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Solar Smart Street Lighting System with Bluetooth Connectivity

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Abstract - *The project is designed for LED (Light Emitting Diode) based street lights with intensity control. These lights are powered by solar energy from photovoltaic cells. As awareness for solar energy is increasing, more and more individuals and institutions are opting for solar energy. Photovoltaic panels are used for charging batteries by converting the sunlight into electricity. An MPPT (Maximum Power Point Tracking) charge controller circuit is used to control the charging. Through a mobile application, the intensity of street lights can be controlled. LED lights are used instead of HID (High Intensity Discharge) lamps as the intensity control is possible in the LED lights. In this way, energy can be saved considerably.*

Key Words: **Solar, LED Street light, MPPT charging, light intensity control, Bluetooth connectivity.**

1. INTRODUCTION

We need to save or conserve energy because most of the energy sources we depend on, like coal and natural gas can't be replaced. Once we use them up, they are gone forever. Saving power is very important, instead of using the power in unnecessary times it should be switched off. In any city "STREET LIGHT" is one of the major power consuming factors. Sometimes we see streetlights are on even after sunrise thus wasting lot of energy. Here we are avoiding the problem by having an automatic system which turns on and off the streetlights at a given time or when ambient light falls below a specific intensity. Light Emitting Diodes (LED) replaces HID lamps in street lighting system to include dimming feature. An Arduino board is used to control the intensity by developing pulse width modulated signals that drives a MOSFET to switch the LEDs according to achieve desired operation. In the present system, mostly the lightning up of highways is done through High Intensity Discharge lamps (HID), whose energy consumption is high. Its intensity cannot be controlled according to the requirement so there is a need to switch onto an alternative method of lightning system i.e., by using LEDs. This system is build to overcome the present day drawbacks of HID lamps. This system demonstrates the usage of the LED's (light emitting diodes) as the light source and its variable intensity control, according to the requirement.

LED's consume less power and its life time is more, as compared to the conventional HID lamps. The more important and interesting feature is its intensity can be controlled according to the requirement during non-peak hours which is not feasible in HID lamps. A cluster of LEDs are used to form a street light. The Arduino board contains programmable instructions which controls the intensity of lights based on the PWM (Pulse width modulation) signals generated. This study is a prototype implementation of Solar energy in Street Light and controlling it via low energy Bluetooth.

Studies have made solar power cheaper and more efficient. This will make solar power smart and more available on the market. This project has smart technology and saves a lot of power because Switching ON and Off the lights as per the need saves 30% of energy, using dumb LED saves 70%, Timer based LED saves anther 30%, Lumen Intensity control saves around 40%, all this makes power conservation. We are using Bluetooth connectivity because Bluetooth technology is useful when transferring information between two or more devices that are near each other when speed is not an issue. It is best suited to low-bandwidth applications, cost is low, Range is 5-30m, Low power consumption and fairly simple to use.

Our project gives optimum results because it has Microcontroller based constant current LED driver, Maximum power point tracking charger, Light intensity programmable via Bluetooth, Temperature compensator battery charging, and Protection features like Battery high, Battery low Array Reverse, Battery Reverse, Load shunt circuit and Temperature compensator. Some special uses of this are Intensity can be controlled with any hardware connections via air, Connectivity available everywhere because all smart streets have Bluetooth connectivity. Smaller solar battery size for smart street lights as intensity decreases after midnight. Installation in villages and rural areas where normal grid electricity is not available. Some new concepts of solar energy that has been implemented is first time are Dusk to dawn control Based on the voltage of the solar panel, the controller turns ON and OFF the LED load corresponding to Dusk and Dawn Temperature compensation.

1.1Simple Block Diagram

Figure 1: Simple Block Diagram showing major components

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1.3 MPPT

An embedded C code is written to implement MMPT algorithm .MPPT or Maximum Power Point Tracking is algorithm that included in charge controllers used for extracting maximum available power from PV module under certain conditions. The voltage at which PV module can produce maximum power is called 'maximum power point'(or peak power voltage). Maximum power varies with solar radiation, ambient temperature and solar cell temperature. Typical PV module produces power with maximum power voltage of around 17 V when measured at a cell temperature of 25°C, it can drop to around 15 V on a very hot day and it can also rise to 18 V on a very cold day. The major principle of MPPT is to extract the maximum available power from PV module by making them operate at the most efficient voltage (maximum power point). That is to say: MPPT checks output of PV module, compares it to battery voltage then fixes what is the best power that PV module can produce to charge the battery and converts it to the best voltage to get maximum current into battery. It can also supply power to a DC load, which is connected directly to the battery. MPPT is most effective under these conditions:

• Cold weather, cloudy or hazy days: Normally, PV module works better at cold temperatures and MPPT is utilized to extract maximum power available from them.

