RURAL ELECTRIFICATION

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Abstract:

In the present day scenario the major problem that India is facing is electrifying the whole country, which has not been possible even after 67 years of independence. This paper presents the design idea of a hybrid standalone system of an optimized PV solar and wind module for a rural home. Apart from the photo voltaic solar cell array and mast mounted wind turbine, the system also has lead acid storage battery, electrical lightning load, a 10W LED light, a 25W DC fan, several fuse and junction boxes and associated wiring. The simulation results give the best optimized sizing of wind and solar array. The system is cost effective and more environmentally friendly than other, conventional electricity generation methods which are available at present.

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1. INTRODUCTION

This paper proposes an integrated wind-photovoltaic-battery hybrid system that features a simple power management strategy, requires a lower number of power-electronic converters, and eliminates the need for dump loads. Thus, it is expected to offer a lower cost and higher efficiency, and to enable easier integration with distribution networks, as compared with a set of three stand-alone systems. The power management strategy of the proposed hybrid system enables rapid control of the wind and photovoltaic (PV) power outputs for tightly regulating the battery current. Further, the proposed hybrid system is expected to have plug-and-play and power sharing capabilities and, therefore, suited for multi-generator remote electrification systems.

India receives solar energy equivalent to over 5,000 trillion kWh per year. The daily average solar energy incident varies from 4 -7 kWh per square meter depending upon the location. The annual average global solar radiation on horizontal surface, incident over India is about 5.5 kWh per square meter per day. There areabout 300 clear sunny days in most parts of the country. Karnataka is ideally suited for exploiting the solar potential for electrification with the available technology.

In our project, energy will be derived from sun as well as wind. Hence we will be using a solar panel in parallel with a vertical axis wind turbine. Output of the panel will be given to a Maximum Power Point Tracking System (MPPT) Controller in order to match the battery levels. Simultaneously, output of the turbine will be given to a charge controller circuit. The energy thus obtained will be stored in the battery.

However, we aim to make this product real time operated. This means, the energy generated by the panel and turbine will be directly given to the load. Under the condition where none of the loads would be in use, then the energy would be stored in the battery. In situations where battery is full as well as no load is on the connection from the supply would be disconnected. This entire operation would be controlled by a microcontroller. In addition to this, the product would be intelligent i.e. for example: In the evening if the battery level is not enough to drive the entire load then the supply to the fan will be disconnected and power will be provided only to lights. In this way according to the requirements of light/fan the algorithm would work.

The most important aspect here is that, along with the output of solar panel, the output of wind turbine would be DC. However to supply power to regular fans, we generally require AC voltage. Hence, after the battery, use of an inverter becomes necessary which would add to the overall cost of the product. Hence we plan to make use of a DC fan wherein the output of the controller block can directly be fed to the load. This will cut down the use of an inverter.

Our project is basically aimed for rural villages where maximum requirement is about 2 lights and 1 fan per house. We intend to provide two LED lights of 5W each and a 25W DC fan along with the product

2. SYSTEM CONFIGURATION

Block diagram:

