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Rural Electrification with Wind Solar Hybrid Generation System Using MPPT

Onkar B. Hedurshetti[1]*, Mohsin A. Mulla[2], Nanda Huchareddi[3]

[1]Assistant Professor (EEE), HIT Nidasoshi

[2]Assistant Professor (EEE), HIT Nidasoshi

[3]Student (EEE), HIT Nidasoshi

Abstract – In India the current situation of electricity transmission and distribution system is consistently falling behind in providing satisfactory supply of electricity. Everyday new appliances are coming up which run on electricity because of which there is continuous increase in demand for electricity. But due to limited resources, climatic conditions and majorly due to greater losses in transmission and distribution system these demands cannot be met conveniently. And hence to manage the demands satisfactorily, a utility goes for load shedding. In country like India the rural areas are the worst affected due to frequent load shedding. And 60% of population lives in rural areas. Therefore in this paper a viable solution is discussed where the environment and geographical advantages, such as abundant open lands and trains available at these remote and rural localities, can be utilized for generating to meet local electricity demands. Thereby both environment and people are benfited and Utilities can manage electricity demands satisfactorily. The wind solar hybrid generation system is a kind of generation system that combines wind energy with solar and cause them complement each other to generate power. Use of Maximum Power Point Tracker(MPPT) charge controller makes the system very efficient and reliable.

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1. INTRODUCTION

Some developing countries and newly-industrialized countries have several hours of daily power cuts in almost all cities and villages because of the increase in demand for electricity exceeds and increase in electric power generation. Wealthier people in these countries may use a power-inverter (rechargeable batteries)or a diesel/petrol-run electric generator at their home during the power cut the use of standby generator is common in industrial and it hubs.

In this paper, a new converter topology for hybridizing the wind and solar energy sources has been proposed. In this topology, both wind and solar energy sources are incorporated together so that if one of them is unavailable then the other source can compensate for it. The average output voltage produced by the system will be the sum of the inputs of these two systems. All these advantages of the proposed hybrid system make it highly efficient and reliable. Hence the ultimate objective of this project is to develop much cleaner cost effective and stable way of power generation method, which in turn helps to bring down the global warming as well as reduce the power shortages.

1.1. Basics of Wind Turbine

A wind turbine is a device that converts kinetic energy from the wind into electrical power. The term appears to have migrated from parallel hydroelectric technology (rotary propeller). The technical description for this type of machine is an aerofoil-powered generator. The result of over a millennium of windmill development and modern engineering, today's wind turbines are manufactured in a wide range of vertical and horizontal axis types. The smallest turbines are used for applications such as battery charging for auxiliary power for boats or caravans or to power traffic warning signs. Slightly larger turbines can be used for making contributions to a domestic power supply while selling unused power back to the utility supplier via the electrical grid. Arrays of large turbines, known as wind farms, are becoming an increasingly important source of renewable energy and are used by many countries as part of a strategy to reduce their reliance on fossil fuels.

In this hybrid generation system, savonious type vertical axis wind turbine is used owing to its numerous advantages such as

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- Turbine does not need to be pointed towards the wind in order to be effective
- VAWTs are suitable in places like hilltops, ridgelines and passes
- Blades spin at a lower velocity, thus, lessening the chances of bird injury
- Suitable for areas with extreme weather conditions like mountains.

Savonius turbines are one of the simplest turbines. Aerodynamically, they are drag-type devices, consisting of two or three blades (vertical – half cylinders). A two blades savonius wind turbine would look like an "S" letter shape in cross section. The savonius wind turbine works due to the difference in forces exert on each blade. The lower blade (the concave half to the wind direction) caught the air wind and forces the blade to rotate around its central vertical shaft. Whereas, the upper blade (the convex half to wind direction) hits the blade and causes the air wind to be deflected sideway around it.

