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DESIGN AND EXECUTING AUTOMATIC SOLAR TRACKING SYSTEM (ASTS) BASED ON ARDUINO - MEGA AND LIGHT INTENSITY SENSOR GY-30

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ABSTRACT

This paper presents the design and executes a Dual Axis light tracking system. The system is designed to track the light in order to get maximum intensity from the light intensity sensor (L.I.S) GY-30 as they follow the direction light incident on it by using two servo motors, the motors can be rotate from (0^{o}-180^{o}) in four directions. This system consist of (L.I.S) and four LDRs where as it has been designed as shape like a cross and we fixed the (L.I.S) and LDRs then putted on a stand which fixed on plastic box that contain all work requirements. The LDRs have been employed to sense direction of the light which is directly connected to microcontroller (MCU) embedded in Arduino Mega. The MCU therefore commands any one of two Servo motor to re-orient the (L.I.S) either vertically or horizontally in order to stay straight to the light. The data of lux is display in the same time on LCD and on the PC by serial monitor or recorded on the Database for Excel, moreover the executing cost is ($20) which is relatively cheap. The system is programmed with Arduino IDE. Based on the results, the three cases proved efficiency, accuracy, reliability, and durability for our not expensive, and easy to maintain the system.

Keywords: Dual Axis, Tracking, Light sensor, Mega, LDR.

1. Introduction

Lighting is one of the main subsystems of building energy systems and after heating, ventilation, and air conditioning consumes large amounts of energy in the buildings. The lighting system accounts for 20 to 45 % of the total energy utilized in the buildings [1]. Light sensor system based on four directions track one of the strategies have been suggested in order to reduce the electrical lighting energy consumption in the buildings. A light sensor is a photoelectric tool which convert the light energy detected to electrical signal. Light sensor with tracking systems appeared in many advanced industrial countries where the design of this system must depend on some basic and important features such as: efficiency, accuracy, not expensive, and easy to maintain. Single-axis schemes [2–5] and dual-axis structures for higher performance systems[6–12] can be used to track methods. The uniaxial tracker usually tracks the movement of the sunlight from east to west throughout day, while a dual axis often tracking the Sun's elevation angle. As literature, many tracker are designed to determine the sunlight and are often supported on one or more LDRs, as instance as, Ponniran et al [13], developed an automatic solar tracking system by used LDR as a sensor and bidirectional DC motor, which will be keep the solar panels aligned with the Sun in order to maximize in harvesting solar energy. As well as, Wang and Lu [14], they used four-quadrant of LDR sensor, dual axis AC motor, a stand alone PV inverter, and simple electronic circuits to design dual axis solar tracking system. Their results show that the improved system raised the power efficiency to (28.31)% for a cloudy day. Other researchers like Lu at el [15] have used other technology to reduce light energy consumption. They suggest a system that solving this problem by Daylight harvesting systems that automatically infers the window orientation & the level of cloudiness from the present sky to estimate the daylight coming and set the Open window accordingly. Other researchers have presented an autonomous light control system. They demonstrated which effect the light on a light sensor depends on the distance and direction of the light source. To this monitor both entire and local lighting systems, they studied a method [16]. Another study, Meugheuvel et al. [17] investigated the adaptation with daylight and occupancy of the distributed lighting control system. In the lighting plan experiment they used a great number of light sensors (up to 80). In 2019 Hoang et al suggested a rotating sensor device for the measurement of light intensity for analysis the resulting data. The system proposed was capable of gathering direction of sensor and intensity of light from various corners. The sensor may detect the sudden shift in the level of light. In addition, the rotating sensor still calculated lux of light in different directions, even though blocked in certain directions [18]. All systems and techniques above are costly and complex based on database storage media specifications and accuracy.

2. Materials and Electronics Components

The proposed of prototype of (ASTS) is came from a closed loop control system which is based on the physical application and electrical engineering. This prototype is used to position four LDR to track the light and read the lux which incident on the lux sensor during the time of the experiment. The components are classified in the following:

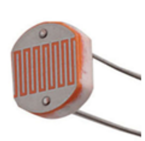
a. Plastic Box: shock resistant & waterproof we used in order to put and fixed all experimental components.

b. Breadboard: medium size, solder less, 400 Tie points.

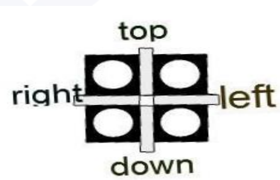
c. LED: Four LEDs with different color each of them indicates one of the four directions.

d. Resistance: Four resistance (220 Ω) connected with four LEDs to protect them and also another four resistance (10 KΩ) connected with the LDR to form voltage divider with Arduino board.

e. LDR and Voltage Divider Unit: Light-dependent resistors (LDR) (Fig. 1 a) they are sensor that allows detecting light, inexpensive, small size, easy used, low-power. It's widely used in electronic devices like toys, watch, and gadgets. Cadmium sulfide (CdS), which is used as a photoconductor and produces no or very few electrons when not illuminated, is the key component for building LDRs. whereas It is designed to have high resistance in the range of megaohms in the absence of light[19]. In our work, we used four LDR where we designed it look like a cross-shape as shown in Fig.1(b).



a



c

b

Fig.1: Light Dependent Resistor (a) and positioning it (b)

The divider of voltage is made up of LDR connected in series to a (10 kΩ) resistance which form network as illustrated in Fig.2 (a, b)[19–21].

