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THE ADVANCED DESIGNING OF LED DRIVER WITH THE DIFFUSIONAL ACCOMMODATION OF CURRENT SENSING TECHNOLOGY WITH OPEN LOOP PWM FOR STREET LIGHTING.

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ABSTRACT

The High Brightness LEDs for street lighting has gained popularity in street lighting owing to energy efficiency and the long life. The amalgamated feature of brightness and the dimming solutions makes it equally adoptable in outdoor lightings. The street lighting utilizes the power supply from the lines. The invent of renewable energy resources for appliances and illumination systems highlights the usage of solar system for lighting and heating systems. The solar photovoltaic panels are most featured solutions. The standalone PV systems require the designing knowledge of electrical, thermal and optical properties of LEDs. These parameters allow the development of driver system for design of the luminaire. Different strategies have been proposed for driver circuits to provide stable characteristics. The selection of Drivers is dependent on various factors like, energy efficiency, cost effectiveness, operation and maintenance, losses associated with the components and the assembly. The aim is to obtain a stable driver system for reliable operation using solar energy. The power supply and the battery management system reflect the efficient operation of the complete system. The approach is to design and manage a driver system for highly efficient HB-LEDs for street lighting and commercial outdoor applications. The multiple stages enhance the efficiency by maintaining the deciding factors such as power factor, losses and the long life. The 3 stage and expandable converter topology uses the maximum power point tracking and empowers the LEDs for required number of hours of glowing. An approach has been made to improve the energy conversion efficiency along with standby power consumption management system during the winter seasons which is a crucial factor around 92% has been made. The innovative methodology provides groundbreaking LED driver systems that help the consumers to gain a competitive edge.

KEYWORDS: LED Driver, solar PV panel, multiple stage buck converter technology

INTRODUCTION

Since the evolution of the illumination from general lighting services to most modern technology of solid state lighting the driver technology developed from basics to advanced technologies promising advanced features and reliability. The technology of Light emitting diodes is rapidly progressing .To make the system reliable the control system must be so designed to ensure the practical energy efficiency.
An LED is a device which emits light when the electric current is passed through it. An LED requires low voltage to turn ON. The drivers are designed to meet the requirement of low voltage for LEDs. The drivers convert the line voltage into low voltage power supply. In addition to this an additional and a prime important feature of dimming could also be assigned depending on the area of application. LED drivers are basically designed operation two modes of operation. One is constant current operation and the other being constant voltage operation. Both proved to possess numerous merits and invariably limitations also. The LED characteristics have been controlled by pulse Width Modulation-PWM technique. The study being carried out in designing a Driver for HB-LEDs to operate on solar power. This study also focuses on phosphorous GaN semiconductors which promise a future for LEDs and its cost effectiveness.

In the beginning the LEDs were used for various colors with a certain wavelength. The current passing through it decides the light intensity. The white LEDs are most promising solution in the area of street lighting and outdoor application. The LEDs consume less power from photovoltaic panels and a boon for energy efficiency. The white LEDs luminous efficiency is more than 80%.

The DC control approach often shows limitations in terms of thermal management of opponents which results in heating of elements and hence reduced energy efficiency. The driver's along with the PWM control works at very high frequency which varies from 100Hz to 150KHz. This technique is helpful in managing the heat dissipation and energy consumption.

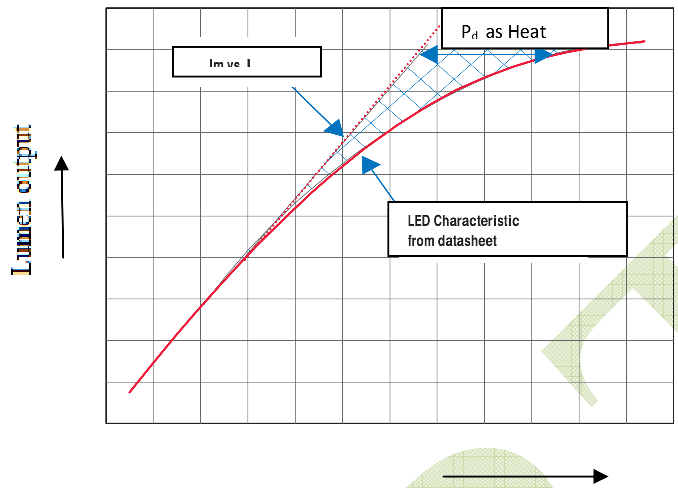


Fig 1: LED output Vs Current (mA)