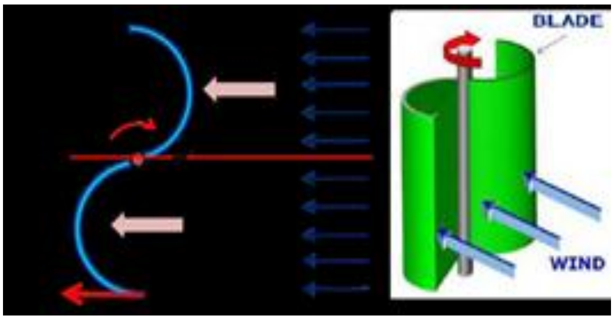

Fig1.1. a. Two blade savonios wind turbine

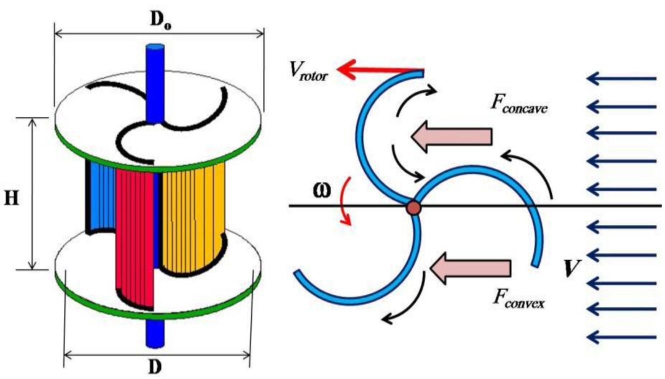

Fig1.1.b. Savonios wind turbine working

Because of the blades curvature, the blades experience less drag force (*Fconvex*) when moving against the wind than the blades when moving with the wind (*Fconcave*). Hence, the half cylinder with concave side facing the wind will experience more drag force than the other cylinder, thus forcing the rotor to rotate. The differential drag causes the Savonius turbine to spin. For this reason, Savonius turbines extract much less of the wind's power than other similarly sized lift type turbines because much of the power that might be captured has used up pushing the convex half, so savonius wind turbine has a lower efficiency. Similarly, the three blade savonius wind turbine is constructed from three half cylinders, they are arranged at (120^o) relative to each other as shown in figure1.1.b.

2. DESIGN OF WIND TURBINE:

The prototype wind turbine is designed for output power of 100 watts.

Therefore design parameters are

Power available in the wind= $(\rho V_1^3)/2$ watt/m^2

Where, ρ=1.226 kg/m^3, on average V_1= 6 m/s

Power available in the wind= 132.4 watt/m^2

Reasonable power density= power available in wind* efficiency

= 132.4*0.25

= 33.1 watt/m^2

Swept area=power output/reasonable power density

= 100/33.1

= 3.02 m^2

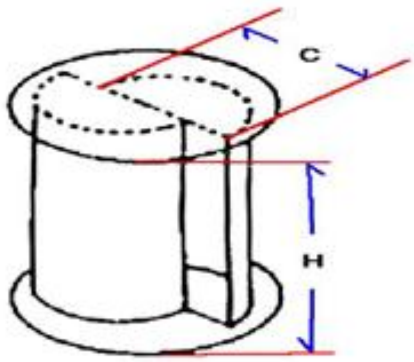

Fig2.a. prototype savonious wind turbine

Prototype savonious wind turbine to generate output power of 100 watts is as shown in Fig.2.a.

Whlile designing the turbine aspect ratio should be maintained between 2 and 3 for reliable and stable operation. Therefore here height of the turbine H is

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selected as 6 ft and diameter of the turbine is selected as 2.5 ft.

Therefore,

Aspect ratio= H/C

= 6/2.5

= 2.4

And overlap length, a = 0.3* C

= 0.3*2.5

= 0.75 ft

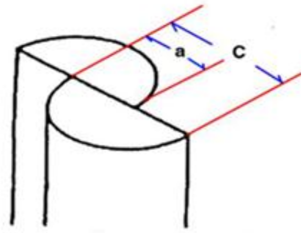

Fig.2.b. Showing overlap length

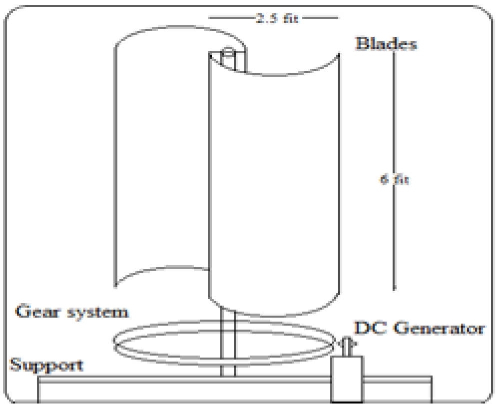

Fig.2.c. savonious wind turbine working model

A working model of savonious wind turbine is shown in fig.2.c. It consists of the turbine mounted on the shaft which is coupled to a permanent magnet DC generator with the help of gear assembly. The entire setup is mounted on a robust triangular shaped structure that provides it a stable base.