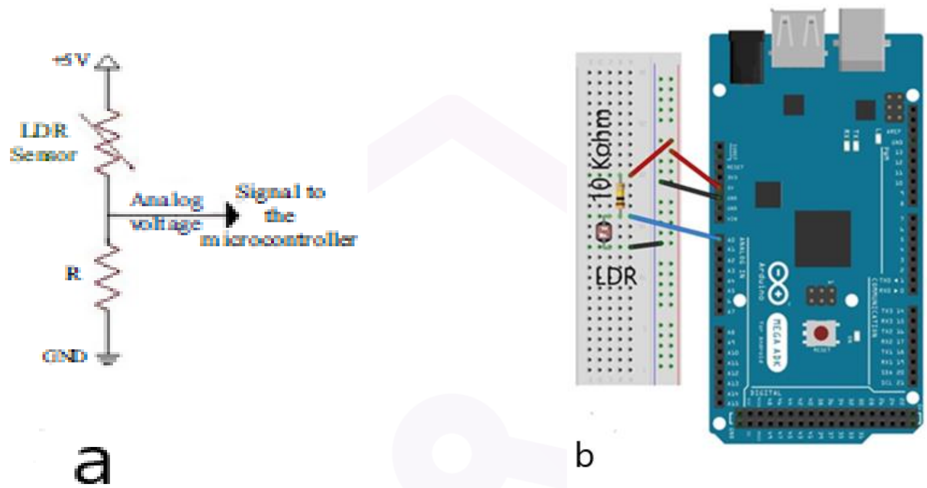


Fig.2: a. LDR network, b. LDR connected with Arduino Mega

f. Light Intensity Sensor (L.I.S): The Chip BH1750 FVI light sensor module GY-30 using in this paper, it is needed power supply (3-5) volt, has internal built-in (16) bit ADC which directly output a digital signal there is no needed for complicated calculation "BH1750 transmits data using I2C communication protocol.", illuminance are wide range and high resolution, in general the measuring range is (0-65535)lx "in IS system lx is the lux symbol ", and the size (L=3.2cm,W=1.5cm) Fig.3(a). We have installed it on a plastic stick holder which designed for this work, as described in the Fig.3 (b). The (L.I.S) can be directly measured the Lux without needing to make calculation [22].

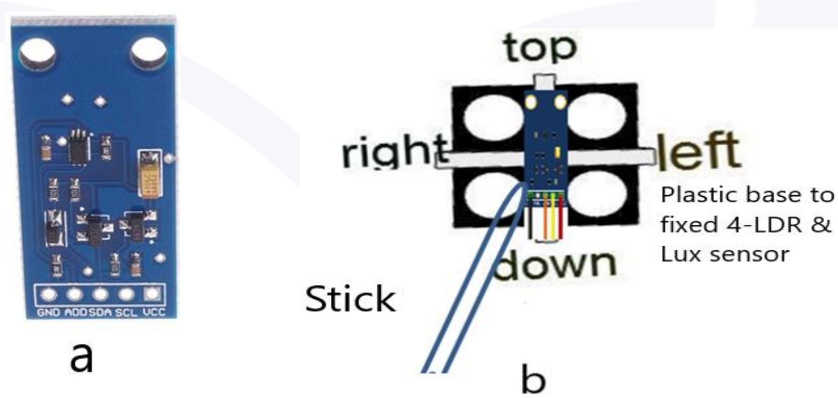


Fig.3: a. Light intensity sensor (L.I.S), b. Holder and Base of (L.I.S) & 4-LDR

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g. Display Unit: The (LCD 16X2) Liquid crystal display connected with Module (I2C) is used to display the Lux read from (L.I.S) are illustrated in Fig.4(a & b) which fixed on the plastic box. The another display is by the PC by Serial monitor and Excel program.

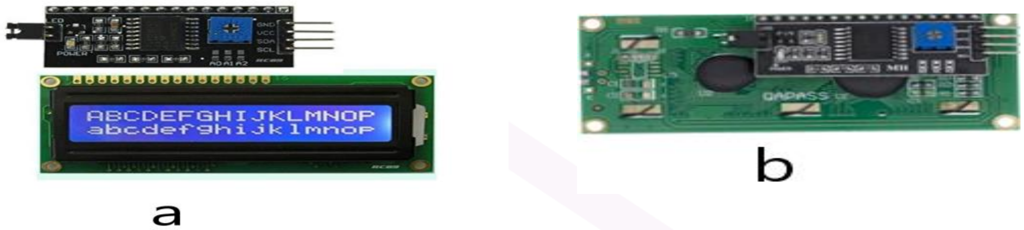

Fig.4: a. LCD without (I2C), b. LCD connected with (I2C)

h. Servo Motor: Two Servo motor SG90 moving from (0^{o}-180^{o}) degree we used, the first moving vertically from east to west and the second moving from up to down and vice versa. Servo engines have a large amount of low-speed torque owing to an optimized gearing system [21,23]. We have designed (by 3D printer) a cover for them to fixed the resistor holder on it which is show in Fig.5(b) and fixed the two motors on a plastic box.

Fig.5: a. Servo motor, b. Two Servo motor with cover

i. Mega Board: a main unit of control that could be programmed by a computer, the board is dependent on processer AT-mega-2560. It has a USB connection, and hardware serial port, to connect it to a computer with a Cable or power it with an (AC-DC) adapter [24], all sensor will be connected to the (MCU) which analysis all input data. When detecting a difference in voltage between the analog voltage sensed by the four-LDR and data from the light sensor, the following steps is achieved by the MCU[25].

1. Analyses the difference between data obtained from four LDRs
2. send order to the servo motor to turn them (on/off) in order to orient the plastic
   base (Fig.5.b) in the right direction of the largest amount of light.
3. Analyses the data received data from sensor of Lux and display it as digital data on the LCD and computer (or record it on Excel program).
4. The Microcontroller then stops the two motors "once there is no longer difference of potential among the 4-LDR".