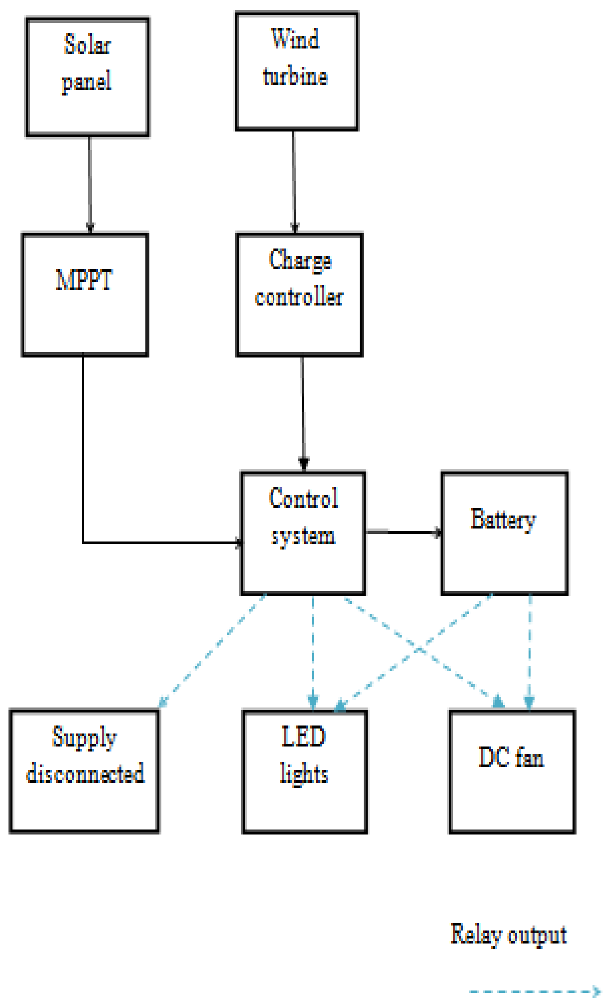

Fig. 1

Calculations and specifications:

Accordingly, here are some calculations for solar panel and wind turbine wattage.

Consider the LED lights are on for 8 hours and the fan for 12 hours per day.

Therefore, total watt-hours consumed per day is:

(10W * 8hrs) +(20W * 12hrs) = 320W-hrs

Lights Fan

Considering the following efficiencies :

1) Battery : 70%
2) Solar panel : 85%
3) Wind turbine : 45%

- If we use only solar panel then:

320W-hrs / 0.7 / 0.85 = 540W-hrs (approx.)

Considering the panel will produce energy for about 5.5hrs,

540W-hrs / 5.5hrs = 100W (approx.)

- If we use only wind turbine then:

320W-hrs / 0.7 / 0.45 = 1016W-hrs

Considering the turbine will produce energy for about 4hrs (min)

1016W-hrs / 6hrs = 170W (approx.)

In both the above cases, we need either 100W solar panel or 170W

- If we go with the hybrid model then:

our requirement is 320W-hrs

130W-hrs (solar) 190W-hrs (wind)

Therefore, 130W-hrs / 0.7 / 0.85 / 5.5hrs = 40W (approx.) solar panel

And 190W-hrs / 0.7 / 0.45 / 6hrs = 100W (approx.) wind turbine

Thus, we require a solar panel of 40W and wind turbine of 100W.

If we consider the present scenario where 1 tube light of 40W and 1 fan of 80W is used, their monthly is approximately Rs. 300.

Tube light : 40W if used for 8hrs a day, then we get 320W-hrs

Fan : 80W if used for 12hrs a day, then we get 960W-hrs

Total : 1280W-hrs ie 1.28KW-hrs per day

1.28 * 30 = 38.4 units per month

Monthly bill :Rs 300 (approx.)

Annual bill :Rs 3600 (approx.)

Our estimated cost of the pilot product is Rs.35,000-40,000 which can be reduced to Rs.20,000 if produced on a large scale.

Hence, from these calculations we can infer that, the estimated payback period would be around 10-11 years.

3. SYSTEMDESIGN

MPPT controller

Maximum power point racking (MPPT) is a technique that grid connected inverters, solar battery chargers and similar devices use to get the maximum possible power from one or more photovoltaic devices, typically solar panel, though optical power transmission systems can benefit from similar technology. It is the purpose of the MPPT system to sample the output of the cells and apply the proper resistance (load) to obtain maximum power for any given environmental conditions. MPPT devices are typically integrated into an electric power converter system that provides voltage or current conversion, filtering, and regulation for driving various loads, including power grids, batteries, or motors.

Maximum Power Point Tracking is electronic tracking - usually digital. The charge controller looks at the output of the panels, and compares it to the battery voltage. It then figures out what is the best power that the panel can put out to charge the battery. It takes this and converts it to best voltage to get maximum AMPS into the battery. Most modern MPPT's are around 93-97% efficient in the conversion. We typically get a 20 to 45% power gain in winter and 10-15% in summer. Actual gain can vary widely depending weather, temperature, battery state of charge, and other factors.

Consider we have a neat 130 watt solar panel. It is rated at 130 watts at a particular voltage and current. The Kyocera KC-130 is rated at 7.39 amps at 17.6 volts. (7.39 amps times 17.6 volts = 130 watts).

The panel puts out 7.4 amps. Our battery is setting at 12 volts under charge: 7.4 amps times 12 volts = 88.8 watts. We lost over 41 watts - but we paid for 130. That 41 watts is not going anywhere, it just is not being produced because there is a poor match between the panel and the battery. With a very low battery, say 10.5 volts, it's even worse - we could be losing as much as 35% (11 volts x 7.4 amps = 81.4 watts. We lost about 48 watts.

