Renewable Energy Efficient Solar Lighting System Design for Buildings in UAE

Mubina I. Zaidy
Department of Electrical and Electronic Engineering,
Heriot Watt University
Dubai, UAE
mubina.iz@live.co.uk

***Abstract*—Over the past few years, the electricity consumption in the United Arab Emirates(UAE) has beyonddoubledaccording to a study done by the management consultancy and strategy and it is still at a constant rise. Lighting accounts for a major part of this consumption. Hence there arises the need to reduce and conserve this energy for the sake of the environment and in turn our future generations. This paper aims at implementing the use of solar energy for electric energy generation for lighting systems in commercial and residential buildings. It also focuses on reducing energy consumptions by making use of LED lighting technology, daylighting and suitable lighting controls. Unlike traditional fossil fuel power generation by coal, oil or gas, energy generated through solar power is Renewable, clean and environment friendly and has no harmful gas emissions.Therefore, a shift to solar power could make a great difference in UAE where it is abundantly available all year round. An experimental prototype of a 20 Watt Solar powered Lighting system using LED's, a solar charge controller and a light detector sensor is constructed to demonstrate the working of such anenergy efficient lighting system on a small scale. Using a light designing software daylight harvesting, LED light planning and energy efficient building architecture has been demonstratedand the results have shown good satisfactory performance of the overall system design.**

Keywords: **Lighting, Solar Energy, Renewable, LED lighting system,daylighting, lighting controls**

I. INTRODUCTION

Over the years, the use of fossil fuels has caused great deforestation which has reduced the recycling of carbon dioxide gas from the atmosphere. This has impacted the climatic conditions, increasing greenhouse gases and giving rise to the phenomenon of global warming. Global warming over time will cause melting of ice caps, floods, and drastic climatic changes affecting human life.

As the world population is on a rise and our resources are depleting we need to look for a renewable alternative of electricity generation. Power for lighting systems in buildings uses traditional fossil fuels for electricity generation. Excessive use of fossil fuels, such as coal, oil, and natural gas, will not only deplete our resources for future generations but also will slowly decease the ecology of earth.

There is around a 58% of carbon dioxide emission each year from residential electric lighting around the world. This increase in carbon dioxide gas(CO_2) and other greenhouse gases destabilize the environment hence causing global warming. This not only increases health risks but also in turn degrades the environment.

In 2030, there is an estimate by the IPPC of a rise in this CO_2 by 50% and hence there comes a great need to change to a safer and sustainable source of energy. Energy control and saving therefore need to be given great importance and sustainable technologies using renewable energy need to be harvested. Solar energy is the best form of renewable energy as it is abundant and infinitely available.

Solar power generation is a sustainable, clean and renewable alternative which if adopted can protect the planet and the coming generations from harmful environment degradations. This energy is abundant and an inexhaustible permanent source on the earth. Solar power converts sunlight into electricity by the usage of photovoltaics' (PV). Solar power can be categorised into two main technologies: Passive and Active solar.

Photovoltaic system is an active solar technique that uses solar panels for power generation. Solar panels are made up of solar cells which consist of wafers of doped silicon.

When the solar cell is exposed to the light energy from the sun(photons), the negative layer of the PV cell absorbs the photons. Thus electrons are now released from the layer and hence a potential difference is developed causing electric current and therefore producing electricity. This renewable generation of power is the most efficient and consistent. It requires low maintenance and easy installation thus making its adoption even easier.

Building energy consumption is among the most highest of the total energy consumptions. Lighting systems in these buildings account for about 35% of total electric consumption according to the International Energy Agency (IEA) and therefore it is an important aspect of energy saving. Energy efficient lighting also reduces the load light puts on air conditioning, refrigeration and the overall electric system. It also greatly reduces the cost of operation.

Energy efficient lighting can be attained by use of solar energy and LED lighting technology along with daylighting and smart light planning techniques.As lighting technologies are developing, light sources now directly convert the energy into visible light without emissions of greenhouse gases. LED lighting technology is an upcoming technology which has the potential to change the future of lighting. LED lighting is the most energy efficient that uses about 70% of less energy as compared to all other

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traditional light sources like Compact fluorescent lighting(CFL), incandescent bulbs, etc. LED's have the potential to change the future of lighting systems and thus are fast developing and upcoming in many countries. Solar energy along with LED technology can substantially reduce power and energy consumption and thus should be widely implemented in residential buildings.

