An Unique Technique for Solar Wind Hybrid Power Generation System

Swarupa Pinninti
Associate Professor, EEE Department
WISTM Engineering college,
Visakhapatnam,A.P,India

Sri Latha Eti
Assistant Professor,EEE Department
WISTM Engineering college,
Visakhapatnam,A.P,India.

Abstract— **Renewable energy sources have become a popular alternative electrical energy source where power generation in conventional ways is not practical. The Hybrid power system provides an economical and sustainable power to the grid. Photovoltaic and wind energy sources are being increasingly recognized as cost effective generation sources in isolated power system. A simple control technique which is also cost effective has been proposed to track the operating point at which maximum power can be coerced from the PV system and wind turbine generation system under continuously changing environmental conditions. The entire hybrid system is described given along with comprehensive simulation results that discover the feasibility of the system. The analysis of the simulated results demonstrates the smooth operation of proposed system in a hybrid system.**

Keywords—Modelling of PV cell, Modelling of wind turbine, DC-DC converters

I. INTRODUCTION

With increasing concern of global warming and the depletion of fossil fuel reserves, many are looking at sustainable energy solutions to preserve the earth for the future generations. Other than hydro power, wind and photovoltaic energy holds the most potential to meet our energy demands. Alone, wind energy is capable of supplying large amounts of power but its presence is highly unpredictable as it can be here one moment and gone in another. Similarly, solar energy is present throughout the day but the solar irradiation levels vary due to sun intensity and unpredictable shadows cast by clouds, birds, trees, etc. The common inherent drawback of wind and photovoltaic systems are their intermittent natures that make them unreliable.

However, by combining these two intermittent sources and by incorporating maximum power point tracking (MPPT) algorithms, the system power transfer efficiency and reliability can be improved significantly. The integration of renewable energy sources and energy-storage systems has been one of the new trends in power-electronic technology. The increasing number of renewable energy sources and distributed generators requires new strategies for their operations in order to maintain or improve the power-supply stability and quality. Combining multiple renewable resources via a common dc bus of a power converter has been prevalent because of convenience in integrated monitoring and control and consistency in the structure of controllers as compared with a common ac type. Dynamic performance of a wind and solar system is analyzed.

Most applications are for stand-alone operation, where the main control target is to balance local loads. A few grid-connected systems consider the grid as just a back-up means to use when there is insufficient supply from renewable sources. They are originally designed to meet local load demands with a loss of power-supply probability of a specific period. Such hybrid systems, focusing on providing sustainable power to their loads, do not care much about the quality or flexibility of power delivered to the grid. From the perspective of utility, however, a hybrid system with less fluctuating power injection or with the capability of flexibly regulating its power is more desirable. In addition, users will prefer a system that can provide multiple options for power transfer since it will be favorable in system operation and management. Control strategies of such a hybrid system should be quite different from those of conventional systems.

A. INTRODUCTION TO HYBRID SYSTEM

1) Solar Cell or PV Cell

It is an important source of renewable energy and its technologies are broadly characterized as either passive solar or active solar depending on the way they capture and distribute solar energy or convert it into solar power. Active solar techniques include the use of photovoltaic systems, concentrated solar power and solar water heating to harness the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light dispersing properties, and designing spaces that naturally circulate air.

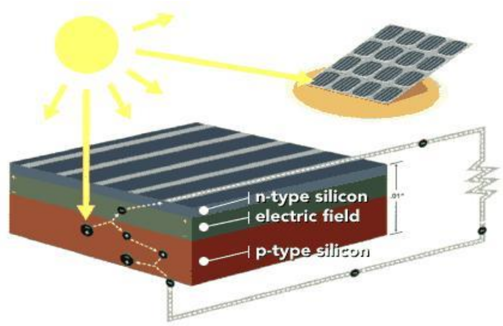


Fig .1 PV cell

2) Wind Energy

The schematic diagram of the wind energy system is manifested in figure 2 shown below.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 10, October-2019

