved in ldt file. Then user start measurement wit button run and pop-up window appear to choose path for new file. This ensure that every measurement will be saved in new file and old files not be overwritten. In application is visualized status (initialization, error) and position of the luminaire in both axes, progress of measurement, and an actual sample of luminous intensity in lux. Also time of whole measurement is estimated.

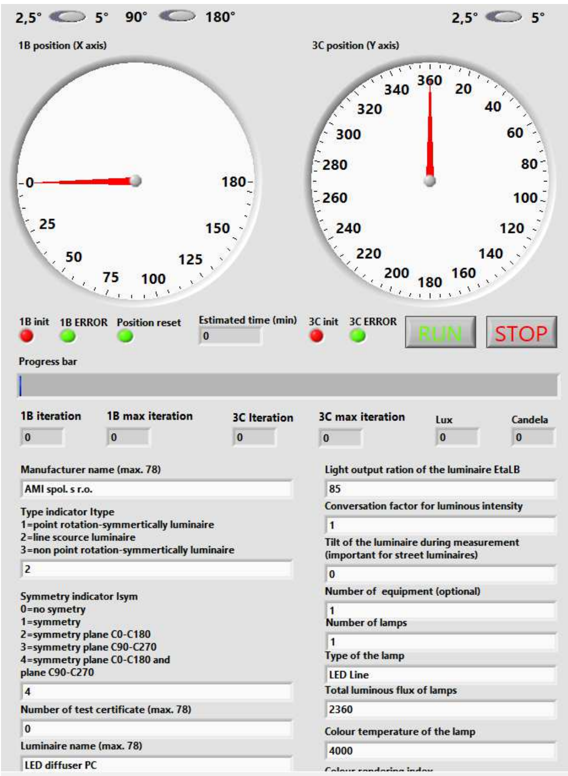


Fig. 5. The front panel of the control program

The algorithm (figure 6.) of the application can be divided into several parts. In the first part or stage of the program CAN BUS communication with motors with a speed of 1Mbit/s is initialized. Serial communication with luxmeter is initialized as well, with a speed of 9600 baud, 8 data bits, no parity, and 1 stop bit. Also, a new ldt file is created and filled with a defined EULUMDAT structure. This EULUMDAT structure contains parameters of luminaire like the type of luminaire, symmetry of luminaire, dimension of the luminaire, and so on. Also, parameters of measurement like angle step and number of steps of each axis. After initialization of communications and file, initialization of position respectively checking the position of the luminaire in both axes is necessary. After the whole measurement is finished, the luminaire is set in the home position so the luminaire should be in the home position, but during measurement can occur errors like overheating and motor stop in the last working position.

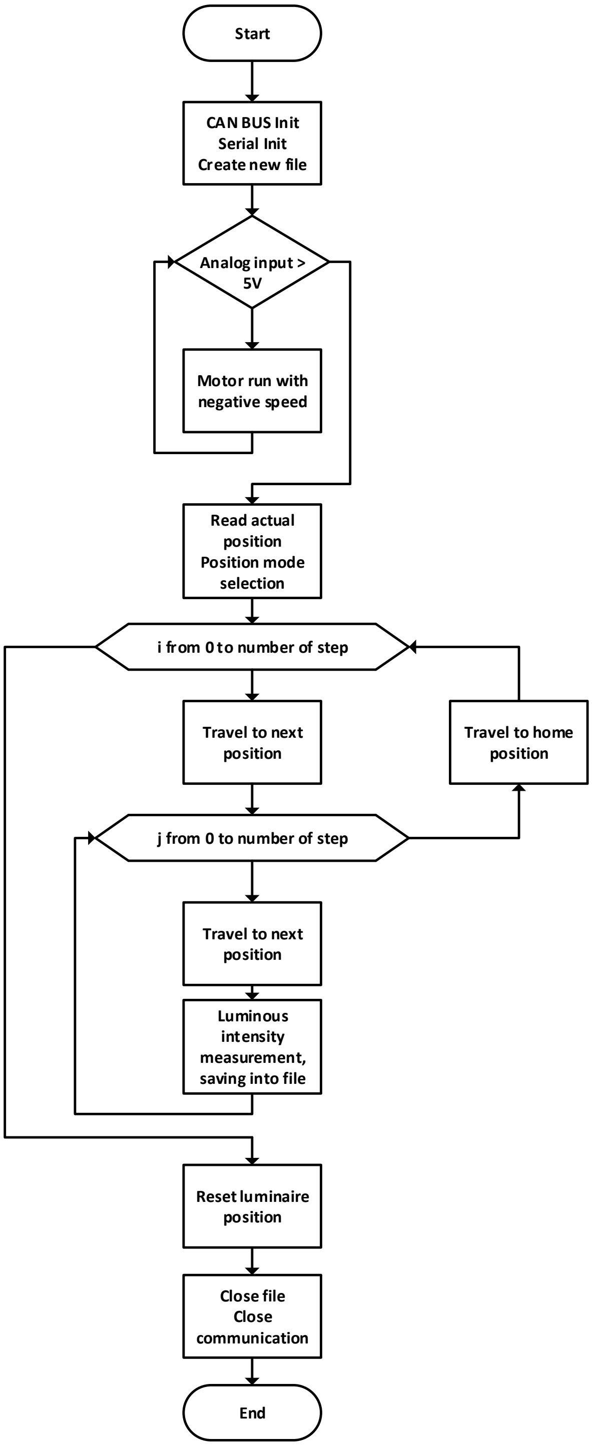
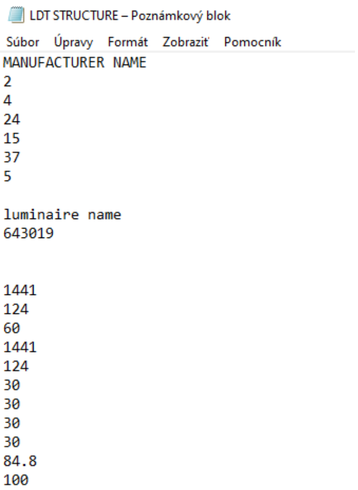


