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DESIGN OF STANDALONE HYBRID LIGHTING SYSTEM

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ABSTRACT

This paper presents the solar-wind hybrid based lighting system. Solar-wind Hybrid Street light is a small scale, intelligent and off-grid LED lighting system. It is composed of solar panels, DC wind generator, batteries, charge controller, high brightness LED light. The LED light utilizes energy from the battery automatically during the night time. The advantage of this idea is to avoid daily running cost and make the system purely off-grid. The proposed design approaches 24V DC system rather than using existing 12V DC system to reduce the charging/discharging current and wire losses. In this paper we design a 24V hybrid based LED lighting system.

Keywords: High Brightness LED, Charge Controller, Photo Transistor, Brushless DC Generator

I. INTRODUCTION

Solar energy and wind energy are clean, illimitable, and environmental friendly. The energy sectors were already attracted to use renewable energy in large scale. Day by day the power crisis increases in our country, the government also attracting the peoples to use renewable energy by giving 50% subsidy. Now we are in the exact time to elevate from conventional power generating system. Both sources are dependent on unpredictable factors such as climatic and weather conditions. Due to complimentary nature of our climate and also because of using both the sources we can overcome the weakness of the existing single source system. Thus we are placing both the sources near the load; it can also be called as hybrid distributed generation. This can also reduce transmission and distribution cost. The proposed system can also be used for home power generation and the capacity will depends on load requirement. The hybrid lighting systems [2] are self-sustaining, standalone solutions and also it reduces the transmission and distribution losses. This proposed system is supreme solutions for many applications in rural and urban areas.

Now a day’s LED based lightings are more preferred than CFLs, fluorescent and halogen lamps for street lighting, because of less power consumption, higher power factor, less carbon emission, etc., The existing solar street lighting system uses mono-crystalline or poly-crystalline panels and stores the energy in a lead acid battery. There will be a control system to control the battery charging and discharging. The battery should be selected depending on cost, return on investment, efficiency and cycle of operation. Influential factors such as response time (ms to hours/day), energy density (size and space requirements), environmental impact and charge time are also considered while choosing the battery. Automatic streetlight needs automatic switching ON and OFF without using manual control. The system itself detects the outside illumination level and controls the brightness of the LED. When outside illumination is very low then automatically LED is switched ON and when the outside illumination is high then the LED is switched OFF. This is done by using light dependent resistor

(LDR), photo transistors, etc., As like that of the solar panels, LEDs are also having two types High brightness LED (HBLED) and High power LED (HPLED), depending on the availability of the power and also depending on the requirement we are choosing the LEDs. In this paper we have chosen high power LEDs of 60W which will give 3500 lumens as output.

II. WORKING OF HYBRID SOLAR-WIND SYSTEM

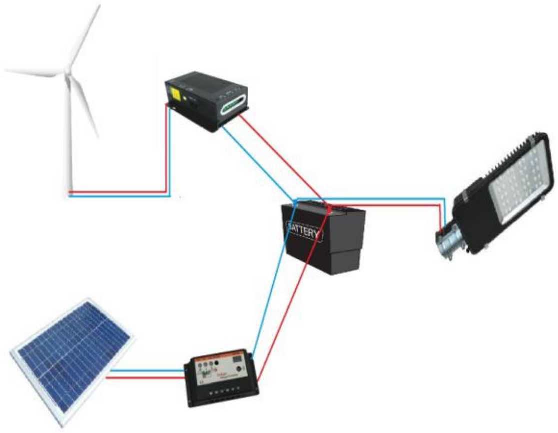

Fig.1 Model of Proposed hybrid solar-wind system

A stand-alone wind system with solar photovoltaic system is the best hybrid combination of all renewable energy systems and is most appropriate for all the applications. This combination supports both our climatic seasons, for example, more energy production through wind system during monsoon months compensates low output generated by solar. Similarly, during winter when the wind energy is dull, solar photovoltaic takes over. The hybrid solar wind power system is as shown in fig.1. Applications of Proposed Solar-Wind Hybrid Power System are given below [3]-[6].

- Remote and rural area electrification,
- General lighting systems for Residential colonies and apartments.
- Street lighting

With the use of proposed system the carbon emission and other harmful gases are reduced to approximately 80% to 90% in the environment.

III. DESIGN OF PROPOSED HYBRID MODEL

A. Energy storage system

The energy storage system is nothing but a lead acid battery. The design for choosing the battery size and its calculations are given below.

Initially we have taken the load power as 60W, 24V LED light which runs for an average time of 10hours a day.

Load power = 60W

For 10 hours the total power consumed by the load = 60*10 hours

Total load power = 600Whr

To find the battery capacity,

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$$\text{Average AH/day} = \frac{\text{Total load power in (Whr)}}{\text{Battery Voltage}}$$

We have taken the battery voltage as 24V [2]. Therefore the battery current as per the above calculation is 25A for an average load for 10hrs a day.