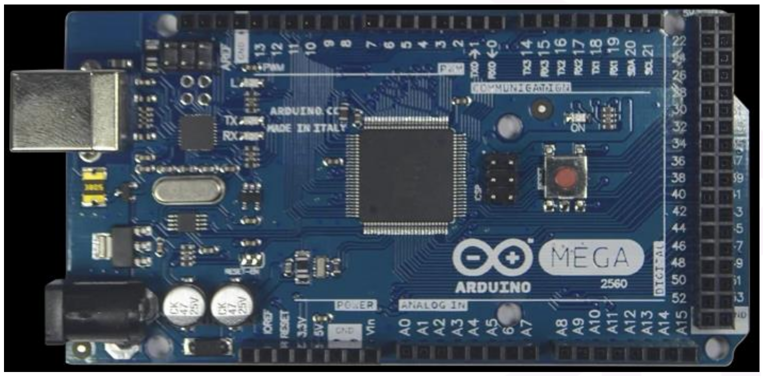

Fig.6: Board of Arduino (Mega)

j. Rechargeable Battery2.11 Rechargeable Battery/ Power Bank: It can be used in our work connecting, their purpose in order to equip the system with power if we use it without computer "portable system if we test outdoor" after uploading the code by the PC.

3. Collect and Install the (ASTS)

1. Inside the box we placed the rechargeable battery, breadboard &Arduino board with drilled of holes for input / output power for all of them Fig.7 (a, b).
2. Measurements of LCD dimensions were taken and fixed on the surface of the Box read the Lux.
3. On the far side of the LCD we made four holes for the 4-leds (indicators) in order not affect the systems work Fig.7.(a).
4. On the surface of the box installed the two motor by (4-screw).
5. Past the (Holder & Base) as in the Fig.3(b) on the upper motor base as in Fig.5 (a). After fixing all parts, we connect to the appropriate points with each other.
6. Fig.8 shows the final diagram of ASTS which drawing by Fritzing program.

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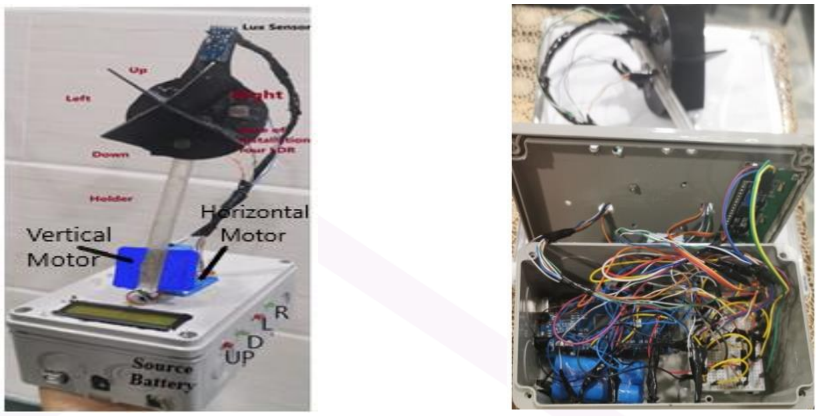

a b

Fig.7 a. Final shape of the system, b. Appropriate points connection

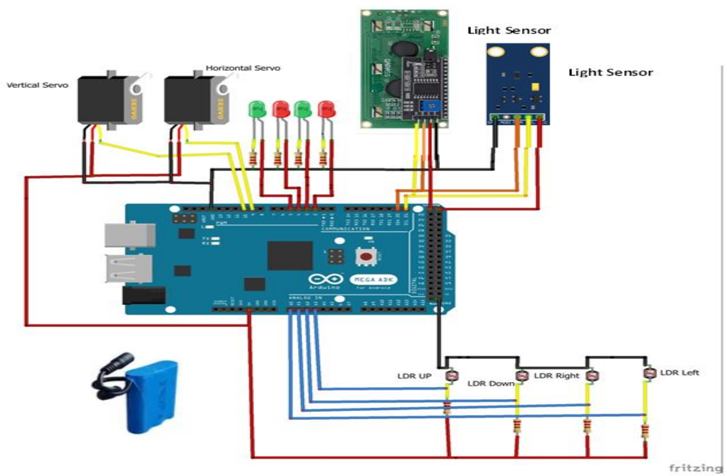

Fig.8 Final Diagram of ASTS

4. Development of Program (D.P)

The D.P depicts the process of Software and Flowchart which are used on the programing of (ASTS)

4.1 Coding

The language (C++) was used in writing the code and runs in the flash memory of the MCU, the Arduino IDE (interactive development environment) which used to code was written, compiled and download into the MCU.

4.2 Flowchart

Fig.9 illustrates the logic and sequential flow after program that run in the MCU used for the processing and control unit. When the system is first turned on

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(Start), the MCU define the required variable then it displays the value of lux on the LCD and serial monitor (PC). The system now moves the mounted Lux sensor and the Base of 4-LDR (Fig.7 a) by the two motors in any direction (Up & Down, Left & Right) by reads the value of light dependent resistors and finds out of the potential difference between the two pairs of LDR through two cases, case1 if the condition for the pair of LDR(1&2) is greater than the threshold of (50) and lesser than (-50) the motor will rotate to Left or Right direction and case2 if the condition for the pair of LDR(3&4) is greater than the threshold of (50) and lesser than (-50) the motor will rotate to Upward or Downward "according to the largest amount of incident on the LDR" with guide to direction by color of led (ON). The threshold (50&-50) was experimentally chosen as a result of many tests and this value will not allow the two-servo motor to be oversensitive (without Fluctuation). Then recorded the (Date, Time and lux) on the Excel Program directly by its software steps prepared for this purpose and show the same value of lux on the LCD directly.

