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Design and Implementation of a Converter for Hybrid Energy Systems

[1]Shilpa Murali, [2]Dr. K Jamuna

VIT University Chennai, India

***Abstract*: This paper focus on presenting the design of a fusion of CUK and Sepic converters for the hybrid model of solar and wind. Due to depletion of fossil fuels and global warming the energy production is reduced to a large extend. There exist the necessities to depend on the renewable sources of energy for power generation. But the output from these systems will be low. A tracking system must be reliable and able to follow the sun and wind with a certain degree of accuracy MPPT methods can be implemented in order to track maximum power and thus solar and wind energy can be utilized in an efficient manner. MATLAB/SIMULINK were employed for simulation studies. Hardware model of Cuk converter has been done**

***Keywords:* Maximum power point tracking (MPPT).**

I. INTRODUCTION

The global energy crisis and degradation of fossil fuels in recent years had resulted in the dependence of the green energy sources for the purpose of power generation. The major factor which makes the renewable sources in use is that it does not cause any kind of environment pollution. The availability of these energy sources made us to use it in economical manner. Out of all energy sources, solar and wind place an important role. The solar energy gets converted into electrical energy by photovoltaic cells. These cells are semiconductor materials which produce electricity by the phenomenon of photovoltaic effect. The wind energy conversion system mainly consists of a turbine generator. The wind turbine converts wind energy into electric power. Hybridization of solar and wind generation sources give a practical sort of power generation. Many other hybrid wind/PV models with MPPT control are proposed and in works [1]-[5]. The tracking systems can be divided into two major categories, namely electrical/electronic systems [4] and mechanical systems [5]. The third method is to maximize the energy conversion from the solar panel by using MPPT controller.

So in this paper, the energy from sun and wind are used in parallel with a fused model of converter. The conversion system consists of solar cell, wind turbine generator as input, the dc- dc converter and dc load.

II. TYPES OF CONVERTERS

A. DC- DC Converter

The main task is to decide and design a highly efficient converter which should exhibit relevant operation. As the output voltage from the sources are often less and changes with load, it should be stepped up and stabilized by a dc- dc converter. So the dc- dc converter should have a less input current ripple and can operate at varied input voltage range.

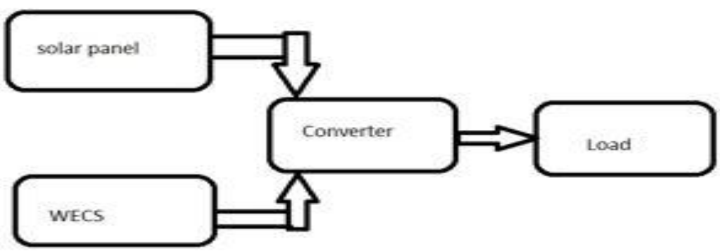

Fig 1: Pictorial presentation of hybrid system

There are different types of dc- dc converters. Buck, Boost, Buck- Boost, CUK converters.

B. CUK Converter

The CUK converter is a classification of Buck – Boost converter. The polarity of output voltage of the CUK converter will be opposite to that of polarity of input voltage. A CUK converter has several advantages over Buck converter and Boost converter. The continuous input current from CUK converter is capable of drawing an output current which is free from ripple.

The Cuk device is a type of DC-DC converter that has output voltage value that's either larger or lesser than the input voltage value. It has the capacity for buck-boost operation. The output polarity of the device is negative in relation with its common terminal.

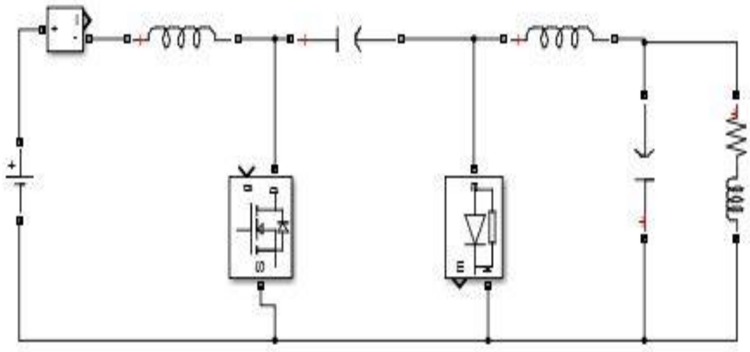

Fig 2.Cuk converter

C. Sepic Converter

Single-ended primary-inductor device (SEPIC) is a category of DC-DC device in which voltage at its output to be larger than, less than that at its input. It is the same as a buck boost device. It has the capability for each step up and step down operation. The output polarity of the device is positive with relation to the common terminal

