Estimation of PV Fed Emergency Message Display System Mounted on LED Street Light Pole

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Abstract- *Global System for Mobile (GSM) communication has reached to every nook and corner within a short period of introduction in comparison to the reach of electricity supply network. During natural calamity the lives can be saved by timely evacuation by broadcasting through a prior notice served by SMS through an authorised person. Also the rescue operation after the attack can be continued in presence of a standalone Light Emitting Diode (LED) street light fed by Photo Voltaic (PV) power where the power network even if present is not restored. This paper concerns about estimating the capacity and cost of PV panel, battery so as to provide PV power for pole mounted emergency message displaying system with streetlight that can backup for one and half day as a solution in the event of natural calamities.*

Keywords- Arduino, emergency message display system, LED street lamp, Proteus, PV.

I. INTRODUCTION

Cyclonic storms hit every coast throughout the world. Its aftermath is destruction of power supply system, communication and transportation system. However, early warning alerts lead to smooth evacuation of lives, and subsequent communication prevents loss of life due to flash flooding after the cyclone [1]. As such, mostly there is a lack of power supply in the rural area due to physical barriers and poor grid connectivity. So, there is a need for off-the-grid standalone power supply and according to the topology solar power is the best available solution.

During the search for the optimal solution of designing a system which can work on our requirements, many scholarly articles are found for PV fed LED streetlight. LED in lighting applications is efficient and durable. Dalla Costa et al. have proposed a Maximum Power Point Tracking (MPPT) controller with battery charger circuit for LED streetlight [2]. It works on low DC voltage and low power consuming hence economical. Ali et al. [3] have presented an alternative solution for load shaving by adopting low power LED lamp fed with solar power and a battery charging control circuit for street lighting system. So it doesn't require supply from the grid. In another case autonomous control of LED street-lighting system powered by PV has been investigated with battery protection and power save mode of operation [4].

Liquid Crystal Display (LCD) possessing low cost, ultra low power consuming non-emissive display property dominates in the market [5]. Patent has also been filed on movable programmable LCD display powered with PV [6]. In [7] data acquisitioned from renewable energy (RE) system is received by RES collector computers with RF transceiver. The collector systems are connected to server by ethernet or internet and so are the remote users' computers that require the measurements. The display is done by using an Applet written in Java. However, the RF range is 200 m only which is short range for communication. Rizam et al. have developed real time remote monitoring of battery voltage for PV fed LED street light battery backup using WASPMOTE V1.1 wireless sensor network [8].

GSM communication has penetrated into rural areas. Alphanumeric data sending by SMS has been tested in agriculture via GSM to conduct field data acquisition and group broadcast. It consumes low power for communication, simple, fast and reliable without loss of data or interrupting voice communication on mobile. Thus, the communication range is up to 100 KM [9]. For stand-alone applications of PV for monitoring and control also none other than GSM device with SMS service is a cheap and simple solution [10].

So, from the survey it is concluded that a system has to be designed to make an efficient PV LED street lamp with a kind of display which has high sunlight readability, low power consumption, high ruggedness and can be remotely updated with the sent messages through a microcontroller (Arduino Uno) and GSM module (SIM900A) along with sufficient battery backup for an autonomous working for one and half a day. GSM facilitates the communication of displaying messages on notice board via user's mobile phones. But, the estimation of the PV power for minimum investment on battery, panel with its control circuit is not detailed in the literature from this application point of view. This paper deals with an innovative grid independent manner of intimating people by displaying the message wirelessly on electronic display board. It is a primary thing in any institution or public place like bus stop, railway station etc. The main advantage of this system is that, during emergencies it can be used to display alert messages or change schedule speedily. It can also be portable, easy to operate and consumes less power.

II. DEVELOPMENT OF THE SYSTEM MODEL

A standalone 9 watt white LED street lamp with charge control and battery backup of additional 0.5 days is to be designed. First the power requirement for the load of the system is estimated. Accordingly rating of the PV module and battery to be used is calculated in a systematic manner. The system model is given in Fig.1. For the notice board a system is designed to transmit message wirelessly as SMS by an authorized person. Its operation is based on a pre-programmed microcontroller ATMEGA328P apriori. A GSM modem with a SIM receives the SMS from mobile phone, and sends to the microcontroller which is displayed on the electronic notice board which is the LCD display.