• When battery is deeply discharged: MPPT can extract more current and charge the battery if the state of charge in the battery lowers. A MPPT solar charge controller is the charge controller embedded with MPPT algorithm to maximize the amount of current going into the battery from PV module. MPPT is DC to DC converter which operates by taking DC input from PV module, changing it to AC and converting it back to a different DC voltage and current to exactly match the PV module to the battery. Examples of DC to DC converter are:

• Boost converter is power converter which DC input voltage is less than DC output voltage.
That means PV input voltage is less than the battery voltage in system.

• Buck converter is power converter which DC input voltage is greater than DC output voltage.
That means PV input voltage is greater than the battery voltage in system. MPPT algorithm can be applied to both depending on system design. Normally, for battery system voltage is equal or less than 48 V, buck converter is useful. On the other hand, if battery system voltage is greater than 48 V, boost converter should be chosen. MPPT solar charge controllers are useful for off-grid solar power systems such as stand-alone solar power system, solar home system and solar water pump system, etc .In any applications which PV module is energy source, this charge controller is used to correct for detecting the variations in the current-voltage characteristics of solar cell and shown by I-V curve. This charge controller is necessary for any solar power systems need to extract maximum power from PV module; it forces PV module to operate at voltage close to maximum power point to draw maximum available power. This charge controller allows users to use PV module with a higher voltage output than operating voltage of battery system. It reduces complexity of system while output of system is high efficiency. Additionally, it can be applied to use with more energy sources. Since PV output power is used to control DC-DC converter directly. This controller can be applied to other renewable energy sources such as small water turbines, wind-power turbines, etc.

2. MAIN COMPONENTS REQUIRED

2.1. ARDUINO UNO:

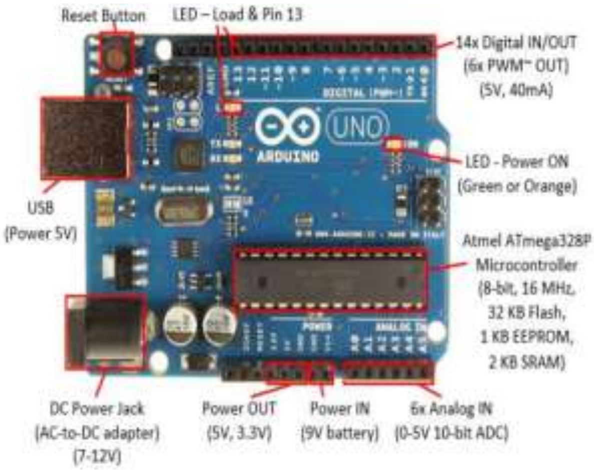

Figure 2: Arduino uno based on ATmega328P

The Arduino Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter. Power The Arduino Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically. External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's powerjack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector.

The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts. The power pins are as follows:

1)VIN. The input voltage to the Arduino board when it's using an external power source(as opposed to 5 volts from the USB connection or other regulated power source). We can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin. 5V. The regulated power supply used to power the microcontroller and other components on the board. This can come either from VIN via an on-board regulator, or be supplied by USB or another regulated 5V supply. 2) 3.3V. A 3.3volt supply generated by the on-board regulator. Maximum current draw is 50 mA. 3) GND. Ground pins.

Memory: The ATmega328 has 32 KB (with 0.5 KB used for the bootloader). It also has 2 KB of SRAM and 1 KB of EEPROM.

Input and Output: Each of the 14 digital pins on the Uno can be used as an input or output, usingpinMode(), digitalWrite() and digitalRead() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected bydefault) of 20-50 kilo Ohms. In addition, some pins have specialized functions: Serial: 0 (RX) and 1 (TX). Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip.

- External Interrupts: 2 and 3. These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attachInterrupt() function for details. PWM: 3, 5, 6, 9, 10, and 11. Provide 8-bit PWM output with the analogWrite() functions.

-SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK). These pins support SPI communication.

