Super capacitor based energy saving LED lighting system

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Abstract: ***Today's world fully depends on energy. There is a huge gap between demand and supply of electricity. So, it is time to use energy saving devices and methods. In this paper, a low-cost super capacitor base LED lighting system is introduced. The proposed system is allowed to use rectified DC voltage from AC mains or power from solar. The rectified DC voltage is used to charge a supercapacitor for few minutes. When fully charged the super capacitor will be automatically disconnected from the supply. The power for LED lighting is taken from the supercapacitor. Before the super capacitor is fully discharged, it recharges automatically. Thus reducing the time of connection between main supply and load and hence the cost of energy and power consumption is reduced to a great extent.***

Keywords: **Supercapacitor, PV panel, LED bulb, OP-amp.**

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1. Introduction

In recent year demand of energy is increasing very fast indeed generation is limited. So, an inflection of electricity is occurring, to solve the inflection many strategies are applied like increasing the price of power, setting up a new generating station and going for renewable[1] but all such strategies cannot happen suddenly because of high expenditure in setup except increasing price. So finding out the new method for energy saving is needed.

A light accounts for approximately 20% of the world's total energy consumption. Various light control systems are introduced in current markets because the installed lighting system is outdated and energy inefficient. However, due to architectural limitation, the existing light control system cannot be successfully applied to home and office buildings. The related studies of an energy efficient lighting system[2] have been done by different researchers around the world. The invention of the light emitting diode (LED) is expected to significantly alter the energy consumption of light because the LED lighting device less consumes 50% of the energy as compared to the fluorescent lighting device. Energy consumption can be reduced through light control according to user's living pattern[3] and advance lighting techniques.

The consistently growing demand much effect has now been put forwardslower the demand for energy through energy efficiency design. Energy efficiency is energy intensity which in simple terms, refers to provide some level of energy service or to do more works with the same unit of energy.

There are several instances in which lightning energy in the building has not been used efficiently. This could be because daylight is not efficiently desegregated with the artificial lighting system[4], or in a case where integration does exist, energy saving using energy efficient lighting technology have not been fully explored.

The problem of energy saving and the achievement of visual comfort condition in the interior environment of a building is multidimensional. Scientists from a variety of areas have been working on it for a few decades but it still remains an open problem, people stay about 80% of their lives inside buildings. So, reached light comfort condition in a building is very important and has a direct sign to the energy efficiency of the building. The achievement of the lighting controller depends on its efficiency and proper new in light level controlled illumination system is well as types of light saves acted.

Many of the research scholars and companies are searching a new strategy for energy saving mainly a lighting system. This paper presents a new strategy for efficient and energy saving led lighting system using super capacitors with some control strategy.

2. Comparison of LED bulb Vs Compact Fluorescents

I. **Table1**: Comparison of LEDs and CFLs

Important Facts	LEDs	CFLs
Contains of Toxic mercury	No	Yes
Carbon dioxide emissions (30 bulbs per year)	451 pounds/year	1051 pounds/year
Sensitivity up to low temperature	None	Yes may not work under-VC 10 degrees Fahrenheit
Sensitivity to humidity	No	Yes
On/Off cycling effect	No effect	Yes can reduce lifespan
Turns on instantly	Yes	No-takes time to warm up
Heat Emitted	3.4 BTU's/hour	30 BTU's/hour
Kilowatts of Electricity used (30 incandescent bulbs per year equivalent)	329 kWh/year	767 kWh/year
Life Span	50,00 hours	8,000 hours`
Lumens (800)	6-8 watts	13-15 watts

3. Conventional methods of LED lighting system

Various ways of LED lighting system had been done in many of the research papers. Some of the methods are described below:

3.1 Rectifier based LED Lightning system.

A simple way for LED lighting is rectifier based LED lighting. The voltage obtained from the mains is reduced and converted into DC voltage. The obtained DC voltage is filtered and used in lighting the bunch of LEDs. In this method energy saving strategy is absent.

3.2 Using Sensors

This method uses multiple sensors and wireless communication technology to control the light according to the users and surroundings. Output lumens of LED will be automatically controlled according to the readings of sensors[5] for energy saving purposes.