3. WORKING OF SOLAR CELL

3.1.Operating principle

Solar cells are the basic components of photovoltaic panels. Most are made from silicon even though other materials are also used. Solar cells take advantage of the photoelectric effect: the ability of some semiconductors to convert electromagnetic radiation directly into electrical current. The charged particles generated by the incident radiation are separated conveniently.

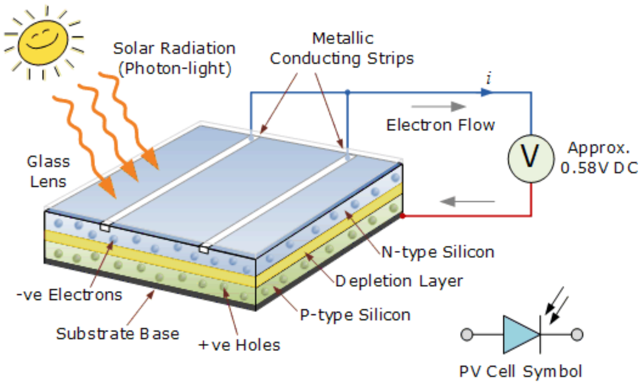

Fig 3.1.a working of solar cell

Metallic contacts are added at both sides to collect the electrons and holes so the current can flow. In the case of the n-layer, which is facing the solar irradiance, the contacts are several metallic strips, as they must allow the light to pass to the solar cell, called fingers.

The structure of the solar cell has been described so far and the operating principle is next. The photons of the solar radiation shine on the cell. Three different cases can happen: some of the photons are reflected from the top surface of the cell and metal fingers. Those that are not reflected penetrate in the substrate. Some of them, usually the ones with less energy, pass through the cell without causing any effect. Only those with energy level above the band gap of the silicon can create an electron-hole pair. These pairs are generated at both sides of the p-n junction. The minority charges (electrons in the p-side, holes in the n-side) are diffused to the junction and swept away in opposite directions (electrons towards the n-side, holes towards the p-side) by the electric field, generating a current in the cell, which is collected by the metal contacts at both sides.

This can be seen in the figure above, Figure. This is the light-generated current which depends directly on the irradiation: if it is higher, then it contains more photons with enough energy to create more electron-hole pairs and consequently more current is generated by the solar cell.

Equivalent circuit of a solar cell

The solar cell can be represented by the electrical model shown in Figure. Its current voltage characteristic is expressed by the following equation (1):

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$$I = I_L - I_0\left(e^{\frac{q(V-IR_S)}{AkT}} - 1\right) - \frac{V - IR_S}{R_{SH}} \qquad (1)$$

where I and V are the solar cell output current and voltage respectively, I0 is the dark saturation current, q is the charge of an electron, A is the diode quality (ideality) factor, k is the Boltzmann constant, T is the absolute temperature and RS and RSH are the series and shunt resistances of the solar cell. RS is the resistance offered by the contacts and the bulk semiconductor material of the solar cell. The origin of the shunt resistance RSH is more difficult to explain. It is related to the non ideal nature of the p–n junction and the presence of impurities near the edges of the cell that provide a short-circuit path around the junction . In an ideal case RS would be zero and RSH infinite. However, this ideal scenario is not possible and manufacturers try to minimize the effect of both resistances to improve their products.

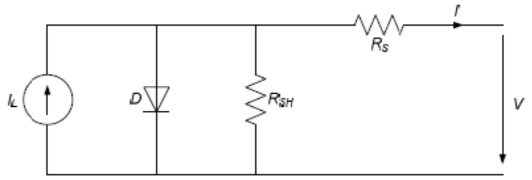


Fig 3.1.b equivalent circuit of solar cell

Sometimes, to simplify the model, the effect of the shunt resistance is not considered, i.e. RSH is infinite, so the last term in (1) is neglected.

