IMPROVEMENT OF LIGHTING EFFICIENCY AS A TARGET

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Abstract - This project present the design of lighting system, where the main objective is to analyze the energy management in a specific location that located in a building such as a classroom. The project focused on lighting energy, since lighting accounts for 20% to 50% of electricity consumption. Significant cost saving can be achieved with energy efficient improvements. Thus, this project was proposed to help users to minimize their electricity usage according to lighting part. Users are able to determine the minimum lamps used in certain room or area without reduce the quality of lighting at that place. There are many factors that affect the lighting quality in order to minimize the quantity of lamps. For example area of room, paint colour of the wall and type of used lamp. New software was developed using Matlab GUI that proposed an energy efficient lighting system which consists of two parts. The first part is user friendly software that can help users to determine the required lamps in the specific place. The second part is the design for improvement of current lighting system. It is called Lamp Replacement which focused on energy efficiency and to minimize the operating costs.

Keywords: energy efficiency, luminaries, lighting design, illuminance

1. Introduction

1.1 Lighting

Light is a flow of energy. Like radiant heat, radio waves and X-rays, it is part of the electromagnetic spectrum and can be described in term of wavelength and power. Light can be mixed from many colours and there is no one to one link between the spectral distribution of radiation and human perception of brightness and hue [1]. For this reason, light is defined uniquely by the response of the human eye. It has its own set of units, which allow it to be quantified and which are linked to other units of power such as watts.

There are several factors that affect lighting performance such as paint colours, reflection factor, maintenance factor and utilization factor [4]. Lighting condition is very important to every building because to be giving a perfect illumination source to each of room [5].

Lighting design is more than the selection of luminaries. Its scope is the composition of brightness and colour across the whole visual field. How a space is perceived or how a visual task is accomplished depends not on illumination alone but on its interaction with the enclosing form of the room and with the pattern, colour and surface texture [11].

1.2 Lighting Efficiency

Electric lighting uses a large proportion of the primary energy consumed by a large commercial building; in the building that is well design thermally, the effect of lighting can be dominant [9]. Energy efficiency is important for some main reasons, such as reduces operating costs and manage the electricity efficiently.

In Malaysia, in 2006, it was estimated that lighting used around 19% of the total energy consumption of commercial and public buildings. However, because this was entirely through the use of electricity, it created much of the Carbon Dioxide (CO2) emission [2]. It is therefore vital to include energy efficiency in any lighting design. This means considering the equipment used the installation design and how it is used.

Considering the lighting equipment, it is necessary to ensure efficient conversion of the electricity into light, by selecting lamps that are appropriate for the purpose and have a high efficacy. Usually this means using discharge lamps that have efficacies if at least 50lm/W [7]. It is also important to use luminaries that emit a high proportion of the lamp light output which direct the light to the targeted area. This implies the use of luminaries that have a high light

output ratio and an appropriate intensity distribution. Efficiency can be assessed by a luminary's utilization factor, although this applies only when fittings are used in a regular array [10].

Installation design for good energy usage begins by ensuring that lighting is not spread unnecessarily [1]. For example, much lighting in commercial building has in the past been provided by regular arrays of ceiling-mounted luminaries which giving uniform illuminance over the specific area.

Energy efficiency is dependent also on the control systems if electric lighting and the usage [8]. Sometime, lighting is often left ON when it is not required, when there is adequate daylight or when the space is unoccupied. People tend to switch lights ON when they are needed such as in the early morning, but forget to switch OFF again as daylight increase. Thus, to overcome this problem, electric lighting can be controlled automatically by using timers, light sensors and occupancy sensors to switch or to dim luminaries so that the designed illumination us maintained [8]. There are several strategies available to minimize energy requirements in a building. For example, specify of illumination requirements for each given use area. Second strategy is analyzed of lighting quality to ensure that adverse components of lighting (for example, glare or incorrect color spectrum) are not biasing the design. Third strategy is the integration of space planning and interior architecture (including choice of interior surfaces and room geometries) to lighting design. Next strategy is design of time of day use that does not expend unnecessary energy. Beside that, the selection of fixture and lamp types that reflect is best available technology for energy conservation. Last strategy is maintenance of lighting systems to minimize energy wastage.