4. Proposed System Model

In this paper, intelligent LED lighting system is proposed in which a new energy saving method is introduced. Supercapacitor takes a minute to charge fully and discharge time is about 5 minutes. During charging and discharging of the super capacitor the voltage obtained across the super capacitor is amplified so that the residual voltage inside the super capacitor can be used for lighting. Amplified voltage is applied to zener diode so that required constant voltage across LEDcan be achieved. A constant forward current of LED is achieved through limiting resistor. The corresponding block diagram is shown below.

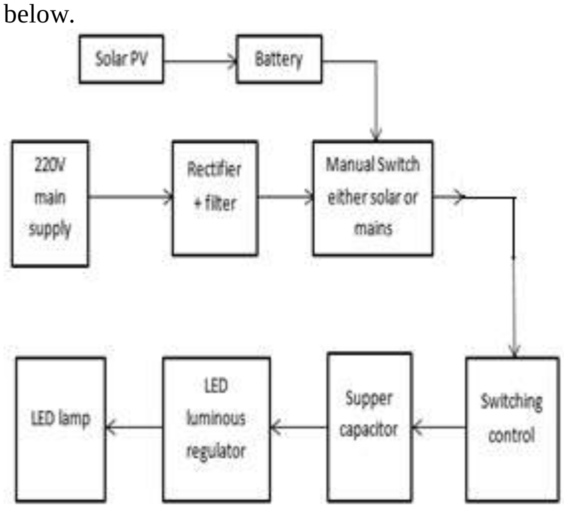

Figure1: Block diagram of proposed system.

5. Circuits

Various circuits are involved in obtaining the desired result. These circuits are described below:

5.1 Rectifier circuit

High voltage AC is fed to the power diode bridge circuits. DC output voltage generated from the rectified circuit fluctuates. Capacitor filter circuit is used to improve the fluctuation. Zener diode is connected across the capacitor to provide a stable output of 5.1V simulator circuit diagram is shown in the figure.

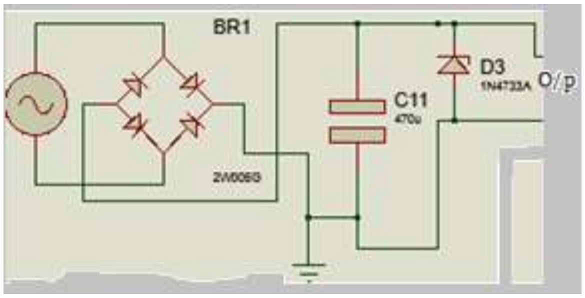

Figure2: Rectifier circuit diagram

5.2 Astable 555 IC Circuit

Astablemultivibrator is an oscillatory circuit that produces rectangular wave continuously without external triggering. It can generate pulse train from microseconds to hours. For generating required frequency capacitors and resistors are connected to the 555 timer IC. The generated frequency is calculated according to this formula.

$$f = \frac{1}{\ln(2).C(R_1 + R_2)} \tag{1}$$

High time for each pulse is given by

$$high = \ln(2).C(R_1 + R_2) \tag{2}$$

And low time for each pulse is given by

$$low = \ln(2).C.R_2 \tag{3}$$

The corresponding a stable multivibrator circuit is shown below.

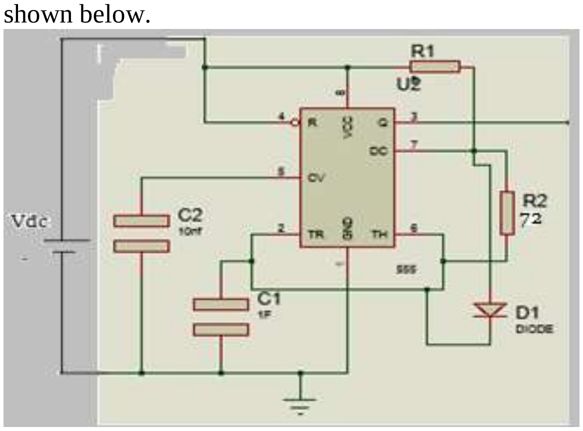

Figure3: A stable multivibrator circuit

5.3OP-amp circuit

Here 741 op-amp is used to amplify the output voltage coming from the super capacitor and supplied to LED. The voltage across the super capacitor is low and the maximum voltage is 5.1V. This voltage cannot drive the zener diode when charge reduces. So this voltage needs to boost up which is achieved by using 741 op-ampin inverting mode with a gain. The formula for calculating gain is given below.

$$A_g=\frac{R_f}{R_{in}} \tag{4}$$

Here $R_f = 10k \quad R_{in} = 1k$

A_g=10

Output voltage =V_{in}×A_g(5)

By this circuit voltage level across the capacitor can be amplified.