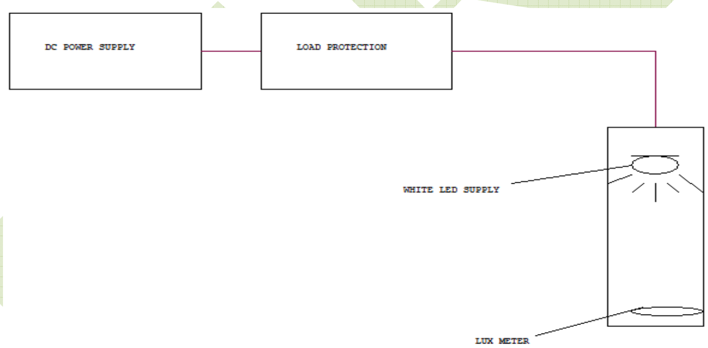


Fig.2 Functional Diagram

The relationship of lumen output Vs forward LED Current is as shown in fig1.1. The relationship is visibly linear over a range of forward current. As forward current increases the nonlinearity region increases. When the operating point crosses the linear region the luminous efficacy seems to reduce. Operation of LED above the safe region results in excess heat dissipation. This heat burdens the driver and demands highly efficient thermal design considerations. The color temperature is subjected to shift in the wavelength. Hence the focus of the paper is considered the electrical and the optical parameters to design the driver for solar powered LEDs.

In this paper the DC current limiting and selection is discussed and proved,. The results can be directly applied to solar powered street lighting. Here the output voltage is varied from 1.2V to 20V. The maximum current is 1.1A. To maintain the constant current a resistor of 100Ω is connected between the output voltage and adjacent voltage. To maintain the power factor and the stability of the system a capacitor is connected. The multiple stages buck and boost converter topology helps in boosting the efficiency of the driver for LED applications.

SOLAR PHOTOVOLTAIC SYSTEM

The solar photovoltaic cell is considered to convert 30-40% of energy incident on it to electric energy. The direct conversion of solar energy into electrical energy by means of photovoltaic effect. A single converter cell is called a solar cell or more generally a photovoltaic cell. The combination of such cells designed to increase the electric power output is called a solar array or solar module. These cells have a theoretical efficiency of the order of 25%. The efficiencies decrease very rapidly almost to half with the fall of the temperature. The solar cells are basically semiconductors made of silicon or any other suitable material such as CdS/Cu_2S material. A Maximum power point algorithm is developed to increase the efficiency of the solar panel. A PV system consists of 1.solar array system 2. Load leveler 3. Storage System 4. Tracking system. The MIS(metal insulator semiconductor) solar cell is very similar to Scotty diode except the thin layer of insulator between the semiconductor and the metallic conductor.
The maximum power of a silicon cell occurs at an output voltage of approximately0.45Volt.The current under full light is approximately 270A. Hence the power output is 120Watts per sq.m. There are different techniques for MPPT such as P&O, incremental conductance, fractional open circuit voltage, Fuzzy control, ANN control etc. Owing to simplicity most used MPPT are P&O method and Incremental conductance methods. The errors are increasing conductance due to the continuously changing maximum power point due to atmospheric conditions this problem is resolved using incremental conductance method. However this efficient method introduces complexity as it considers more than a sample of voltage and current for sampling.
The system efficiency also depends on the type of converter used. The buck converter always provides higher efficiency as compared to buck boost converter topology. Analog techniques are found to be efficient when the solar modules are connected in parallel. This technology is based on equalization of operating points.
To meet the energy requirements the solar cells are arranged in series parallel fashion. Cells may be connected in series to derive required current and are connected in parallel to derive desired voltage. The optimum operating voltage of a solar cell is generally about 0.45volt at normal temperatures. The current in full sunlight may be around 270amps/sq.m. The decrease in the radiation has direct effect on current whereas little effect on voltage.