II. OBJECTIVES

The main aim of the project is to demonstrate the proficiency of energy efficient lighting systems using renewable power which can consequently be implemented for use in residential and commercial buildings in UAE.

A practical implementation of a lighting system using solar power and LED lighting is created by designing a small scale prototype of a 20W LED lighting system that is capable of lighting an entire average room. The Electricity is generated by solar energy instead of traditional fossil fuel energy and the building lighting power is saved by usage of high performance LED technology.

The lighting system is designed and planned using a professional light planning software called DIALUX Evo to enable least energy consumption. Daylight harvesting is successfully done and displayed.The complete building design is planned and lux levels of all rooms are calculated.These calculations are then used for creation of a solar powered prototype.

III. SYSTEM DESIGN METHODOLOGY

The system design firstly requires the installation of a solar panel on the exterior of the building. The output of the solar panel is then connected to a solar charge controller which regulated the voltage/current coming from the solar panel and going into the battery. A 12V DC battery is used to power the lighting. LED lights are used for this system due to their maximum efficiency

A light detecting sensor is made and integrated into this circuit which detects the amount of light or darkness. It automatically switches off when the lightness levels are detected to be bright enough and switches on when there is darkness.

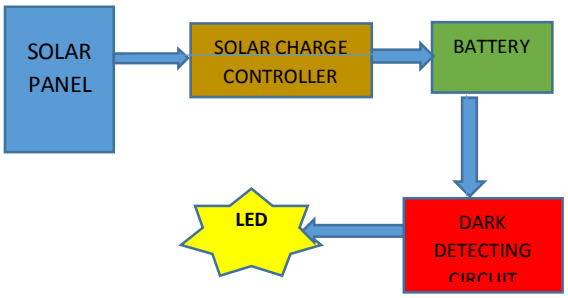


Figure 1: Solar LED lighting system design

LED Lights:

With developing lighting technologies, light sources now directly convert the energy into visible light without emissions of greenhouse gases. LED lighting technology is an upcoming technology which has the potential to change the future of lighting. LEDs consist of light emitting diodes which are a semiconductor device. When current goes through the LEDs, it emits white light due to reaction at the junction.

LEDs have the lowest power consumption and save upto 75% of energy than the traditional incandescent lighting. They have no mercury content or greenhouse gases emission making them the most clean and non-hazardous source of lighting. The energy efficiency of LEDs is characterised using efficacy and their efficacy is about 200lm/W as compared to others like CFL having only 100 lm/W.

Dark Detecting Sensor Circuit:

The lighting system is integrated with a dark detection circuit which automatically switches on/off the lights depending on lightness levels around it. It is made using a diode, transistor and resistor on circuit board. The transistor acts as a switch in this circuit, it turns off when it receives full power from the solar cell indicating there is sufficient light and switches on when this power starts reducing. The diode acts as a protection voltage regulator diode which only allows the current to flow through one path.

IV. LIGHTING DESIGN AND SIMULATION

For the project execution, it was first required to estimate the lighting levels and flux requirements for a given building plan. Hence the lighting planning software called DIALUX Evo was used to achieve this. DIALUX enables light planning of entire buildings with the calculation of all the necessary photometric data and the selection of the types of luminaires to be used along with their ratings.

A building plan was first constructed and for this project a one story residential buildingDwg plan was created and integrated. Materials and objects were placed to enable glare calculation,reflectance and flux requirements.

The rooms were then fitted with required energy efficient low wattage LED luminaires and the arrangement

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was done in such a way so as to enable minimal and uniform lighting.

The Unified Glare rating (UGR) was calculated for each room surface and adjusted to obtain optimum glare rating. Daylight harvesting was done by placing ample of windows, skylights and photo sensors to minimize power usage. Photometric calculations were then donefor each room and light scene. Energy levels and light flux were obtained for the building using lower power due to the above techniques.

Daylighting:

Daylighting is a technique of admitting natural light into buildings for the required work places or homes through appropriate controls for saving energy. This upcoming technique if harvested in unique and smart ways can save an enormous amount of electrical energy consumed by lighting and in turn even the HVAC energy which is used to cool these lighting systems.