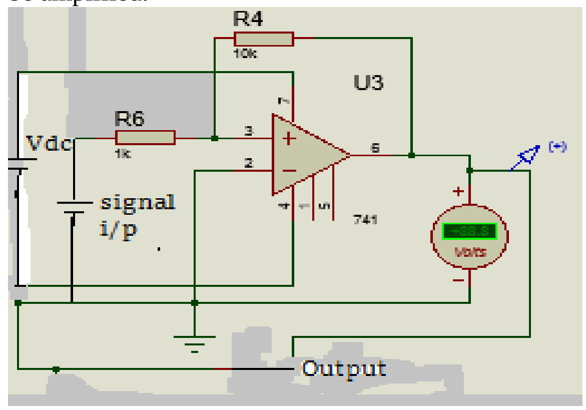

Figure4: Inverting- OPM circuit

5.4LED Lightning circuit

Consists of supercapacitors which are connected in parallel to increase the capacitance which in turn increases the charge stored in the capacitor. The potential drop across each parallel capacitor is same. Zener diode connected in parallel with the capacitor gives an output voltage of 5.1V. DC voltage is fixed evenif the potential drop across the capacitor is high or varied.Acurrent limiting resistor is connected in series to provide constant current, hence constant luminous intensity is achieved. Value of resistor for constant luminous is calculated as

$$R = \frac{Supply\ \ voltage - LED\ forward\ \ voltage\ \ drop}{\text{Current required for LED}} \tag{6}$$

For Power LED 12W

V_s=5.1V,V_f=4V,I=350mA,R=3.17mΩ

Supercapacitor possess a special property, charging time takes seconds and discharging times takes longer minutes. LEDs are connected in series to get the same forward current across the zener diode that will start to glow when astable multivibrator starts generating the signal. LED will glow continuously with constant luminous. The corresponding LED Lighting circuit is shown below.

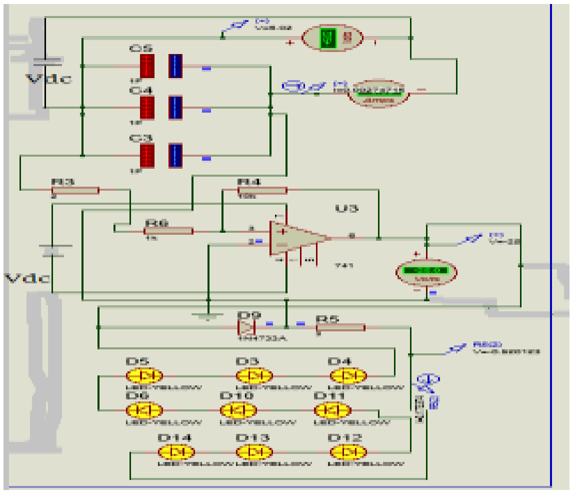

Figure5: Circuit diagram for LED Lighting

6. Calculation of Charging And Discharging of supercapacitor

Charging time is given by

$t = RC$ (7)

For $R=2\Omega$ $C=3F$ $t=6$ sec

Percentage of charge attain at time t is given by

$$\frac{Q}{Qmax} = 1 - e^{\frac{-t}{RC}} \quad (8)$$

For the above value

$$\frac{Q}{Qmax} \ atains\ 0.99\%\ at\ 1\ minute$$

Time taken to discharge capacitor is calculated as

$Z_D = R_0 \times C$ (9)

value $R_0 = 200\Omega$ $C=3F$

Hence $Z_D = 600$sec

Voltage level and current level during discharge are

$$V_D = Ve^{\frac{-t}{Z_D}} \quad (10)$$

$$I_D = -\left(\frac{V}{R_0}\right) e^{\frac{-t}{Z_D}} \quad (11)$$

At 1 min

$V_D=4.97$ i.e decreasing of 0.03V from 5.5

$I_D= -2.488$ remains

At t =5min

$V_D=3.33$ i.e decreasing of 2.16V from 5.5

D= -1.66 remains.

