Analysis of a Solar Wind Integrated Energy System using SEPIC Converters

S. Senthilrani[1] B.Ashok Kumar[2]
[1]Assistant Professor
[1,2]Department of Electrical & Electronics Engineering
[1]Velammal College of Engineering & Technology, Madurai, India [2]Thiagarajar College of Engineering, Madurai, India

Abstract— This paper introduces, Design and Analysis of hybrid solar wind energy system using two SEPIC converters. Wind energy is among the world's fastest growing sources of energy. Solar energy has the greatest potential of all the sources of renewable energy when other sources have depleted. The power Electronics play crucial role of conversion and control of electric power. Therefore power electronics based power converters are also broadly used in renewable energy systems. This project presents a new system of configuration of the rectifier stage topology for a hybrid wind/ photovoltaic energy system in order to simplify the power system and reduce the cost. This configuration allows the two sources to supply the load separately or simultaneously depending on the availability of the energy sources. The proposed design is the fusion of two SEPIC converters. The inherent nature of these SEPIC converters eliminate the need for additional input filters to eliminate high frequency harmonics. Harmonic content is determined for the generator lifespan, heating issues and efficiency. The fused multi input converter stage also allows maximum power point tracking (MPPT) algorithm to be used to extract maximum power from the sun when it is available. When a source is unavailable or insufficient in meeting the load demands. The other energy sources can compensate for the difference. The proposed design is mathematically modelled which is simulated via MATLAB software.

Key words: Solar System; Wind System; SEPIC Converter; Hybrid System

I. Introduction

Resources can never be exhausted are called renewable resources. Some of them like air, wind, water, sunlight etc., are continuously available and their quantity is not affected by human consumption [1]. They cause less emissions and are available locally. Their use can, to a large extent, reduce chemical, radioactive and thermal pollution. They stand out as a viable source of clean and limit less energy. These are also known as non-conventional source of energy. The presence of wind is an extremely unpredictable factor since at some time it can be very high above cut-off point in situations like tsunami, cyclones etc., In solar energy, the irradiation levels keep on varying depending on the natural conditions such as shadows cast by clouds, rains etc., Thus intermittent natures of the wind and solar energy make them unreliable sources of energy [2]. Hence hybrid PV and wind energy system can swell up system efficiency.

Several alternatives can be used for hybrid PV-wind configurations such as DC/DC boost, buck & buck boost converters. These configurations inject high frequency current harmonics [HFCH] into hybrid system. But these converters do not have the capability to eliminate the harmonics. In order to filter the harmonics sepic converters can be used. But the use of sepic converter makes the system more bulky & expensive[3]. The inverter's parameters are modelled mathematically, the designed inverter is simulated via MATLAB software to verify the inverter's output performances.

II. Design of Proposed Solar System

Under Standard Test Condition (STC) Sanyo HIP-210HKHA6 panel with 100W maximum output power is being tested. At STC condition of 25º temperature and the panel is simulated to produce the output voltage of 12V[3].

Due to the nature of solar energy two components are required to have a functional solar energy generator. These two components are

1) Collector(Photovoltaic cell)
2) Storage unit

The collector simply collects the radiation that falls on it and converts a fraction of it to other forms of energy (either electricity and heat or heat alone). The storage unit is needed because of the non-constant nature of solar energy; at certain times only a very small amount of energy produced by the collector will be quiet small. The storage unit can hold more energy produced during the periods of maximum productivity and release it when the productivity drops. The solar collectors that converts radiation into electricity can be either focusing collectors or the silicon components of these collectors are photovoltaic cells.

III. Design of SEPIC Converter

The design of a SEPIC converter is illustrated below. This converts an unregulated dc voltage to a fixed dc voltage[1].

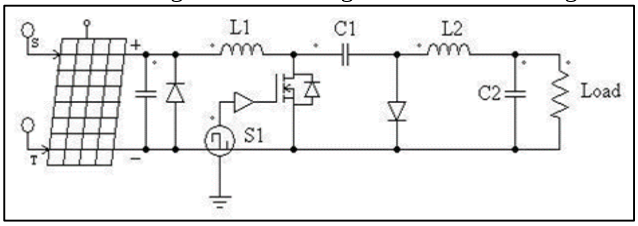

Fig. 1: Design of SEPIC converter

Single-ended primary-inductor converter (SEPIC) is a DC-DC converter allowing the electrical potential (voltage) at its output to be greater or less than or equal to that at its input; here only the step up capability is considered. The output of SEPIC is controlled by the duty cycle of controlled transistor.

Turning on S1 causes the input voltage to be appeared across the inductor L1 and the current IL1 is increased. The voltage across the capacitor C1 is appeared across L2 and the energy is stored in the inductor L2. During this period the diode D3 is reverse biased. But D3 conducts when S1 is turned off. The energy stored in both L1 and L2 is delivered to the output and for the next period C1 is recharged again by L1.

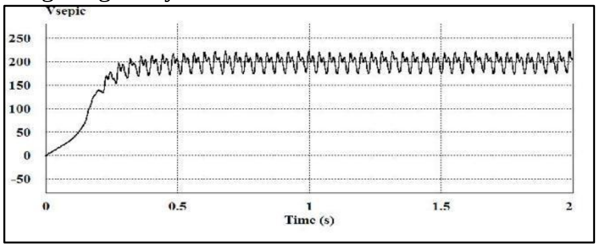

Fig. 2: Simulated output of SEPIC converter

IV. DESIGN OF PROPOSED

Wind system wind energy is among the world's fastest growing source of energy. Because wind power is an abundant, widely distributed energy resources that has zero fuel cost, zero emissions, non-polluting, so it has no adverse effects on the environment[4].

