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DESIGN OF A SUSTAINABLE POWER SOURCE FOR PORTABLE ELECTRONIC APPLICATIONS

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Abstract: ***This paper describes a power source which can be used to power up the portable electronic devices. The proposed system combines the solar energy and wind energy along with battery storage to provide supply to the low power device. If the energy produced from the renewable sources is surplus, then the excess energy is stored in a battery, and if the energy is not enough, then the battery gives energy to the device. When the energy generated sufficient enough to meet the load demand, the battery is neither recharging nor charging. The power management unit which includes the pulse width modulation (PWM) for each converter is designed in such a way that the optimized use of the sources is ensured and selects the apt source according to the climatic conditions. The whole system is simulated using MATLAB/SIMULINK and the simulation results are presented to show the response of the system to low power devices.***

Keywords: portable device, sustainable power supply, solar cell, wind turbine, power management.

I. Introduction

Energy requirement in day to day life is increasing year by year. There are possibilities that the fossil fuels cannot satisfy the energy requirement in the coming future. It is shocking that the fuel reserve left in the whole world will come to an end in a span of 100 to 200 years. It is necessary that an efficient alternate system that can match the fossil fuels is found. Natural resources such as solar energy, hydraulic energy, wind energy, geothermal energy are good sources of energy that is readily available nowadays. Also these sources have the advantage that consuming this energy produces no pollution, which is not the case for the fossil fuels.

It is found that the solar energy can be used as the main alternate power source to meet the energy requirements in the world. The available photovoltaic cells can convert 30 - 40% of the incident solar energy into electrical energy . It is clear that we are unable to utilize most of the available solar energy [7]. During the night time, where the solar energy is not present, we have to find an alternate energy source in order to provide uninterrupted power supply to the device. This can be done by integrating other renewable energy sources along with the photovoltaic cells. Wind turbine can provide energy according to the availability of the sufficient wind speed [9]. Portable power supplies mainly consist of rechargeable batteries and these require frequent recharging which makes them unreliable.

The proposed system is a sustainable portable power source which accepts energy from

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different renewable energy sources like photovoltaic cells and wind turbine and also equipped with battery storage as shown in the figure 1. The sources are connected directly to the load. The power management unit selects the source or combination of sources to power up the load according to its load demand and input available energy. The power management unit consists of a DSP controller with generates the Pulse Width Modulation (PWM) for the DC to DC converters included in the system.

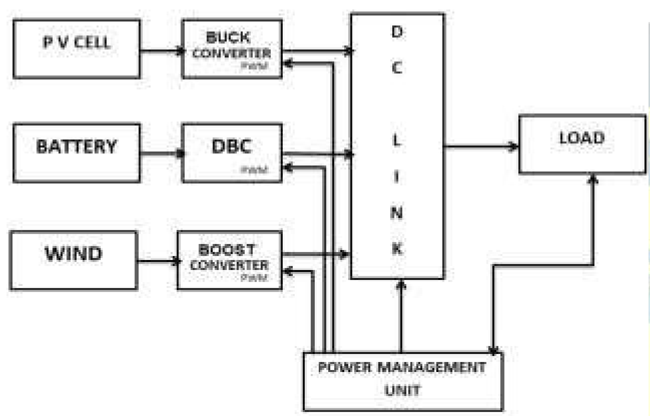

Figure 1: Block Diagram

II. Proposed System Description

The system consists of three primary sources which are PV panel, wind turbine and battery. Three sources are connected to the load parallelly through their corresponding converters. The PV panel is connected to the load through a DC to DC buck converter to give a voltage output of 5V. Buck converter down converts the input voltage to a low voltage Because of the non-linear P-V and I-V characteristics of the PV array, and the consequences of varying environment conditions, particularly irradiation and temperature, tracking the correct Maximum Power Point (MPP) is a challenging task [9][10]. Using the information provided (MPP current or voltage) by MPPT, the duty cycle of the DC-DC buck converter is adjusted using PID controller to match the MPP, which in turn forces the converter to extract the maximum power from the PV array [1].