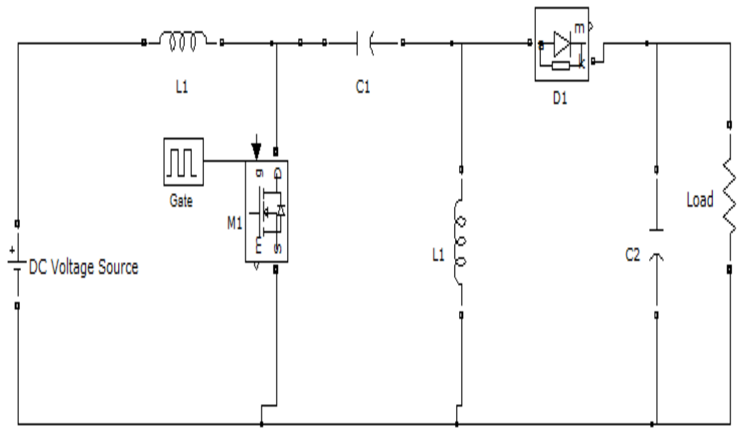

Fig2.b.Sepic converter

A Cuk converter and a Sepic converter is analyzed and a new model is proposed. A fused model of multi input can be choosed for the operation which utilize the features of Cuk and Sepic converters

III. PROPOSED MULTI INPUT STRUCTURE

A system diagram of the rectifier stage of a hybrid energy system is shown in Fig. 3 wherever one amongst the inputs is connected to the output of the PV array and the other input connected to the output of a generator [7]. The features of the proposed design are separate input filters for PFC is eliminated, ripple free input current, low switching loss, better input output characteristics, more efficient, individual and simultaneous operation is supported, MPPT can be realized for each source.

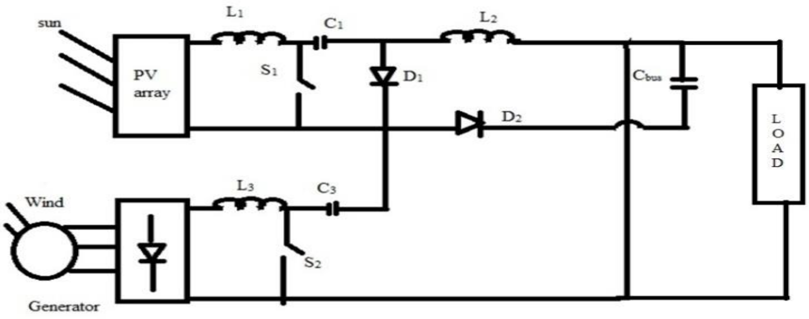

Fig 3: Proposed model of hybrid energy system

IV. OPERATING PRINCIPLE

A diagram of the proposed multi input structure is shown in Fig 3.This system is a rectifier structure for a hybrid energy system .In this, one of the source (solar) is connected to the PV cell/array. The other input is the wind energy which is connected to a generator. The inductor at the output end of the system is utilized for the reconfiguration of the diodes. The system can operate by itself individually when only one source is available and also when both sources are available.

The operation of the system can be defined as the biasing of the diodes takes place .When the diode D_1 is forward biased the input source to which the diode is configured will get enhanced to the converter, then the system becomes a Cuk converter as shown in Fig 6..The relation of input- output can be equated and is given by (i) When the diode D_2 is forward biased the first diode will get reversed biased thus turning off the operation of the system as a Cuk converter and starts to operate as a Sepic converter .Fig 5 represents the case when only the wind is available..The relation of input- output can be equated and is given by (ii)