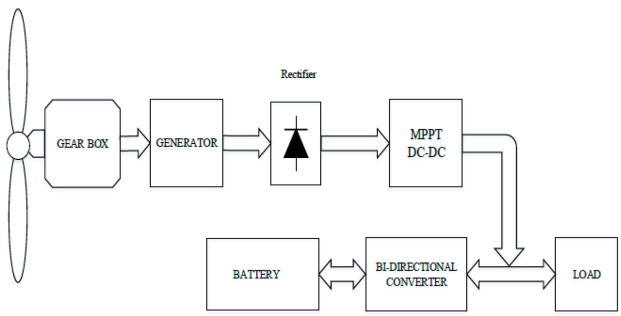


Fig .2 Overall block diagram of wind energy system

This system comprises of a wind turbine which transforms wind's kinetic energy into rotating motion, a gear box to match the turbine speed to generator speed, a generator which converts mechanical energy into electrical energy, a rectifier which converts ac voltage to dc, a controllable dc-dc converter to trace the maximum power point, a battery is charged and discharged through bi-directional converter

II. MODELLING OF RENEWABLE ENERGY SOURCES

A. MODELLING OF PV CELL

The photovoltaic system converts sunlight directly to electricity without having any disastrous effect on our environment. The basic segment of PV array is PV cell, which is just a simple p-n junction device. The fig.2.4 manifests the equivalent circuit of PV cell [1]. Equivalent circuit has a current source (photocurrent), a diode parallel to it, a resistor in series describing an internal resistance to the flow of current and a shunt resistance which expresses a leakage current. The current supplied to the load can be given as.

$$I = I_{PV} - I_0 [\exp ((V+IR_S)/(a V_T)) - 1] - (V + IR_S)/R_P \qquad (1)$$

Where
I_{PV}–Photocurrent current,
I_O–diode's Reverse saturation current,
V–Voltage across the diode,
a– Ideality factor
V_T –Thermal voltage
Rs– Series resistance
Rp–Shunt resistance

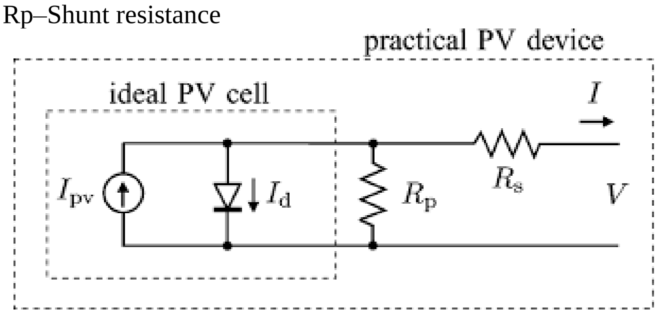


Fig. 3 Equivalent circuit of Single diode modal of a solar cell

PV cell photocurrent, which depends on the radiation and temperature, can be expressed as.

$$I_{PV} = (I_{PV\_STC} + K_1 \Delta T)G/G_{STC} \qquad (2)$$

Where
K_I– cell's short circuit current temperature coefficient
G–solar irradiation in W/m2
G_{STC}–nominal solar irradiation in W/m2
I_{PV_STC}– Light generated current under standard test condition

The reverse saturation current varies as a cubic function of temperature, which is represented as

$$I_O = I_{O\_STC}\left(\frac{T_{STC}}{T}\right)^3 \exp\left[\frac{qE_g}{aK}\left(\frac{1}{T_{STC}} - \frac{1}{T}\right)\right] \qquad (3)$$

Where
I_{0_STC}– Nominal saturation current
Eg – Energy band gap of semiconductor
T_{STC}–temperature at standard test condition
q – Charge of electrons
The reverse saturation current can be further improved as a function of temperature as follows:

$$I_O = \frac{\left(I_{SC\_STC} + K_I \Delta T\right)}{\exp\left[\frac{\left(V_{OC\_STC} + K_V \Delta T\right)}{aV_T}\right] - 1} \qquad (4)$$

I_{SC_STC}- short circuit current at standard test condition
V_{OC_STC}– short circuit voltage at standard test condition
K_V– temperature coefficient of open circuit voltage

B. MODELING OF WIND TURBINES

A wind turbine converts kinetic energy of air i.e. wind power into mechanical power i.e. rotating motion of the turbine that can be used directly to run the machine or generator. Power captured by wind turbine blade is a concomitant of the blade shape, the pitch angle, speed of rotation, radius of the rotor . The equation for the power generated is shown below:

$$P_M = \frac{1}{2}\pi\rho C_P(\lambda, \beta)R^2 V^3 \qquad (5)$$

Where
PM– Power captured by wind turbine
ρ–Air density
β–Pitch angle (in degrees)
R– Blade radius (in meters)
V– Wind speed (in m/s)
The term λ is the tip-speed ratio, given by the equation

$$\lambda = \Omega R/V \qquad (6)$$

Where
Ω is Rotor speed of rotation (in rad/sec)
CP can be expressed as the function of the tip-speed ratio

$$C_P = \frac{1}{2}\left(\frac{116}{\lambda_1} - 0.4\beta - 5\right)\exp^{\frac{-16.5}{\lambda_1}} \qquad (7)$$