How Maximum Power Point Tracking works:

Here is where the optimization, or maximum power point tracking comes in. Assume the battery is low, at 12 volts. A MPPT takes in 17.6 volts at 7.4 amps and converts it down, so the battery now gets is 10.8 amps at 12 volts. Now we still have almost 130 watts

Block diagram:

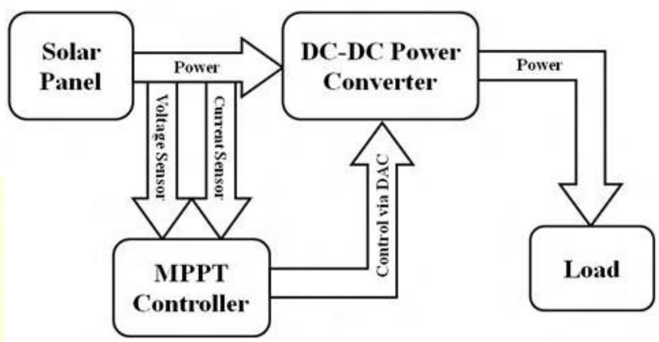

Figure 2

Sensing circuits:

Voltage sensor:

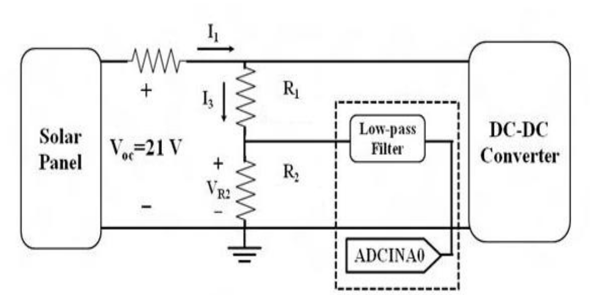

Figure 3

In order for the MPPT controller to measure the voltage provided by the solar panel, two resistors, R1 and R2, are employed in parallel with the solar panel to act as a voltage divider. The voltage across R2 in the voltage divider is fed into an analog-to-digital converter (ADC) driver circuit (op-amp in a voltage follower configuration that feeds into a low-pass filter) before being delivered to the ADCINA0 channel of the MPPT controller.

Current sensor:

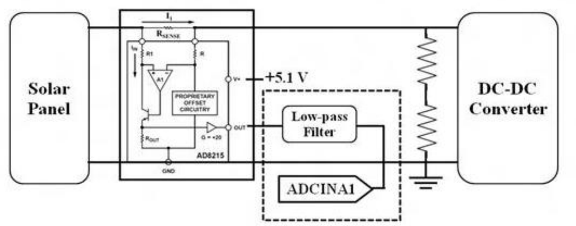

Figure 4

In order for the MPPT controller to measure the current provided by the solar panel, a single resistor (R sense) is placed in series between the solar panel and the DC-DC converter. The voltage across R sense is fed into an AD8215 current sensor manufactured by Analog Devices whose output voltage is then fed into an ADC driver circuit (op-amp in a voltage follower configuration that feeds into a low-pass filter) before being delivered to the ADCINA1 channel of the MPPT controller.

MPPT Algorithm:

Various algorithms may perform MPPT. Important factors to consider when choosing a technique to perform MPPT are the ability of an algorithm to detect multiple maxima, costs, and convergence speed.

The irradiance levels at different points on a solar panel's surface tend to vary. This variation leads to multiple local maxima power points in one system. The efficiency and complexity of an algorithm determine if the true maximum power point or a local maximum power point is calculated. In the latter case, the maximum electrical power is not extracted from the solar panel.

The type of hardware used to monitor and control the MPPT system affect the cost of implementing it. The type of

algorithm used largely determines the resources required to build an MPPT system.

For a high-performance MPPT system, the time taken to converge to the required operating voltage or current should be low. Depending on how fast this convergence needs to occur and your tracking system requirements, the system requires an algorithm (and hardware) of suitable capability.