- LED: 13. There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off. The Uno has 6 analog inputs, labeled A0 through A5, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin and the analogReference() function. Additionally, some pins have specialized functionality:

- TWI: A4 or SDA pin and A5 or SCL pin. Support TWI communication .There are a couple of other pins on the board:

-AREF. Reference voltage for the analog inputs. Used with analogReference().

- Reset. Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board.

Communication: The Arduino Uno has a number of facilities for communicating with a computer, another Arduino or other microcontrollers. The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). An ATmega16U2 on the board channels this serial communication over USB and appears as a virtual com port to software on the computer. The '16U2 firmware uses the standard USB COM drivers, and no external driver is needed. However, on Windows, an *.inf file is required. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board. The RX and TX LEDs on the board will flash when data is being transmitted via the USB-to-serial chip and USB connection to the computer (but not for serial communication on pins 0 and 1).A Software Serial library allows for serial communication on any of the Uno's digital pins.

2.2 BLUETOOTH SPP (Serial Port Protocol) module (HC 05):

Figure 3: SPP Bluetooth HC05

HC-05 module is an easy to use Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup. Serial port Bluetooth module is fully qualified Bluetooth V2.0+EDR (Enhanced Data Rate) 3Mbps Modulation with complete 2.4GHz radio transceiver and baseband. It uses CSR Blue core 04-External single chip Bluetooth system with CMOS technology and with AFH (Adaptive Frequency Hopping Feature). It has the footprint as small as 12.7mmx27mm.

Pin Number	Pin Name	Description
1	Enable / Key	This pin is used to toggle between Data Mode (set low) and AT command mode (set high). By default it is in Data mode
2	Vcc	Powers the module. Connect to +5V Supply voltage
3	Ground	Ground pin of module, connect to system ground.
4	TX – Transmitter	Transmits Serial Data. Everything received via Bluetooth will be given out by this pin as serial data.
5	RX – Receiver	Receive Serial Data. Every serial data given to this pin will be broadcasted via Bluetooth

6	State	The state pin is connected to on board LED, it can be used as a feedback to check if Bluetooth is working properly.
7	LED	Indicates the status of Module • Blink once in 2sec: Module has entered Command Mode • Repeated Blinking: Waiting for connection in Data Mode • Blink twice in 1 sec: Connection successful in Data Mode
8	Button	Used to control the Key/Enable pin to toggle between Data and command Mode

Figure 4: Table shows pin configuration of HC 05

Bluetooth Connectivity

• Distance: About 30 to 50 meters

• Data rate: Up to 1 Mbps

• Number of devices in a piconet: 8, unlimited in Bluetooth low energy version.

• Spreading: FHSS (Frequency Hopping Spread Spectrum).
The great advantage here of using Bluetooth over other technology is economy, as no separate routers or networks are needed. Additionally, the smart devices themselves are generally less expensive than those for either Wi-Fi or ZigBee. Bluetooth doesn't interrupt our cellular network like WIFI.

2.3 SOLAR PANEL

Figure 5: 45W, 17V solar panel

Solar street lights are raised outdoor light sources, which are powered by PV(photovoltaic)panels. These panels are mounted on the lighting structure or connected in the pole. PV panels have a rechargeable battery, providing power to the fluorescent or LED lamp during the entire night.

2.4 LED PANEL

Figure 6:LED panel for street light

A light-emitting diode (LED) is a two-lead semiconductor light source. It is a p–njunction diode that emits light when activated. When a suitable current is applied to the leads, electrons are able to recombine with electron holes within the device, releasing energy in the form of photons. This effect is called electroluminescence, and the colour of the light (corresponding to the energy of the photon) is determined by the energy band gap of thesemiconductor. LEDs are typically small (less than 1 mm2) and integrated optical components may be used to shape the radiation pattern. LED lights are up to 80% more efficient than traditional lighting such as fluorescent and incandescent lights. 95% of the energy in LEDs is converted into light and only 5% is wasted as heat. Less energy use reduces the demand from power plants and decreases greenhouse gas emissions. It is energy efficient.

2.5 BATTERY

Figure 7: simple 12V lead acid battery is used.