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 10, October-2019

$$\lambda_1 = \left(\frac{1}{\frac{1}{\lambda + 0.089} - \frac{0.035}{\beta^3 + 1}} \right) \quad (8)$$

Where

CP – Wind turbine power coefficient
λ–Tip- speed ratio
λ1–Constant

III. TYPES OF DC-DC CONVERTER

A. CUK CONVERTER

The Cuk converter is a type of DC/DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. It is essentially a boost converter followed by a buck converter with a capacitor to couple the energy.

The non-isolated Cuk converter can only have opposite polarity between input and output. It uses a capacitor as its main energy-storage component, unlike most other types of converters which use an inductor. It is named after Slobodan Cuk of the California Institute of Technology, who first presented the design

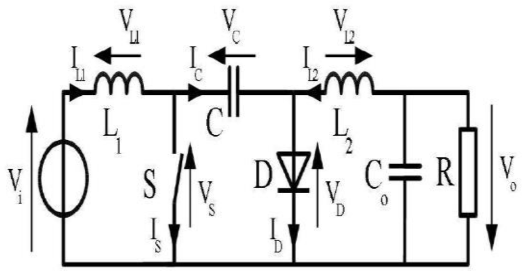


Fig. 4 Schematic circuit of Cuk converter

1) OPERATING PRINCIPLE

A non-isolated Ćuk converter comprises two inductors, two capacitors, a switch (usually a transistor), and a diode. Its schematic can be seen in figure 4. It is an inverting converter, so the output voltage is negative with respect to the input voltage.

The capacitor C is used to transfer energy and is connected alternately to the input and to the output of the converter via the commutation of the transistor and the diode .

.

As with other converters (buck converter, boost converter, buck-boost converter) the Ćuk converter can either operate in continuous or discontinuous current mode.

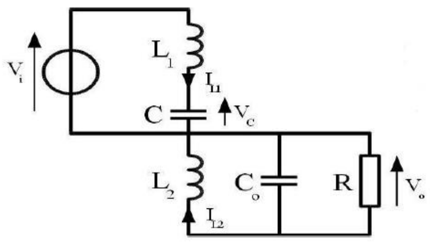


Fig .5 Off-state cuk converter

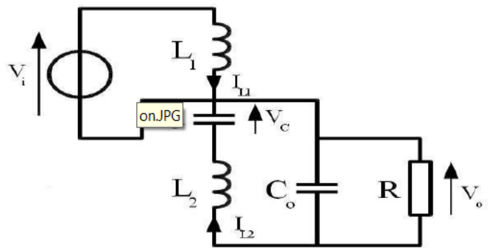


Fig .6 On-state cuk converter

2) CONTINUOUS MODE:

In steady state, the energy stored in the inductors has to remain the same at the beginning and at the end of a commutation cycle. The energy in an inductor is given by:

$$E = [1/2]Li^2 \quad (9)$$

This implies that the current through the inductors has to be the same at the beginning and the end of the commutation cycle. As the evolution of the current through an inductor is related to the voltage across it:

$$V_L = L\,(di/dt) \quad (10)$$

.

If we consider that the capacitors C and Co are large enough for the voltage ripple across them to be negligible, the inductor voltages become:

1. In the off-state, inductor L1 is connected in series with Vi and C . Therefore $V_{LI} = V_i - V_c$ .As the diode D is forward biased (we consider zero voltage drop), L2 is directly connected to the output capacitor. Therefore $V_{L2}=0$.

2. In the on-state, inductor L1 is directly connected to the input source. Therefore $V_{LI} = V_i$ inductor L2 is connected in series with C and the output capacitor, so $VL2 = V_0 + VC$.