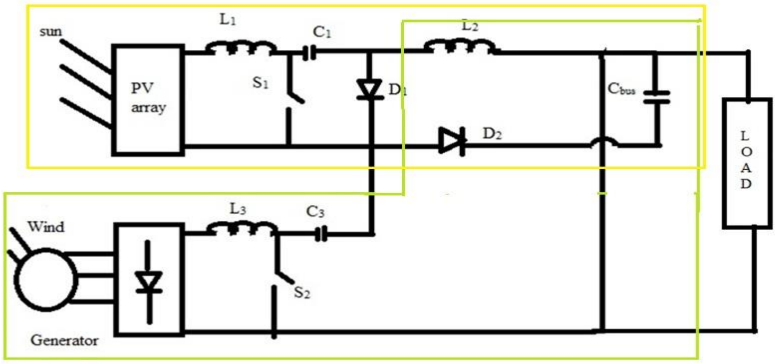

Fig.4 Operation of hybrid model converter

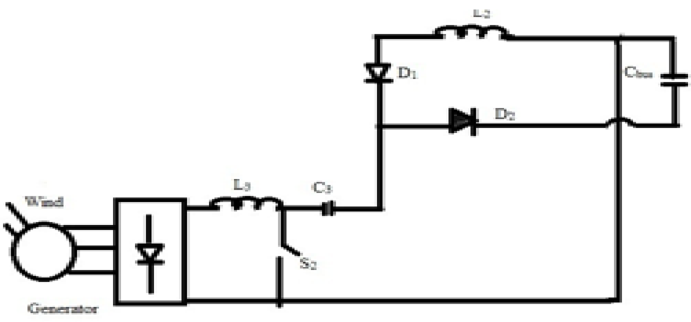

Fig.5 Operation only when wind is available

The voltage relationship of the whole system acting in combined mode is given by (iii). As the Cuk and Sepic has voltage buck-boost capability, the control of duty ratio can be focused thereby ensuring design flexibility.

$$V_{dc}=\left[\frac{d1}{1-d1}\right]V_{pv} \text{------ ----------------------------------} \quad \text{(i)}$$

$$V_{dc}=\left[\frac{d2}{1-d2}\right]V_{W} \text{--} \quad \text{(ii)}$$

$$V_{dc}=\left[\frac{d1}{1-d1}\right]V_{pv}+\left[\frac{d2}{1-d2}\right]V_{W}\text{---------------} \quad \text{(iii)}$$

It is determined that $V_{dc}$is merely the addition of the inputs of the Cuk and SEPIC device. V_{dc} is controlled by d_1 and d_2 singly or at the same time

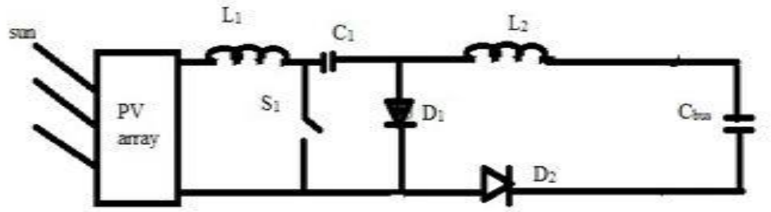

Fig 6.Operation only when solar is available

V. SELECTION OF DUTY RATIO

A graph was plotted was plotted for the selection of the appropriate duty ratio for the converter. The duty ratio was chosen such that the value of voltage is maximum at the output side. The maximum output was obtained for the duty cycle of 75%.

Fig.7 Graph of output voltage with different duty ratio

VI. MODELLING OF SOLAR PANEL

The solar panel which serves as the output of the Cuk converter is modeled for different irradiation level. The rating of the available solar panel was 16v, 1.5A, 10w.S the modeling was done in MATLAB for the values ranging from 15v to 20 and the variation of current is noted.