7. Calculation of Power Consumed

Power consumed by following circuits

OP-amp,P=14mW.

555IC, P=30mW

Zener Diode, P=0.2499mW

Bridge Rectifier, P=100W

Power Led

Forward voltage, $V_f= 4.1$V

Flux 90lm per LED

Forward current = 350mA

For producing 900 lumens Required LED is 9

So, total current required is 9 × 350mA=3.15A

Power = 3.15 × 4.1 = 12.915 W

8. Calculation of Power Store in Capacitor

Power stored in capacitor is given by

$$W = \frac{1}{2} CV^2 \quad (12)$$

$=\frac{1}{2} \times 3 \times (5.5)^2 = 45.375$J

Capacitor Power Generated

$$P = \frac{dw}{dt} \quad (13)$$

where

P= potential power (w)

dt= dissipation time (s)

Energy dissipated within 5µ is P= 9075KW

Capacitor Time to Discharge at constant Power load.

$$dt = \frac{\frac{1}{2}\left(V_s^2 - V_f^2\right)}{P} \quad (14)$$

where dt= discharge time (s)

V_s= start voltage (V)

V_f= final voltage (v)

dt= 4.83µS

9. Calculation of energy and cost saving

Power consumed by all circuit when SCR turn on for 1 minute

P_{Total}= 0.216Wmin

Power consumed by power supply, 555IC timer, OP-amp circuits for 1 hour

P_{Total}= 0.044Whr

Within 1 hour SCR will turn on 10 times

Power consumed by all circuit is

P_{Total}=2.16Wmin

Power consumed in kilowatt-hour= 0.36 X 10^{-4}KWhr

Cost estimated is Rs. 0.000216 at 1KWhr =Rs. 6

For 1 month estimated cost is Rs 9.33

And all the circuits are on for 1 hour continuously

P_{Total}=0.216 X 10^{-3}KWhr

Cost estimated is Rs. 0.001296

For 1 month estimated cost is Rs 55.98

Save amount is Rs 46.65

Save power is 7776W

11. Working of proposed system

AC voltage source coming from mains supply is rectified by the rectifying circuit. Solar PV panel is used to charge the battery. The manual control switch can be controlled by the user to switch ON either from mains source or from solar PV. The output of rectifier circuit and PV cell is kept constant by zener diode at 5.1V. Power supply for 555 timer IC and the inverting amplifier circuit is applied either from rectified circuit or from battery according to the manual switch. A stable multivibrator is going to control the gate terminal of the SCR.SCR transistor is acting as an on-off switch for the charging of supercapacitor bank. When high pulse comes from the a stable multivibrator, SCR will turn on and allow the supercapacitor to start charging. A stable multivibrator output signal will be set high for 1 minute for full charging the supercapacitor then automatically generates a low signal for 5 minutes. After 5 minutes high signal will be generated for 1 minute and again off for 5 minutes. This will repeat continuously. 741 IC circuit is used in an inverting mode to amplify the voltage from the super capacitor. The advantage of this system is that it allows extending the time for the lighting of LEDs.

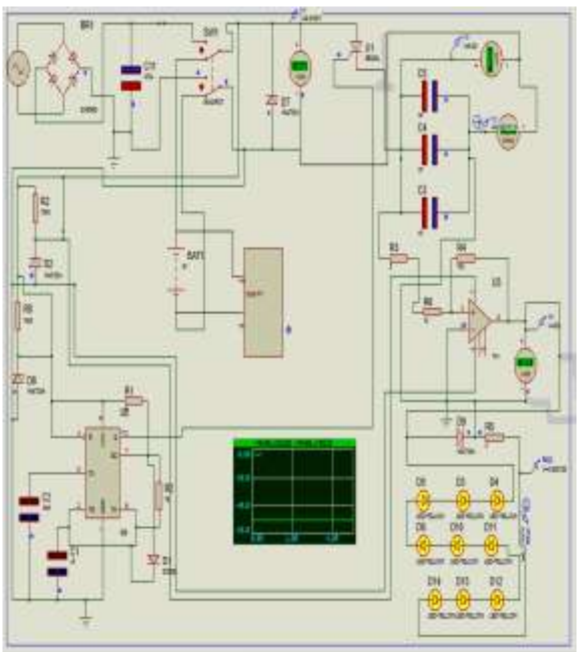

Figure6: Complete circuit diagram of led lighting system

10. Simulation Results

The following graphs are obtained from the Proteus simulation:

