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Output Regulation of Hybrid Renewable Energy System through Hysteresis Control

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Abstract

This paper intends a hybrid energy conversion system coalescing photovoltaic and wind turbine as a small-scale alternative source of electrical energy where conventional generation is not practical. The Photovoltaic panels, wind turbines and storage batteries reside in this hybrid system. A novel system conformation of the front-end rectifier stage for a hybrid wind/photovoltaic energy system is presented in the paper. Its configuration allows the two sources to supply the load separately or simultaneously depending on the availability of the energy sources. Due to this intrinsic behaviour of this Cuk-SEPIC fused converter, additional input filters are not required to filter out high frequency harmonics. For the generator lifespan, heating issues and efficiency harmonic content is detrimental. Inspite of the input variations controller is used to regulate the output voltage. Simulation and hardware results are given to highlight the merits of the proposed circuit.

Keywords: *Hybrid energy system, renewable, Cuk-SEPIC, photovoltaic, wind energy*

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INTRODUCTION

Due to the increasing needs and growing technology, consumption for energy is increasing day by day across the world. In the recent state, almost all the electricity generation takes place at central power station which utilizes coal, oil, gas etc. as the primary fuel source. There are numerous glitches connecting to the further development of generating methods based on any of these conventional fuels. To ensure quality of life in our society, energy is very much essential.

The growth in price and ecological worries including conservative electrical energy posed a great question in today's world. Thermal power plants are the main source of electricity which is costly and it uses coal as raw material which is non-renewable and hence exhausting. The constraint of Hydro-power generation is that as it is suitable for selected geographical areas. The probable menaces of nuclear power have been much exposed, predominantly those concerning the storage and military usage of nuclear waste. Renewable energy sources are those energy sources which are not destroyed when their energy is harnessed. Human use of renewable energy requires technologies that harness natural phenomena, such as sunlight, wind, waves, water flow, and biological processes such as anaerobic digestion, biological hydrogen production and geothermal heat. Amid these solar and wind energy along with wind turbines are proved to be the most reliable source of renewable energy.

The simple characteristic of the wind turbine from an energy source to be an active power source is transformed by use of power electronics. In latest years, Hybrid PV/Wind System (HPWS) has

gained feasible options to meet environmental protection obligation and electricity needs. With the matching characteristics between solar and wind energy resources for certain locations, hybrid PV/wind system presents an unbeatable option for the supply of small electrical loads at remote locations where no utility grid power supply is available. When combination of solar and wind power production is used, the reliability of the system is enhanced; this is the advantage of solar/wind hybrid system. For they can offer a great consistency of power supply, their solicitations and surveys gain more concerns nowadays.

As water supply is an important problem in all parts of the world. With increasing population need for water has also increased. In India, electrical and diesel-powered water pumping systems are widely utilized for irrigation applications. The unremitting fatigue of conventional energy sources and their environmental impressions have moulded an attentiveness in electing RESs such as solar-photovoltaic, solar-thermal, wind energy, producer gas and biomass sources to power water pumping systems which utilizes water in the most efficient type [1]. A recently anticipated resolution to this delinquent is the usage of autonomous wind generators to electrically propel centrifugal water pumps.

Based on wind generation and control by rotor frequency autonomous water pumping system is possible [2]. The power flow control is achieved through the rotor winding of the generator by changing the frequency and voltage of its excitation. During the last decade, the need for the best utilization of water and energy resources has become a vivacious issue and it will gain more importance in the future. The investigations reported with renewable energy source water pumping systems are categorised into five major groups: (i) Solar photovoltaic water systems (SPWPSs), (ii) Solar thermal water pumping systems (STWPSs), (iii) Wind energy water pumping systems (WEWPSs), (iv) Biomass water pumping systems (BWPSs) and (v) Hybrid renewable energy water pumping systems (HREWPSs).

SOLAR ENERGY SYSTEM

The easily obtainable and has huge potential to generate energy is solar energy, as it is non-polluting and is for free. The sunlight can be converted directly into electricity only through the photovoltaic effect. The photovoltaic has become popular mode of generation of electricity due to this feature of directness of conversion.

Earth surface receives $1.2x10^{17}$ W of power from sun. Energy delivered by the sun in one hour is approximately equal to the amount energy obligatory by the human population in one year. Typically the sunshine hour in India is about 6 h annually also the sun shines in India for about 9 months in a year. Solar energy has become good choice for electric power generation. The solar photovoltaic module helps directly to convert solar energy into electrical energy.

Solar powered water pumping schemes entails of PV array, motor and pump. It requires storage batteries and charge regulator depending on the system design. The choice of motor is according to power requirement and the type of current output of the system. Battery-less system is more economical. In the countries located in tropical regions use of solar photovoltaic energy is considered to be a primary energy source with solar radiation up to 1000 W/m^2.

