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Authorized Timer for Reduction of Electricity Consumption and Energy saving in Classrooms

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Abstract
In recent years, reduction of energy consumption and energy savings are highly important and demanding issues in either residential or commercial applications. Many research studies focus in this field and among others, re-retrofitting energy efficient lighting fixtures and using energy STAR appliances (such as energy efficient air conditioning (AC) units) are some of the suggested solutions for reducing electrical energy consumption. The work in this paper proposes the use of specially designed electronic timers for further reduction of electrical energy consumption and consequently save energy. The timers are integrated with efficient Light Emitting Diode (LED) lamps and air conditioning units in order to achieve minimal energy consumption. Only authorized persons are able to access and configure the timers so as to manage the working hours of the classroom electrical load units such as lighting, air conditioning, and other appliances. The analysis of the collected data reflects the effectiveness of the proposed system in electrical energy consumption reduction and energy saving.

Keywords: authorized timer, power reduction, fluorescent, light emitting diode (LED), air conditioning unit.

INTRODUCTION

In recent years, consumption of energy reduction or energy saving is becoming one of the main environmental issues due to the increasing level of pollution and global warming that arises from excessive use of fossil fuel energy sources. Among others, building energy efficient houses is an alternative solution in reducing the greenhouse gas emissions and creating a sustainable environment [1]. Other research studies also focus on energy saving and consequently environmental protection using renewable energy sources (such as solar power) in order to achieve green power/electricity in spite of many technical or cost difficulties [2]. Energy saving through energy efficient appliances or devices is an additional choice or solution that can reduce the greenhouse gas pollution and consequently reducing the problem of global warning. Moreover, energy saving leads to have lower cost of electricity generation and consumption at the end improving the level of our life [3]. One of the first steps to achieve energy saving is through electricity audit in order to determine and understand the level of consumption [4]. Electricity audit was done at American University of Ras Al Khaimah (AURAK) campus in order to analyze and understand the daily, weekly, monthly or yearly electricity consumption in the campus buildings. Significant energy saving can be obtained when using a low power consumption lighting fixtures made of Light Emitting Diodes (LED). On the other hand, using energy efficient Air Conditioners (ACs) is another important step in the objective of energy saving. Adjusting sleeping mode cycle of the computers in the unused classrooms or laboratories is also mentioned in [4] to achieve additional energy saving.

In [5], achieving energy efficiency from the point of view of both narrower and broader objectives as well as device-centered mechanisms in general were discussed for energy efficiency improvement. In [6], green building as a prototype is designed and practically implemented through automated power management system. The proposed prototype is capable of enhancing energy efficiency through reducing energy wastes. An intelligent system is proposed to have continuous monitoring of the energy consumption based on installed sensors. Experimental results and analysis reflects that significant energy savings can be provided by construction of green building. A certain method of continuous monitoring and displaying data is used in [7], [8] to serve in energy saving. This method adopts wireless sensing and a central server processes collected data to support the users and researchers in a real time measurement. Researchers can easily analyze their electricity usage patterns and energy consumption in addition to knowing the cost of electricity. On the other hand, the works in [7], [8] offer remotely power on/off capability of the individual devices. Smart home technology is proposed in [9] to achieve power management by using some installed sensors. Improvement in energy saving and power consumption is obtained using the smart home appliances such as air conditioning units and efficient lighting fixtures. The proposed technique takes into account three assumptions of time spent with different usage behavior. A sensor system is also adopted in [10] to have energy saving through controlling ON time of the lighting loads. Sensing some sounds such as claps or other type of sound will be used to activate and switch ON a lighting system through a suitable driving electronic circuit. Many buildings like restaurants, hospitals, hotels, and some rooms of kids may have an interest from this proposal and the system may save significant power and/or energy that could have been spent unnecessarily for lighting system.