1.3 Types of Lamp

Lamp commonly called 'light bulbs' [6]. Lamps are the removable and replaceable portion of luminaries which converts electrical energy to both visible and non-visible electromagnetic energy. There are several of lamps that use in the buildings. For example:

1.3.1 Fluorescent lamp

The most common application of this technology is in tubular fluorescent lamps. The standard fluorescent tube has a diameter of 38mm. More recently, such lamps are available in both circular form as well as compact fluorescents utilizing folded tubes of much smaller diameter.

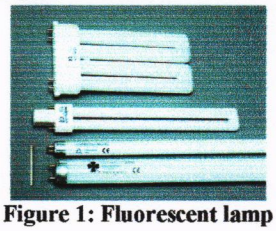

Figure 1: Fluorescent lamp

1.3.2 Incandescent lamp

Incandescent lamps are cheap to install but expensive to run. It can be justified if initial costs must be kept to a minimum and the annual hours of use are small or they are to be used intermittently with frequent switching. In some cases, the effects required in display or prestige interiors may warrant the use of small incandescent sources due to the precise control possible. However, this lamp should not normally be used for the general lighting of interiors.

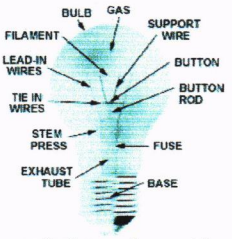

Figure 2: Incandescent lamp

1.3.3 High Intensity Discharge (HID) lamp

HID is the term commonly used to designate four distinct types of lamps that actually have very little in common. They are high pressure sodium, low pressure sodium, metal halide, and mercury vapor. Each requires a few minutes to come up to full output. Also, if power to the lamp is lost or turned off, the arc tube must cool to a given temperature before the arc can be re-struck and light produced.

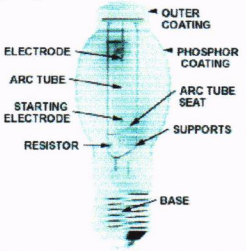

Figure 3: High Intensity Discharge (HID) lamp

2. Methodology

Figure 4, shows flowchart for designing Matlab GUI program. Firstly, an existing GUI is opened and a new GUI from one of the GUIDE templates was chosen. Then, all the required components are created in the component palette. Then, it is need to save the figure. Hence, the GUI is activated.

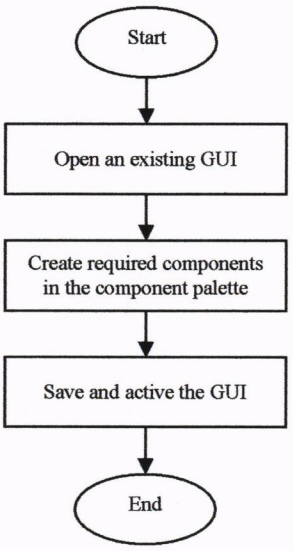

Figure 4: Flowchart for designing Matlab GUI program

In this project, the proposed software program is divided to two main parts. The first part will allow users to determine the suitable number of lamps or luminaries for specific room. It is important to obtain the ideal illuminance level in that room while minimizing the operation costs.

Users just need to enter the required data or parameters. Then, click the "Calculate" button. Next, the program will display the suitable number of luminaries required for that room. Second part of the proposed program is the lamp replacement. It starts with the initial design, and then the new design was proposed for the lamp replacement. Software proposed for lamp replacement is an energy efficient lighting system that will reduce the cost, without reducing the quality of lighting system.