A PV panel is composed of many solar cells, which are connected in series and parallel so the output current and voltage of the PV panel are high enough to the requirements of the grid or equipment. Taking into account the simplification mentioned above, the output current-voltage characteristic of a PV panel is expressed by equation (2), where np and ns are the number of solar cells in parallel and series respectively.

$$I \approx n_p I_L - n_p I_0\left(e^{\frac{q(V-IR_S)}{AkTn_s}} - 1\right) \qquad (2)$$

Open circuit voltage, short circuit current and maximum power point

Two important points of the current-voltage characteristic must be pointed out: the open circuit voltage VOC and the short circuit current ISC. At both points the power generated is zero. VOC can be approximated from (1) when the output current of the cell is zero, i.e. I=0 and the shunt resistance RSH is neglected. It is represented by equation (3). The short circuit current ISC is the current at V = 0 and is approximately equal to the light generated current IL as shown in equation (4).

$$V_{OC} \approx \frac{AkT}{q} ln\left(\frac{I_L}{I_0} + 1\right) \qquad (3)$$

$$I_{SC} \approx I_L \qquad (4)$$

The maximum power is generated by the solar cell at a point of the current-voltage characteristic where the product VI is maximum. This point is known as the MPP and is unique, as can be seen in Figure 3, where the previous points are represented.

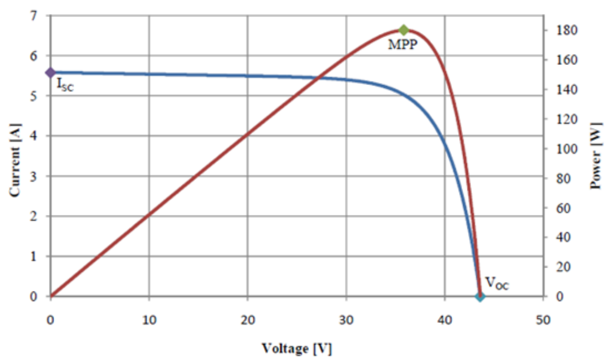
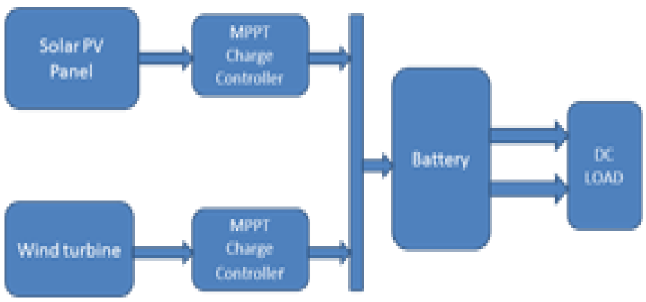


Fig 3.1.c max power point in characteristics curve

4. HYBRID POWER GENERATION:

Block Diagram



4.1. Solar PV Cell

Absorption of incident photons to create electron - hole pairs. Electron-hole pairs will generate in the solar cell provided that the incident photon has an energy greater than that of the band gap. However, electrons (p-type material), and holes (n-type material) are meta-stable and will only exist, on average, for a length of time equal to the minority carrier lifetime before they recombine. If the carrier recombines, then the light-generated electron-hole pair is lost and no current or power can be generated.

Collection of these carriers by the p-n junction prevents this recombination by using a p-n junction to

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spatially separate the electron and the hole. The carriers are separated by the action of the electric field existing at the p-n junction. If the light-generated minority carrier reaches the p-n junction, it is swept across the junction by the electric field at the junction, where it is now a majority carrier. If the emitter and base of the solar cell are connected together (i.e., if the solar cell is short-circuited), then the light-generated carriers flow through the external circuit.

4.2.Wind Mill

A wind mill is a device that converts wind energy into mechanical energy which is later converted into electrical energy. A windmill typically consists of following parts:

Blades- A windmill can consists of any number of blades from four to twenty. Some special windmills have higher number of blades.

Shaft- The shaft is responsible for joining the blades with the tower and for the smooth rotation of blade.

Gear system- Gear system is consist of gear box used to increases the speed of rotor to the rated speed of generator.