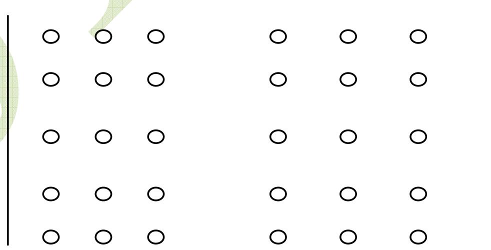
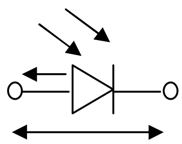


Fig 3 Arrangement of Solar Cells

To extract the maximum power the operating point has to be marked. Operating at other than the maximum power point will mean that the cell will produce a lesser electrical power and more thermal power. The maximum power point can also be readily found by plotting cell power versus cell voltage. If a rectangle of maximum possible area is inscribed in the area defined by the *I-V* characteristics and *I-V* axes, it meets the characteristics at the peak point. Closeness of the characteristics to the rectangle shape is a measure of the quality of the cell. An ideal cell would have a perfect rectangular characteristic.



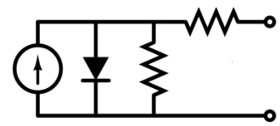


Fig.4 Schematic symbol of solar photovoltaic cell Fig. 5 Equivalent Circuit of a photo cell

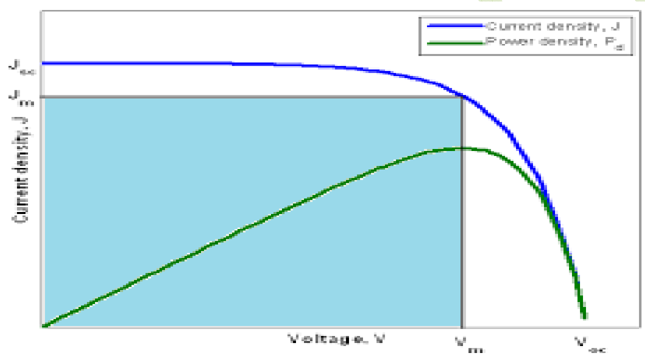


Fig. 6 I-V Characteristic, maximum power point

An ideal solar cell will have a fill factor of unity. By increasing the ratio of photocurrent to reverse saturation current the internal series resistance will be minimized and the shunt resistance will be maximized. This increases the fill factor considerably. Typically, the commercially available silicon cell fill factor lies in the range of 0.5 to 0.83.To maximize the performance of the solar cell by decreasing the losses due to leakage on the perimeter of the cell. The high doping of the semiconductor reduces the series resistance but it increases the width of the depletion layer, which in turn decreases the photocurrent.

When a solar PV system is deployed for lighting applications, the *I-V* characteristics keeps on changing with insulations and temperature. In order to receive maximum power, the load must adjust itself accordingly to track the maximum power point. If the operating point departs from the maximum operating point, it may be required to interpose a electronic maximum power point between PV system and load. The adaptation of dc to dc switching regulator is the idea behind MPPT. To provide maximum power transfer to the load the regulator is to provide a higher voltage at lower current or vice versa. Here multiple stage regulator is provided or tied up into a feedback loop to vary the switching times. The converters use MOSFET as the switching device. The two stage topology proves to be a efficient technology for LED streetlight driver. The common driver for raw power supply and the solar power gives utmost cost effectiveness and efficiency. The topology is modeled using MATLAB and the simulations are carried out.