Other research studies also focused on using renewable energy sources to reduce the level of pollution [11]-[21]. These studies aimed for different objectives in the field of solar photovoltaic energy sources. Pulse width modulation technique is adopted in [11] to design a single phase PWM inverter to work together with DC-DC boost converter to deliver alternating current (AC) power to AC loads through a standalone system supplied by suitable array of PV panels. A single axis solar tracking system is proposed in [12] to track the path of the sun radiation during the all-day hours. A full design and simulation results of dual axes solar tracking system are presented in [13] to achieve dual plane solar radiation tracking for more energy absorption. The studies in [14]-[16] focus on proposing a suitable DC power supply fed by certain PV panels with different objective. A detailed electronic design of a general purpose DC power supply for PV systems application is presented in [17]. Simulation results reflect the effectiveness of the proposed DC power supply and indicate for promising practical applications. wire and wireless AC power control as well as AC voltage regulation methods studies are dealt with in [18]-[21].

In this paper, a different method of energy saving will be proposed through controlling the ON time (working time) of the air conditioning units and the lighting fixtures through a specially designed timer with an authorized person accessing and configuring its operation. On the other hand, the system will be adopted for LED lighting system instead of the conventional lighting lamps in the classrooms. The proposed electronic design with simulation results will be presented with data analysis to prove the effectiveness of the proposal. The remaining of this paper is organized as follows: the proposed system will be introduced in section II, electronic design and simulation results are presented in section III. Data analysis with discussion will be in section IV and finally the findings of the study will be presented and concluded in section V.

PROPOSED ENERGY SAVING SYSTEM

The idea of the proposed energy saver adopts digital timer, which is initialized and enabled by authorized persons. In the class case study, the authorized persons are the faculty members. Authorized person can enter the desired working minutes (for instance, number of minutes for the class session) with maximum 254 minutes. The system starts by identifying the authorized person code through a code identifier, which represents the first block of the system. This block produces a pulse with time width based on the period of code identification. The second block represents pulse trigger generator, which is designed to produce a fixed period pulse equal to 1 second for each code identifier pulse.

Figure 1 shows the main block diagram of the proposed system. Step up binary counter (8-bits) is designed to count (1/60) Hz pulses when enable by authorized person. Conventional oscillator design by 555 timer integrated circuit is done to produce 1 Hz pulses, these pulse enter a suitable frequency divider with division over 60 to have one pulse for each one minute. The pulses (1/60) Hz enter the up counter, which starts the counting work with manually preset pulse that follows trigger generator pulse. A one second trigger pulse works on triggering the counter through an output of an OR gate supplied to the enable input of the counter. To have continuity of the enable state of the counter, one of the inputs of the OR gate is the logical state of the comparator output. Logic comparator (8-bits) receive two 8-bits data; one from up counter (A), and other one from selector block, which is used to enter the desired number of working minutes of the electrical load. The output terminal of the comparator (A<B) is used to activate the driving circuit block. This block includes transistor, relay, and contactor with enough load current ability to switch ON the connected loads (Lighting system and air conditioning units). It is worth to mention that the proposed energy saver can be customized to work for different load currents: only the last step of drive circuit need to be modified to make it suitable for the desired load currents.

ELECTRONIC DESIGN AND SIMULATION RESULTS

In this section, the part of the electronic design and simulations were done to prove the effectiveness of the proposed authorized timer system.

The first block in the proposed design is represented by code identifier; the function of the identifier is to produce a certain pulse (active high) when put the correct two digits and pressing the push button switch PB1. For example; Figure 2 shows the code identifier circuit with activated code of two digits equal to (96). The duration of the pulse will be different from person to person based on the pressing time. To avoid the big variation of the pulse time, a fixed period pulse generator is designed. The generator is started by a differentiator circuit which works on producing an analog pulse signal as shown in Figure 3 at the diode output (CH-B of XSC1 first oscilloscope). This signal enters an inverter NOT gate to produce a digital pulse with very narrow width at TP2 as shown in Figure 4. This pulse will be used as trigger pulse to the next electronic circuit of monostable multivibrator 555 timer to have a fixed duration pulse as shown in Figure 4. The pulse duration can be decided based on the values of RC circuit through (1);