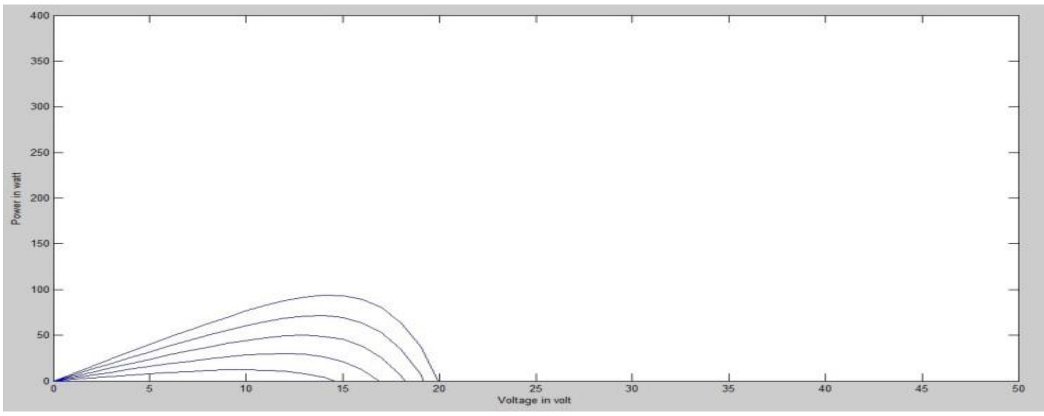

Fig 8.power v/s voltage curve

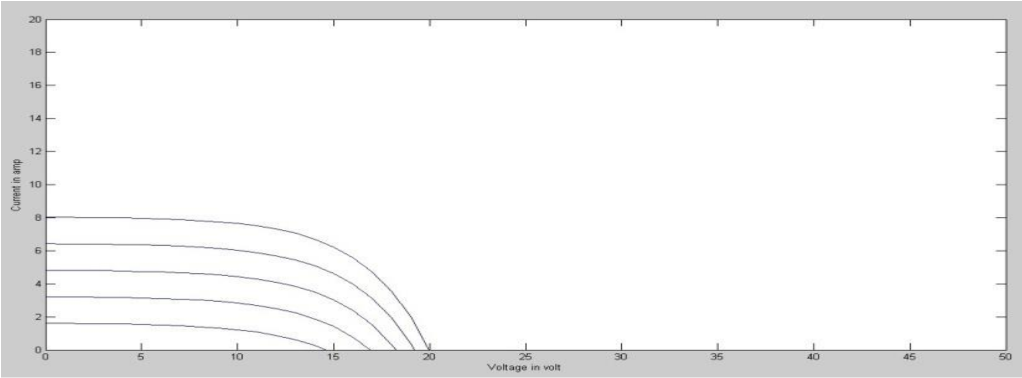

Fig.9 current v/s voltage curve

From the above figures, it was clear that the current varies from 1.5 to 8A for the variation of voltage from 15v to 20v

VII. MODELING OF WIND ENERGY CONVERESION SYSTEM

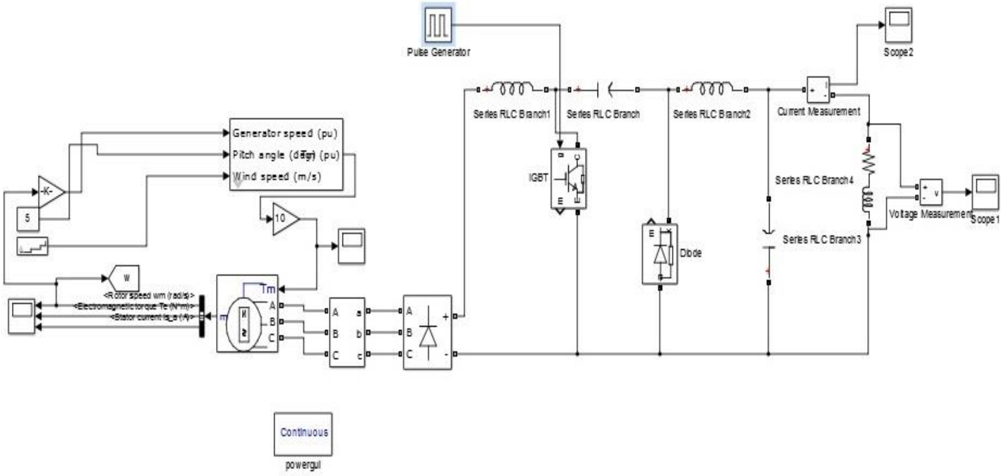

Fig.10 Simulink model of WECS with Sepic converter.

The wind energy conversion system consists of a turbine to capture the energy of the wind, a drive train to speed up the rotational speed of the shaft and a generator. A variable speed turbine is used here.