Stage 1: MPPT Converter: The full bridge rectifier along with the Boost converter provides a regulated boost output along with power factor correction. The switching device being MOSFET which is highly adoptable for high frequency operations provides fast switching

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.The input to the rectifier is given through inverter for dc to ac conversion. The dc input voltage from the solar panel is directly given to the MPPT tracker which sources maximum power at all point of time.

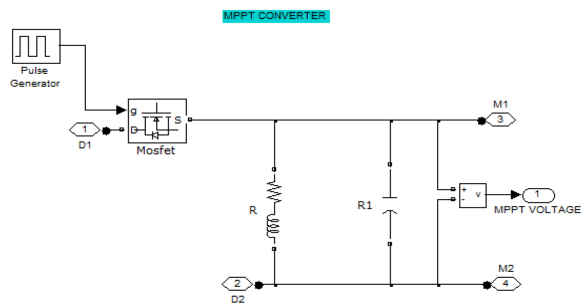

Fig. 7 Proposed Model of MPPT Converter in stage 1

The capacitor value is calculated as 20mF and the value of the inductor 50mH. The value of the resistor proposed is 0.4Ω. The MOSFET is switched at the 10msec and the time period is set at 76%. The mechanism for synchronization is to be accommodated. The dc power is then converted to ac by inverter. The Harmonics are filtered and then the ac power is fed to the full bridge rectifier. Fig 8 shows the model of the inverter built on MATLAB.

Stage 1: Inverter

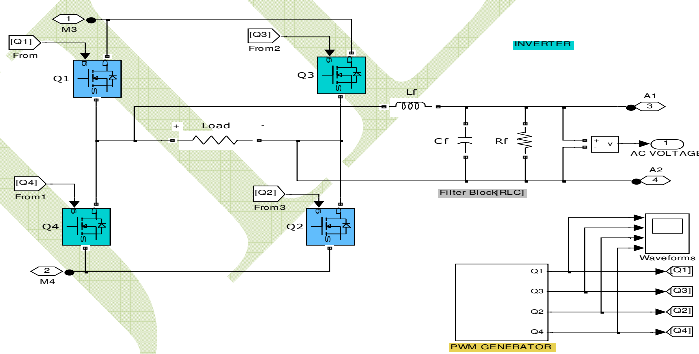

Fig. 8 Proposed Model of Inverter in stage 1

The inverters are DC to AC converters. The output voltage waveform of inverters can be square wave, quasi-square wave or low distorted sine wave. The output voltage is controlled with the help of drives using switches. The Pulse width modulation techniques are most commonly used to control the output voltage of the inverters. Such inverters are known as PWM inverters. Proper control schemes are designed to control the harmonics. The inverters are basically classified in to voltage source inverter or current source inverter. When the input voltage is maintained constant it is termed as Voltage Source Inverter and termed as Current Source Inverter when current is to maintained constant. The sinusoidal PWM is the most popular PWM method used in inverters. The purpose is to control the voltage. The width of each pulse is weighted by the amplitude of the sine wave at that instant. The carrier signal is a triangular wave and the reference signal is a sine wave. The sine wave is compared with the triangular wave and the PWM signal is prepared. From this PWM, the drives for the switches in the inverter are prepared. The width of the pulses depends on the amplitude of the sine wave. Fig 9. Shows the MATLAB model of PWM generator.

