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Sandwich Toplogy of Converters for Maximum Power Point Tracking in Hybrid Wind-PV-Wind System

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A B S T R A C T

Renewable energy gives clean,cheap,non-exuastible sources for electricity generation.Hyribridizing of these sources is more advantageous than single sources. This paper presents maximum power point tracking with new converter technology in hybrid wind- pv –wind.To remove necessity of passive input filters fused cuk-zeta-sepic converters is used.P&O algorithm is used for maximum power point tracking.Fusion of sepic-cuk-zeta converter is connected with wind-PV-wind energy system. For this work MATLAB software is used.

Keywords: Sandwich Topology , Zeta Converter,Cuk Converter,Sepic Converter,Renewable Energy,MPPT,P&O Algorithm

1. Introduction

Increasing demand of electrical energy forces us to search new ways to generate electricity.There are many sources of electricity generation .These are divided in two types renewable and non renewable energy sources.Because of non-exhaustible nature of renewable sources ,it is preferred for electricity generation. Radiation of sun and wind are known as advantageous sources of electricity generation.When it is used combined,it is say term hybrid system.Generation of electricity form hybrid system is more benificial than single energy system.To find constant load and remove necessity of passive input filters new converter topology is used .

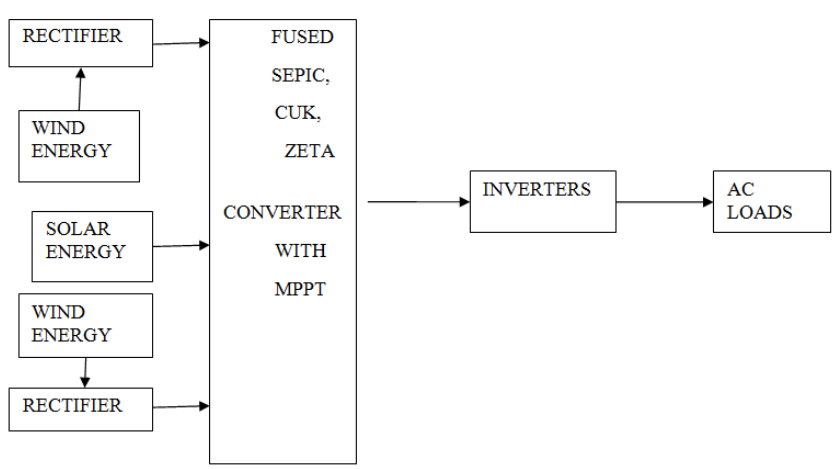

Fig 1: Block diagram of Hybrid system connected with sandwich converter with MPPT

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2. MPPT Techniques

To maximize power extraction under all types of conditions, Maximum power point technique is used. It is mostly used in PV Panel and wind turbine. By the impedance, operating point can be found in PV panel. It can be see that operating point depends on impedance. Varying the impedance is to arrive operating point at peak. Panels works as DC-DC machines. As it is known that DC – Dc machines work to exchange impedance in one circuit to another circuit. So it can vary impedances. Impedances depends on duty ratio of DC-DC converter. Change in duty ratio vary impedance. To set impedance at fix value ,operating point occurs its peak power transfer point. Due to the change in climate condition, PV curve is changed because PV curve is based on temperature and irradiance and these are change with change in climate condition. Due to this it is not possible to fix the value of duty cycle. So MPPT is used for this purpose. MPPT sample out voltages and current by, it change duty ratio accoding to the need. Many algorithms are used for find peak power. They all are different from each other in many aspects like efficiency , sensors ,complexity etc. Generally we use P&O algorithm to attain highest power from wind turbine and PV cell. This technique has a benefit that it is easy to implement. When this algorithm is used there is to be seen a slight disruption. This disruption effects on power. According to this, perturbation is continued in a direction only, if power increases with the perturbation. When power reaches on its peak, it shows maximum power. After peak , at next instant power decreases and then perturbation reverses its direction. On highest point, it shakes algorithm after accuring steady state. Having disturbance size small is the one way to generate less variation of power. By this algorithm reference voltage of module can set itself compatible to peak voltage of module.