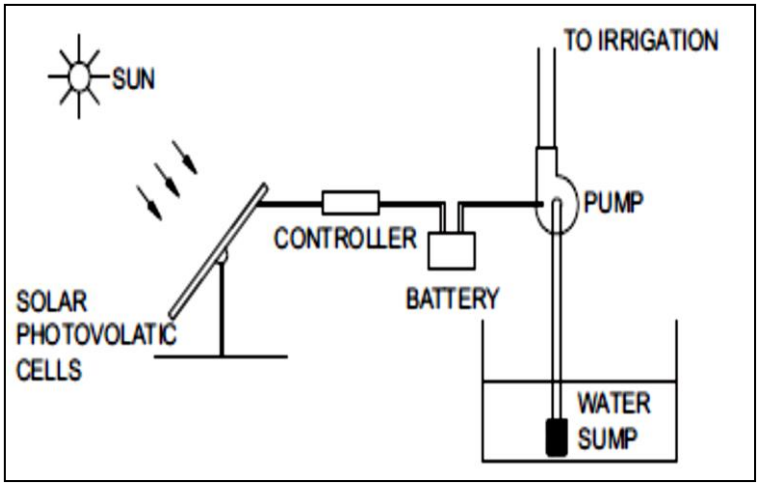

Fig. 1: *Layout of Solar Photovoltaic Pumping System.*

PV Array

The PV array is designed by many series or parallel connected solar cells [3]. Each solar cell is designed by a junction semiconductor, which produces currents by the photovoltaic effect. The core technical factors over the past decade that have led to improved PV system performance include:

a. Enhanced PV module cell manufacturing techniques and scale that have lowered PV module costs and ensued in higher module efficiency.
b. Enhanced inverter performance.
c. Additional operative application, design and integration of PV systems and standardized interconnection necessities for grid interaction system.
d. Subsidies delivered by the governments.

WIND ENERGY SYSTEM

The conversion of wind energy into a useful form of energy is wind power, such as using wind turbines to make electrical power, wind mills for mechanical power, wind pumps for water pumping or drainage, or sails to propel ships. In large wind farms hundreds of individual wind turbines are connected to the electric power transmission network. For fresh constructions, onshore wind is a low-cost source of electricity, modest in many places economical than fossil fuel plants. Small onshore wind farms provide electricity to isolated locations. The wind power installed in India on 31 Jan 2013 has capacity 18634.9 MW, India ranking the 5th largest country regarding installation of wind power. A wind turbine is powered by conversion of the force of the wind into torque (turning force) which acts on the rotor blades. The amount of energy transferred by wind to the rotor depends on the density of the air, the rotor area, and the wind speed. There are fundamentally two types of wind turbine available:

1. Vertical Axis Wind Turbine (VAWT);
2. Horizontal Axis Wind Turbine (HAWT).

The mechanical power generated by wind turbine in order to describe the power characteristic is given by:

$$P_m=0.5\rho A\, C_p(\lambda, \beta)V_w^3$$

Where;
ρ=air density,
A=rotor swept area,
$C_p(\lambda, \beta)$=power coefficient function,
β=pitch angle,
V_W=velocity of wind.
A rotor powered by wind is coupled to a synchronous generator with permanent

magnets, which converts the wind energy into electrical energy. Then for water pumping the generator is coupled to a common induction motor, which drives a centrifugal pump.

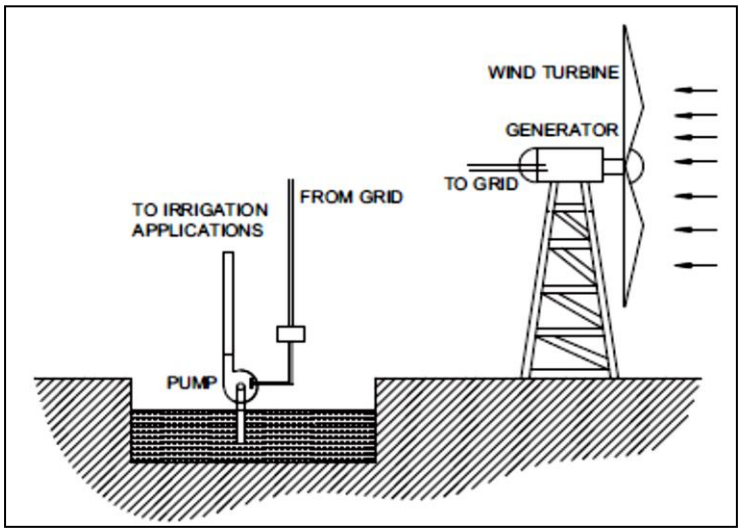

Fig. 2: *Layout of Wind Powered Pumping System.*

HYBRID SOLAR WIND ENERGY SYSTEM

Hybrid systems is the incorporation of two or more sources, here wind and solar. The multi input converter employed here offers higher reliability and flexibility. If one source is inaccessible, the other source can deliver the required or smaller power, for ensuring continuous power supply. Multiple-input converter (MIC) for hybrid power systems is enticing courtesy because of lesser components, compression and centralized control[4,5]. The MICs projected are fundamentally centred on parallel connection at the output of a number of boost converters and buck-boost converters [6-9].