The converter operates in on state from t=0 to t=D·T (D is the duty cycle), and in off state from D·T to T (that is, during a period equal to (1-D)·T). The average values of VL1 and VL2 are therefore

$$\overline{V_{L1}} = D.V_i + (1-D).(V_i - V_c) = (V_i - (1-D).V_c)$$

$$\overline{V_{L2}} = D.(V_o + V_c) + (1-D).V_0 \quad (11)$$

As both average voltage have to be zero to satisfy the steady-state conditions, using the last equation we can write

$$V_c = -V_o/D \quad (12)$$

So the average voltage across L1 becomes

$$V_{L1} = (V_i + (1-D)V_o/D) \quad (13)$$

Which can be written as

$$V_o/V_i = -D/(1-D) \quad (14)$$

3) DISCONTINUOUS MODE

Like all DC/DC converters Cuk converters rely on the ability of the inductors in the circuit to provide continuous current, in much the same way a capacitor in a rectifier filter provides continuous voltage. If this inductor is too small or

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 10, October-2019

below the "critical inductance", then the current will be discontinuous. This state of operation is usually not studied in much depth, as it is not used beyond a demonstrating of why the minimum inductance is crucial.
The minimum inductance is given by

$$L_{1min} = \frac{(1-D)^2 R}{2D f_s} \quad (15)$$

Where f_s is the switching new frequency.

B. SINGLE ENDED PRIMARY-INDUCTOR CONVERTER (SEPIC)

The single-ended primary-inductor converter (SEPIC) is a type of DC/DC converter allowing the electrical potential (voltage) at its output to be greater than, less than, or equal to that at its input. The output of the SEPIC is controlled by the duty cycle of the control transistor.

A SEPIC is essentially a boost converter followed by a buck-boost converter, therefore it is similar to a traditional buck-boost converter, but has advantages of having non-inverted output (the output has the same voltage polarity as the input), using a series capacitor to couple energy from the input to the output (and thus can respond more gracefully to a short-circuit output), and being capable of true shutdown: when the switch is turned off, its output drops to 0 V, following a fairly hefty transient dump of charge.

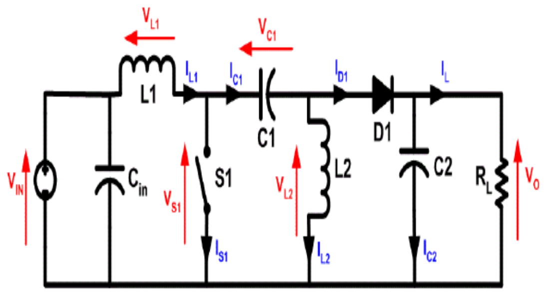


Fig .7 Schematic circuit of SEPIC converter

1) OPERATION

The schematic diagram for a basic SEPIC is shown in Figure 7. As with other switched mode power supplies (specifically DC-to-DC converters), the SEPIC exchanges energy between the capacitors and inductors in order to convert from one voltage to another. The amount of energy exchanged is controlled by switch S1, which is typically a transistor such as a MOSFET. MOSFETs offer much higher input impedance and lower voltage drop than bipolar junction transistors (BJTs), and do not require biasing resistors as MOSFET switching is controlled by differences in voltage rather than a current, as with BJTs).

2) CONTINUOUS MODE

A SEPIC is said to be in continuous-conduction mode ("continuous mode") if the current through the inductor L1 never falls to zero. During a SEPIC's steady-state operation, the average voltage across capacitor C1 (VC1) is equal to the input voltage (Vin). Because capacitor C1 blocks direct current (DC), the average current through it (IC1) is zero, making inductor L2 the only source of DC load current. Therefore, the average current through inductor L2 (IL2) is the same as the average load current and hence independent of the input voltage.

Looking at average voltages, the following can be written:

$$V_{IN}=V_{L1}+V_{L2}+V_{C1} \quad (16)$$

The average currents can be summed as follows (average capacitor currents must be zero):

$$I_{D1}=I_{L1}-I_{L2} \quad (17)$$

When switch S1 is turned on, current IL1 increases and the current IL2 goes more negative. (Mathematically, it decreases due to arrow direction.) The energy to increase the current IL1 comes from the input source. Since S1 is a short while closed, and the instantaneous voltage VC1 is approximately VIN, the voltage VL2 is approximately −VIN. Therefore, the capacitor C1 supplies the energy to increase the magnitude of the current in IL2 and thus increase the energy stored in L2. The easiest way to visualize this is to consider the bias voltages of the circuit in a D.C. state, then close S1.