Flowchart in Figure 5 shows the step on how to run the proposed software. Firstly, the user should know the required parameters and insert the data into the box given in the software. Then, the user need to press the "Calculate" button to execute the program. Next, the software will calculate all the assigned parameters and displayed the results in the box. Beside that, if the user still wants to run the program, pressing the "Reset" button, will clear all the parameters. Then, the user just needs to follow the step as before.

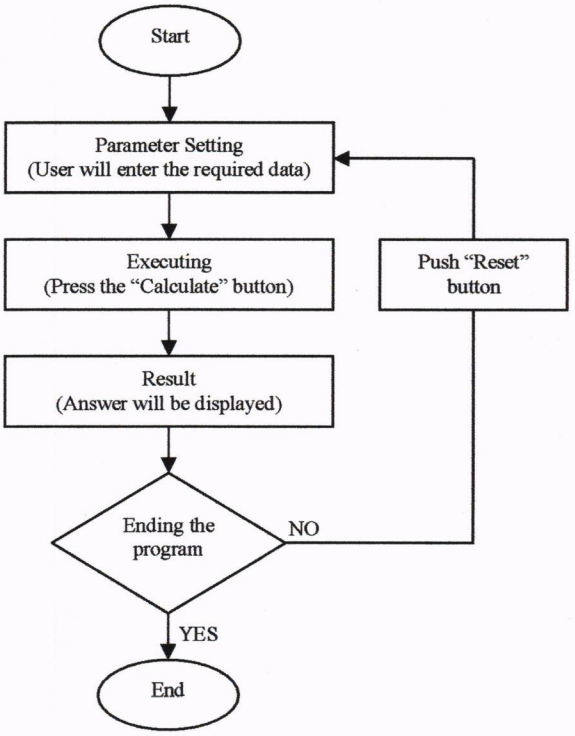

Figure 5: Flowchart for using the proposed Matlab GUI program

Figure 6 shows the proposed software that can use to calculate the ideal number of luminaries needed in the specific room. Beside that, it also will show the user about the room index, maintenance factor and utilization factor of a room.

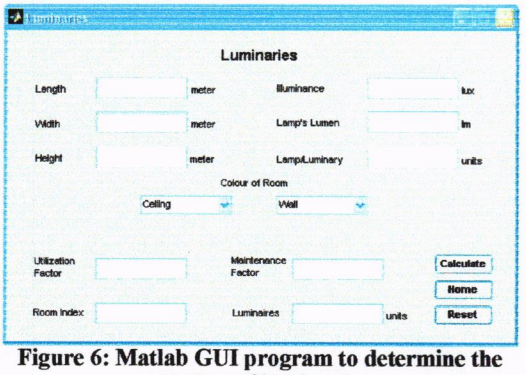

Figure 6: Matlab GUI program to determine the number of luminaries

Figure 7 shows the proposed software that can be used to calculate the amount of saving cost that can be achieved in a year. The amount of saving cost was calculated according to electricity, tube and labour costs. Beside that, this software also shows the user about the illuminance level in that room, whether it decreases or increases.

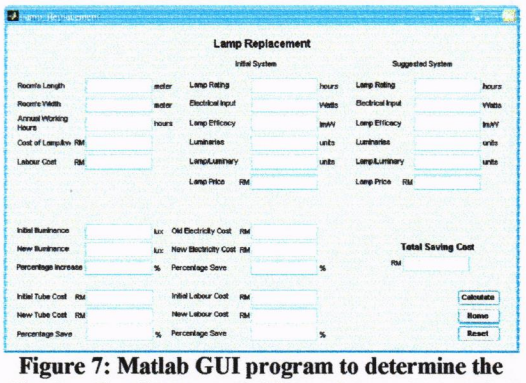

Figure 7: Matlab GUI program to determine the "Saving Cost" between initial and suggested design

3. Results and Discussions

3.1 Effect of lamp's luminous flux

Table 1: Tabulated data to identify relationship between area (A), lamp's luminous flux (F) and number of luminaries (N)