The purpose of this paper is to introduce a new multi-input inverter for grid-connected hybrid PV/wind power system. It has the following advantages:

1) Power from the PV array or the wind turbine can be delivered to the utility grid or the load.
2) An input voltage variation of wide range caused by different insolation and wind speed is acceptable.

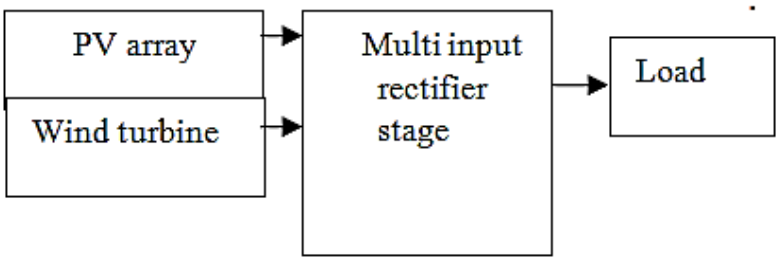

Fig. 3: *Block Diagram of Multi Input Converter.*

MULTI-INPUT INVERTER OPERATING PRINCIPLE

Figure 4 shows a schematic diagram of the projected rectifier stage of a hybrid energy system where one input is connected to the output of the PV array and the other input connected to the output of a generator [6-9].

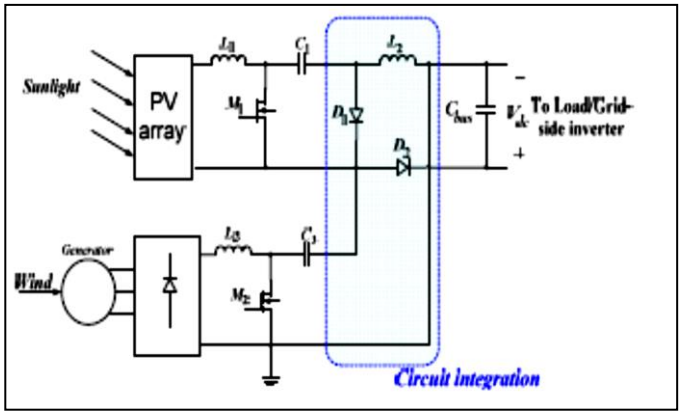

Fig. 4: *Multi Input System Rectifier Stage.*

The combination of the two converters is attained by rearranging the two existing diodes from each converter and the shared utilization of the Cuk output inductor by the SEPIC converter [10]. This arrangement permits each converter helps to function normally individually in case when one source is unavailable. When only the wind source is available as is depicted in Figure 5.

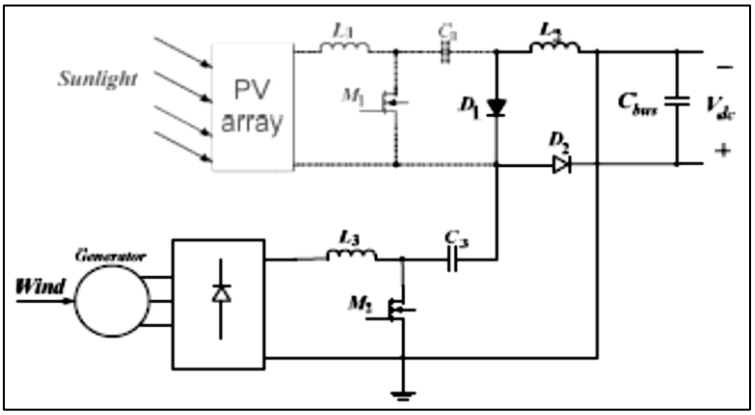

Fig. 5: *Operation of Wind source (SEPIC).*

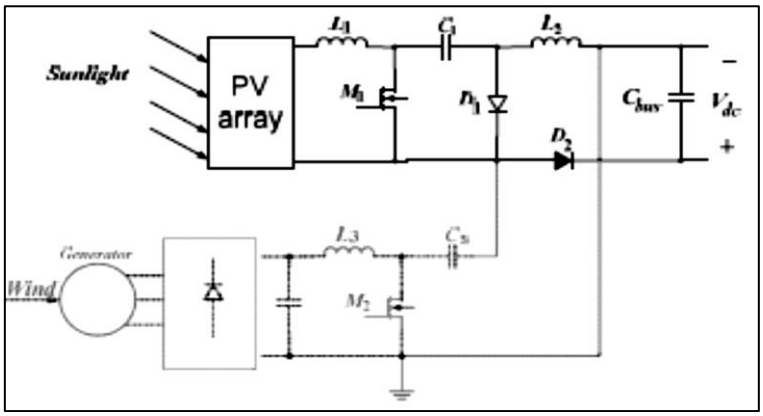

Fig. 6: *Operation of PV Array (CuK).*

In this case, D_2 turns on and D_1 turns off; the circuit acts as a SEPIC converter and the input to output voltage relationship is given. On the other hand, if only the PV source is available, D_1 is on and D_2 turns off. The circuit acts as a Cuk converter.