Wind turbines use wind to produce electricity. The wind exerts force on the blades, which spin a shaft, which is connected to a generator and produces electricity.

4.3. MPPT Charge Controller

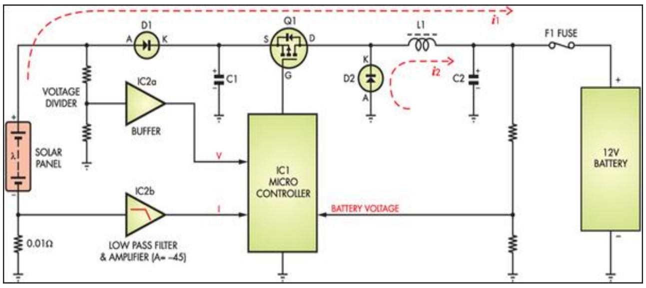

Fig 4.3. Circuit Diagram of MPPT charge Controller

PWM and MPPT charge controllers are both widely used to charge batteries with solar power. The PWM controller is in essence a switch that connects a solar array to the battery. The result is that the voltage of the array will be pulled down to near that of the battery. The MPPT controller is more sophisticated (and more expensive): it will adjust its input voltage to harvest the maximum power from the solar array and then transform this power to supply the varying voltage requirement of the battery plus load. Thus, it essentially decouples the array and battery voltages so that there can be, for example, a 12 volt battery on one side of the MPPT charge controller and panels wired in series to produce 36 volts on the other.

It is generally accepted that MPPT will outperform PWM in a cold to high temperate climate, while both controllers will show approximately the same performance in a subtropical to tropical climate. In this paper the effect of temperature is analyzed in detail, and a quantitative performance comparison of both controller topologies is given.

4.4. Battery storage system:

Energy output obtained from dc to dc converter is simultaneously given to both load and battery. During normal operation battery is charged and whenever there is insufficient supply or at off period, battery act as backup supply for the lighting load.

4.4.1. Bulk Charge

The primary purpose of a battery charger is to recharge a battery. This first stage is typically where the highest voltage and amperage the charger is rated for will actually be used. The level of charge that can be applied without overheating the battery is known as the battery's natural absorption rate. For a typical 12 volt AGM battery, the charging voltage going into a battery will reach 14.6-14.8 volts, while flooded batteries can be even higher. For the gel battery, the voltage should be no more than 14.2-14.3 volts. If the charger is a 10 amp charger, and if the battery resistance allows for it, the charger will put out a full 10 amps. This stage will recharge batteries that are severely drained. There is no risk of overcharging in this stage because the battery hasn't even reached full yet.

4.4.2. Absorption Charge

Smart chargers will detect voltage and resistance from the battery prior to charging. After reading the battery the charger determines which stage to properly charge at. Once the battery has reached 80%* state of charge, the charger will enter the absorption stage. At this point most chargers will maintain a steady voltage, while the amperage declines. The lower current going into the battery safely brings up the charge on the battery without overheating it. This stage takes more time. For instance, the last remaining 20% of the battery takes much longer when compared to the first 20% during the bulk stage. The current continuously declines until the battery almost reaches full capacity.

4.4.3. Float Charge

Some chargers enter float mode as early as 85% state of charge but others begin closer to 95%. Either way, the float stage brings the battery all the way through and maintains the 100% state of charge. The voltage will taper down and maintain at a steady 13.2-13.4 volts, which is the maximum voltage a 12 volt battery can hold. The current will also decrease to a

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point where it's considered a trickle. That's where the term "trickle charger" comes from. It's essentially the float stage where there is charge going into the battery at all times, but only at a safe rate to ensure a full state of charge and nothing more.

4.4.1Specification Of Battery:

Lead acid tubular type

Voltage =12V

Ampere hour =100Ah

4.5. DC Load and generator

SPECIFICATIONS:

- Power: 10 watt.
- Voltage:12 volt

DC GENERATOR:

SPECIFICATIONS:

- Power: 100 watt.
- Voltage:12 volts.
- Current: 10 amps.
- Speed: 600 rpm.