Area, A (m^2)	Luminous Flux, F (lm)	Luminaries, N (units)
25	500	39
40	1000	25
50	1500	21
65	2000	20
80	2500	17
100	3000	17

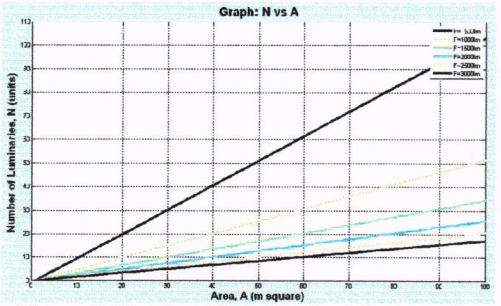

Figure 8: Number of luminaries (N) versus Area (A) graph

From the simulation data in Table 1, it shows the number of required luminaries in a specific area according to different values of lamp's luminous flux. The relationship between area of room (A), number of luminaries (N) and lamp's luminous flux (F) was shown in Figure 8. There are 6 different lamp's luminous flux values shown in graph which are 500lm, 1000lm, 1500lm, 2000lm, 2500lm and 3000lm.

From the graph, it shows that the numbers of luminaries are proportional to the area where if the area increases, then the numbers of luminaries also increase. Here, user can reduce the number of luminaries in a room by using the lamp with high luminous flux. This is due to highest available luminous flux in the lamp will provide the highest brightness to the room.

This is important for every user to obtain the suitable number of luminaries to maintain illuminance or brightness level in their room. Since the users can determine the suitable number of luminaries or lamp in their room, it will help users to minimize the electricity usage in that building. Thus, they can minimize the annual or monthly electricity cost.

3.2 Effect of room's dimension

Table 2: Tabulated data to identify relationship between room index (RI) and number of luminaries (N) at same area (A)

Dimension, L×W (m×m)	Room Index	Luminaries, N (Units)
10×10	2.08	18
12.5×8	2.03	18
20×5	1.67	20
25×4	1.44	22
50×2	0.80	29

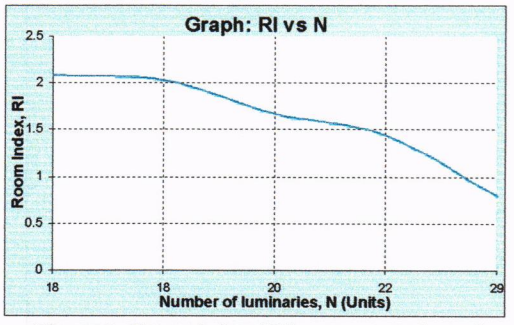

Figure 9: Room index (RI) versus number of luminaries (N) graph

The graph above shows the relationship between room index (RI) and number of

luminaries (N). It shows that the room index is disproportional to the number of luminaries.

Table 2 shows the effect of room's dimension to the number of luminaries. For this case the area of the room was set to $100m^2$, but the dimension of the room can be various. From the tabulated data, it was explained that if the difference between the length and width are large, the value of room index would be small. Hence, it will increase the number of luminaries.

Therefore, in order to minimize the number of luminaries or lamps, the difference of room's dimension (between length and width) should be less or same. In other word, the room should be designed in square dimension.

3.3 Lamp replacement

Table 3: Data of lamp replacement

Information	Given Data
Part 1: Space Information	
Area (125m×120m)	$15000m^2$
Annual total working hours	3000 hours
Cost of lamp per kWh	RM0.30
Labour cost per luminary	RM30.00
Part 2: Initial Design	
Lamp life rating	8000 hours
Number of lamp per luminary	2 units
Number of luminaries	500 units
Electrical input	80 W
Lamp price	RM18.00
Lamp efficacy	60 lm/W
Part 3: New Design	
Lamp life rating	10000 hours
Number of lamp per luminary	1 unit
Number of luminaries	100 units
Electrical input	560 W
Lamp price	RM120.00
Lamp efficacy	100 lm/W