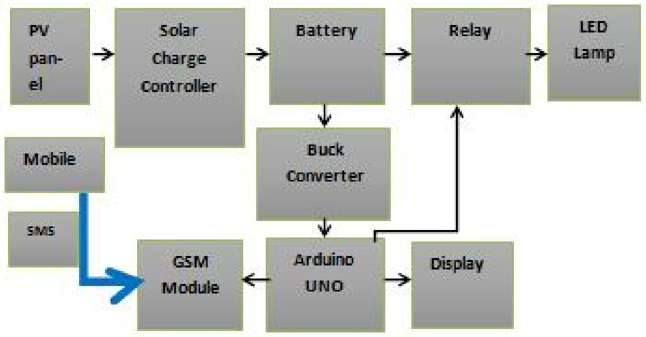

Fig. 1 Block diagram of the system

The DC-DC converter acts as an interface between the system and the load. A buck converter steps down to provide power at reduced voltage of 5V to the microcontroller, GSM module and display. The relay is used to switch on and off the LED street lamp as per daylight sensor automatically.

The output voltage of the buck converter, $V_o = V_s \frac{D}{1-D}$

Where V_s=Output voltage of battery supply and D= Duty ratio.

A. Designing Stand-alone PV system

The load has been estimated taking one full day and for next 8 hours back up for message display system as following a storm the irradiation may be less than that required to charge the battery on a normal day. This enables enough back up to send any important SMS further such as the re-strike of storm or any other information on weather and rescue operation on next day.

Table 1. Load estimation [12]

NAME	WATTS	HOURS	NUMBER	WATT-H
Street Light	9	12	1	108
Arduino Uno	0.3	24+8	1	9.6
GSM Module	2.6	24+8	1	83.2
LCD	0.04	24+8	1	1.28
Total Watt (A)				202.08

Considering the efficiency of charge controller and dividing the estimate Watt-h load by efficiency to get the corrected load.

(Correction factor= 1/efficiency of charge controller)
Efficiency of charge controller 0.85
Correction factor (B) = 1.1764
Watt-h/day(Corr.)= A/B=238.30 Watt
System Voltage= 12V
Amp-h/day= Watt-h/day(Corr.)/ System Voltage=19.81 Amp-h
Therefore, total Amp-h/day = 20(approx.).
The battery and PV panel capacity is calculated accordingly in table 2 and 3 respectively.

Table 2. Sizing of batteries

Steps	Value	Unit
Total daily Amp-h load per day required to be supplied from the PV array	20	Amp-h (or Ah)
Estimate total Amp-h required including autonomy. The total Amp-h capacity including autonomy is obtained adding extra Amp-h required for given autonomy. If daily requirement is X then total Amp-h including n days of autonomy is X+nX. The value of n can vary from 0 to 7 days or more.	20	Amp-h
Consider for the useful battery charge capacity as given in terms of depth of discharge (DoD); the DoD can vary from 20% to 80%. It depends on the type of batteries that you have planned to use. For PV system, batteries of higher DoD should be used.	0.75	
Effective Amp-h required after considering the DoD. (estimate Amp-h /DoD)	26.67	Amp-h
Choose the battery capacity. Depending on the size of the load small or big batteries can be chosen. Typical higher battery capacity as available is taken(Normally 12 V batteries are used.)	28	Number
Number of batteries required in parallel. (Amp-h / battery capacity).	1	Integer Number
Divide the system voltage (...V) by battery voltage (...V). This will give the number of batteries to connect in series for the desired system voltage.	1	Number
Required number of batteries	1	Number

Table 3. Sizing of PV module

Steps	Value	Unit
Total Amp-h per day required from step 1	20	Amp-h
Write down the battery efficiency for charging and discharging; it accounts for the battery loss during charge/discharge. Normally battery efficiency is in the range of 70% to 90%	0.8	%
Losses from the PV module due to higher temperature. This loss depends on the ambient temperature. It can vary approximately from 0% to 30 %. (20% variation taken)	0.8	%
Total losses (battery loss + loss due to temperature + any other losses, e.g. Due to dust). Calculate the total loss factor = (1/battery eff.*temperature eff.*other loss eff.)	1.4	A number greater than 1
The corrected daily Amp-h. This is obtained by multiplying the total Amp-h per day by total loss factor	28	Amp-h
Average number of sunshine hours (equivalent to 1000 W/m^2) per day in region. This number can vary between 4 and 7.	7	Days
Total Amp current to be produced by the PV modules. This is obtained by dividing the above 2 steps	4	Amp
Choose the peak power capacity of the module to be used in the system (10, 20, 40, 75 W_p etc.)	10	W_p
Total number of PV modules required in parallel = (Total Amp current produced by PV module/Peak Module Current)	1	Number
Number of PV panels to be connected in parallel. (Round off the above result)	1	Integer Number
Number of modules to be connected in series = (System voltage / Unit battery voltage)	0	Number
Total number of modules required in the PV system. This is obtained by adding the above two results.	1	Number