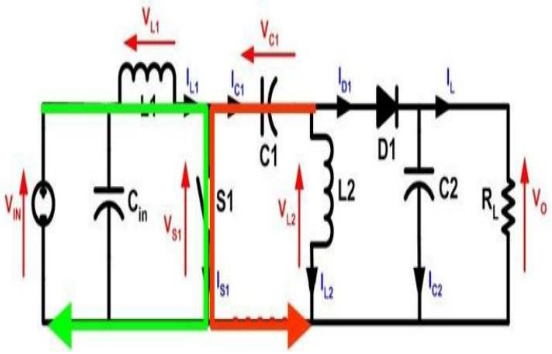


Fig .8 S_1 closed

When switch S1 is turned off, the current IC1 becomes the same as the current IL1, since inductors do not allow instantaneous changes in current. The current IL2 will continue in the negative direction, in fact it never reverses direction. It can be seen from the diagram that a negative IL2 will add to the current IL1 to increase the current delivered to the load. Using Kirchhoff's Current Law, it is be shown that ID1 = IC1 - IL2. It can then be concluded, that while S1 is off, power is delivered to the load from both L2 and L1. C1, however is being charged by L1 during this off cycle, and will in turn recharge L2 during the on cycle.

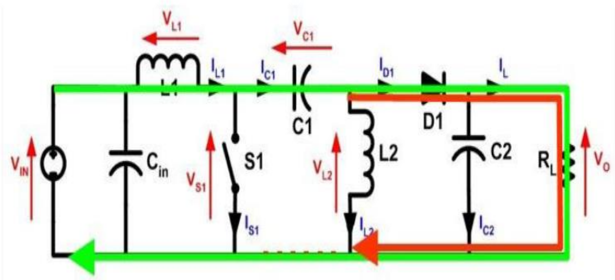


Fig. 9. With S_1 open

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 10, October-2019

The capacitor CIN is required to reduce the effects of the parasitic inductance and internal resistance of the power supply. The boost/buck capabilities of the SEPIC are possible because of capacitor C1 and inductor L2. Inductor L1 and switch S1 create a standard boost converter, which generates a voltage (VS1) that is higher than VIN, whose magnitude is determined by the duty cycle of the switch S1. Since the average voltage across C1 is VIN, the output voltage (VO) is VS1 - VIN. If VS1 is less than double VIN, then the output voltage will be less than the input voltage. If VS1 is greater than double VIN, then the output voltage will be greater than the input voltage.

3) DISCONTINUOUS MODE

A SEPIC is said to be in discontinuous-conduction mode or discontinuous mode if the current through the inductor L1 is allowed to fall to zero.

C. WORKING MODELS OF HYBRID SYSTEM

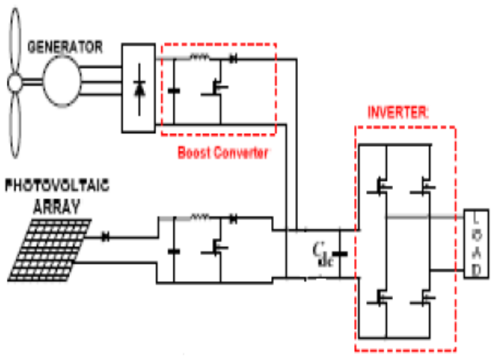


Fig .10 Hybrid system with multi connected boost converter

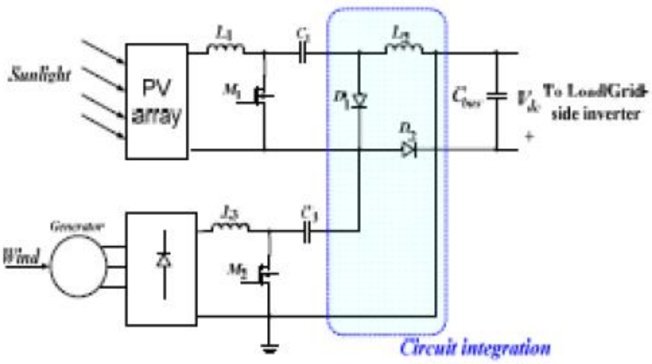


Fig.11 Hybrid wind/PV system

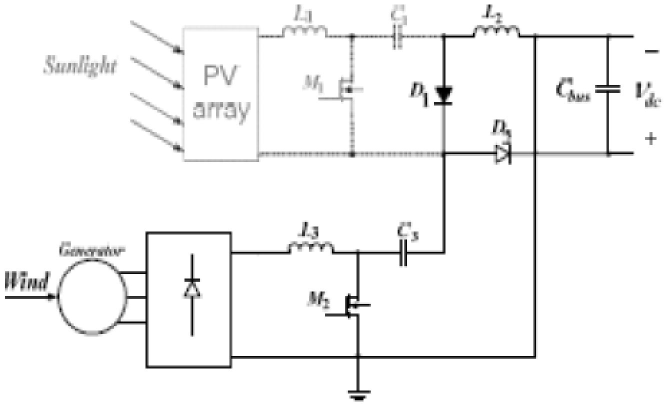


Fig. 12 Only wind source is operational (SEPIC)