If the irradiation is very low, then solar panel cannot alone drive the load. To rectify this problem, wind turbine is connected along with the PV panel. The micro wind turbine output voltage is boosted or up converted using a DC to DC boost converter and then connected to the load. The output voltage of the PV panel is proportional to the cube of the wind speed. If there is no sufficient wind speed, then we cannot obtain enough voltage to drive the load. Then a battery source is connected so as to drive the load [3]. Under favourable conditions, the renewable sources will produce energy more than enough to drive the load, this surplus charge is stored in the battery. The battery is connected to the load through DC to DC bidirectional converter, which is a synchronous buck converter. This converter includes two switches which is switched using complementary PWMs. Modelling of renewable energy systems

This section presents the mathematical modelling of the renewable energy sources and power converters.

a) Modelling of the PV

The PV system consists of PV arrays and corresponding DC/AC converter modules. When exposed to sunlight, photons which have energy greater than the band gap energy of the semiconductor are absorbed and create some

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and load resistance R. It can be seen from the circuit that when the switch S is commanded to the on state, the diode D is reverse-biased. When the switch S is off, the diode conducts to support an uninterrupted current in the inductor.

b) Modelling of Wind Turbine

The wind turbine rotor consists of two or three blades mechanically coupled to an electric generator. The power captured by the wind turbine is given by the relation.

- $P_w = 0.5*C_p*\rho*A*V_w^3$

Where ρ is the air density, which is equal to 1.225 kg/m^2, C_p is the power coefficient, V_w is the wind speed in (m/s) and A is the area swept by the rotor in (m^2). [4]

The amount of aerodynamic torque Tw in (N-m) is given by the ratio between the power extracted from the wind Pw and turbine rotor speed W_w in (rad /s) as follows

- $T_w = P_w*w_w$

c) Modelling of DC to DC Buck Converter

Boost Converter

It consists of dc input voltage source V_S, boost inductor L, controlled switch S, diode D, filter capacitor C, and load resistance R. The DC to DC boost converter (figure 3) up converts the input voltage to a higher voltage. When the switch S is in the on state, the current in the boost inductor increases linearly and the diode D is off at that time. When the switch S is turned off, the energy stored in the inductor is released through the diode to the output RC circuit.

d) DC to DC Bidirectional Converter

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DC to DC bidirectional buck boost converter can control current flow in both directions. Hence this circuit is commonly used to charge and discharge a battery storage connected to a DC link. If the State of Charge (SOC) of the battery is more than 80% then, the battery can discharge energy to the DC link and if it is less than 40%, then the battery charges by Taking energy from the DC link. Here the synchronous buck converter is used as the bidirectional converter. The circuit will work in buck mode, while it is discharging its energy to the DC link and will work in boost mode while charging from the DC link to battery. In the circuit, when switch S1 is ON the battery will discharge and when switch S2 is ON the battery will charge. The switches S and S2 are provided with complementary PWMs. [8] discussed about Positioning Of a Vehicle in a Combined Indoor-Outdoor Scenario, The development in technology has given us all sophistications but equal amounts of threats too. This has brought us an urge to bring a complete security system that monitors an object continuously.

e) Power Management Unit

Power management unit is mainly comprises of a controller which generates the PWMs for the power converters. The output voltage supplied to the load is kept constant by feed backing the output voltage[5]. The output voltage is fed back and compared with the desired voltage level. The error voltage is given to the PID controller whose Kp, Ki, Kd constants are tuned in such a way that it generates a control voltage which can be compared with ramp signals to generate Pulse Width Modulation (PWM) for the DC to DC converters (figure 5). The boost converter is controlled by the PWM which is generated by feed backing the output voltage[3]. If the state of charge of battery is greater than 80% and if there is no enough energy to drive the load in the DC link, the switch S2 of the DBC is turned ON. The buck converter which is connected along with the PV panel is controlled using PWM in such a way that it extracts the maximum power from PV cells.

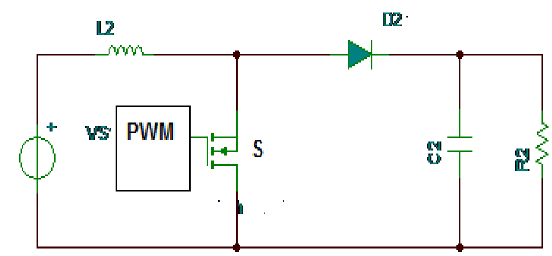

Figure 3: Boost Converter

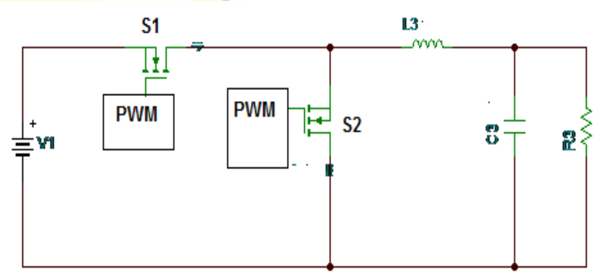

Figure 4: DC to DC Bidirectional Buck Boost Converter

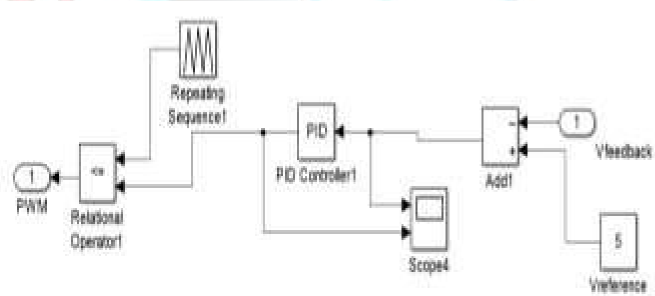

Figure 5: PWM Control

III. SIMULATION RESULTS

The whole system is simulated in MATLAB/SIMULINK. The hybrid system consists of a solar panel with 6V, 1A is modeled and simulated. The open circuit voltage of this panel will range up to 7V, and