Table 4. Battery specifications

Type	Lithium-Ion
Voltage output (V)	12.6
Rated capacity (Ah)	28
Initial state-of-charge (%)	20
Battery response time (s)	75

As per the specification derived in table 4, for field implementation the Li-ion battery though costly is suggested when pole mounted in field as it will give maintenance free operation for a longer period. However, for laboratory scale to reduce cost, lead acid battery of convenient rating is proposed. Also the PV panel capacity is doubled (20Wp) to take up further research with additional facility. As per the above methodology, the cost of laboratory scale for 9W lamp and actual field setup for 30W street lamp are given in Appendix A and B respectively.

B. *Hardware, its design in simulation*

The hardware of the message display system before actual design in experimental set up is first simulated using Proteus [11]. The error free response was first checked and then developed in hardware. The power supply part (PV panel, buck converter, relay, battery and battery charger) as estimated is integrated. Proteus is used for designing the microcontroller, GSM and display circuit due to availability of Arduino microcontroller and sim9000A GSM module along with ease of use.

Proteus

Proteus (Processor for text easy to use) has many functions built in to handle data, string, files and mathematical calculations.

Arduino software (IDE)

Arduino is an open source platform, very useful for prototyping. It consists of a physical board and IDE (Integrated development environment) for easy prototyping and checking of the codes.

Arduino Uno

The Arduino UNO used herein (fig.2) is a low cost light weight board that contains of microcontroller ATMEGA328P. It is 8 bit AVR RISC based microcontroller. It is programmed in embedded C. It consists of 6 analog pins, 14 digital I/O pins out of which 6 are for provision of PWM. It works at 16MHz clock speed with SRAM, EEPROM and flash memory of 2kb, 1kb and 32kb respectively. The pin arrangement is shown in fig.3.

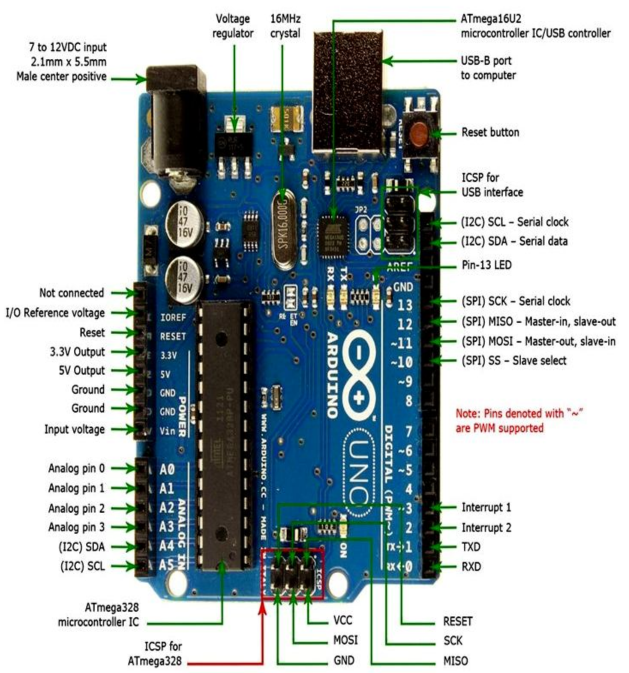

Fig. 2 Arduino Uno Board [11]

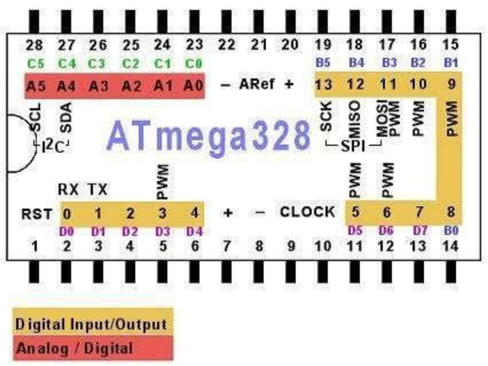

Fig. 3 Pin diagram of ATMEGA328P [11]

GSM Modem

Global System for Mobile Communication (GSM) is an - ETSI (European Telecommunication Standard Institute) standard for a PAN – European Communication System. GSM system uses carrier frequencies around 900MHz. GSM MODEM sends and receive message through radio waves.