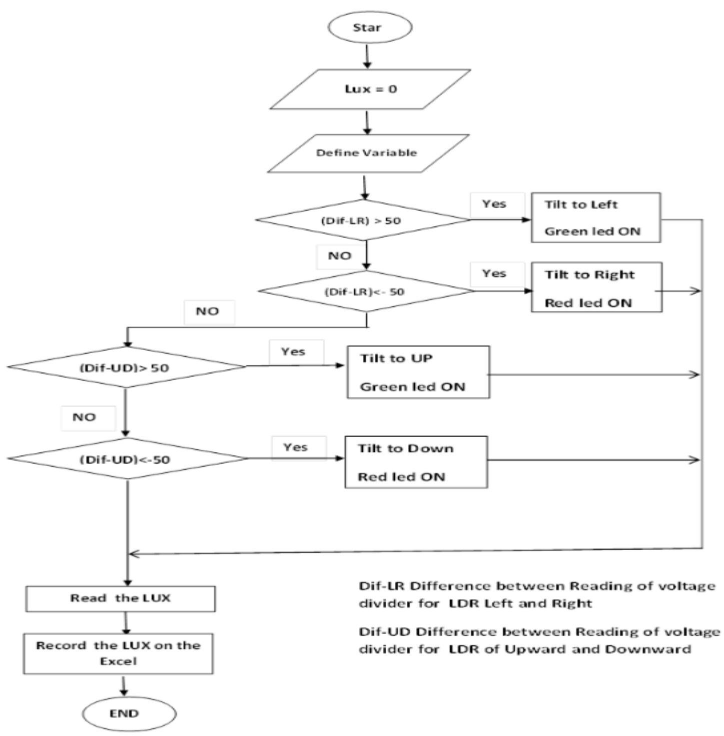

Fig.9 Flowchart of ALTS

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5. Experiments and Results

We carried out experiments using the system designed is shown in Figure(10), which include four lamps installed on the square room ceiling, one window covered with semi-transparent curtains in order to pass the light during the period of recording measurements during the day; the system was putting in the center of room. The experiments performed in three stages, at each stage the recording of the measurement at day and night in order to compare the results that we obtain in the same conditions. We used a tool to block the lighting while recording the measurements, consisting of a wooden stick, one meter long put at the end a circle piece of cardboard.

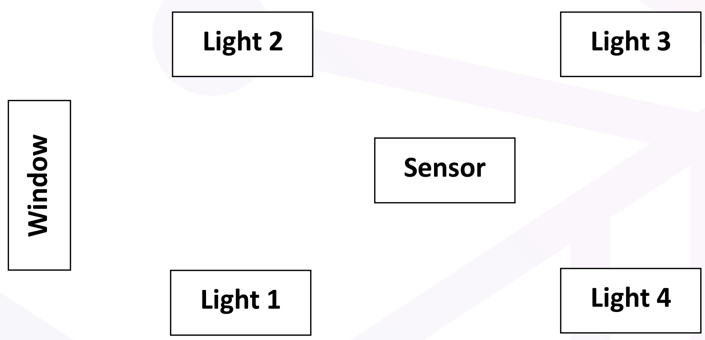

Fig.(10) Top view of the workroom

All the results we gather from this system are shown simultaneously on each of the (LCD and Serial monitor for Arduino IDE). Save the results and refer to them at any time through programming in the development environment for Arduino. Average of the date, time, and Lux value is recorded in the Excel program. The number of readings per second is ten readings that can be controlled through programming. We conducted the experiments and registered the measurements in three cases

1. The first case: It is divided into two sections. The light intensity measurements as a function of the number of reading per time for one lamp during the daytime (section one) and at night (section two), as shown below

a. The first section: during the day, Turning on the lamp and then blocking it successively the results shows in figure 11 where it's in start noticed that during the day the light intensity measured starts from (26 lux) and not from (zero) which due to the presence of the lighting from the window through the curtains this prove the accurate measurements of our device and sensitivity. then the value of the lux increases until it stabilizes at the value (95 lux) then when the lamp is obscured by the masking device, the lux value will decrease until it reaches (32

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lux) and stabilizes at it, as shown in Fig. (11). then we remove the blocking tool and note that the lux value increases until it reaches the value (92). Then we block the lamp lighting again noted that the lux drops to the value (30), and stabilizes at it, then we remove the blocking tool again, the lighting value will rise to reach (92), and then stabilize. Finally, we put the blocking tool; the lighting value will decrease to (30) and stabilize which is the value of the window lighting from the curtains, as shown in Fig. (11).