Perturb and Observe:

The concept behind the "perturb and observe" (P&O) method is to modify the operating voltage or current of the photovoltaic panel until you obtain maximum power from it. For example, if increasing the voltage to a panel increases the power output of the panel, the system continues increasing the operating voltage until the power output begins to decrease. Once this happens, the voltage is decreased to get back towards the maximum power point. This pertubulance continues indefinitely. Thus, the power output value oscillates around a maximum power point and never stabilizes.

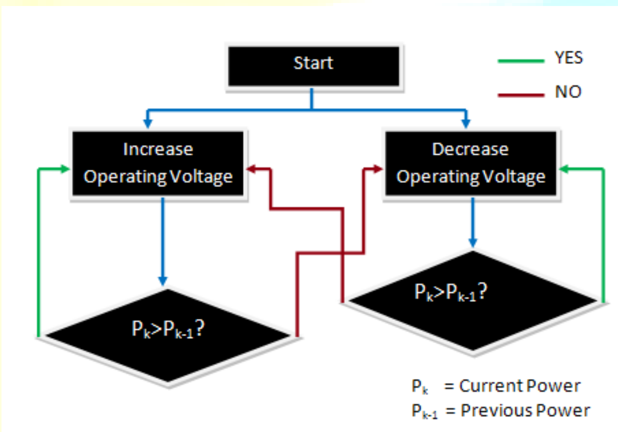

Figure 5

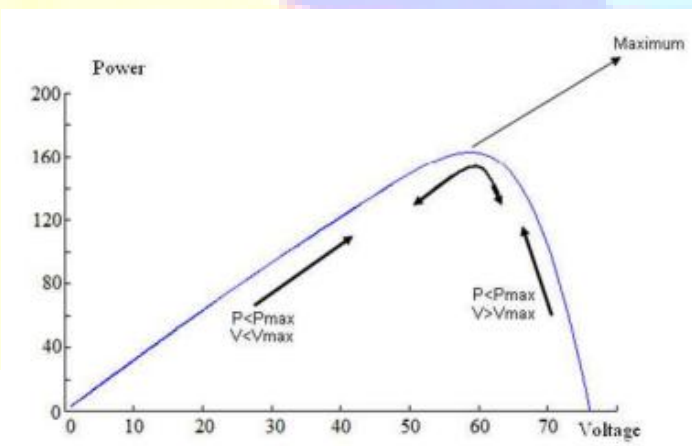

Figure 6

P&O is simple to implement and thus can be implemented quickly. The major drawbacks of the P&O method are that the power obtained oscillates around the maximum power point in steady state operation, it can track in the wrong direction under rapidly varying irradiance levels and load levels, and the step size (the magnitude of the change in the operating voltage) determines both the speed of convergence to the MPP and the range of oscillation around the MPP at steady state operation.

BUCK Converter:

The conceptual model of the buck converter is best understood in terms of the relation between current and voltage of the inductor. Beginning with the switch open (in the "off" position), the current in the circuit is 0. When the switch is first closed, the current will begin to increase, and the inductor will produce an opposing voltage across its terminals in response to the changing current. This voltage drop counteracts the voltage of the source and therefore reduces the net voltage across the load. Over time, the rate of change of current decreases, and the voltage across the inductor also then decreases, increasing the voltage at the load. During this time, the inductor is storing energy in the form of a magnetic field. If the switch is opened while the current is still changing, then there will always be a voltage drop across the inductor, so the net voltage at the load will always be less than the input voltage source. When the switch is opened again, the voltage source will be removed from the circuit, and the current will decrease. The changing current will produce a change in voltage across the inductor, now aiding the source voltage. The stored energy in the inductor's magnetic field supports current flow through the load. During this time, the inductor is discharging its stored energy into the rest of the circuit. If the switch is closed again before the inductor fully discharges, the voltage at the load will always be greater than zero.

Switching circuit:

According to the algorithm to operate it in real time (which increases the efficiency of the battery and its life), we have used three switches in our project. The connections of the relays would be between:

1) Solar panel to Load: If the source is sufficient to drive the load as well as if the battery level is atleast 80%.
2) Solar panel to Battery: If the source is not sufficient and the load is off.
3) Battery to Load: If the source is not sufficient to drive the load.

4. CONCLUSION

This paper presents an approach for implementation ofthe real time operating and low cost hybrid system that can be used and replaced with the existing solar models available in rural homes where there is no electricity.

5. REFERENCES

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