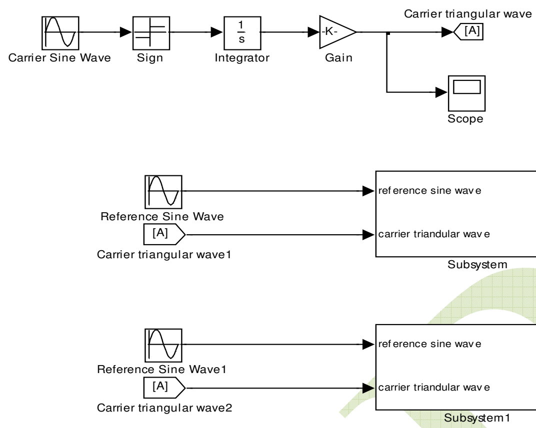

Fig. 9 Proposed Model of PWM generator for Inverter in stage 1

Stage 2: Rectifier with Filter

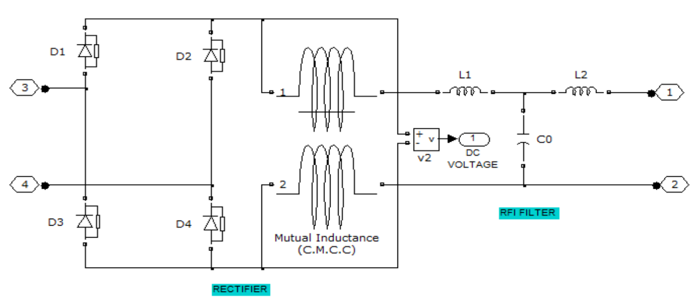

Fig. 10 Proposed Model of Rectifier with filter in stage 2

The function of the rectifier is to regulate the output of the stage 1. IRF150 MOSFETs are chosen .The mutual inductance provides the continuity of the current. To provide a ripple free output of stage 2 the filter is designed with inductor and capacitors. The suitable value for LC filters are calculated and modeled. The value of the inductance for LC filter is set at 10µH and the value of the capacitor is set at 2.2PF.The output from stage 2 is ripple free .The filters eliminates the lower order harmonics and the ballasts or drivers will have a longer life as the humming and the noise levels are reduced to a larger extent.

Stage 2: Boost Regulator with Filter

The Boost regulators are known for power factor correction as well. The average value of the output voltage is higher than the input voltage. The capacitance and inductance are calculated so as to provide continuous current along with the filtering of harmonics to some extent. The Gate is given a pulse which is a sin PWM to drive the switch. The continuity of the current is brought by the inductor. During first mode of operation i.e when the switch is closed the inductor stores energy.

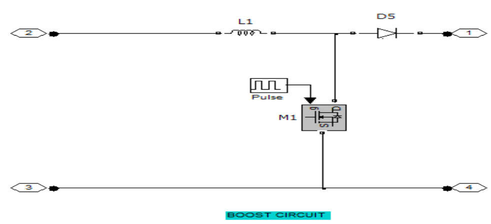

Fig. 11 Proposed Model of Boost Converter with filter in stage 2

Normally a capacitor is connected across the load to smooth out the output. The value is calculated for 1000µF.The diode D_5 blocks the reverse flow of output current when switch is turned ON. During mode 2 the voltage in the inductor maintains the current in the same direction. The value of the inductor is designed for 500mH. The diode D_5 is forward biased during this mode and passes current to the load. The voltage induced in the inductance adds to the supply voltage and appears across the load. Hence the output voltage is higher than input. The best advantage of boost regulator is that it increases the output voltage without the aid of transformer.

Stage 3: Buck Regulator for LED strings

The limitations of the single stage topology are overcome by three stage topology. With this the usage of capacitors for boosting the power factor could be avoided to a larger extent. The innovation in the design is that each LED string is driven by a single buck converter. The individual control helps in reducing the current stress across the LEDs. The constant current requirement of LEDs is met .This reflects in the longer life of LED lights and majorly helps in energy conservation. The LED in a string will provide the same wattage irrespective of any discontinuity caused due to failure of any one LED in the string. The Third stage is modeled with three buck converters as shown in the fig. 12

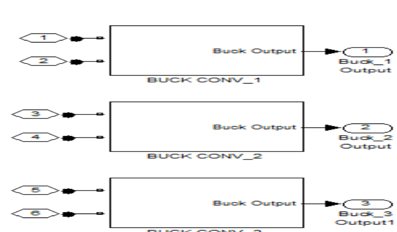

Fig. 12 Proposed Model of buck Converter in stage 3

The proposed topology is considered for 3 LED strings as shown in fig.12 Each string is controlled by an individual buck converter. The Model of buck converter is as shown in fig 13.