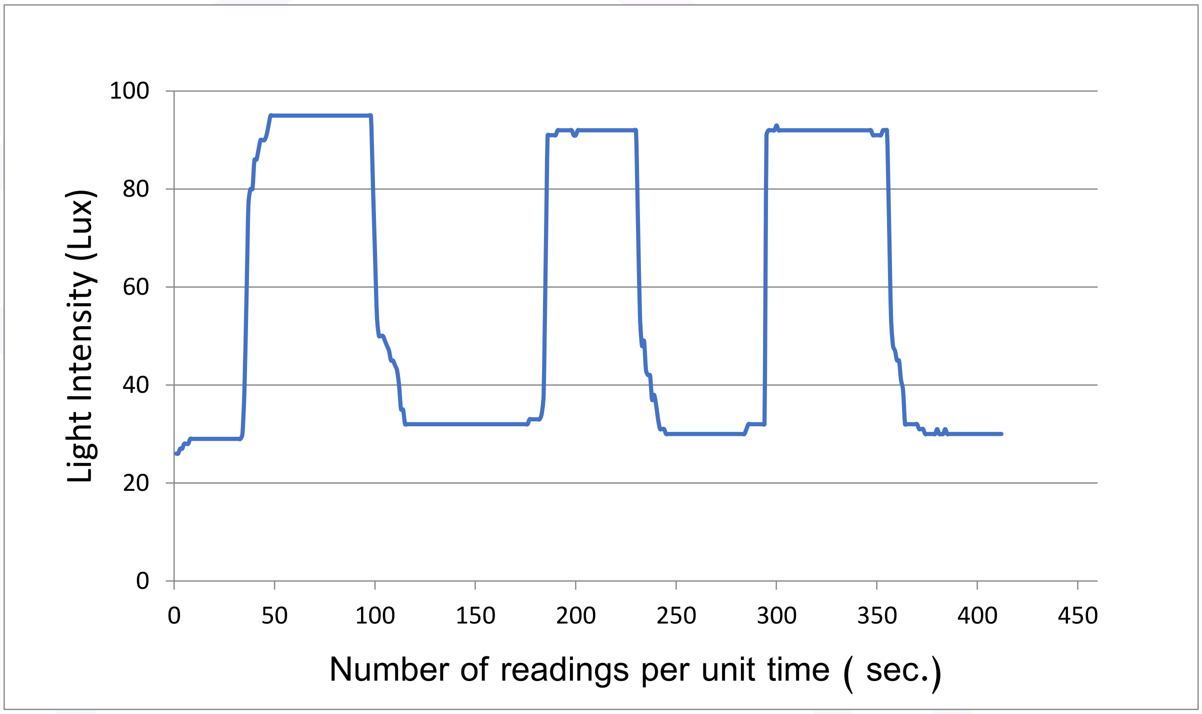

Fig.(11) the light intensity as a function of the number of readings per sec of the using one lamp at the daytime

b. The second section: we operate the same lamp and block its lighting, but during the night. compared with the case (a) it's noticed that when the system starts operating it starts from the value (zero) and then rises to the value (56) and when blocking the lux of lamp, the lux value will decrease until it reaches (zero) and by repeating the masking and raising the blocking tool the lighting remains between (zero) and the value (56), i.e. it is stable during taking readings of this lamp at night, as shown in Figure (12).

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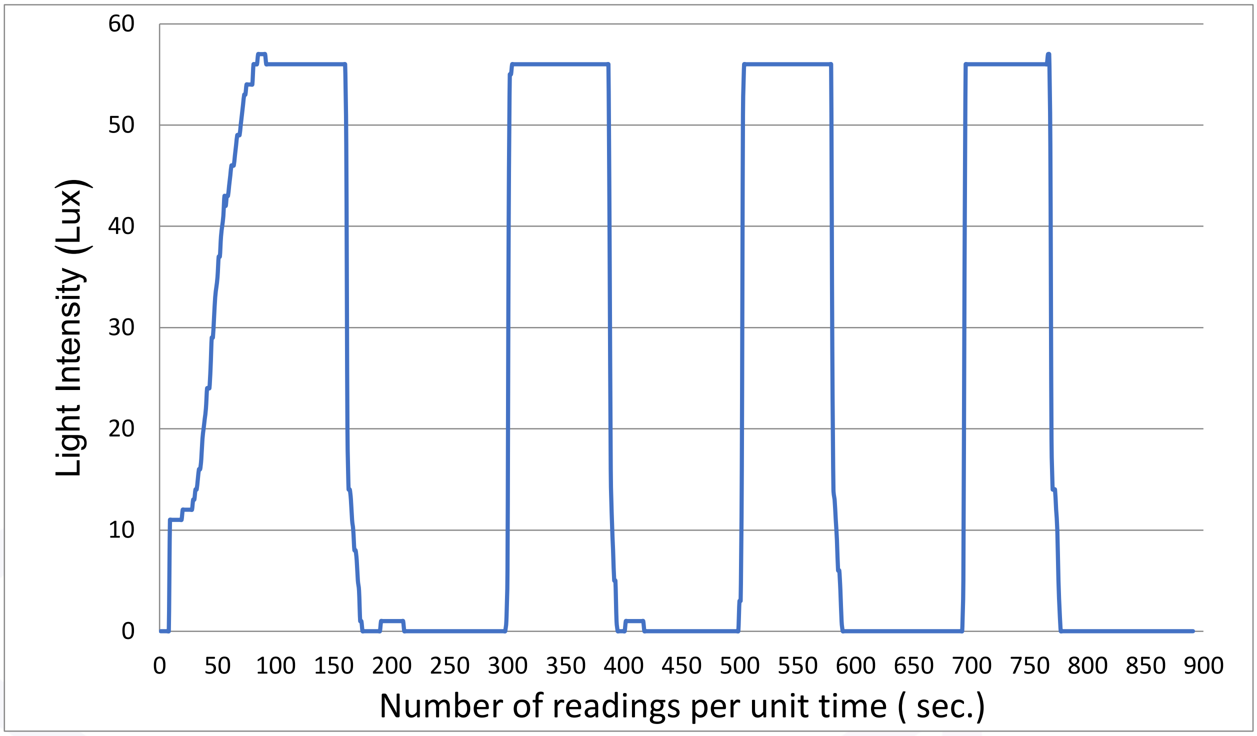

Fig.(12) the light intensity as a function of the number of readings per sec of the using one lamp at night

2. The second case: this case distributed into two sections also. The light intensity measurements as a function of the number of reading per time for one lamp in four different location (Fig. 10) during the daytime (section one) and at night (section two), as shown below

a. the first section: as shown in figure 13 the light intensity recorded (71 lux) when turning on the first lamp and settle at this value, and then we turn off the first lamp. The light intensity did not decrease to (zero) but rather to the value (23 lux) and stabilized at it, which is the value of the illumination from the window. After that, we turn on the second lamp, it's noticed that the lux value increases and then stabilizes at the value (76), and then we turn off the second lamp the lighting decreases to (25). When the third lamp is turned on, the lighting value increases until it reaches (57) and stabilizes at it. After the third lamp is turned off, the illumination value decreases to range between (25-26). Finally, we turn on the fourth lamp, it's showed an increase in the illumination close to (48), then the luminance value will decrease and it will be within the range (21-25) after we turn off the fourth light. as shown in Figure (13).