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in order to maintain 5V in the DC link, The PV panel is connected to the DC link through a buck converter. The switching of the MOSFET is controlled by PWM by feed backing the PV voltage in order to ensure the extraction of maximum power from the panel. The wind turbine is of low voltage output about 2 to 3V and it is up converted using a boost converter.

The battery used to store the excess charge is Lithium ion rechargeable battery. Synchronous buck converter connected between the battery and the DC link to charge and discharge the battery. The controls of the converters are provided by the power management unit by feed backing desired voltages from the system.

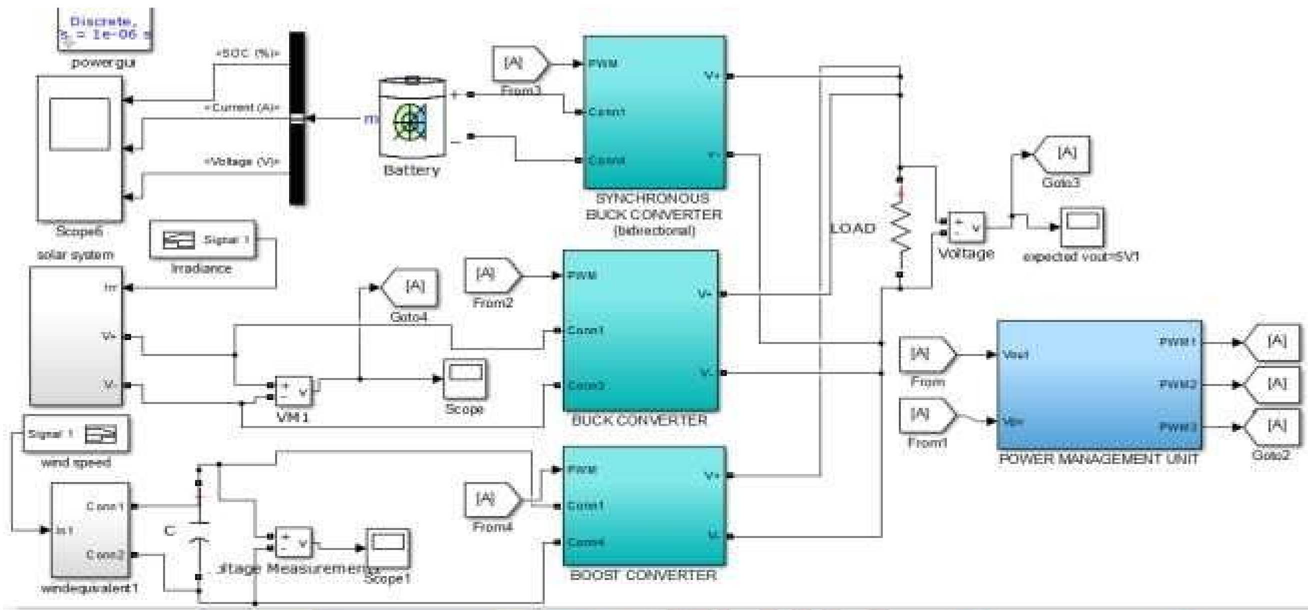

Figure 6: Simulink Model of Whole system

The system is simulated in MATLAB/SIMULINK to verify its behaviour in varying conditions of irradiance and wind speed. The performance of the PV panel is affected by the variation in the irradiance even after it is equipped with maximum power extraction. During low irradiation times, or during night, the wind turbine and battery drives the load. It is possible to give wind speed data to this simulation so as to check the variation in the performance of this system. If the conditions are unfavourable for the solar as well as wind, then the battery discharging rate increases as the battery has to discharge more energy so as to drive the load.

The variation in the demand of power can also be met by this system as the voltage remains the same and the power increases, the current drawn from each source increases. The least priority is given to the battery in order to increase the life of the battery.