Daylight harvesting uses direct sunlight through windows and apertures or diffused skylight. A daylighting system in addition to this requires appropriate controls to control the amount of light entering and a systematic complete design that takes into consideration the building architecture, climatic conditions, building components(windows/apertures/skylight types), lighting controls, lighting design, glare control and reflectance & space of surfaces.*All these aspects* were taken into account in this project and worked upon to obtain satisfactory results.

The control for daylighting was made which detects the amount of light in the surrounding and automatically switches off/on the lighting system to save energy and make use of natural lighting as much as possible. The designing aspect of it was all implemented using the DIALUX software in which appropriate windows, apertures, skylights, sensors were placed in the necessary areas and the glare, reflectance and light levels were calculated.

Figures 2 and 3 show the comparison of light scene calculations with and withoutdaylight factor respectively. Figure 4 shows the implementation of photo sensors which detect the amount of light and automatically adjust the lighting accordingly to save energy.

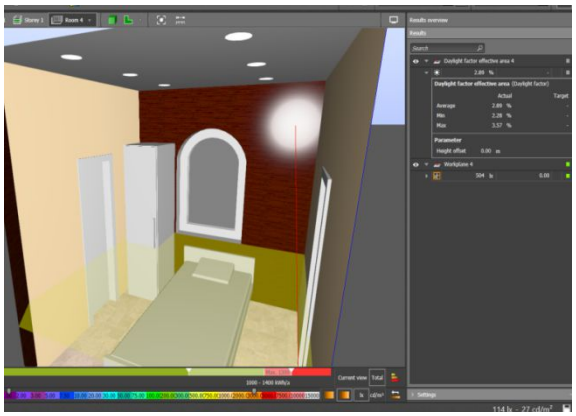


Figure 2: Light scene for daylight factor

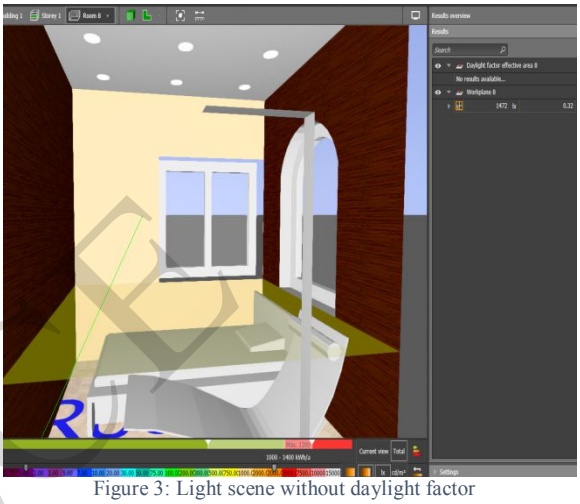


Figure 3: Light scene without daylight factor

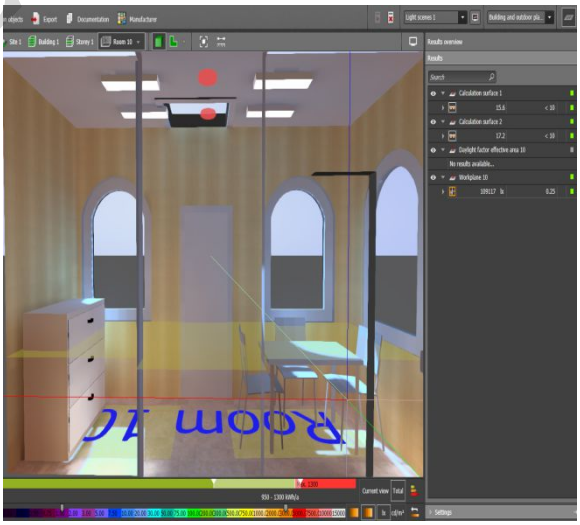


Figure 4: Daylight harvesting with photo sensor, skylight and windows

V. EXPERIMENTAL PROTOTYPE

A small scale prototype of the system was designed and tested to see its performance. The overall system is prepared using the following main components: 1. Solar PV Panel; 2. Solar Charge controller; 3. DC Battery; 4. 2 LED lights of 10W each 5. Detection Sensor Circuit

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The components were selected based on the following calculations of load:
Load (Lighting)=**20 Watts**

The Watt Hour of the lighting is an energy unit which is equivalent to 1W of power used for 1 hour given by:
Watt hour = Power rating of Lighting x Time of run(Hrs) = 20W x 5Hrs = 100
Watt hour = Voltage x Current x Time

Battery Rating:

For a system of 12V, Battery voltage required = 12V
Battery capacity = Load/Voltage = 100/ 12 = 8.33 Ah
Assuming a 80% efficiency of the battery, Battery capacity = 0.8 x 8.33 = 6.66 Ah
Hence keeping some margin a 10Ah deep cycle lead acid battery was selected.