3. CIRCUIT DIAGRAM

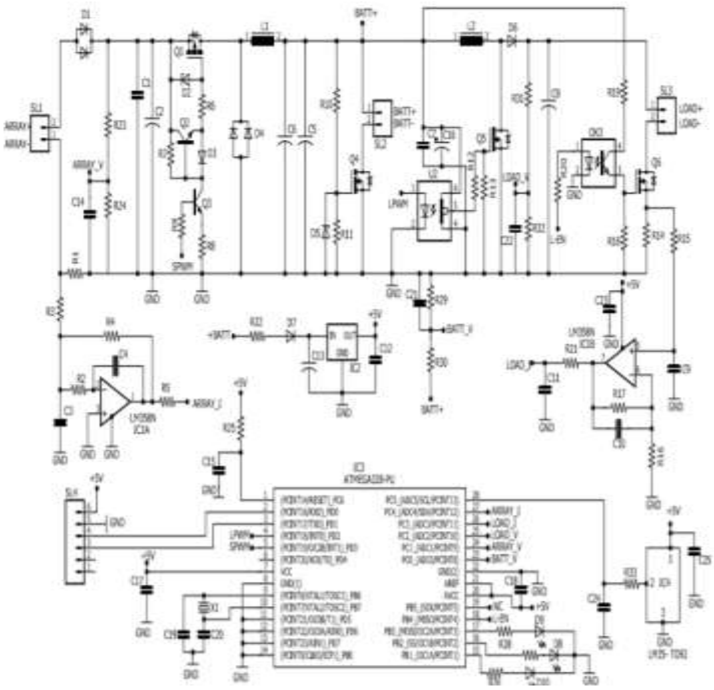

Figure 8: Circuit diagram for PCB design

4. PCB FABRICATION AND SOLDERING

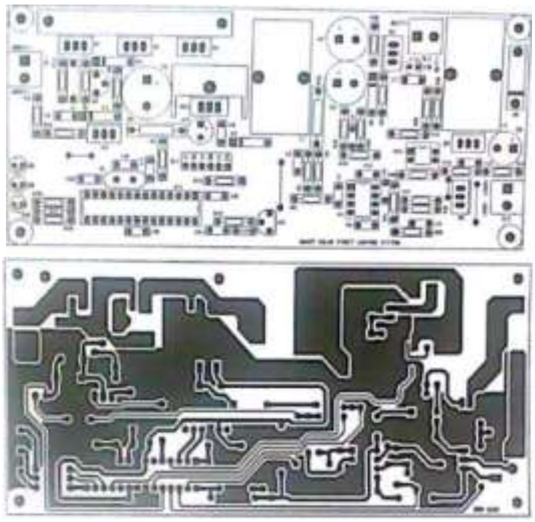

Figure 9: PCB design front and back

According to the pcb design the parts list is made and the required items are procured. Later soldering on pcb is done.

Figure 10: PCB with soldered components

Figure 11: PCB connections to the LED panel

5.WORKING:

D1 is a double diode. It is a low forward voltage drop Schottky diode that is used to prevent reverse polarity connection of the solar panel.R23 and R24 form a voltage divider which basically divides the array voltage so that the microcontroller can read the array voltage. It is scaled down typically to within 5V range for the reading purpose. Series with the array negative is R1, which is a 10 milli ohm shunt used to measure the array current.The voltage across R1 will be amplified by IC1A and the amplified output voltage will be at pin 1. IC1A is an inverting amplifier. Only the DC component is amplified whereas the AC component is shunted by C4.Capacitor C1 which has a smaller value forms the filter capacitor, eliminating the noise.Capacitor C2 acts as a local reservoir and this has a comparatively higher value. Q2 is a p-channel MOSFET. Array input comes to the source. The source to gate voltage is clamped to safe limits of 15V by D2.