For both cases, the two converters have step-up/down capability, which provides flexibility to design in the system.

$V_{dc}/V_{PV}=d_1/1-d_1$
$V_{dc}/V_W=d_2/1-d_2$

SWITCHING STATES OF SWITCHING CYCLE

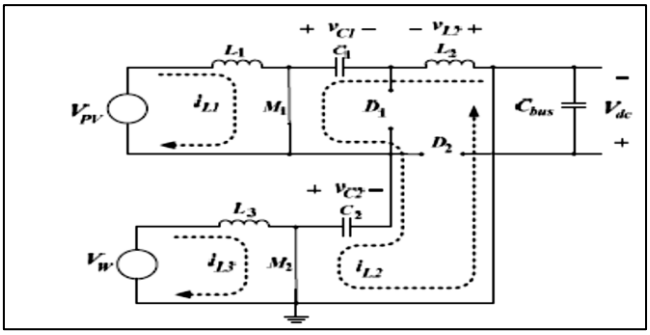

Fig. 7: *State I-M_1 and M_2 ON.*

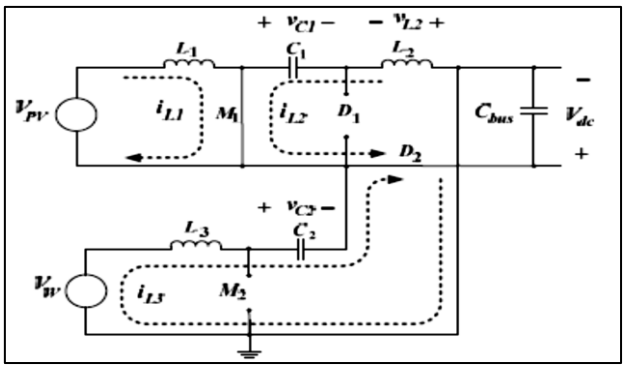

Fig. 8: *State II-M_1 ON and M_2 OFF.*

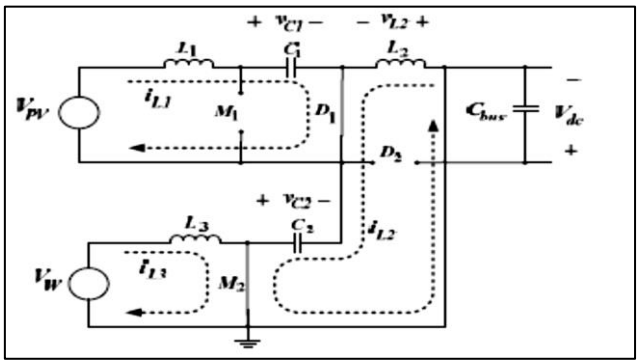

Fig. 9: *State III-M_1 off and M_2 ON.*

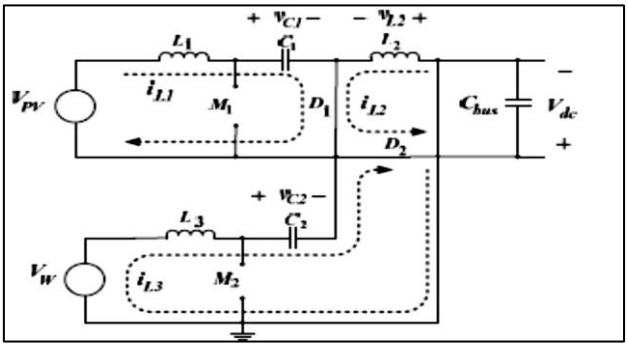

Fig. 10: *State IV-M_1OFF and M_2 OFF.*

SIMULATION RESULTS

The wind and solar were considered as fixed DC sources for performing simulation. Thus input and output voltage was obtained.