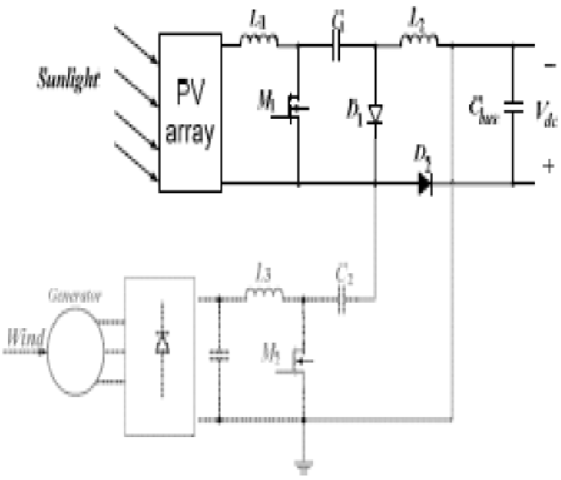


Fig.13 Only PV source is operational (CUK)

IV. SIMULINK MODELS

A. SIMULINK MODEL OF HYBRID SYSTEM WHEN ONLY PV SOURCE IS AVAILABLE:

The blocks and their parameters used in the design of PV system are mentioned below:

Discrete PWM Generator:-
Generator mode:3 arm bridge-6 pulses
Carrier frequency=1080 Hz
Sample time=50e-6
Modulation index=0.4
PV module:
Timer:- Time[0 1]s Amplitude[30 30]
At standard test condition,
T_{stc}=301.18
$I_{o\_stc}=I_{rr}$=2.0793*10^-6
q=1.6*10^-9
k=1.5*1.38*10^-23
q_1=1.602*10^-19
k_1=1.38*10^-23

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 10, October-2019

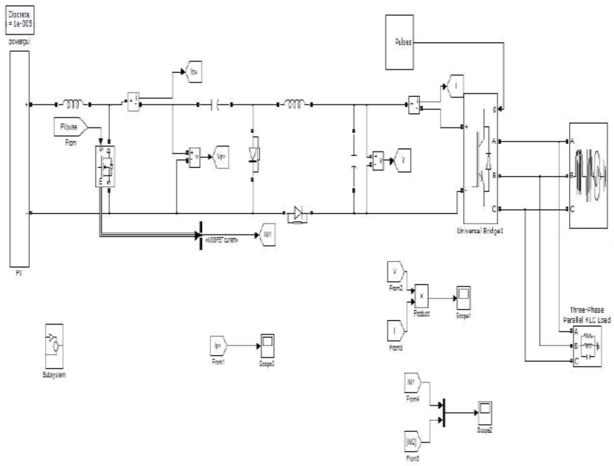


Fig.14 Simulink model with only PV source

B. SIMULINK MODEL OF HYBRID SYSTEM WHEN ONLY WIND SOURCE IS AVAILABLE:

The blocks and their parameters used in the wind system are mentioned below:

<u>Wind system</u>:-
Wind speed=9 m/s
Pitch angle=45˚
Gain: k=1/1500
Sample time=-1
<u>Wind turbine:</u>
Nominal mechanical output power =1.5e6 W
Base power of generator=1.5e6/0.9 VA
Base wind speed=12 m/s
Maximum power at base wind speed=0.73 pu of nominal mechanical power
Base rotational speed=1.2 pu of base generator speed
Pitch angle beta=0˚