Fig. 4 SIM900D GSM Module

The SIM900D GSM module shown in fig.4 is a low power consuming, compact GSM modem for four bands for communication, voice, SMS, data and fax [11]. It has a single chip processor with TCP/ IP protocol stack. It is controlled by AT commands. The SMS from mobile of authenticated user can be displayed in the display by communication via the modem and microcontroller.

Liquid crystal display (LCD)

LCD is an electronic device that works at 5V, 1.2 mA. A 14 pin 16X2 LCD as shown in fig.5 represents 16 characters in 2 lines. LCD is economical and easily programmable to display text and special characters.

Fig.5 LCD module

Connections to Arduino board

To wire LCD screen to Arduino board, the pins of LCD such as RW is joined with GND; D&, D6, D5, D4, E and RS are connected to digital pins 4,5,6,7,11 and 12 respectively.From GSM SIM900D TX and RX pins are joined with digital pins 2 and 3 of Arduino board respectively. A virtual terminal is connected to the RX and TX pins to observe the data transferred by serial port from modem to Arduino. After establishing the connections as discussed, running the Proteus simulation as in fig.6 displays the sent message "Cyclone Approaching" in the virtual terminal and LCD. Two unique characters '#' and '*' are used as first and last characters of the string of message as an authentication given to user. The Arduino IDE written sketch given in Appendix C serves the following purpose:

1) First the connection of LCD to Arduino Uno is checked.
2) The LED built in pin 13 is set as output.
3) The LCD is initialized.
4) The GSM is initialized and sends the message to LCD.
5) The connection of GSM to Arduino is checked sending AT command and GSM module is set to text mode by AT+CMGF==1.
6) AT+CNMI=2,2,0,0,0 sets the response mode of modem to serial input of SMS.

7) According to the daylight sensor LDR value, the LED lamp is turned on or off on which the relay acts.
8) After serial reading of up to 100 characters, the LCD shows “message received” following which the message up to 32 characters displays on LCD and then scrolls left.
9) Delays of different durations are applied in between to pause the program for scrolling and appearing of message on the board which can be adjusted as required during Arduino IDE coding.

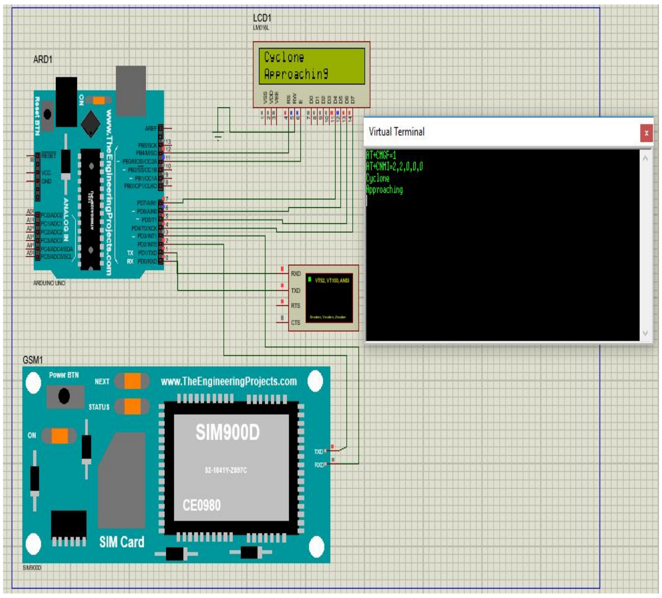

Fig. 6 Proteus simulation of the notice board model

III. CONCLUSION

In this paper the optimum size of PV array and battery is estimated for the application of single pole mounted PV fed message and streetlight system. The integration of Arduino with LCD was simulated in Proteus. Further research for making this work a reality with reduced cost is utmost necessity. The hardware implementation in field, studying its characteristics and improved design for multipurpose use is of future interest.