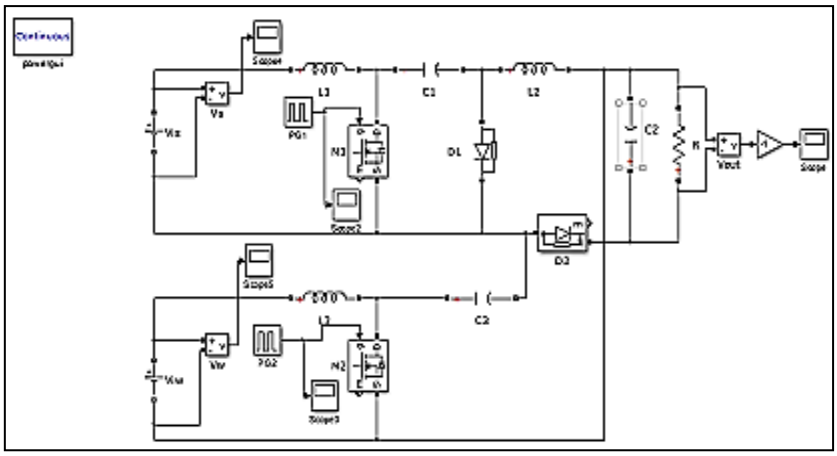

Fig. 11: *Schematic Simulink for Solar and Wind as Fixed DC Source.*

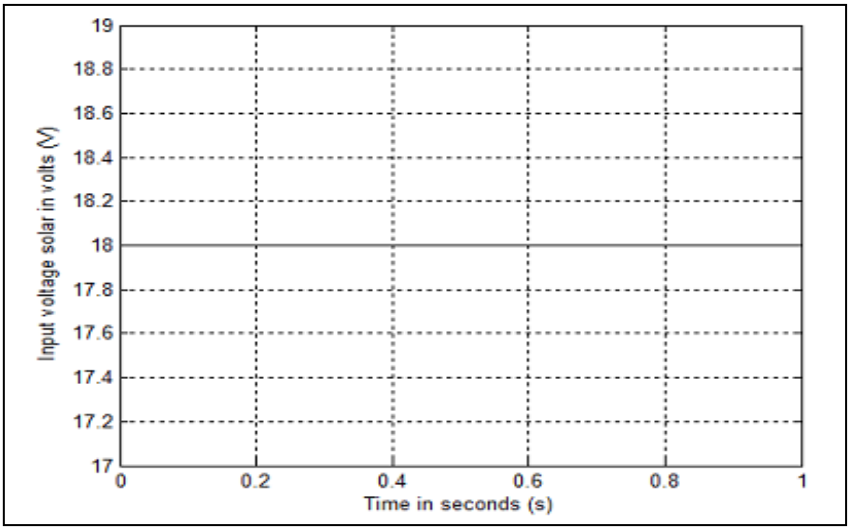

Fig. 12: *Solar Input Voltage.*

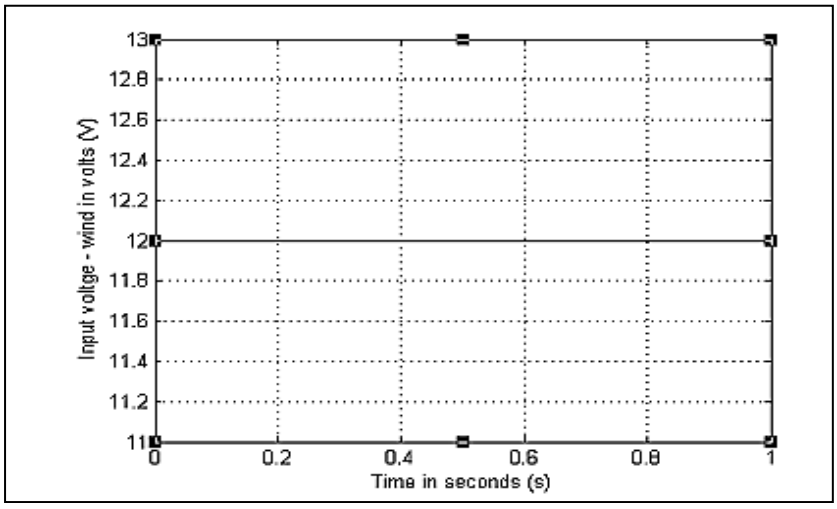

Fig. 13: *Wind Input Voltage.*

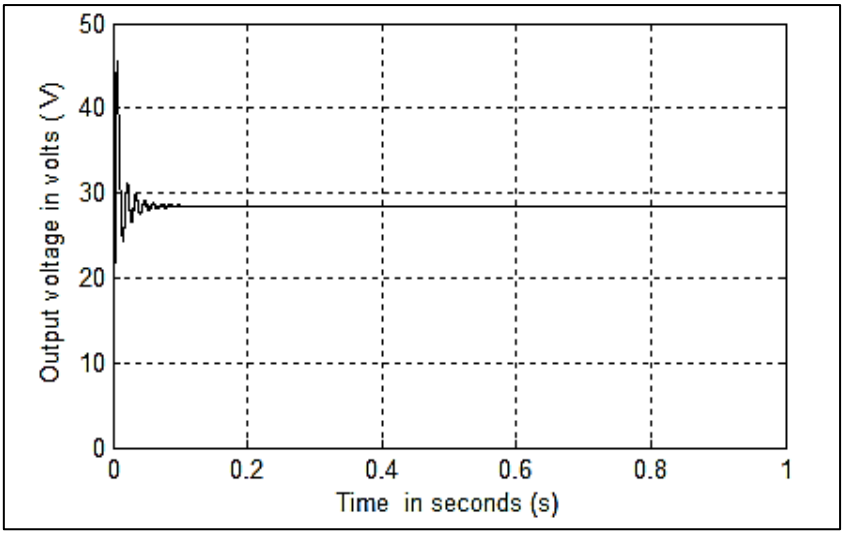

Fig. 14: *Output Voltage.*

We cannot represent the sources as fixed DC voltages as the sources are variable. Hence variable sources were used for simulation considering the intermittent nature of the wind and solar[11].