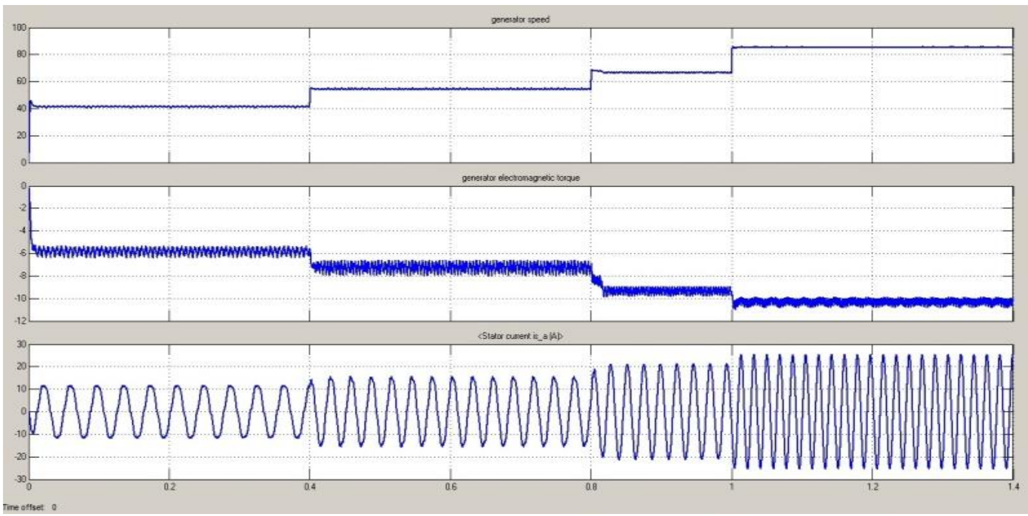

Fig.11 Simulation output from WECS

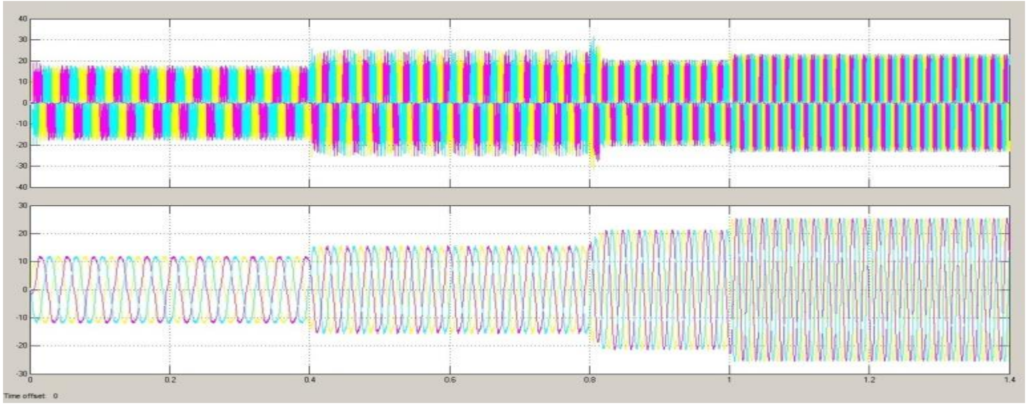

Fig.12 Simulink output from wind generator

VIII. MPPT METHODS FOR SOLAR AND WIND ENERGY

The presence of wind is unpredictable which a relevant factor when considering the power generation is. Another drawback is that the irradiance level of solar also changes. These drawbacks of the energy sources pave the way for the better control of the system with maximum energy utilization .A method for controlling the power generation is MPPT method .Maximum power point tracking optimizes the power value to the reference value.

MPPT	SPEED	COMPLEXITY	RELIABILITY	IMPLEMENTATION
Fractional V_{SC}	Medium	Medium	Low	Digital/Analog
Fractional I_{SC}	Medium	Low	Low	Digital/Analog
Incremental conductance	Varies	Medium	Medium	Digital
Hill climbing	Varies	Low	Medium	Digital/Analog
Fuzzy logic	Fast	High	Medium	Digital
Neural network	Fast	High	Medium	Digital

Fig.13. Table of comparison of solar MPPT methods

Incremental conductance method is used for the maximum power tracking of solar energy due to its advantage over the other methods. The hill climbing and perturbation method fails where it develops steady state oscillations which results in waste of energy. These oscillations can be suppressed by smaller perturbation but it may cause the system to slow down during tracking. The incremental Conductance methods works on the pattern by adjusting the array terminal voltage each time according to the MPP voltage. It also eliminates the use of PI controllers. The control algorithm used for tracking maximum power shown below.