$$t = 1.1\, R_t C_t \quad (1)$$

where t is pulse duration, R_t is the timing resistor value, and Ct is the timing capacitor value. In Figure 4, R_t is represented by R4, while C_t is represented by C2. The function of the fixed duration pulse generator is shown in Figure 5 through TP2 as a trigger pulse, and TP3 as a fixed duration pulses which explained in Figure 6.

On the other side of the proposed block diagram, an oscillator is designed to produce approximately 50% duty pulses with frequency of 1 Hz. This oscillator is needed with a frequency divider to produce pulses with lower frequency to use it later as input pulses to the step up binary counter. In this line, the first block is the astable multivibrator as shown in Figure 7, this oscillator is designed to produce pulses with a certain ON time t_{ON} and OFF time t_{OFF} based on (2), and (3);

$$t_{ON} = 0.693\, (Ra + Rb)\, C \quad (2)$$

$$t_{OFF} = 0.693 \cdot Rb \cdot C \quad (3)$$

where Ra is the first timing resistor, Rb is the second timing resistor value, and C is the timing capacitor value. In Figure 7, Ra is represented by R1, Rb is represented by R2, and Ct is represented by C1. Figure 8 shows the output 1 Hz pulses from the astable multivibrator circuit, it is clear from Figure 8 that the duty cycle of the oscillation is around 50%.

The next part before a general purpose step up 8-bits binary counter is represented by a digital frequency divider with division rate (1/60) as shown in Figure 9. This divider is designed to produce an accurate pulses with lower frequency which equals (1/60) Hz. In other word, the divider produces one pulse each one minute as shown in Figure 10. To have the required division rate, the divider should be designed to divide the input pulses frequency over 60 to produce the desired one pulse each one minute. The division rate is obtained based on the relation (4) of the reset pulse in the frequency divider, and to have reset pulse for the frequency divider, the suitable binary numbers should be in this sequence (32 + 16 + 8 + 4 = 60);

Reset pulse (MR) = Q5 Q4 Q3 Q2 (4)

The remaining in the electronic design is represented by a general purpose 8-bit up binary counter, and 8-bit digital comparator.

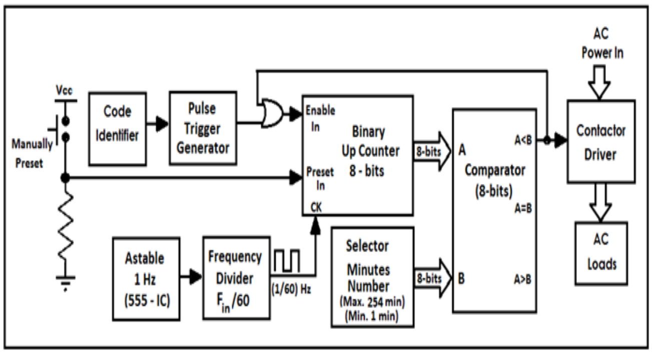


Figure 1: Main block diagram of the proposed energy saver

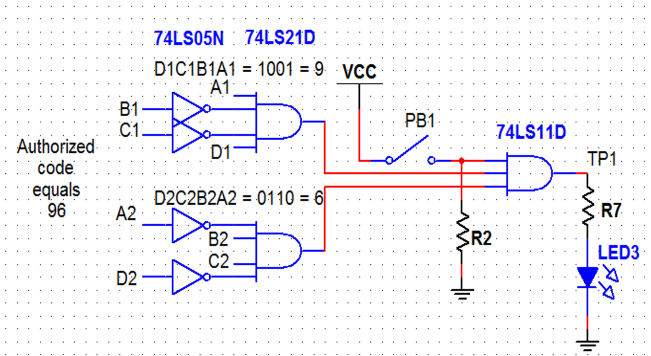


Figure 2: Code identifier circuit (Activated code = 96)