5. WORKING OF HYBRID SYSTEM:

Solar panel refers to a panel designed to absorb the sun's rays as a source of energy for generating electricity or heating. A photovoltaic (in short PV) module is a packaged, connected assembly of typically 6×10 solar cells. Solar Photovoltaic panels constitute the solar array of a photovoltaic system that generates and supplies solar electricity in commercial and residential applications. Each module is rated by its DC output power under standard test conditions, and typically ranges from 100 to 365 watts. In this hybrid system the solar power we generating is 250 watt.

Wind turbine is coupled DC generator which converts rotational energy into electrical energy, which is in the form of DC and totally depends on kinetic energy of wind. The power generation by using wind in this hybrid power generation is 100 watt by using the 100 watt, 12volt, 600 rpm DC permanent magnet generator.

Since, we are using MPPT charge controller for both solar and wind power generation as a charge controller for charging of battery MPPT will operate the whole module at the voltage and current rating so that the module can deliver its maximum available generated power. The MPPT uses the buck and boost type converters to to reduce or to increase the voltage for charging of battery.

Charging of the battery will takes place in three different stages, viz,

1] Bulk charge

2] Absorption charge

3] Float charge,

which will ensure the safe and sure charging of the battery.

The DC load is either directly connected to the battery or there is provision in the MPPT charge controller for connecting the DC load.

6. RESULTS

Table6.1 Output of Wind Generation

Velocity in m/s	Speed in rpm	Voltage in volts	Power In Watts
1.3	98	2.2 V	10
2.0	120	3.1 V	23
2.4	155	3.5 V	38
3.1	210	4.4 V	49
4.1	290	5.8 V	57
4.5	310	6.6 V	61
5.2	380	7.5 V	73
5.4	405	8.3 V	78
5.5	490	9.8 V	85
6.5	550	11.1 V	90
7.4	610	12.45 V	98

Table6.2 .Output Of Solar PV Panel

Time	Voltage	Current	Power
9:00 am	12 V	-	Insufficient solar radiation
10:00 am	16 V	4.7 A	75.2 W
11:00 am	18 V	5.0 A	90 W

12:00 pm	18 V	6.1 A	109.8 W
1:00 pm	18 V	7.6 A	136.8 W
2:00 pm	18 V	7.9 A	142.2 W
3:00 pm	18 V	7.2 A	129.6 W
4:00 pm	18 V	5.3A	95.4 W
5:00 pm	17 V	4.5A	75.5 W
6:00 pm	11 V	-	Insufficient solar radiation

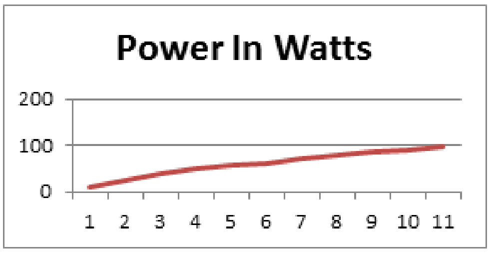

Fig.6.1. Graph of Output power Vs wind velocity in m/s

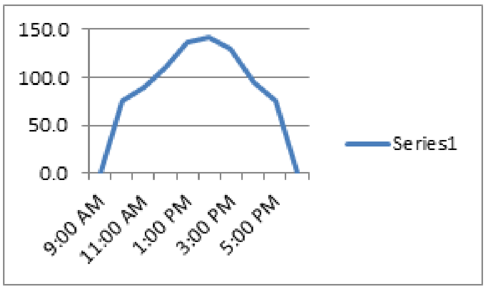

Fig.6.2. Graph of Output power of Solar PV Cell

9. CONCLUSION:

The energy generated from the renewable energy sources like solar and wind is still costlier for industrial and commercial application than the convention energy sources but some of the applications like remote area electrification the use of this energy sources justified in terms of cost. As solar and wind energy is available in variable form throughout the day and throughout the year, but if we see the pattern of their availability we can say that these two energy sources are complimentary to each other, so the hybrid of this two provides the continues power to load. We have generated the power of 250 watt from the hybrid solar and wind power generation by investing 35,000 to 40,000 rupees. The areas where, there is ample amount of solar radiation and wind speed are available like hills and deserts, this project provides the way to produce the electric power for lighting load.

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Corresponding Author

Onkar B. Hedurshetti*

Assistant Professor (EEE), HIT Nidasoshi

E-Mail – mamulla.eee@hsit.ac.in

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