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Algorithm of P&O technique is shown below:

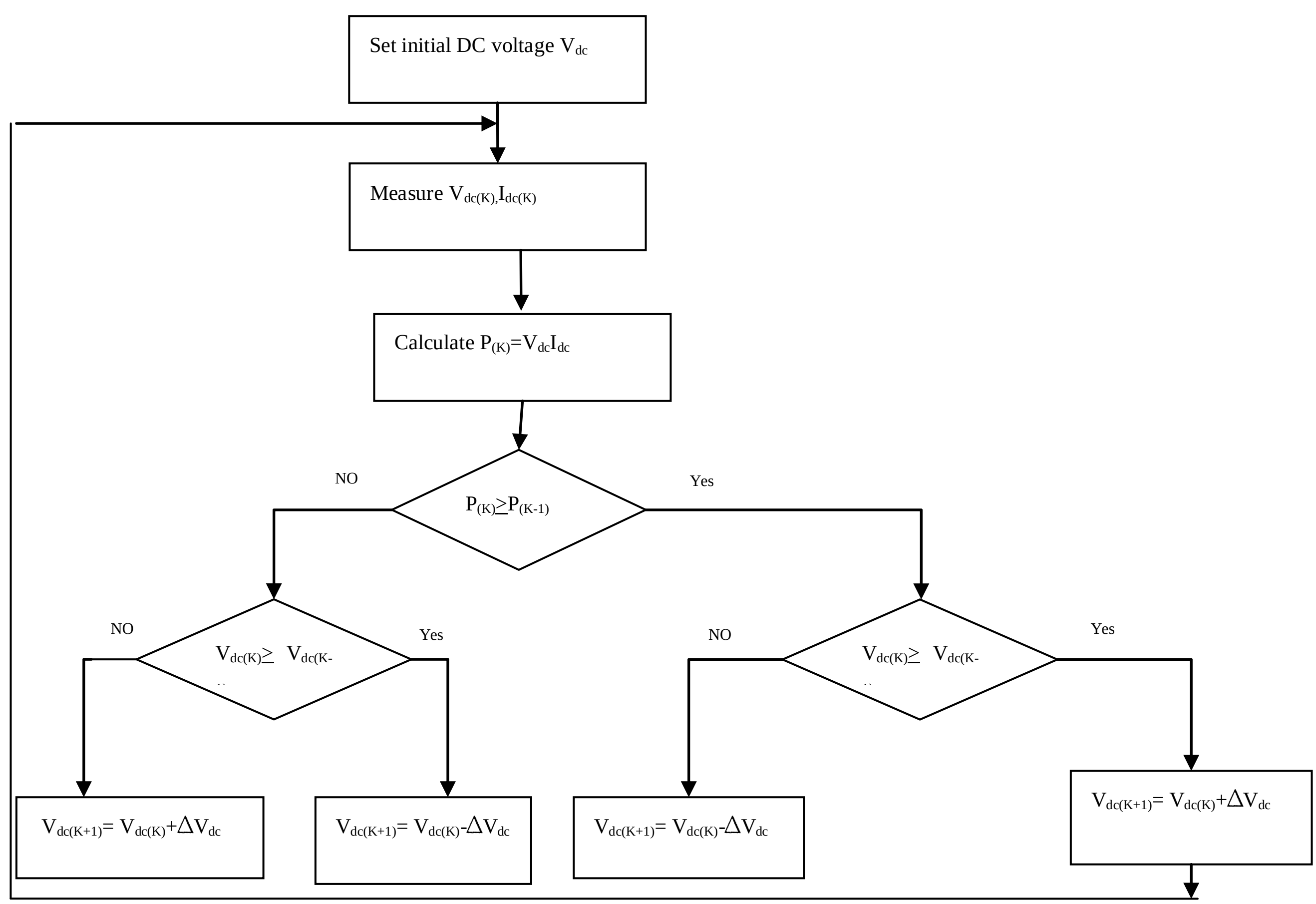

Fig 2 : Flowchart of P&O algorithm

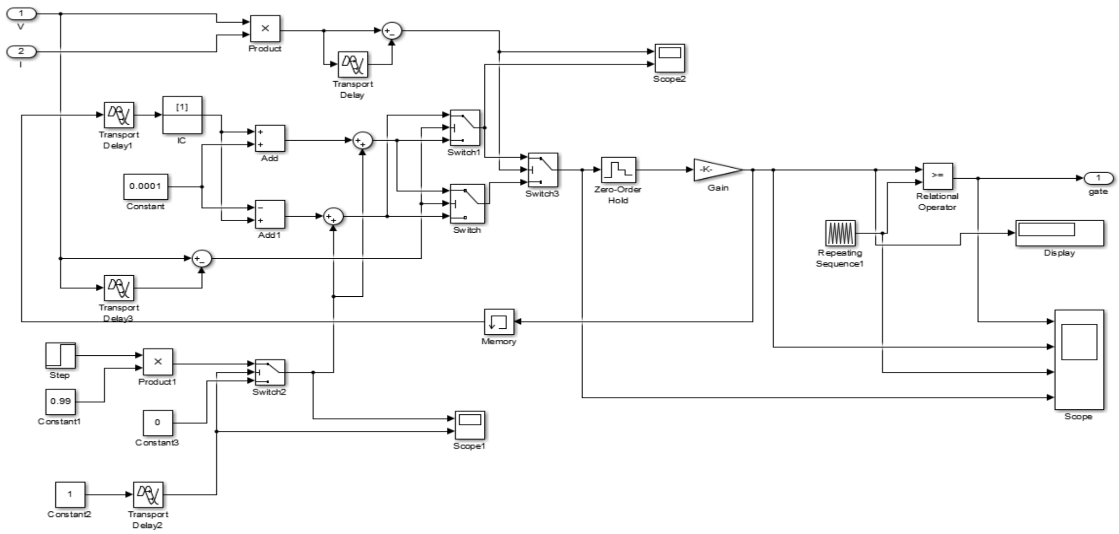

Fig 3: Mathematical modeling of MPPT

3. Converters and its Functioning

DC-DC converters are used to convert unregulated DC voltage to regulated DC output voltage. It works as switching mode regulators.PWM is used to recieved regulation .MOSFET,IGBT is used as swithing devices.

There exists many types of converter.Three types of converter is used in this Technology these are given below:

- Cuk converter
- Sepic converter
- Zeta converter

[1]. **Cuk converter:** In this operation process of step up and step down takes place. Voltage magnitude of output voltage can be more or less than input voltage.

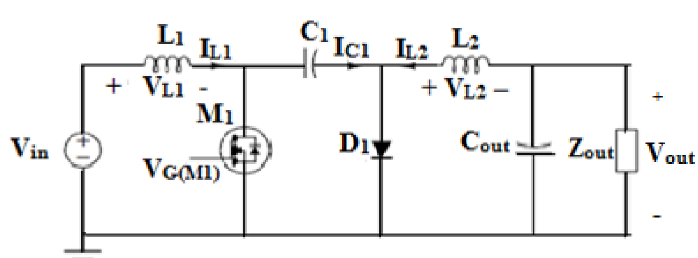

Fig 4: Cuk Converter

Continuous conduction mode is one and only mode in which cuk converter works It has negative output polarity with respect to the common terminal When capacitor transfers the energy,it works according to it.There are two tyupes of operation:

- When M_1 is turned on-Diode D_1 goes in reverse bias state and due to this the process of increasing current in both inductor L_1 and L_2 takes place and after it ,it can be seen that power is delivering to the load.
- When M_1 is turned off-DiodeD_1 goes in forward bias state and the process of recharging of capacitor c1 takes place. .

The voltage conversion ratio M_{CUK} of the Cuk converter is given by:

$M_{cuk}=$ [$(V_{out} \div V_{in})$ = {$-t_{on} \div (t_{cw}-t_{on})$}]= $-D \div (1-D)$]

2. Sepic converter:

Single-ended primary-inductor converter (SEPIC) is a type of DC-DC converter which has a property like buck-boost converter that is to step up or step down voltages by adjusting its input voltage.opposite to the cuk converter it has a positive output polarity.