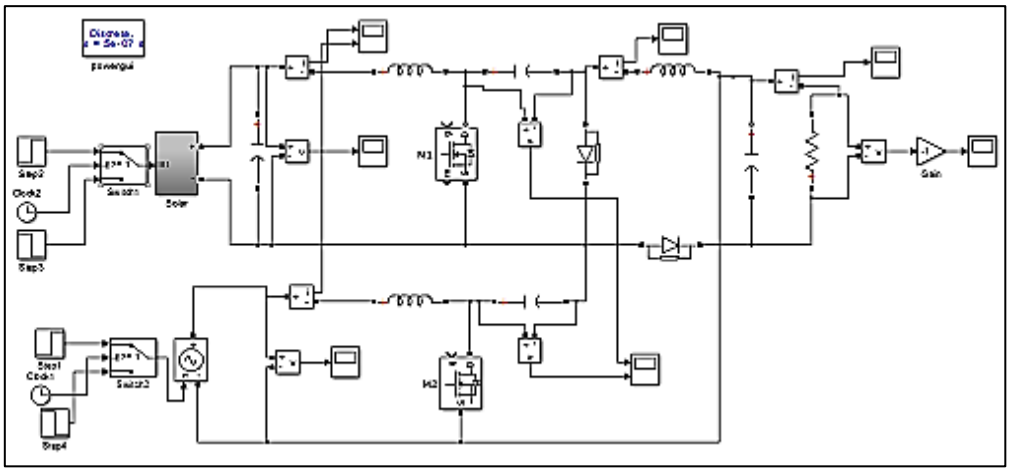

Fig. 15: *Solar and Wind as Variable Sources -Simulink Diagram.*

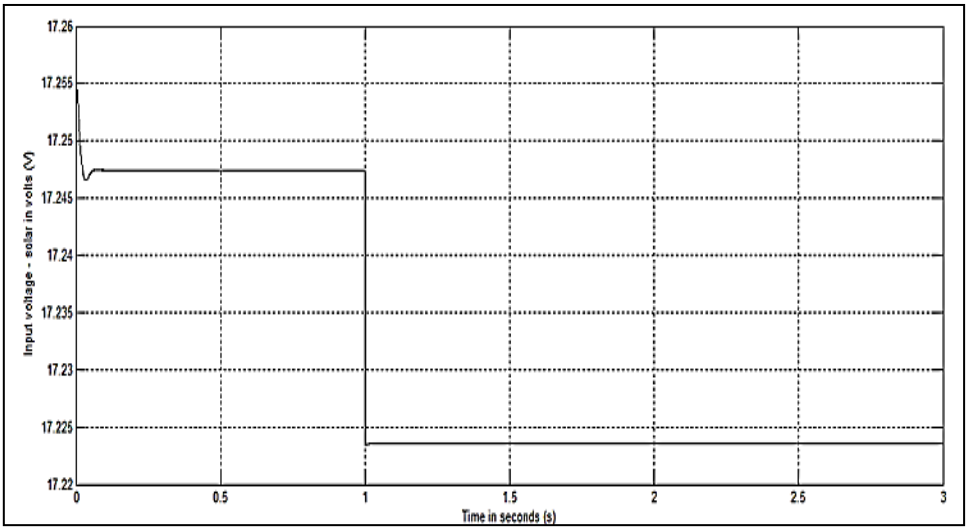

Fig. 16: *Solar Input Voltage.*

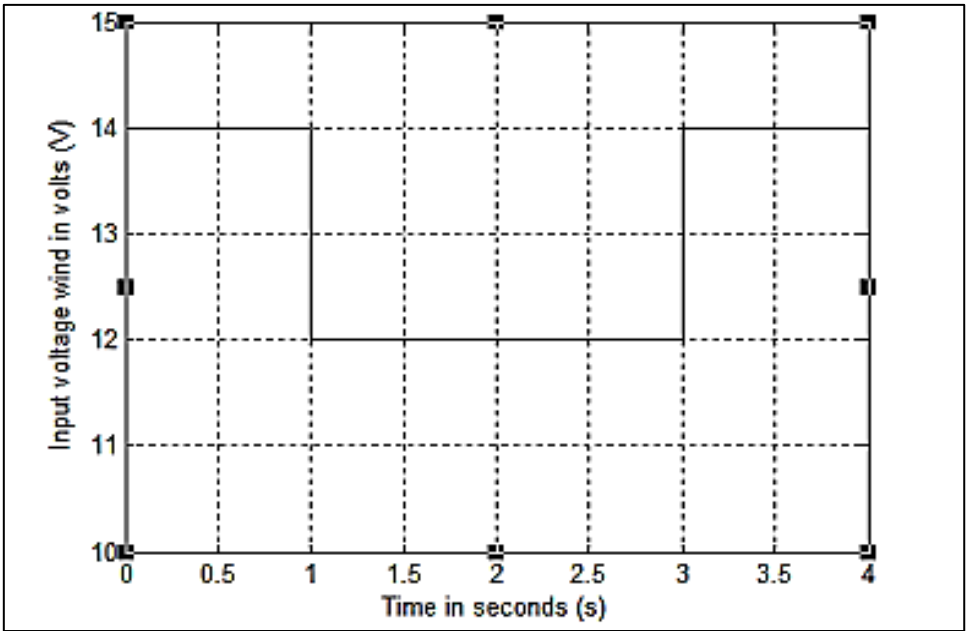

Fig. 17: *Wind Input Voltage.*

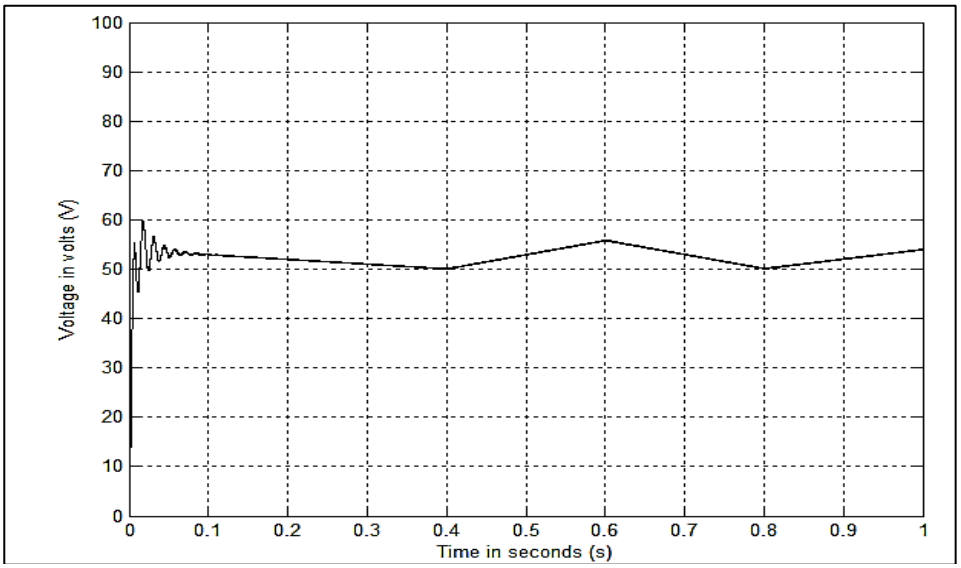

Fig. 18: *Output Voltage.*

As the solar and wind both are tremendously fluctuating, it has effects on the load. The sun intensity and unpredictable shadows cast by clouds, birds, trees, etc. cause variation of the solar irradiation levels. Similar is the case with wind energy which is proficient of delivering huge amounts of power but its presence is highly unpredictable. The sporadic nature of these two sources makes the system highly irregular and hence diminutions the efficiency of the overall system. Hence the voltage and current parameters must be controlled in order to accomplish maximum efficiency. The wear and tear of the system components is caused by variation in voltage and current and thus results in the fault of the whole system. Hence a simple controller is proposed for closed loop operation of the converter[12].