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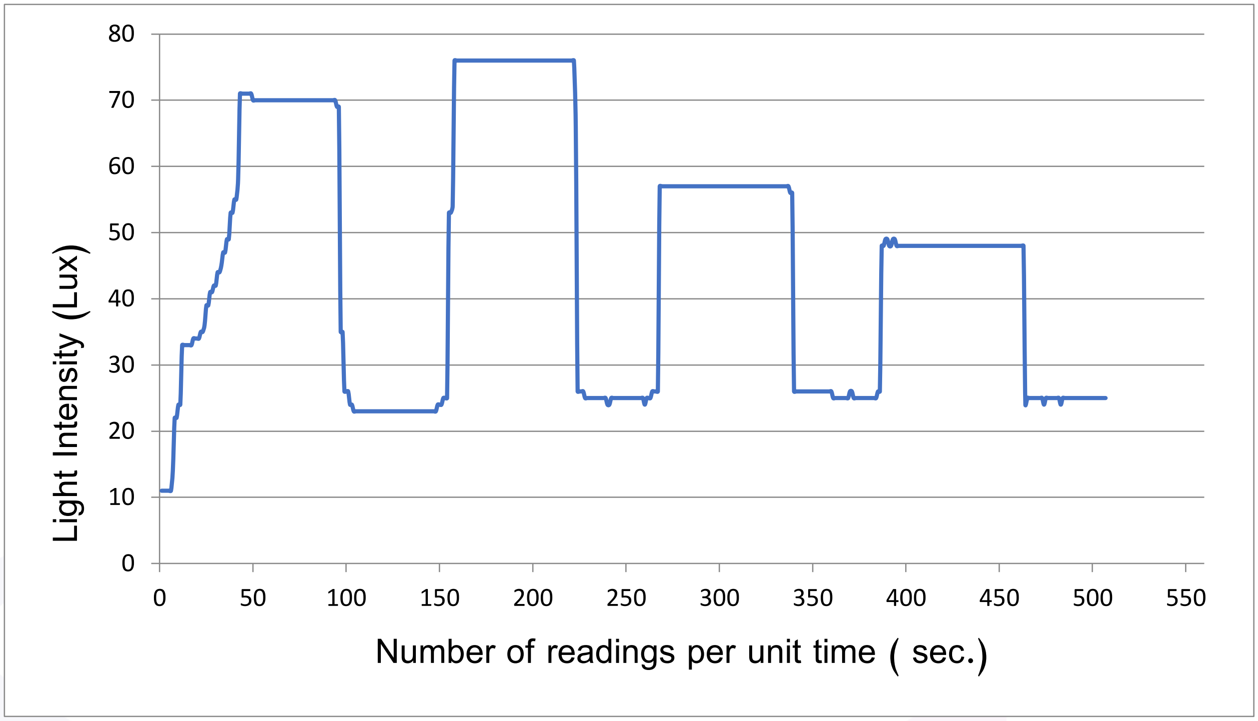

Fig. (13) the light intensity as a function of the number of readings per sec of lighting four lamps successively on daytime

b. The second section: when operating the system at night, the light intensity value is zero because of still the lamp is turned off, and when the first lamp is turned on, the light intensity value increases until it reaches the value (45) and stabilizes at it, after the lamp is turned off, the lighting value decreases to zero. Now we turn on the second lamp it's noticing the value of lighting it increases until it reaches the value (58 lux) and stabilizes at it, and after that, we off this lamp, therefore, the illumination will decrease to zero. Then we turn on the third lamp. We mention that the value of illumination increases until it stabilizes at the value (44), after we close the lamp, the illumination value decreases to zero, finally, in this section, we turn on the fourth lamp, and we notice the increase in the lighting value until it reaches the value (36) and then stabilizes it. After the lamp is closed, the lighting value decreases to zero, as shown in Figure (14).