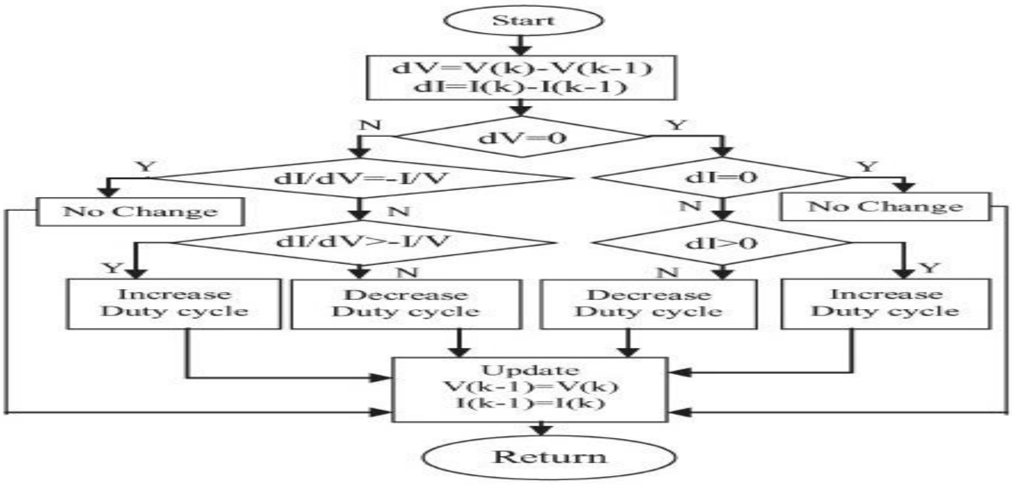

Fig.14. Control algorithm for incremental conductance method

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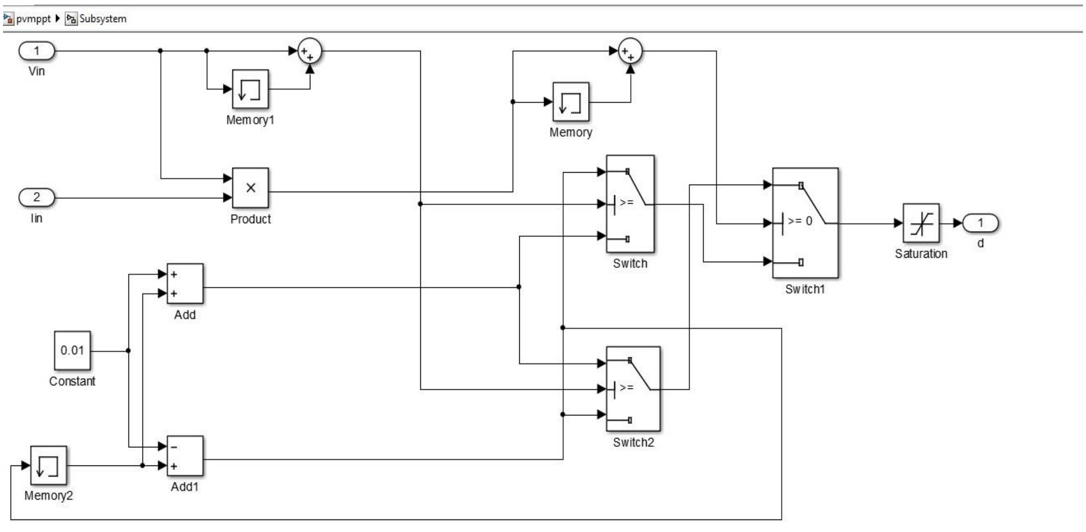

Fig.15 Simulink model of MPPT for solar powered Cuk converter

There are different MPPT methods for tacking maximum wind energy. The power signal feedback method is used here. It is based on tracking the maximum power even without having any information about wind speed or the generator parameters. Another feature is that it eliminates the use of speed transducer.