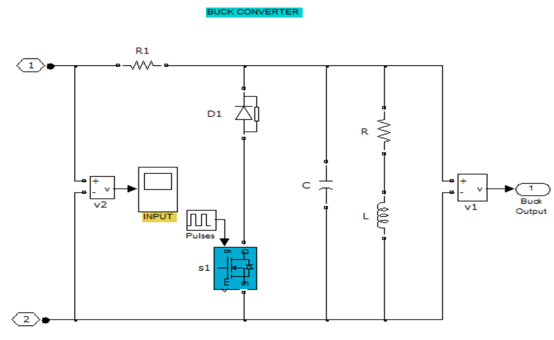

Fig. 13 Proposed Model of buck Converter in stage 3

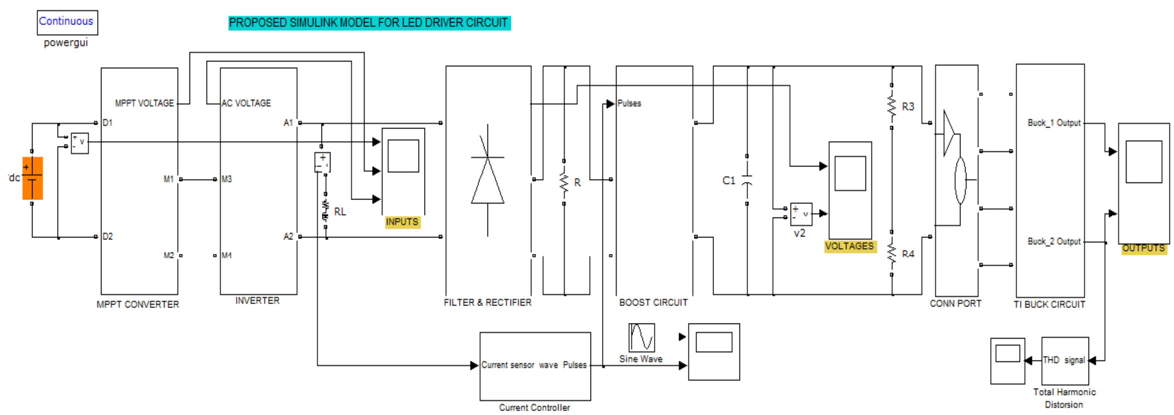

Fig. 14 Proposed Model of 3 stage Driver system

Experimental Calculations

Example Design of one Buck Converter

Input voltage: 255V (arbitrary)

LED string Voltage: 30-60V dc

Current in mA: 350mA

Efficiency projected actual: ≥91%

Consideration of input voltage for Buck: 8.0V-500V

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Frequency of oscillator: 20KHZ - 150kHz

Design Purpose:

No. of LEDs: 25

Frequency: 40kHz

Value of resistor:720KΩ

Calculations

Input voltage V_{in} =325V

First stage after filter output = 310V

A C input voltage= 325V

Duty Cycle =15%

C=2,2μf, stability requirements demands the maximum LED string voltage should be less than half of the minimum voltage

$V_{in} = 2 \times V_{0(max)} = 120V$

$V_{out} = ή \times V_{LED} = 54V$

Total theoretical values for Power loss-1389W

Ripple less than 9%, overall efficiency 91% and individual efficiency 92% and above for multistage connections.