Fig. 6. Flow chart of control system

The next stage is the main part of the control algorithm which is the positioning of the luminaire and measuring of luminous intensity. In this stage, the program is also checking the status of each motor before moving of motor to the next position using the heartbeat function of the motor controller. For checking the home position, the home switch is connected between one analog input and a 10V auxiliary power supply of the motor controller. If home switched is pressed, the position is initialized, and the program continues. If the home switch is not pressed, the motor is set in velocity mode and starts to spin at a negative speed. Motor spins and voltage at analog input are constantly monitored. If the voltage is higher than 5V which means that the home switch is pressed, the command to stop the motor will be sent, motors are set to positioning mode and the program continue to the next stage where measurement is realized. The movement of the luminaire during measurement is realized in a way that the luminaire spin first around its own axis. After measuring a defined number of samples (360° travel of luminaire) luminaire travel to home position and platform with construction move to next defined step. The predefined step, in which the user selects the front panel of the program, is 2.5° or 5°. After the luminaire reaches a defined position, measured luminous intensity using luxmeter which communicates with serial communication. Every measure is started with sending the character "M" over serial communication. Luxmeter replies with a sentence containing the value of luminous intensity and temperature. After measurement of the actual sample, the value of luminous intensity is saved in established unit LUX into ldt file (figure 7.). After, that, the luminaire starts to travel to the next position. After successful measurement of all samples – the platform reaches 180°, last stage of the program start. Measurements can speed up, under the condition that the luminaire is symmetrical so only half of the measurement is sufficient. In this case, the platform travel only 90°. At the last stage of the program, the luminaire travel to the home position in both axes. After reaching the home position, the file is closed and communication with motors and luxmeter is also closed.


LDT STRUCTURE – Poznámkový blok

Súbor Úpravy Formát Zobraziť Pomocník

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MANUFACTURER NAME
2
4
24
15
37
5

luminaire name
643019


1441
124
60
1441
124
30
30
30
30
84.8
100
```

Fig. 7. Example of LDT file with EULUMDAT structure

IV. Conclusion

In this paper, a type C goniophotometer with an automated measurement system was presented. The near-field type of goniophotometer was chosen because of its simpler construction, thus no mirrors are needed. This goniophotometer consists mainly of motors with an integrated controller for positioning the luminaire in two axes and luxmeter which is used for measuring luminous intensity. The Control system is implemented in the graphical programing language LabVIEW. Control system positioning luminaire through sending a message with the position on CAN-BUS to a defined angle. The standard angle step in the proposed control system is 2.5 or 5-degree. The smaller step is suitable for LED reflectors with a narrow-angle of light emission and the bigger angle step is sufficient for a luminaire with a wide angle of light emission. In the proposed system is possible to easily change this angle step by the user based on the measured luminaire. With a smaller angle step, measurement is significantly longer. This time of measurement can be reduced if the luminaire is symmetrical so only half or even a quarter is necessary. Thus, the proposed control system has the option of a measurement range of 90 or 180 degrees. The benefit of the proposed control system is that results, measured samples, are saved in ldt file. This file is in EULUMDAT format which is the structure of file supported by special software for lighting designs like DIAlux. Comparing datasheet values of light distribution of the selected luminaires with results of control measurements confirmed the functionality and accuracy under 2% of the proposed system.

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