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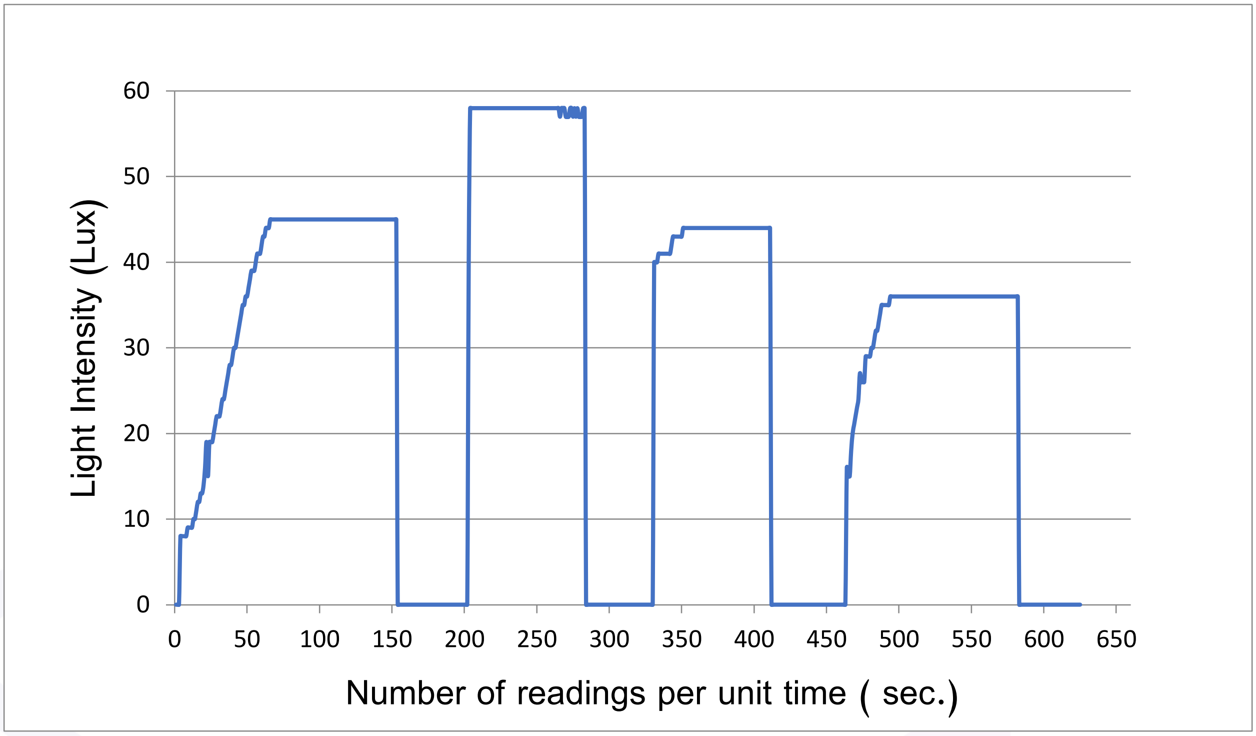

Fig. (14) the light intensity as a function of the number of readings per sec of lighting four lamps successively at night

3. The third case: It is divided into two parts. The light intensity measurements as a function of the number of readings per time, for four lamp turn on all and block it one by one during the daytime (section one) and at night (section two), as shown below

a. The first section: it also appeared to us in the previous two cases In the daytime, the lighting value starts from (26), which is the value of lighting from the window. Now the four lamps turn on, the light intensity begins to increase until stabilizes at the value (176 lux). After that, it will block the lighting of the first lamp by the tool of the blocking. We notice that the lighting value decreases and stabilizes at the value (113 lux), and when the blocking tool is raised, the lighting value will rise to range between (174-176 lux) and settle at the value (176 lux). After which we will block the second lamp we note the value of lux will decrease to (140 lux) and stabilize on it, now we remove the blocking tool form the second lamp returns the value of the lighting by increasing to reach the value (177 lux) and settles at it. Then we block the third lamp we notice that the value of the lighting decreases until it reaches the value (163 lux) and stabilizes from it, and then we remove the blocking tool we notice that the value of the lighting increases until reach to the range between (176 -177 lux) and settle at (176 lux), Finally, we block the fourth lamp. We notice that the lighting value decreases and reaches the value (147 lux) and stabilize on it, when removing the blocking tool, the lighting value returns to its normal position within the range (175 – 176 lux), and settle down which is shown in Figure (15).

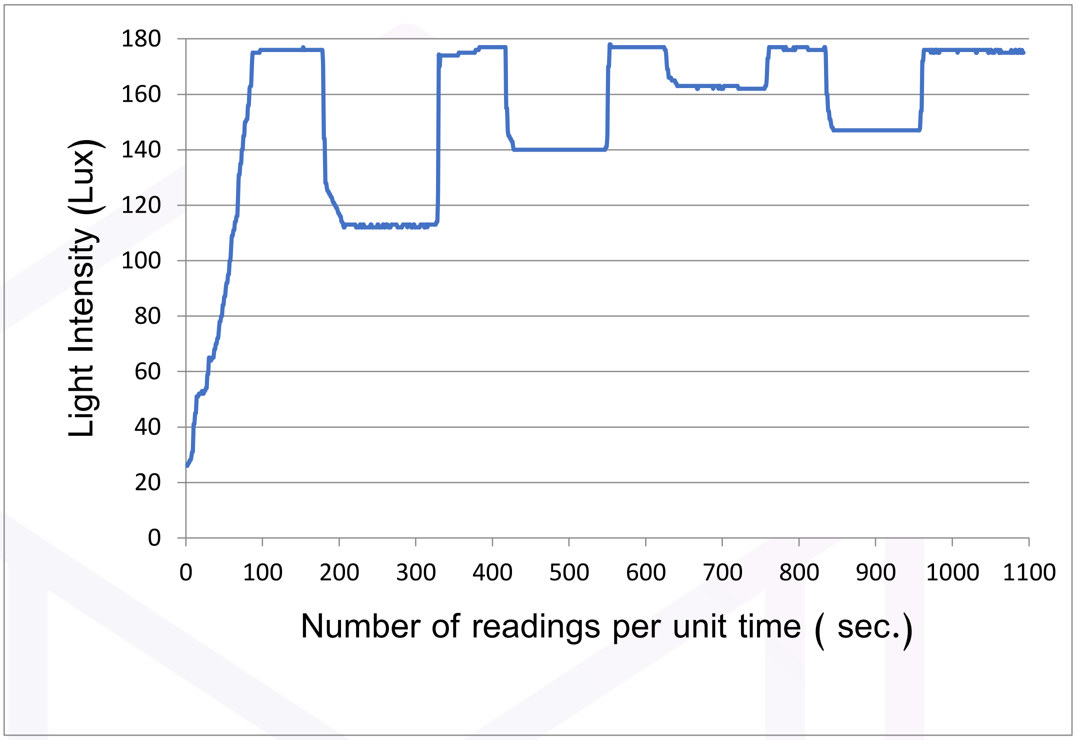

Fig.(15) the light intensity measurements as a function of the number of readings per time, for four lamp turn on all and block it one by one during the daytime