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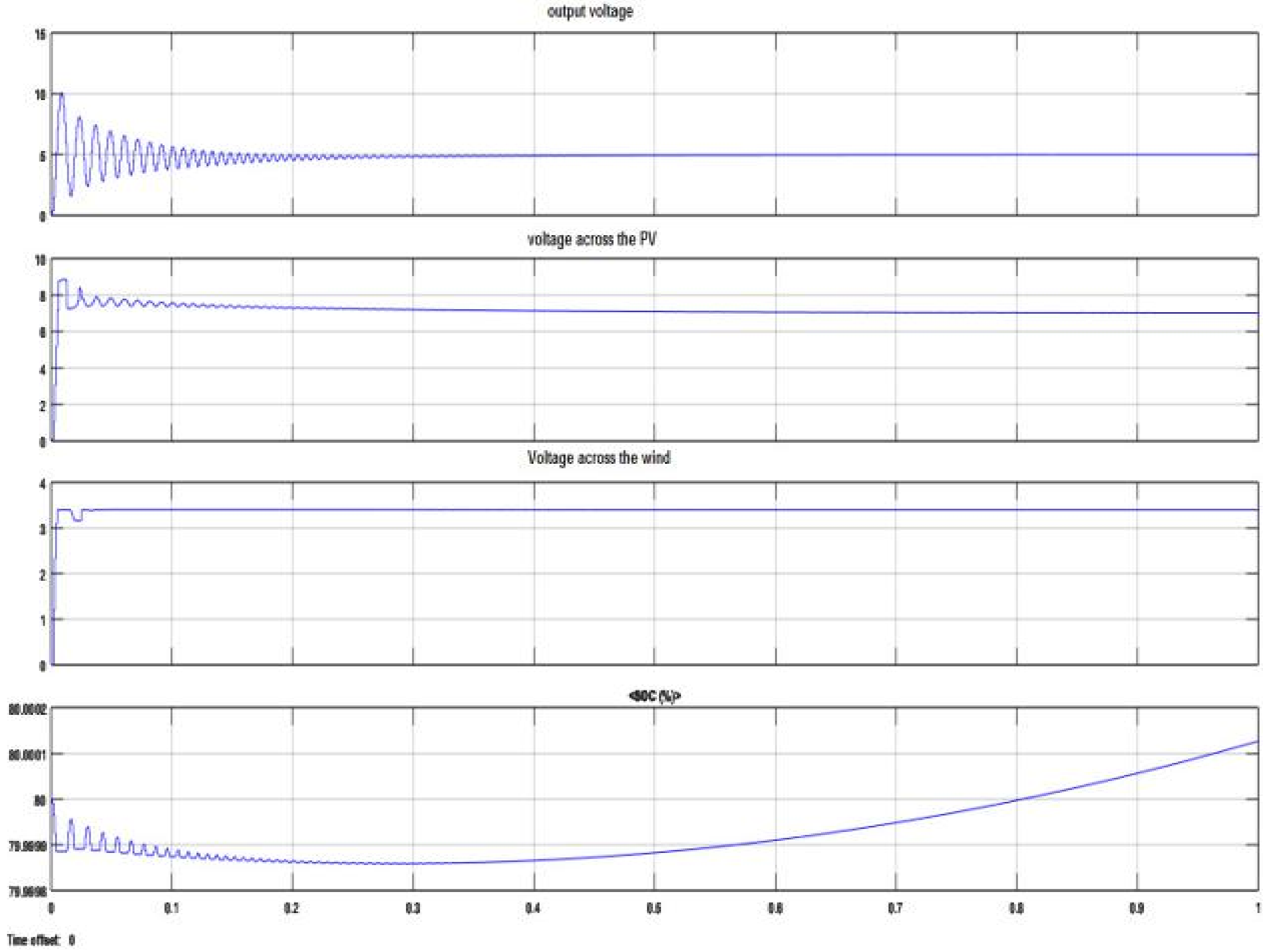

Figure 7: Output Wave forms

IV. Conclusion

This paper has described a sustainable power source for portable electronic applications which includes the PV panel, micro wind turbine and rechargeable lithium ion batteries as the sources. The modelling of the sources as well as the simulation of the whole circuit is done with MATLAB/SIMULINK. It is found that the system can supply uninterrupted power to the load even under the unfavourable conditions like less irradiation and low wind speed. The battery charges from the DC link as the energy produced by the renewable sources is more than enough to meet the requirements of the load. The battery will work in discharging mode as there is no sufficient energy available from the renewable sources to drive the load. If the energy produces by the load is enough to drive the load and the State of Charge (SOC) of the battery is 100%, the battery is neither recharging and nor charging. The simulation model is flexible so that we can check the system performance in each location according to climatic condition of that location by giving the irradiation values as well as the wind data to this model. Power management unit is and load requirements.

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