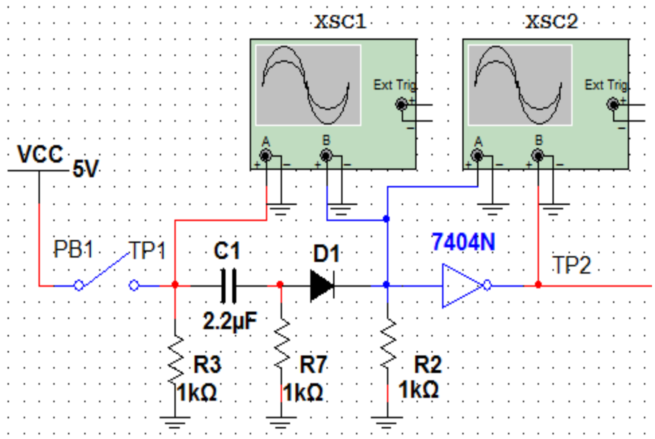
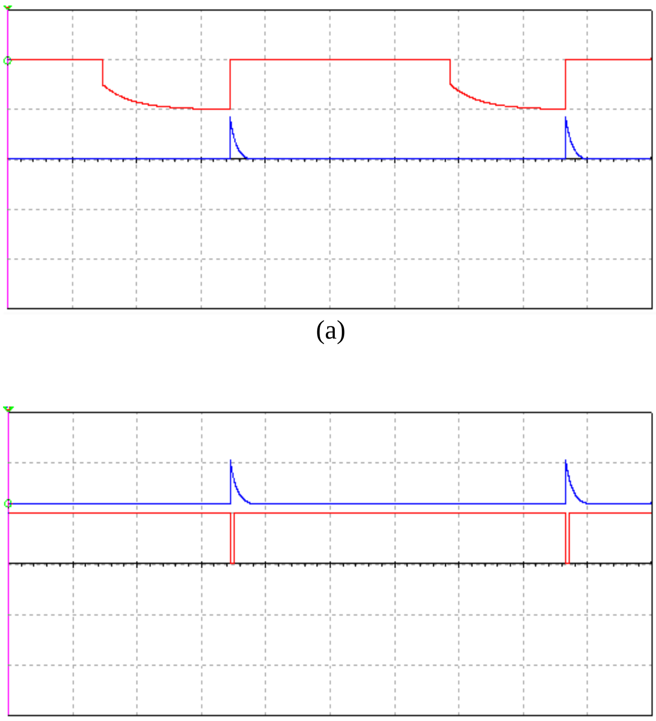


Figure 3: Differentiator circuit



(a)

(b)

Figure 4: Digital pulse with very narrow width; (a) TP1-red color PB press, output of differentiator – blue color, (b) output of NOT gate – red color.