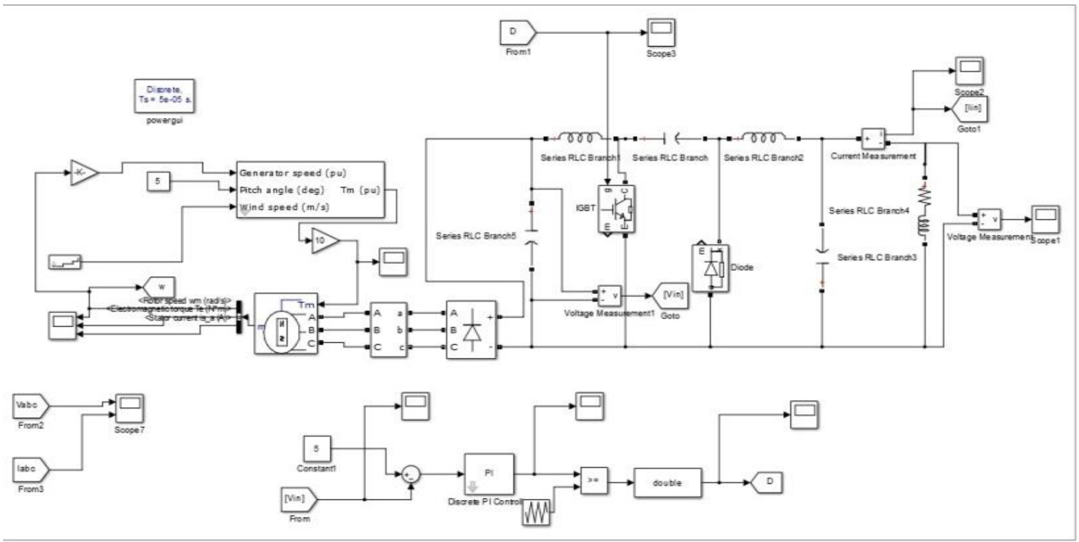

Fig.16 Simulink model of WECS based Sepic converter with MPPT

IX. DESIGN OF THE CUK CONVERTER

Input voltage	16v
Input inductor	.336µH
Output inductor	.275µH
Input capacitor	2.25µF
Output capacitor	1.25µF
Output voltage	64v

Fig.17 Table showing calculated design values of components

The Fig.11 represents the theoretical value derived from the conventional equations of Cuk converter for a duty cycle of 75%.Fig 12 represents the output waveform from the Cuk converter. The waveform includes dynamic and steady state response and hence the output settles to a value of 64v after a fraction of millisecond.

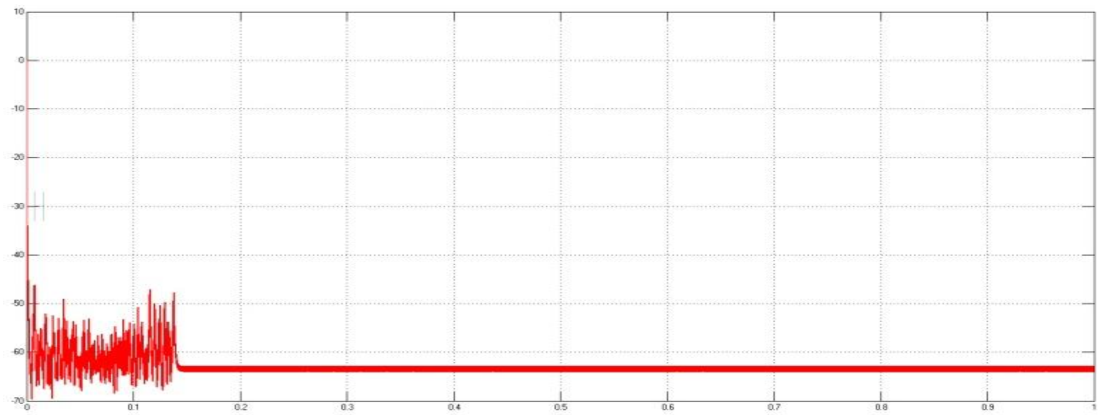

Fig.18 Simulink output of Cuk converter

X. SOFTWARE COMPILERS

The PIC 16F877A is a family of modified Harvard Architecture microcontrollers made by microchip technology. PIC initially referred as peripheral interface controllers. Two inbuilt CCP modules are available with a PIC 16F877A MCU. CCP stands for Compare Capture and PWM mode. The CCP module consist of 16 bit registers each for the three modes which modify its operative feature depending on the user requirement as capture, compare and PWM duty cycle register.

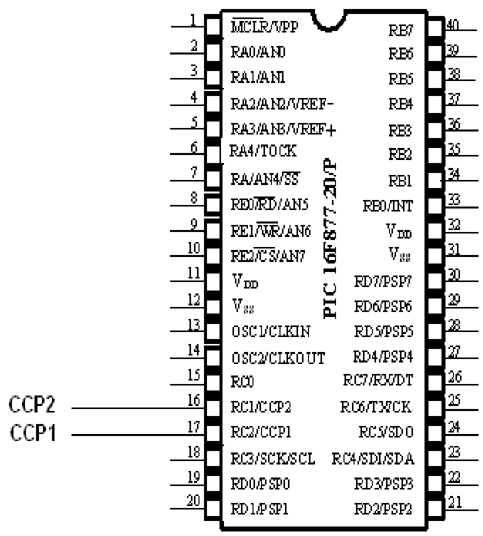

Fig 19 .Pin diagram of 16F877A

CCs Compiler provides management of embedded software development which can be done from design. The programming of the device along with debugging also gives a platform to develop C code program. This has indulged itself with integrated inbuilt functions, also analyzation of performance and statistics. The debugging code is complied in real time while running on micro chip PIC devices.