Electricity is generated, when moving air exerts force on the propeller like blades around the rotor of the wind turbines. The rotor is connected to a gear box which is responsible for increasing the rotational speed of the shaft which is connected to generator. Then electricity is produced with the help of the generator.

V. WIND POWER GENERATION

Wind possess energy by virtue of its motion. Any device capable of solving down the mass of moving air, like a sail or propeller, can extract part of the energy and convert it into useful work. Three factors determine the output from a wind energy converter.

- Wind speed
- Cross section of wind swept by rotor
- Overall conversion efficiency of the rotor, transmission system and generator or pump

The power of the wind can be computed by using the concept of kinetics[4]. The wind mill works on the principle of converting kinetic energy of the wind to mechanical energy. The energy available is the kinetic energy of the wind. The kinetic energy of any particle is equal to one half of its mass times the square of its velocity.

$$K.E=1/2mv^2 \quad (1)$$

Where

m=mass

v=velocity

In practical available wind power is given as

$$P=1/8\ \rho \Pi D^2 V^3 \quad (2)$$

Where

P=wind power

= air density

D=diameter of the turbine shaft

From the equations (1) & (2), wind machines intended for generating substantial amounts of power should have large rotors and be located in areas of high wind speeds. The design and performance of the proposed wind power generation system were simulated through the MATLAB software.

VI. PROPOSED WIND-PV HYBRID SYSTEM

The solar cell and wind turbine are fed to the SEPIC converters. These converters can be fused together by reconfiguring two existing diodes D1 & D2. Due to this configuration each converter can operate individually when one source is unavailable [6].

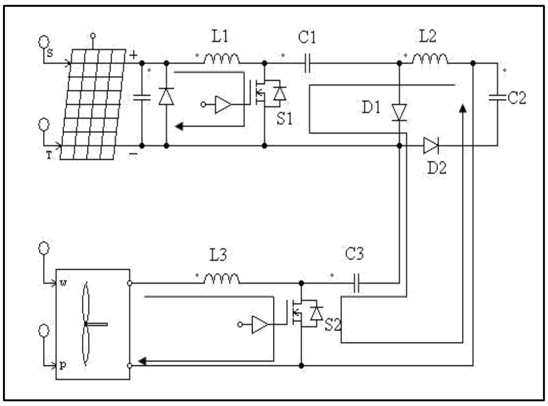

Fig. 3: Design of hybrid system when PV is available

Voltage conversion relationship only when PV source is available

$$Vdc/Vsolar = D1/(1-D1) \quad (3)$$

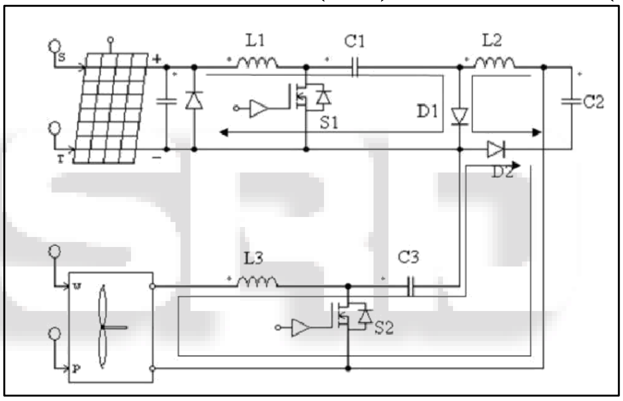

Fig. 4: Design of hybrid system when wind is available

Voltage conversion relationship only when wind source is available

$$Vdc/Vwind = D2/(1-D2) \quad (4)$$

VII. DC OUTPUT

The average output voltage is given by

$$Vdc = D1/(1-D1)*Vsolar + D2/(1-D2)*Vwind \quad (5)$$

The performance of the hybrid solar wind energy system is simulated via MATLAB software.

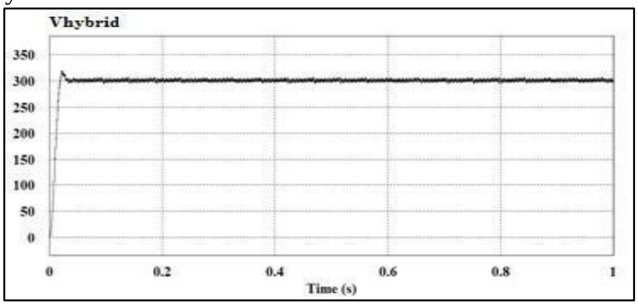

Fig. 5: Simulated output of the hybrid system

VIII. CONCLUSION

This paper illustrates the design, analysis, mathematical model and computer simulation of hybrid solar-wind energy system. The optimal operating points have been tracked by Maximum Power Point Tracking (MPPT) technique to improve the system's power transfer efficiency. The power electronic converters were used in circuits for voltage level conversion. The converters were used as it has the ability of power conversion control. Since it uses SEPIC converter, Total Harmonic Distortion (THD) has been reduced and thereby improves the quality of the power. The operation of the proposed configuration for the hybrid system has been analysed. The maximum power point tracking algorithm was implemented for the photovoltaic system. The results were simulated using MATLAB software.

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