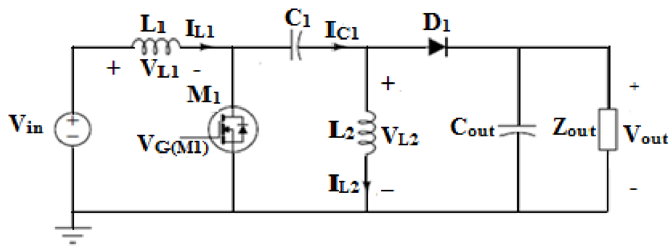

Fig 5:Sepic converter

Two types of operation takes place in it:-

- . When the switch M_1 is turned on- Diode D_1 goes in reverse bias state.Inducor current which is I_{L1} is increased because of input voltage reaches to inductor.Inductor L_2 stores energy after the voltage reaches to capacitor C_1 .
- When the switch M_1 turns off- D_1 conducts. The output receive the energy which is stored in inductor L_1 and L_2, and for the next period L_1 recharges to C_1.
- The voltage conversion ratio M_{SEPIC} converter is given by

. M_{Sepic}= [$(V_{out} \div V_{in})$ = $\{t_{on} \div (t_{cw}-t_{on})\}$]= D÷(1-D)]

3. Zeta converter:

The ZETA converter is another option for regulating an un regulated input-power supply, like a low-cost wall wart. To minimize board space, a coupled inductor can be used. This article explains how to design a ZETA converter running in continuous-conduction mode (CCM) with a coupled inductor. Basic operation

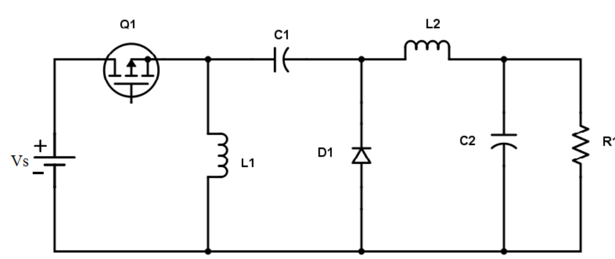

Fig 6: Zeta converter

M_{zeta}=[$(V_{out} \div V_{in})$ = $\{t_{on} \div (t_{cw}-t_{on})\}$]= D÷(1-D)]

4. Sandwich Topology of Converters

In this, fusion of zeta-cuk-sepic converter is done. Hybridization of two wind source and one solar source is done. Input for zeta, cuk, sepic converter is wind, solar, wind simultaneously.

In this There are three input sources:

- Input source of zeta converter is wind turbine
- Input source of cuk converter is PV panel
- Input source of sepic converter is wind turbine

From this we have output voltage equation here:

$V_{dc}=d_1/(1-d_1)V_{Pv}+d_2/(1-d_2)+d_3/(1-d_3)$

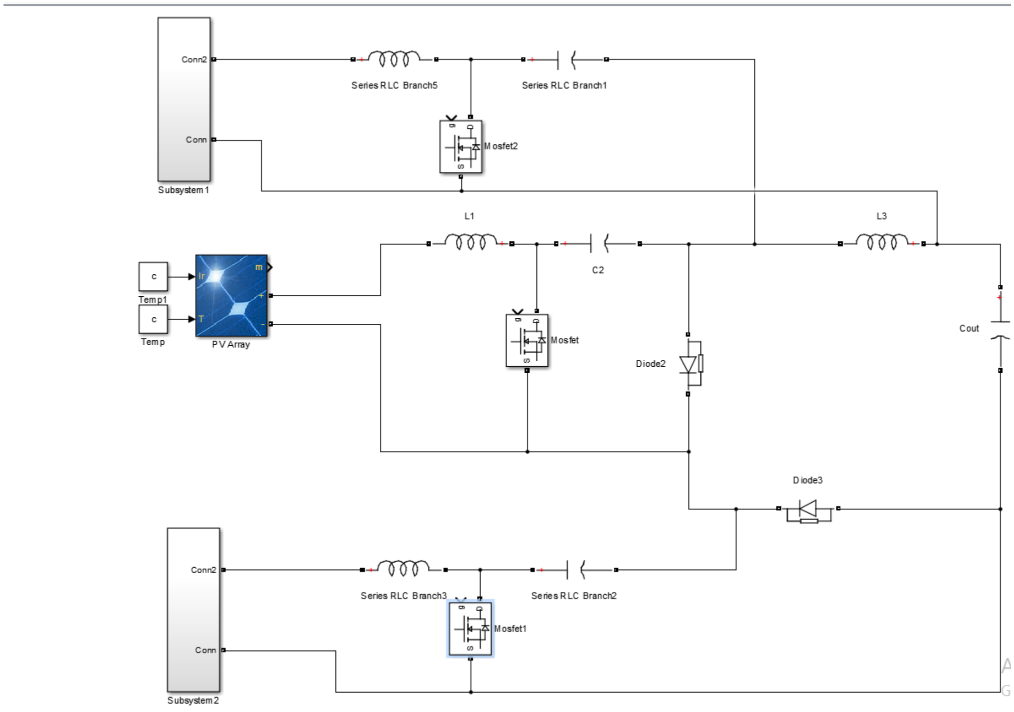

Fig 7: Fused converter topology

So from this we have step up output voltage which is combination of all output voltages of all three sources. This is block diagram for hybrid system. It is done for Maximum power point tracking. By this we found output voltage which is greater than all voltages given by separately.

5. Modeling of Systems

5.1 Modeling of Solar panel

Solar panel consist of many numbers of solar module which is connected in series.Solar module made by several numbers of solar cell.To extract energy from sun there are two main component first sand and second offcourse sun.From sand we get sillicon by adding sand into carbon on 2000 degree celcius temperature.By this process we get raw silicon.Then converted it in gaseous silicon and add hydrogen in it to get highly purified pollycrystalline and after this ,pollycrystalline converts in thin silicon wafer. In these silicon wafers,silicon atoms are strongly bonded with each other.They can not flow and can't generate current.Dopping is the solution of this problem.P-N semiconductor is generate from dopping of aluminium and phosphorus in silicon.Now electron can flow when electricity is given to P-N semiconductor and it generates current.By this current is generated.In this N type semiconductor is highly dopped and its thickness is less compared to P-type.

Characteristics of PV cell:

In PV cell there is a source of current which is parallelly joint together to diode. It has two type of conditions:

- When it is lighted: Generation of current is take place.
- When it is not lighted: There is no generation of current

There is two type of resistances:

- Series resistance (R_s):It lies in the form of intrinsic series resistance which has very small value.
- Shunt resistance(R_p): It lies in the form of intrinsic shunt resistance which has large value.

There are equations related to PV cell characteristics:

$$I = n_pI_{ph} – n_pI_{rs}[exp(qv/KTAn_s) -1]$$

$$I_{rs}=I_{rr}(T/T_r)^3[exp\{qE_G/KA(1/T_r – 1/T)\}]$$

$$E_G = E_G(0) – \alpha T^2/T+\beta$$

$$I_{Ph} = [I_{scr} + K_i(T-T_r)]S/100$$

Here :I = current of cell;I_{ph} = Isolation current;I_{rs} = reverse saturation current; I_{rr}=Reverse saturation current of cell ;Iscr= Short circuit current of cell(at reference temperature) ;q = one electron charge;V=voltage of cell;k=Boltzmn constant;T=Temperature(k); T_r=Temperature of cell reference ;A=Ideality factor; n_p ,n_s=No.of cells in parallel and series respectively;E_G=Semiconductor band gap;S=Radiation by sun.