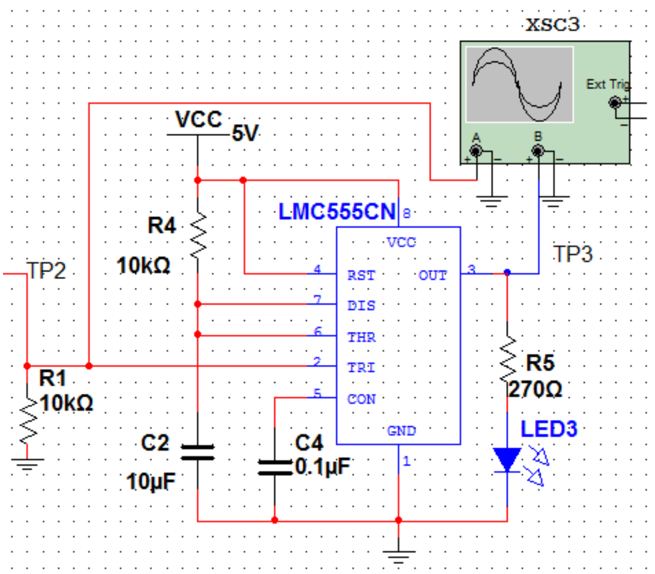


Figure 5: Fixed duration pulse generator

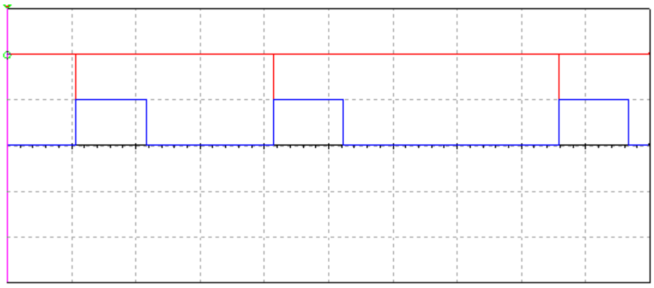


Figure 6: Trigger pulse TP2 – red color, and fixed duration pulses TP3 – blue color