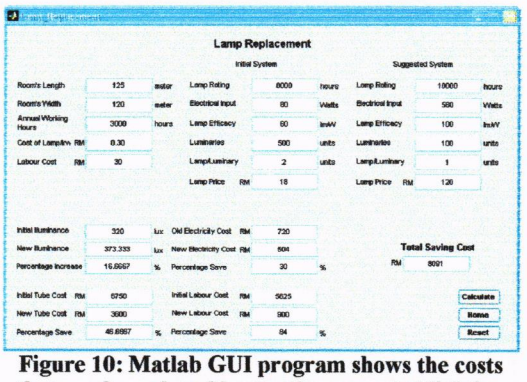

Figure 10: Matlab GUI program shows the costs that can be reduced by use the suggested lighting design

Table 3 shows the example of data replacement worksheet. It is consists of the specification of the room, the overall costs (such as labour cost and tube cost), requirement of initial lighting design and proposed lighting design for the room. Figure 10 shows the result of cost saving that can be achieved by replacing the initial lighting design with the proposed lighting design.

From the result obtained, it shows that the main factor that can lead to the cost saving is the characteristics of the lamp (such as electrical input, lumen and lamp efficacy). All factors are important to be considering in order minimizing the operating costs.

Different electrical input is required for different lamp which is depends on the lamp's lumen. If the lumen is increase, the amounts of electrical input also increase. In fact, the lamp's electrical input was assigned by the lamp manufacturers.

Lamp efficacy is also important in order to reduce the number of luminaries. Lamp efficacy is refers to luminous efficacy. Luminous efficacy is a figure of merit for light sources. It is the ratio of luminous flux (in lumens) to power (in watts). As most commonly used, it is the ratio of luminous flux emitted from a light source to the electric power consumed by the source, and thus describes how well the source provides visible light from a given amount of electricity.

Beside that, the lamp with high efficacy is important for energy efficiency. The luminaries must emit a high proportion of the lamp light output and have an intensity distribution to light only the areas required. This was proved by the Lamp Replacement Method as shown above.

4. Conclusion

In this project, the main objective is to determine the minimum required lamps in a specific place without reduce the quality of lighting was succeeded. Beside that, the benefits of lighting efficiency in terms of minimizing the operation costs and maintaining or improving illumination level were analyzed.

It is important to reduce the usage of electricity. Thus, it will reduce the user's annual or monthly expenses for electricity bill. Beside that, it is important to decide the ideal lighting condition for a certain room. This is because to prevent any problem that can happen to people such as eye trouble (become dim).

It can be concluded that, the ideal value of lamps and luminaries for best lighting design was estimated depends on the rooms' size, dimension and illuminance level. If there is more lumen that available in the lamp, it will provide more brightness to the room.

Based on the results obtained from the proposed software, it also can be concluded that square dimensions of room is the most suitable design for an energy efficient lighting system. This is due to constructing the square room will reduce the number of luminaries used. Thus, it will reduce the amount of electricity cost and other costs.

5. Future Development

In order to achieve more cost saving, this project should be continued further. For example, analyze the lighting efficiency according to lighting control systems such as dimmer and wireless sensor.

Dimmer is a device that can be used to vary the brightness of lamp. By decreasing or increasing the voltage, it is possible to vary the intensity of the light output. It is shows that the dimmer can be used to manage the electricity in the buildings. Thus, it will contribute to the amount of cost saving.

Sensor is a device that measures a physical quantity and converts it into a signal which can be read by other instruments such as photo sensor. This device also can help people to manage the electricity efficiently. It can be used to control the lamps whether to switch on or off at the suitable time. For example, the lamps will be switch on during the night time.

Therefore, the usage of dimmer or sensor in the lighting control system will provide more in lighting efficiency. Hence, it will reduce the electricity cost and manage energy efficiently.

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