Output voltage equation: $V=(n_sKTA/q)\ln\{(n_p\text{-}I_{ph}\text{-}1/n_pI_{rs})+1\}$

Mathematical modeing of PV panel is done by this equation which is shown below;

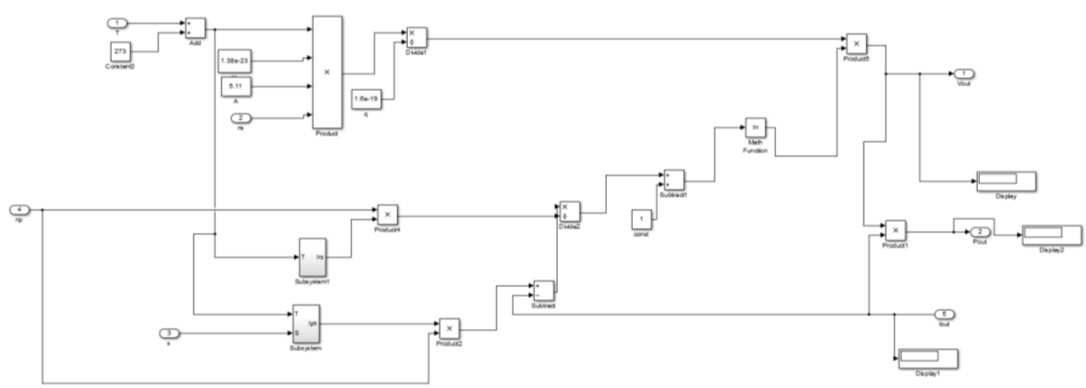

Fig 8: Mathematical modeling of solar panel

5.2 Modeling of wind turbine

By wind ,wind turbine makes electricity. At first, wind is catches by blades then it convert wind power to mechanical power. After it generator converts it to electrical energy.

$$\mathbf{P_{wind\ turbine} = 0.5\rho CpAV_{\infty}^{3}}$$

- $C_{p\ =}$ Pwind turbine Pair(Maximum value of Cp can be defined by the Lanchester-Betz limit);*p* is the air density (1.225 kg/m^3 at 15°C and normal pressure);A represents the swept area in (square meter); V_∞ represents the wind velocity without rotor interference (in meter per second).
- The permanent magnet synchronous machine(generator) is connected to wind turbine. For making electrical energy at first wind energy is taken by blades and mechanical energy is obtained by it and then PMMC is changed this energy to electrical energy.

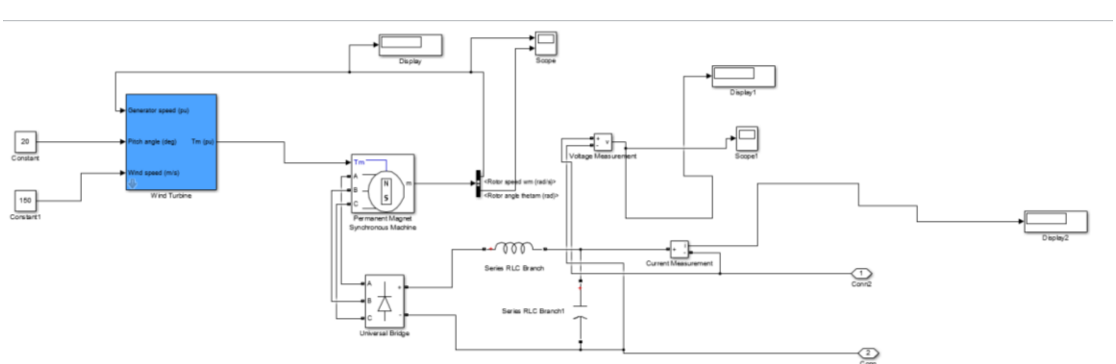

Fig 9: Modeling of wind turbine

6. Simulations Models

- **Simulation model of zeta converter fed wind turbine**:

  It is designed to input voltage 30V and output voltage 180V.Below figure shows that zeta converter fed wind turbine with MPPT.