Solar Panel Rating:

The rated power generated by the sunlight varies from place to place depending on the number of hours of effective sunlight in that region. Assuming 5 hours of net effective sunlight under all weather conditions in the UAE:
Total power output of Panel = 12V x 10Ah = 120Wh
Power to be generated per hour = 120/5= 24W
Therefore keeping margin, a 50W /12v solar panel was selected.

Charge Controller Rating:

For a system of 12V, charge controller rating = 12V
Current rating = Output Power of Solar panel / Voltage = 50/12 = 4.16A
Hence a charge controller of 12V and more than 4.16A ie. 10A was selected.

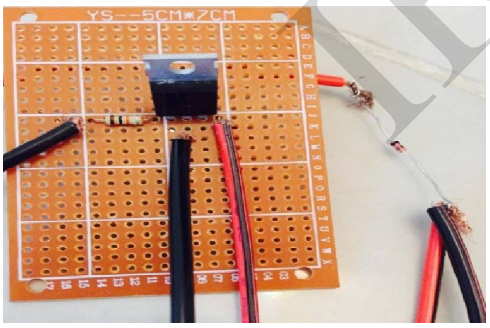


Figure 5: Darkness sensing circuit

Figure 6 shows the complete working model of an energy efficient lighting system which consumes only 20 W of energy but has enough luminosity (above 500 lx) to light up an average room of area under 200 sq. feet. Replacing the current room lighting that consumes 60 Watts of power with this lighting system, an energy saving of **75%** is achieved in a single room. If implemented in a complete building this could save us enormous amounts of power and energy.

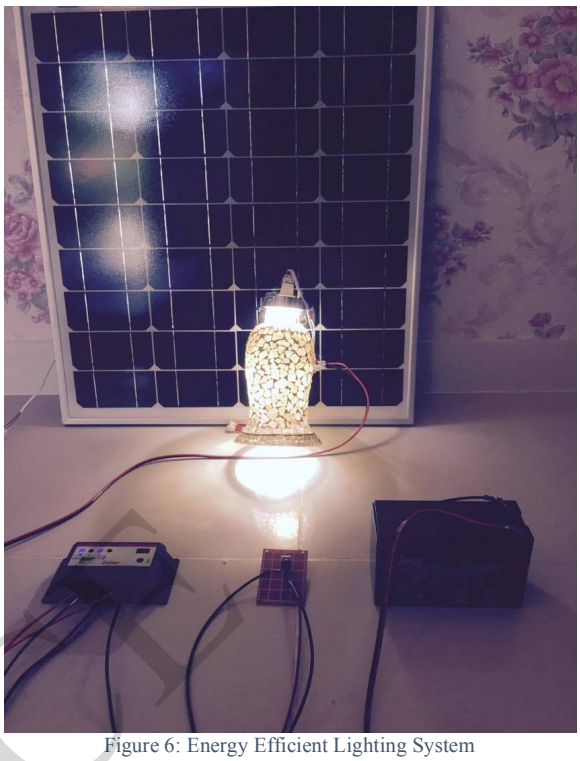


Figure 6: Energy Efficient Lighting System

VI. CONCLUSION

The renewable solar lighting system was designed and created for demonstrating its energy efficiency as well as its perfect performance using a renewable source of energy which is abundantly available in the UAE. Solar power, LED lighting, light sensors and daylight harvesting if implemented in buildings with the right and smart architecture can not only save energy but also safe guard our coming generations as fossil fuels and oil are non-renewable sources which will not last us long.

New techniques of daylight harvesting using different kinds of photo sensor controls and unique building architecture was thought of implementing to get maximum power saving. Using the lighting software successful results were obtained showing its effectiveness if used.

There was also no requirement of usage of an inverter in our system as the solar panel outputs simple direct current (dc) and LED's also work on DC power. The system therefore executes good performance along with being cost efficient and environment friendly.

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