b. In the second section at night, the lighting value starts from zero, after that, the four lamps turn on. It's noticed the high lighting value to (145 lux) and stabilizes at it. Now it blocks the first lamp noticed that the lighting values decrease to (88 lux) and settle at it, we remove an instrument blocking from the first lamp we note that the value of the lighting rises to reach the value (144 lux) and stabilizes at it, and then we block the second lamp it notices that the value of lighting decreases to the value (98 lux) and stabilizes at it, and after raising the blocking tool the lighting will rise to reach the value (145 lux) and it stabilizes at it, we put the blocking tool on the third lamp, we notice the decrease in the lighting value to reach a range of illumination ranging between (129 - 130), after removing the blocking tool, the lighting rises to the value (145) and it stabilizes at it. Finally, it blocks the fourth lamp it notes the lighting values within the range (121-120),

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after removing the blocking tool, the lighting value increases to reaches (144 lux) and stabilizes at it, as shown in Figure (16).

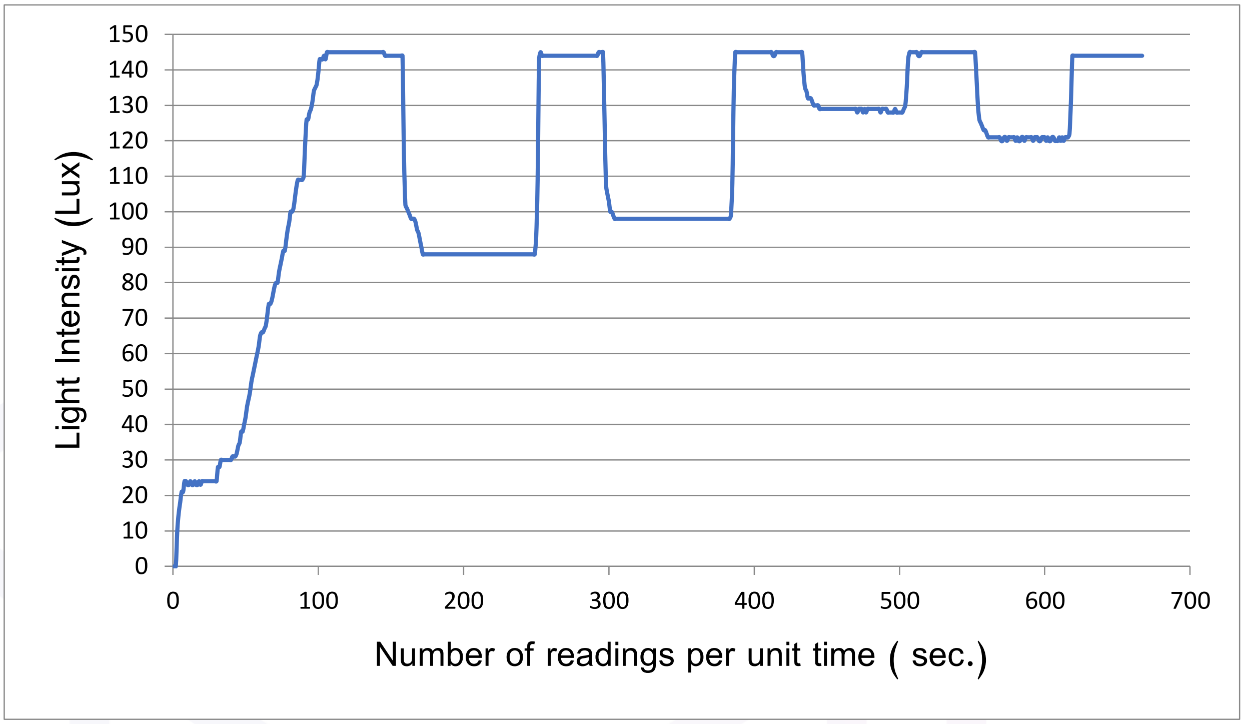

Fig.(16) the light intensity measurements as a function of the number of readings per time, for four lamp turn on all and block it one by one at night

6. Conclusion

This project focuses on the design and execution of a rotating system for track and measuring light intensity in dual axis and its PC software supervisory user interface is proposed. The main feature of this work is its ability to calculate the intensity of light in different directions and recording it in database. The system is precise, reliable, and efficient with respect to the direct angle system. Close loop strategy used in this work the MCU that embedded in (Arduino mega) to locate the position of Servo motor to ensure point to point intermittent motion resulting from geared of Servo motor. The Light intensity sensor (L.I.S) and Set 4-LDR are used to get maximum of light as in Fig. (7), the set 4-LDR placed strategically to detect the light position that could be Up, Down, Right or Left (which is basically the difference voltage between the two LDR) based on the indicator on by the four LEDs, after the light incident on the (LDRs) and gets the illumination it will send the signal to MCU that convert it to digital data (ADC) and then give instructions to the two motors to tilt in the direction of the light as to form a perpendicular angle with the (L.I.S) in order to capture the maximum incident light on it, then the data is displayed on the LCD and the same time on the PC (serial monitor) or recording and stored as (Date, Time and Lux) into database (Excel). Additionally, the cost of this project was ($ 20) which is comparatively cheap.

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