IV. APPENDIX

A. Cost for experimental setup

Sl.	Name of the Item	Unit cost (Rs.)	Quan-tity	Cost (Rs.)
1	PV panel (20W)	15000	1	15000
2	Lead Battery (26Ah, 12V)	3588	1	3588
3	Buck Converter (21V to 12V DC) (12V to 5V DC)	800	2	1600
4	MPPT Charge	1200	1	1200
5	Arduino Uno ATMEGA328P	1400	2	2800
6	GSM Module with SIM900	2000	1	2000
7	LCD with driver circuit	1000	1	1000
8	Light Detecting Register for day night	250	1	250
9	Relay	150	1	150
10	LED Street Light (9W,12V DC)	1600	1	1600
11	Miscellaneous	1000	1	1000
	Total Cost			30888

B. Cost for field implementation

Sl.	Details of expenditure	Unit Cost (Rs.)	Quan-tity	Estimated Cost (Rs.)
1	PV array (40W, 12V) with MPPT and charge controller	25000	1	25000
2	Lithium Ion Battery (12.6 V, 81 Ah)	43000	1	43000
3	Battery Charger	8000	1	8000
4	Buck converter	800	2	1600
5	30 W LED street lamp	4000	1	4000
6	Lamp post	6000	1	6000
7	Clamp, fixtures, cable & casing etc	4000	LS	4000
8	GSM module with SIM900	2000	1	2000
9	Arduino Uno board with microcontroller	1400	2	2800
10	LCD display with driver	1000	1	1000
11	Soldering iron	500	1	500
12	Relay	150	1	150
13	Day night sensor (LDR)	250	1	250
14	PCB set	1000	1	1000
15	Connecting wires	LS	LS	500
16	SIM Card	100	1	100
17	Miscellaneous Cost			3000
	Sub-total			102900
18	R &D cost 10%			10290
19	Import & Transportation cost 20%			20580

	Total Cost			133770
	Total Cost		1337	

C. Arduino sketch for control

```
#include <SoftwareSerial.h>
#include <LiquidCrystal.h>
#define LDRpin9  // pin for LDR
intLDRValue = 0; // read the analog pin and give result
LiquidCrystallcd(7,6,5,4,3,2);//RS,E,D4,D5,D6,D7   RW,VSS-G,VDD-5V
SoftwareSerialmySerial(11,12);//rx,tx
int temp=0,i=0,x=0,k=0;
charstr[100],msg[32];
void setup()
{
pinMode(LED_BUILTIN, OUTPUT); // set digital pin 13 to be output
lcd.begin(16,2); // initialize LCD
Serial.begin(9600);
mySerial.begin(9600); // initializing GSM module
lcd.print("GSM Initilizing...");
lcd.setCursor(0,0);
lcd.print("Wireless Notice");
lcd.setCursor(0,1);
lcd.print("    Board      ");
delay(1000);
lcd.clear();
mySerial.println("AT"); //Send AT command to GSM to test connection
delay(1000);
mySerial.println("AT+CMGF=1"); // GSM in text mode
Serial.println("AT+CMGF=1");
delay(1000);
mySerial.println("AT+CNMI=2,2,0,0,0"); //Set serial input of SMS to the modem Serial.println("AT+CNMI=2,2,0,0,0");
delay(1000);
digitalWrite(led, LOW);
}
void loop()
{
LDRValue = digitalRead(LDRpin);// read from the LDR
Serial.println(LDRValue);         // print the value to the serial port
delay(100);                   // wait a little
if(LDRValue==1)
  {
digitalWrite(LED_BUILTIN, HIGH);     // turn the LED on (sets voltage HIGH )
delay(1000);// wait for a second
  }
else
  {
digitalWrite(LED_BUILTIN, LOW);       // turn the LED off (sets voltage LOW)
delay(1000);                    // wait for a second
  }
for(unsigned int t=0;t<60000;t++)
  {
serialEvent();// serially reads the characters of SMS starting with a '*'
if(temp==1)
  {
    x=0,k=0,temp=0;
while(x<i)
    {
while(str[x]=='#')
      {
x++;
while(str[x]!='*')
        {
msg[k++]=str[x++];
        }     }
x++;
    }
msg[k]='\0';
lcd.clear();//Clear LCD
lcd.setCursor(0,0);
lcd.print(msg);
delay(10000);
Serial.println(msg);
delay(1000);
temp=0;
    i=0;
    x=0;
    k=0;
  }  }
lcd.scrollDisplayLeft();
}
voidserialEvent()
{
while(mySerial.available())
  {
charch=(char)mySerial.read();
str[i++]=ch;
if(ch == '*')
    {
temp=1;
lcd.clear();
lcd.print("Message Received");
delay(1000);
    }  } }
```

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