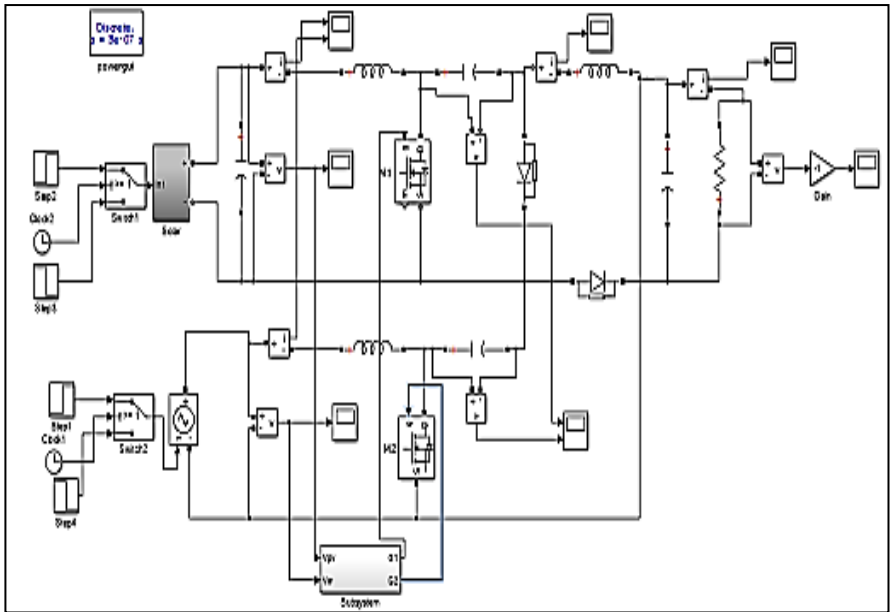

Fig. 19: *Solar and Wind as Variable Sources using Controller Simulink Diagram.*

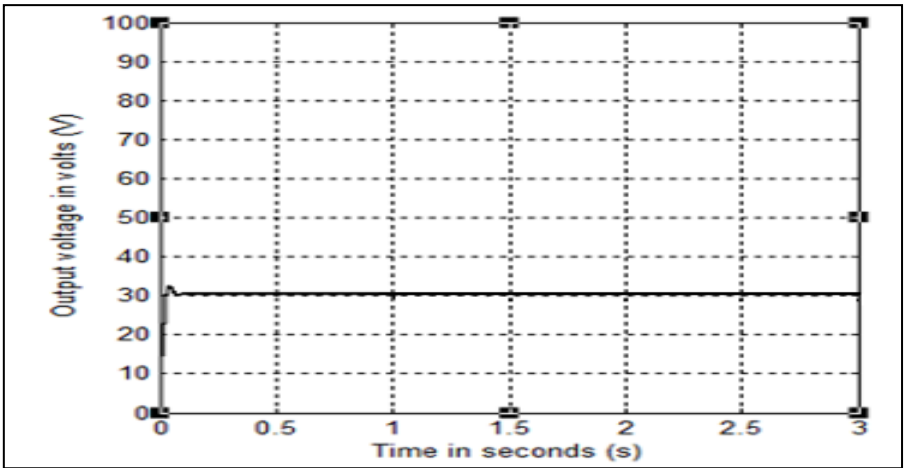

Fig. 20: *Output Voltage.*

Control

The hysteresis controllers are used for controlling input voltage variations.

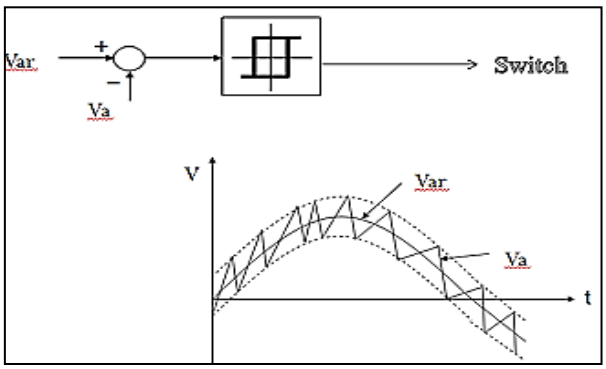

Fig. 21: *Hysteresis Controller.*

In hysteresis control, both current and voltage mode control is possible. Variation in the input voltage is controlled by varying the duty ratio of the switch using a

hysteresis controller. This controller is easy to implement, less expensive and simple.

HARDWARE IMPLEMENTATION

A prototype of the solar wind hybrid model was implemented and results were obtained from the experimental set up. A 12 V DC motor is used as the load.

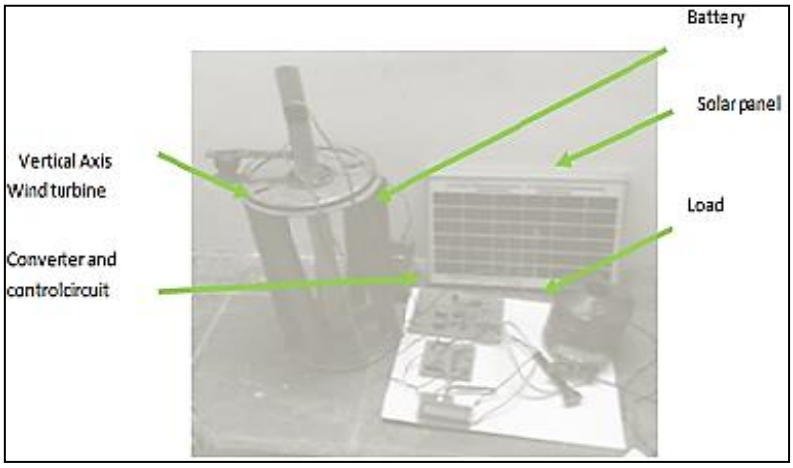

Fig. 22: *Hardware Set Up.*

Fig. 23: *Prototype Model of Water Pumping.*

CONCLUSION

A new multi-input CUK-SEPIC rectifier stage for hybrid wind/solar energy systems has been proposed in this article. The characteristic of this circuit are:

1) For filtering of high frequency harmonics additional input filters are not necessary.
2) The PV and wind input both renewable sources can be stepped up/down.
3) Both individual and simultaneous operation can be supported.

In India as there is abundant potential of solar and wind energy availability, the implementation of such systems are more viable, cost-effective and eco-friendly.

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