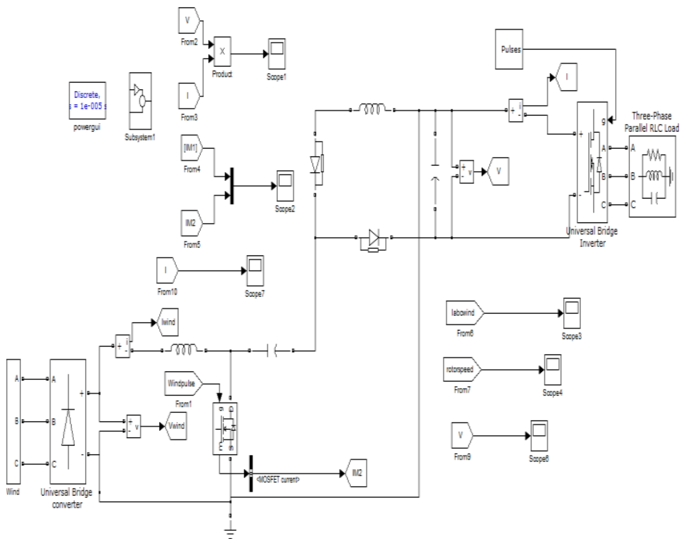


Fig.15 Simulink model with only wind source

C. SIMULINK MODEL OF HYBRID SYSTEM:

The complete Hybrid Model is obtained by coupling the PV system and Wind system using the before mentioned blocks and their respective parameters .Thus the well-defined model of solar PV and wind Hybrid system is established as shown in figure 16.

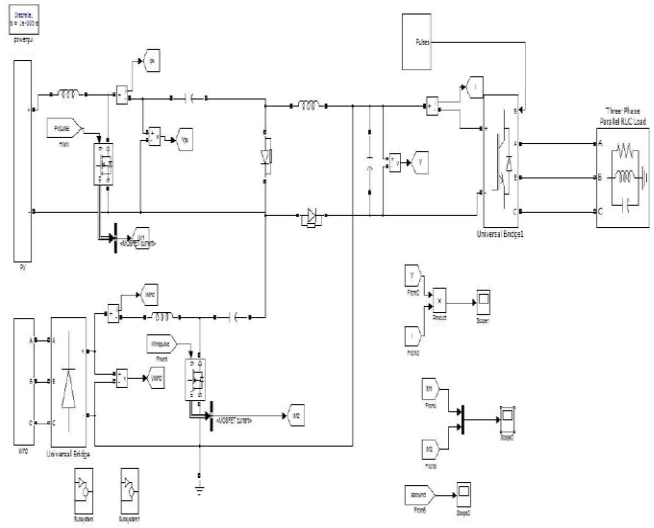


Fig.16 Simulink model for hybrid wind-solar energy system

V. RESULTS

The figure below shows the output power when only solar PV source is available.

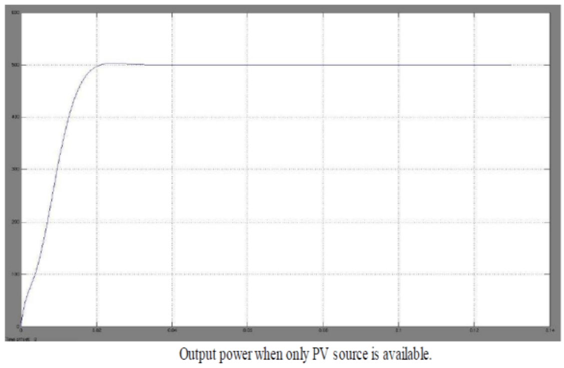


Fig. 17 Output power when only Solar PV source is available

The figure below shows the output power when only wind source is available.

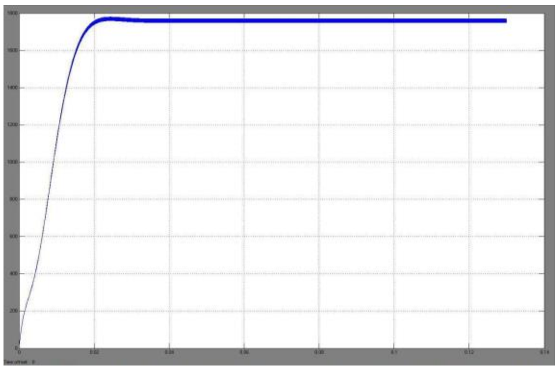
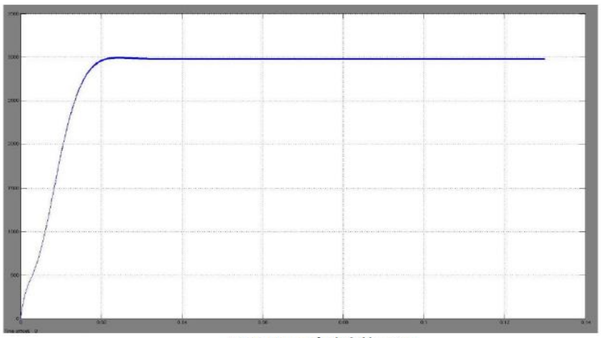