Proteus is software for microprocessor simulation, schematic capture and printed circuit boards. The system has the advantage of simplicity for user programming requirement and reliability. The easiness and the user friendly context of the software help it to demand for more precise results.

USB PIC program is an USB in circuit programmer for microchip PIC processor. The hex code is generated and loaded to the microcontroller with the help of this software. The migration between all microchip PIC MCU devices is possible and comparatively easy. It is used to define, set-up and manage interrupts.

XI. SIMULATION RESULTS

The microcontroller is simulated in Proteus software and the output pulses are generated (Fig 21). The same is connected to CRO using driver circuit and output pulses are generated. (Fig. 22).Fig 20 represents the gate pulses generated by the system in open loop.

Fig 20.gate pulses of the converter

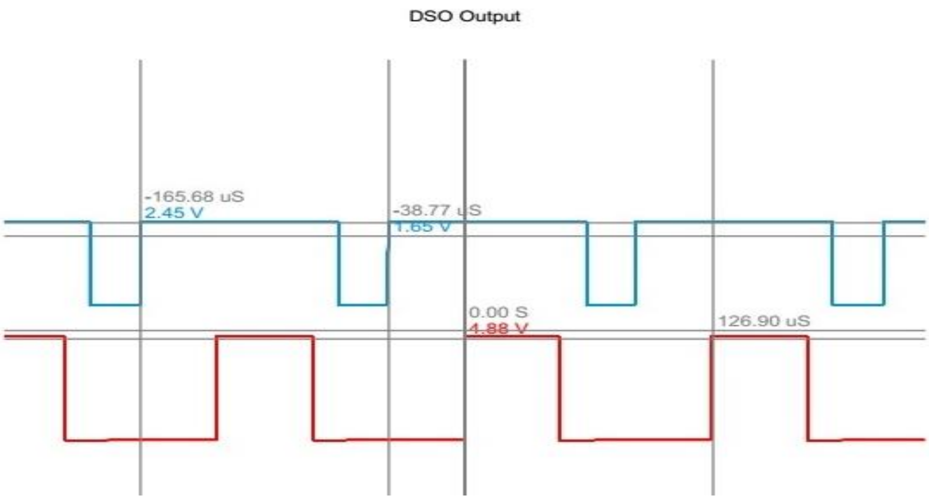

Fig 21. Simulation waveform of proteus

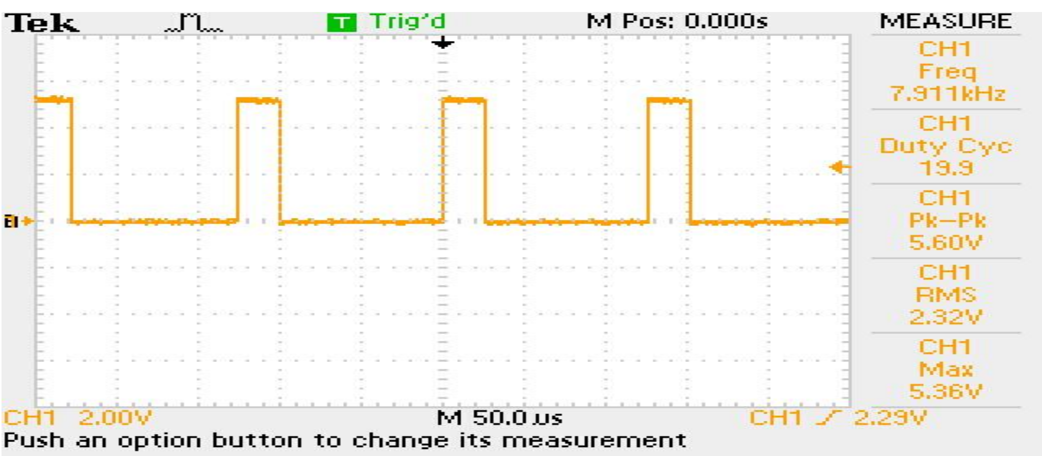

Fig. 22 CRO generated waveform

XII. CONCLUSION

The work focused on a hybrid energy source model with the fusion of Cuk and Sepic converter for power generation. The maximum power point tracking is realized for both the sources individually. The control pulses were given from PIC 16f877a.The microcontroller was simulated in Proteus and the output pulses was generated. The driver kit and the hardware model of Cuk converter was completed

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