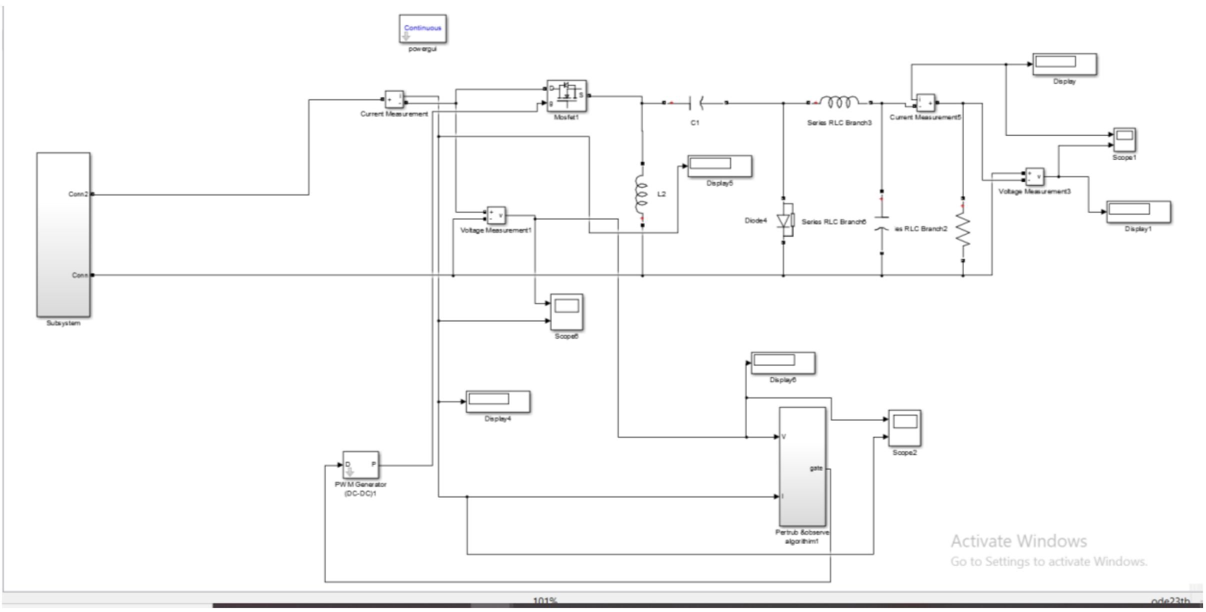

Fig 10: Zeta converter fed with wind turbine

Parameters of zeta converter fed with wind turbine:

Input Voltage	30
Output Voltage	120
Input Current	1.438
Output Current	0.4003
Inductor L1	5.371mH
InductorL2	7.1433mH
Resistance	150Ω
CapacitorC1	$3.625*10^{6}$f
CapacitorC2	$1*10^{6}$f
Duty Cycle	0.8691
Switching frequency	20kHz