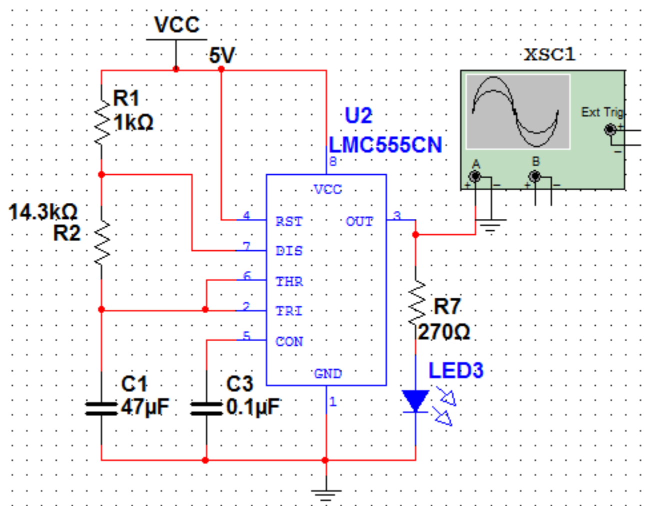


Figure 7: Astable multivibrator-1 Hz

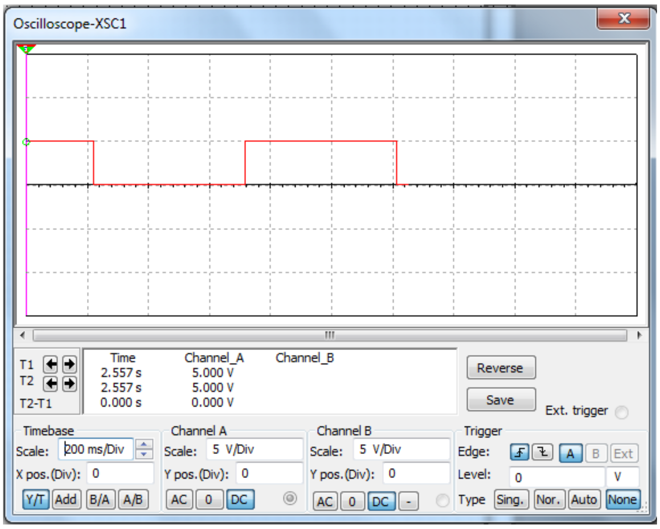


Figure 8: Astable multivibrator-1 Hz output pluses

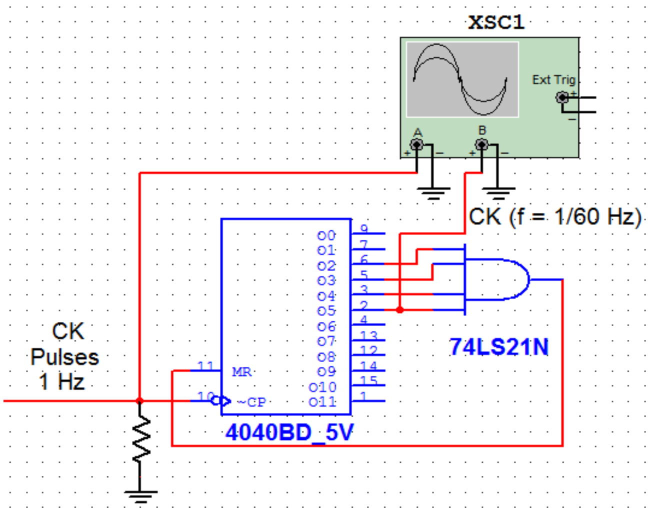


Figure 9: Digital frequency divider with division rate (1/60)

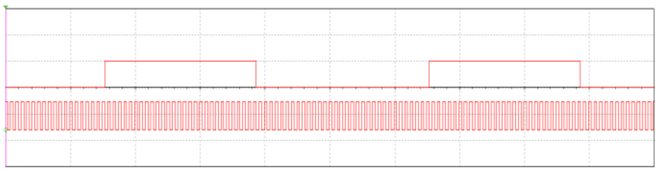


Figure 10: Input (down) and output (up) pulses of frequency divider

ENHANCEMENT ANALYSIS OF THE ENERGY SAVING

The positive effect of the proposed energy saver is explained in this section through analysis and the collected data from the classroom which represents the case study. The case study is represented by a classroom in the campus of American University of Ras Al Khaimah (AURAK). Each classroom includes 16 lighting units, each unit includes four standard T8

Fluorescent tube, and each tube consume 18 Watt. The total consumed power of classroom lighting equals (18 Watt X 4 X 16 = 1152 Watt). The working hours of the classroom lighting units at working day are starting 8:00 AM to 6:00 PM i.e. 10 hours continuously. In other words, the total consumed power of lighting units in working day equals 11.52 KWh. The enhancement in efficiency of the lighting system comes from two sides; firstly replacing the Fluorescent tube lamp (18 Watt / tube) by LED lamp (10 Watt / tube). The accurate saving in energy by this LED replacement for all units in the classroom (10 Watt X 4 X 16) will be equal to 640 Watt. Secondly, the merit of proposed authorized time which reduces the working time of the lights to the exact limited time of the classroom lecture time schedule. The timing details of the individual lectures in the classroom under study are as follow; (8:00 AM – 9:30 AM), (10:00 AM – 11:30 AM), (12:00 PM – 1:30 PM), (2:00 PM – 3:30 PM), and (4:00 PM – 5:30 PM). The total period of working hours through adopting the proposed timer is 7.5 hours instead of 10 hours. This working time reduction leads to minimize the total energy consumed in the lighting units of the class room to 4.8 KWh per working day including the LED replacement merits. Figure 11 shows the analysis regarding power consumption of the lighting units in the class room. Figure 12 shows the total KWh per day of the lighting system without and with the proposed system in this study.

Regarding air conditioning units, the case classroom includes two AC units type; Split unit-York-H20A030A78A, the unit power equals 3200 W with consideration of 60% active period (duty cycle) of the effective energy consumption during their switched ON periods [4]. The working hours of the two AC units are 10 hours (8:00 AM – 6:00 PM) with total KWh per working day equals (2 * 3200 Watt * 0.6 * 10 = 38.4 KWh). The positive effect of the proposed authorized timer on reducing the power consumption comes through minimizing the total working hours to 7.5 hours in working day. This working time reduction leads to reducing the total energy to 28.8 KWh/day. Figure 13 shows the details of KWh/day reduction through the presented study. The figure clearly shows the savings in energy from the lighting units, air conditioning units and the total from both the lighting and the air conditioning in using the proposed system. This saving will also be multiplied by the number classrooms to get the total overall energy saving which will be a significant amount. The system achieves a significant reduction in the electric bill of the campus and at the same time achieves sustainability of our campus by gaining the merit of reducing energy consumption.