Days of autonomy = 2

Discharge limit is 50%

$$\text{Total Battery AH capacity} = \frac{\text{Average AH/day*Days of autonomy}}{\text{Discharge Limit}}$$

So the battery capacity to supply the load for 10 hours a day is 100AH. Actually we have chosen 2*12V batteries of 100AH from the Exide manufacturer. So both 100AH batteries will be connected in parallel to get 24V.

B. Design of charge controller and pv module

The installed capacity of solar power in India is only 3,744 MW while the available energy potential is 749 GW. Inability to harness the abundant renewable power sources has led to power shortage in the rural sectors.

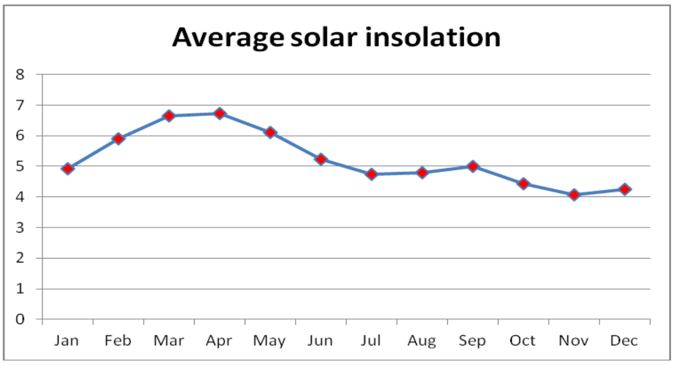

Fig.2 Average solar insolation

The photovoltaic control is a voltage regulator. The primary function is to prevent the battery from being overcharged by the array. Fly-back converter is more efficient when it is used for less than 70W load. And also it is having the advantage of an isolation as well as voltage regulation [1]. The charge controller may be a shunt controller, single stage controller, multistage controller or pulse controller depending upon the requirement of output power quality and protection [7]-[8].

The 24V DC battery that will power the LED light will be connected to the solar panels via the charge controller for charging purpose [12]-[13]. The street light pole will be constructed such that it will hold the LED light.

$$\text{Input energy required to charge controller} = \frac{\text{Battery AH}}{\text{Efficiency of charge controller}}$$

The following table shows the average solar insolation

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Table.1 [11]

Month	Average solar insolation
Jan	4.93
Feb	5.89
Mar	6.64
Apr	6.72
May	6.12
Jun	5.24
Jul	4.73
Aug	4.80
Sep	5.01
Oct	4.42
Nov	4.06
Dec	4.24

So as per the above formula the charge controller should have the current rating of 111.1AH.

Calculation of PV panels and rating required are given below,

$$\text{Input required from PV module} = \frac{\text{Input of charge controller}}{\text{Number of sun shine hours}}$$

We assumed average number of sun shine hours in our country for a day is takes as 6 hours. So the required current from PV module is 19A and the number of panels required is,

$$\text{Number of panels} = \frac{\text{Required current from PV module}}{\text{Average current of a single panel}}$$

2 panels are required with the average current of a single panel is 9A.

Fig.3. Design of Solar System

Power extracted by the wind turbine is $P_{w} = 0.5 * A * C_p * \rho * \upsilon^3$

Where C_p is the power coefficient and is given by

$$C_{p} = \frac{\text{Power in the wind turbine}}{\text{Power in the air}}$$

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The value of C_p is limited by Betz limit to 0.593

Power in the air = $P_{air} = 0.5 * A * \rho * \upsilon^3$

ρ is the air density in $Kg/m^3 = 1.3$

Where A is the area swept by the rotor in m^2

υ is the wind speed in m/s

The swept area A is given by

$A = \pi r^2$

Where r is rotor blade diameter in m

C. Wind energy system

Wind power harnessing has improved exponentially in the last few decades with enhanced rotor designs. The revolution in power electronics has led to the operation at variable wind speeds thus reducing the generating cost.

The most commonly used generators for wind energy are

- Doubly Fed Induction generator
- Wound rotor induction generator
- Squirrel cage induction generator
- Permanent magnet synchronous generator

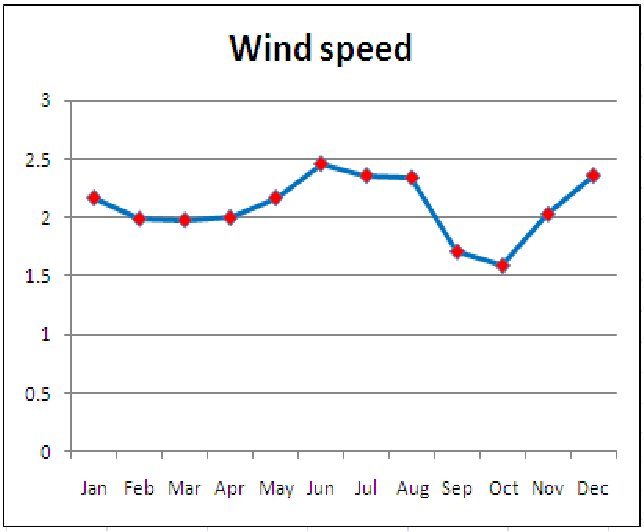

Fig 4. Wind speed (m/sec) Vs Months of a year

Electrical Power can be generated from wind using a wind turbine which extracts the kinetic energy of wind and converts it to mechanical energy. This is further converted to electrical energy by means of a generator. Stand alone Wind power generation uses batteries to store power due to non uniformity of wind.