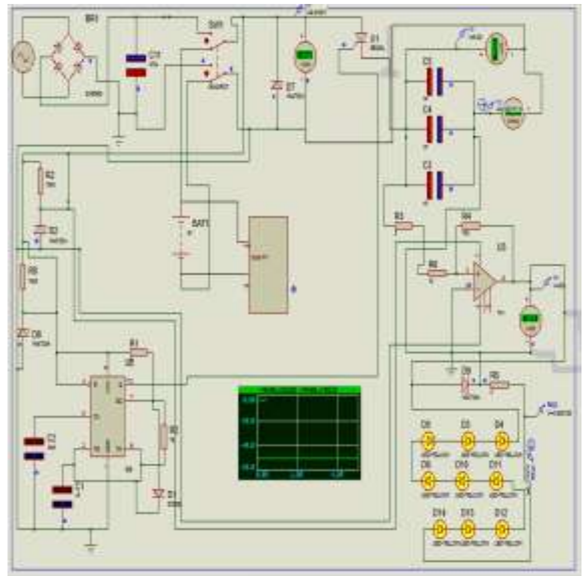

Figure7: output of simulation of led lighting system

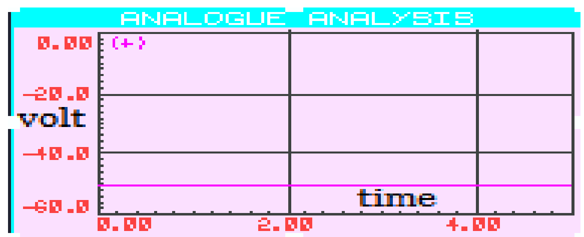

Figure8: output graph for 741 op-amp

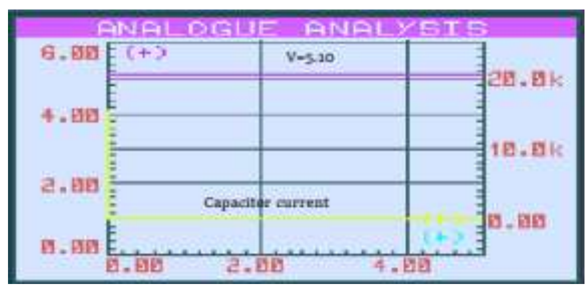

Figure9:Charging characteristics of super capacitor

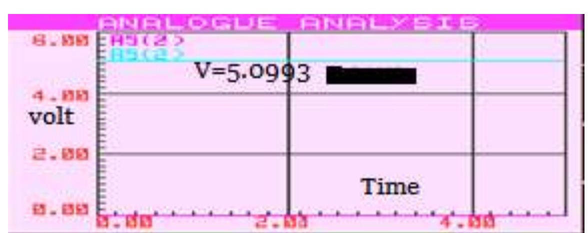

Figure10: Voltage Vs Time across LEDs

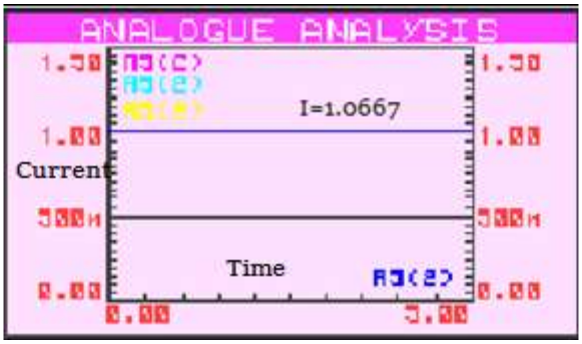

Figure11: Current Vs Time across LEDs

11. Conclusion

Use of super capacitor in the lighting of LED bulb is done successfully. For 14W LED bulb Lighting, obtained power saving is 7776W and cost saving isRs.46.65 for a month. The comparison between the use of a supercapacitor an done without the use of a supercapacitor is shown in numerical analysis. Hence such LED lighting system can marketize and can reduce energy demand and cost. The system is highly useful both to the customers as well as energy management also.

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