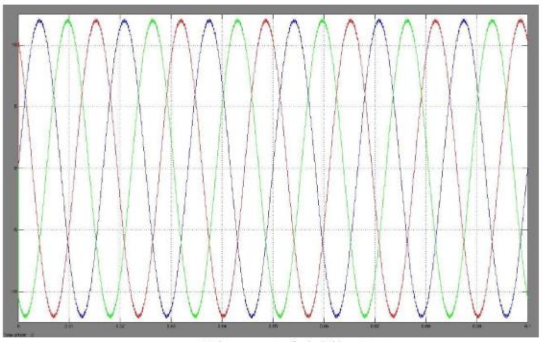
Fig. 18 Output power when only wind source is available

The figures below shows the output power and Three phase current waveforms of Hybrid system when both Wind source and Solar PV source is available.



Output power for hybrid system

Fig. 19 Output power for hybrid system



3-phase currents for hybrid system

Fig. 20 Three-phase current of hybrid system

VI. CONCLUSION

In this paper, load demand is met from the combination of PV array & wind turbine. An inverter is used to convert output from solar & wind systems into AC power output. Circuit is used to connect a load of 3KW in the given time. This hybrid system is controlled to give maximum output power under all operating conditions to meet the load. Either wind or solar system is supported by the battery to meet the load. Also, simultaneous operation of wind and solar system is supported by battery for the same load.

A new multi-input Cuk-SEPIC rectifier stage for hybrid wind/solar energy systems has been presented. Both PV cell and wind energy systems are integrated and the hybrid system is used for battery charging and discharging. Additional input filters are not necessary to filter out high frequency harmonics. Both renewable sources can be stepped up/down (supports wide ranges of PV and wind input).

VII. FUTURE SCOPE

The losses incurred at the initial working stage of wind turbine can be controlled through optimum modelling of essential parameters .Transformer can be added to distribute supply variedly to the load .PID controllers can be used to control current in required circuit. Other methods of MPPT can be implemented and compared .A current controller is designed to react to and absorb unanticipated power disturbances in the utility grid.

REFERENCES

[1] T. Salmi, M. Bouzguenda, A. Gagtli, "MATLAB/Simulink based modelling of solar photovoltaic cell," *International journal of renewable energy research,* vol.2, no.2, 2012.

[2] S. Meenakshi, K.Rajambal, S. Elangovan "Intelligent controller for stand-alone hybrid generation system," *IEEE,* May. 2006.

[3] Nabil A. Ahmed, Masafumi Miyatake, "A stand-alone hybrid generation system combining solar photovoltaic and wind turbine with simple maximum power point tracking control," *IPEMC* 2006, *IEEE,* 2006.

[4] M. G. Villalva, J. R. Gazoli, "Modelling and circuit based simulation of photovoltaic arrays," *Brazilian power electronics conference (COBEP),* 2009.

[5] Marcelo Gradella Villalva, Jonas Rafel Gazoli, "Comprehensive approach to modelling and simulation of photovoltaic arrays," *IEEE transaction on power electronics,* vol.24, no.5, May 2009.

[6] Hiren Patel and Vivek Agarwal, "Matlab based modelling, to study the effect of partial shading on PV array characteristics," *IEEE transaction on energy conversion,* vol.23, no.1, March 2008.

[7] Mohammed Abdulazeez, Ires Iskender, "Simulation and experimental study of shading effect on series and parallel connected PV modules," *IEEE transaction on energy conversion,* vol.27, no.2, March 2008.

[8] SiyuGuo, Timothly Michael Walsh, "Analyzing partial shading of PV module by circuit modeling," *IEEE* 2011.

[9] Zhou Xuesong, Song Daichun, Ma Youjie, Chen Deshu, "The simulation and design for MPPT of PV system based on Incremental conductance method," *Wase International conference on information engineering,* 2010.

[10] Azadeh Safari, Saad Mekhilef, "Simulation and Hardware Implementation of Incremental Conductance MPPT with Direct Control Method Using Cuk Converter," *IEEE transaction on industrial electronics,* vol. 58, no. 4, april 2011.

[11] Mihnea Rosu-Hamzescu, Sergiu Oprea, "Practical guide to implementing Solar panel MPPT algorithm," *Microchip technology Inc,* 2013