A transistor is present between the source and the gate. Transistor Q2 is normally forward biased, hence the source is directly connected to gate and the device is normally off. But when PWM starts, PWM is given to R9 through Q3, hence Q3 turns on and pulls the gate through R6 via D3 to the ground. Hence the gate is closed.For every turn on, the current flows through L1. The moment power is supplied, inductor becomes magnetic and stores energy in the form of magnetic field. Once the supply stop, the stored energy flows to battery through the diode D4. D4 is a double diode that recovers the fly back energy.Capacitors for C5 and C6 filter the signal. Battery negative is in series with the MOSFET, it is not directly connected to ground. Battery negative and ground are connected through a MOSFET.In case battery is connected in reverse, as the gate of Q4 does not have any bias, it is turned off. Hence there is protection from reverse polarity. This constitutes the charging part, the MPPT part. Basically, array current and voltage are multiplied to obtain maximum power from the panel.Once the maximum power is achieved, MPPT continuously tracks to that particular point. Now consider the battery full condition. When the battery is full, then we come out of the MPPT loop and the same point is continuously maintained. It is now made into a float power supply. It is just a power supply regulating the output voltage to the battery voltage. This is a small power supply. A series drop resistor R22 is there to drop a small voltage across IC2. A reverse polarity protection is provided by D7.The driver should on and off at very high frequencies and hence we use a dedicated IC whichis optically isolated and hence power at the input does not go to the output. Optical isolator is mainly used to protect the microcontroller from any kind of high voltages if they are present near the input side. Inductor L2 charges, the fly back energy flows through D6 and gets stored in C8.Switch OK3 is present between load and battery to avoid any damage to battery during short circuit conditions. Load current is measured along R21. 1C1B is a non-inverting amplifier that is used to measure current. The buck boost converter is a DC to DC converter. The output voltage of the DC to DC converter is less than or greater than the input voltage. The output voltage of the magnitude depends on the duty cycle. These converters are also known as the step up and step down transformers and these names are coming from the analogous step up and step down transformer. The input voltages are step up/down to some level of more than or less than the input voltage. By using the low conversion energy, the input power is equal to the output power. The following expression shows the low of a conversion. Input power (Pin) = Output power (Pout).

For the step-up mode, the input voltage is less than the output voltage (Vin < Vout). It shows that the output current is less than the input current. Hence the buck booster is a step-up mode.

Vin< Vout and Iin> Iout
In the step-down mode the input voltage is greater than the output voltage (Vin> Vout). It follows that the output current is greater the input current. Hence the buck boost converter is a step-down mode.
Vin > Vout and Iin <Iout

6. RESULT AND CONCLUSION

An MPPT charge controller is designed to efficiently charge the battery from the solar panel. This is done with the help of a buck and boost converter and works on the principle of PWM. The led array's intensity is controlled with the help of a Bluetooth mobile application named 'SSL'. The control signal from Bluetooth module communicates with the microcontroller and with the help of PWM technique, the light intensity is controlled. The battery charges above 17V and discharges below 17V. The output can be displayed on the CRO (Figure is shown below). The waveform shows the charging of the battery. Maximum point is tracked and the point is maintained (Float state). The android application controls the intensity from 0% to 100%.

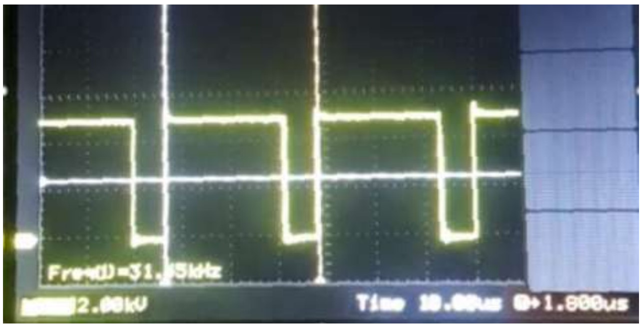

Figure 12: The output waveform of MPPT charging

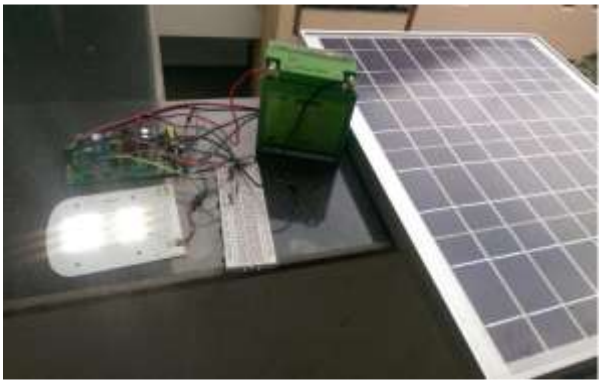

Figure 13: The working set up

Smart Street Lighting can be a conduit to achieve the following:

1. Smart traffic control: For ambulance, VIP vehicles.
2. Smart city surveillance case of any threat, we can divert all the cameras to a particular area.
3. Smart street lighting can a health monitoring and reporting system without a technician physically going there to inspect.

BLUETOOTH mesh gives rise to group and individual control. Application point of view constraint is that return of investment is less.100W for 12hrs is not viable.

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