The following table shows the monthly average wind speed

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Table.2

Month	Average wind speed
Jan	2.17
Feb	1.99
Mar	1.98
Apr	2.00
May	2.17
Jun	2.46
Jul	2.36
Aug	2.34
Sep	1.71
Oct	1.59
Nov	2.03
Dec	2.36

As per the above table we have taken the annual average wind speed as 2.1m/s.[10]

D. Design of wind energy system

The generated wind power capacity in India is 7456MW. Wind plants are set up based on the availability of wind speed in the area. When a free moving air molecule is struck by any object, it produces a pressure which is felt in the vicinity of the object. So a wind turbine can be mounted atop the street lamp pole where wind from moving vehicles enables the wind turbine to rotate. The installed capacity of wind power in India is 23,439.26 MW, but the available wind energy potential in India is 302 GW. The tapping of unexploited wind energy is the most important aspect to dwell upon so as to meet the national power demand. The wind module has a wind turbine coupled to a PMBLDC generator and a charge controller. The output of the charge controller is connected to a battery which in turn feeds the DC load.

The components of the proposed wind module are Wind generator (PMBLDC), charge controller, Batteries and Load

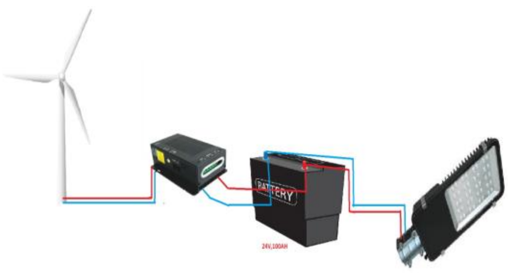

Fig.5. Design of Wind energy system

Wind generator: The proposed solar-wind hybrid system uses a PMBLDC generator. The output available from the generator is DC and hence can be given to the batteries directly through the charge controller. This reduces the size of the design and the cost due to the elimination of a rectifier. It eliminates the use of gear box and hence reduces losses in the gear box.

Charge controller: The wind generator operates on variable wind speeds thus generating a variable voltage. The charge controller [9] here plays a major role in regulating the generated voltage. It protects the battery from over charging. The output voltage of the charge controller is regulated by the duty cycle of the PWM signal from the MPPT controller.

To charge a 100 Ah battery, the required charge controller calculations are,

$$\text{charge controller ampere rating} = \frac{\text{total ampere hour}}{\text{efficiency of charge controller}}$$

Thus the required ampere rating for the charge controller is 112A for a 24 V DC load.

$$\text{Required current to the charge controller} = \frac{\text{input current to the charge controller}}{\text{No of hours of wind availability}}$$

Considering the wind availability for 4 hours,

to charge a 100Ah battery we need a current of 26A.

Required generator rating = Total current * dc supply Voltage

So we need a generator of 700W.

Specifications of wind generator:

Table 2: Specification of Wind Generator

Rated Power	350W
Maximum Power	700W
Blade quantity	3
Start up wind speed	2.5m/s
Rotor blade diameter	1.7m
Rated wind speed	10m/s
Working wind speed	2.5m/s
Charging voltage	12/24V
Generator type	PMBLDC

The proposed hybrid wind-solar model is set up at latitude13.0826, longitude 80.2707, 16m above sea level.

IV. DESIGN OF PROTOTYPE

The proposed model is designed as a prototype and installed as a study lamp with mobile charger. The total power of 18W supplies a 12W LED light and a 5W mobile phone. Lithium ion battery bank is used as a backup to store the power when the solar and wind power is available. The prototype comprises of two sources to meet the required demand of 18W. It has a solar panel and a wind generator which supplies power of 10W each. The wind generator is a BLDC motor which acts as a generator. The mini solar wind hybrid prototype is shown in Fig.5. The stem of the hybrid prototype model is 1.5 feet high with four arms. Each arm contains a 3W LED light that makes a total of 12W. The prototype supplants the solar panel with thin film solar panels, which will charge the battery bank even at low light conditions.

Fig.6. Prototype model of the proposed system

The wind solar hybrid model is placed near the window to acquire wind and solar power for the battery.

V. CONCLUSION

As discussed above the study lamp with mobile charger is successfully installed in our research lab. The future work is to reduce the cost of the working model and to make it available to the needy. Scholars should work towards making India a nation with affordable and clean energy by tapping the renewable energy assets in an ideal way. The prototype of the proposed model is made and tested for optimum output. Based on the prototype design, the real time implementation will be done at latitude13.0826, longitude 80.2707, 16m above sea level location.

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