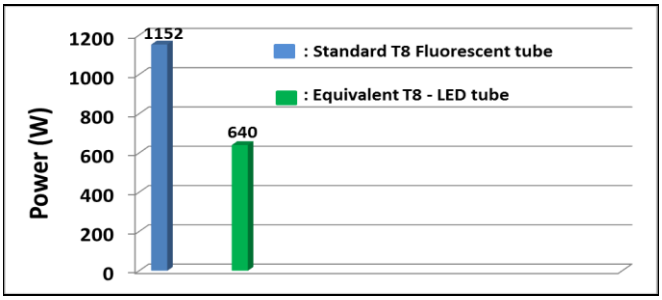


Figure 11: Power consumption data per lighting units in a class room

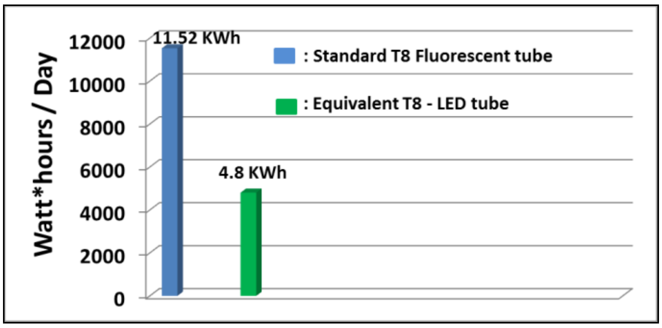


Figure 12: Total KWh/day of the lighting system in a class room without (blue bar) with (green bar) of the proposal of this study

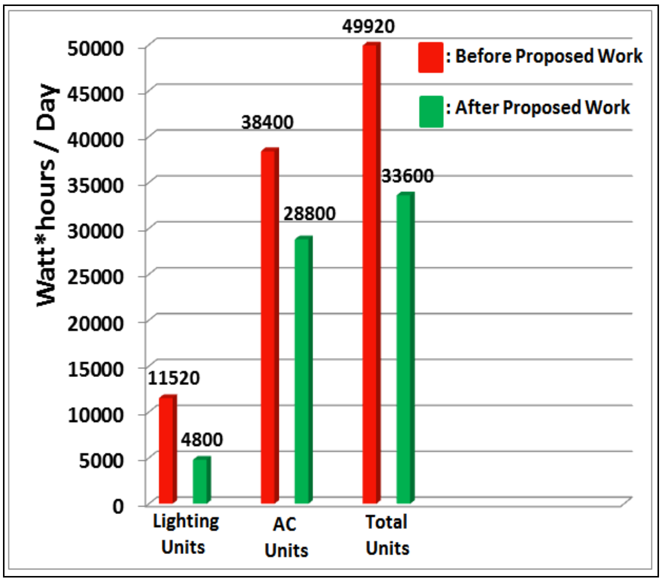


Figure 13: Details of KWh/day reduction through the presented study

CONCLUSION

The study in this paper works on reducing the daily consumed power of lighting and air conditioning units in the classrooms of American University of Ras Al Khaimah through proposing an authorized timer besides replacing the conventional T8 Fluorescent tubes by Equivalent T8-LED tubes. Full electronic design with related relationships and simulation results are presented by using National Instruments Multisim software. In addition to simulation results, the data are collected to do analysis and explain the effectiveness of the proposed system. The detailed analysis and calculations show clearly the advantages of the proposed study in reducing the energy consumption of the lighting as well as air conditioning units. In addition, the mentioned electronic design reflect the promising indications of the practical application of the authorized timer working as an efficient energy saving system. The implementation of the proposed system achieves a significant reduction in the campus electric bill and at the same time fosters the creation of green campus through reducing energy consumption.

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