SIMULATION RESULTS

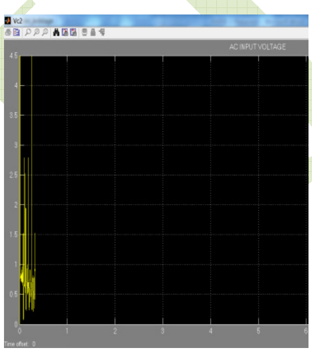

Fig. 15 Harmonic Analysis AC output Voltage) of Stage 1

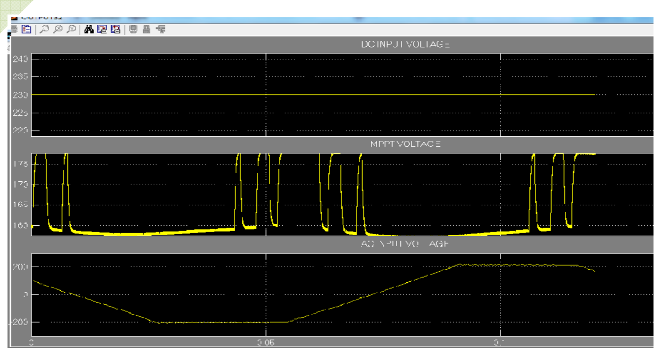

Fig. 16 Output Voltage (MPPT converter, Dc input,

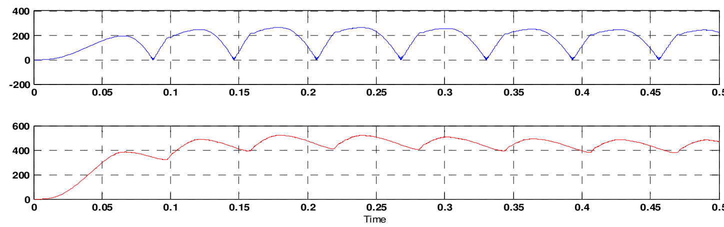

Fig. 17 Rectifier voltage and Boost regulator Output Voltage of Stage 2

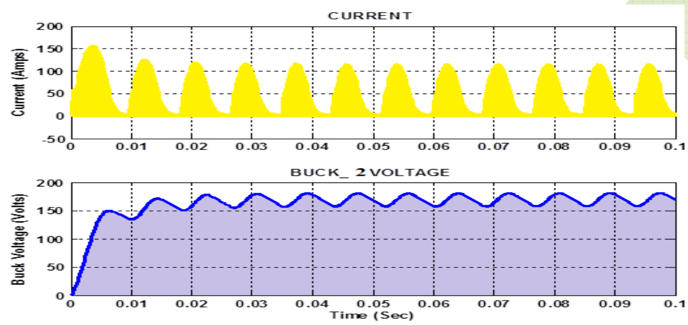

Fig. 18 Output of Third Stage

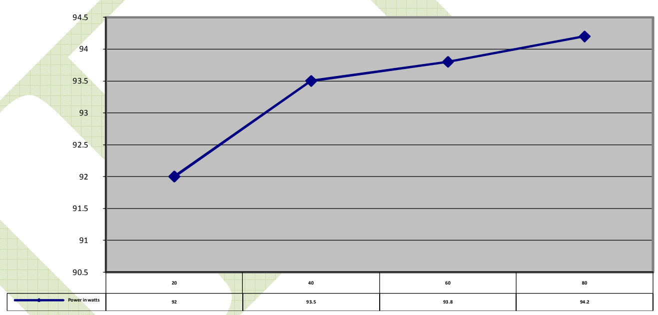

Fig. 19 Efficiency Vs output voltage

CONCLUSION

The study has enabled the provision to improve the performance of the LEDs to give maximum brightness along with longer life. Then, simple interface of solar power extraction has been done with A C power supply so as to enable LED street lights to work on any available source. The multistage solution of buck and boost converter in stages to improve the performance an deficiency of LEDs is designed, modeled using MATLAB. Simulation results are observed. The LEDs luminaries are the future and a very promising technology for future development of LED applications. The overall efficiency calculated and proved to be above 91% giving all the practical considerations. This has the potential to replace the Buck-Boost converter in single stage commonly employed for the purpose of street lighting.

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