- **Cuk converter fed PV panel**

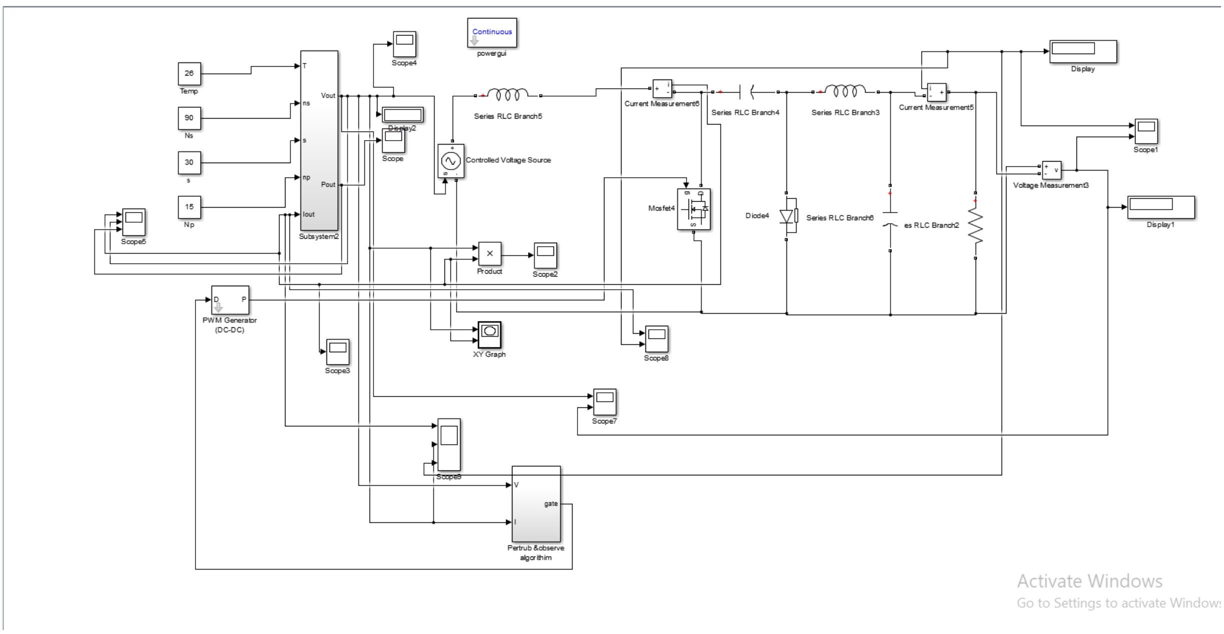

Fig 11: Cuk converter fed with PV panel

Input Voltage	39.26
Output Voltage	280
Input Current	15.8
Output Current	1.283
Inductor L1	0.6436mH
InductorL2	5.36mH
Resistance	150Ω
CapacitorC1	$2.657*10^{6}$f
CapacitorC2	$1*10^{6}$f
Duty Cycle	0.8691
Switching frequency	20kHz

- **Sepic converter fed wind turbine:**

This system is designed to input volage 30v and output voltage 180 v.Simulink of sepic converter fed wind turbine with MPPT is shown below:

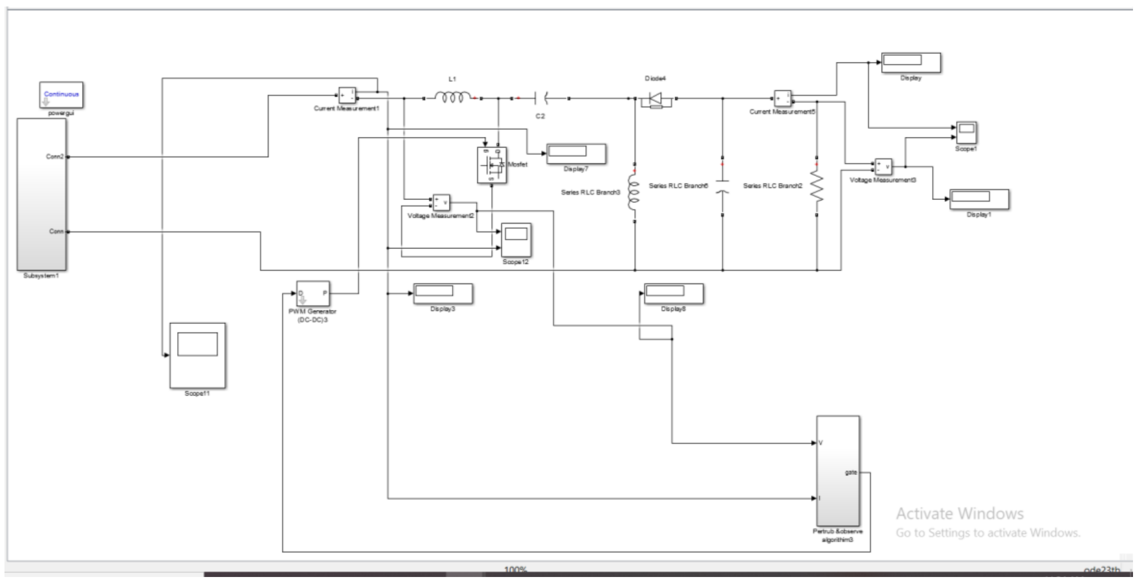

Fig 12: Sepic converter fed with wind turbine

Input Voltage	30
Output Voltage	100
Input Current	1.438
Output Current	0.4003
Inductor L1	5.371mH
InductorL2	7.1433mH
Resistance	150Ω
CapacitorC1	$3.625*10^6$f
CapacitorC2	$1*10^6$f
Duty Cycle	0.8691
Switching frequency	20kHz

- **Fusion of converter for Hybrid system**:

This research tells about sandwich topology of converters. Fusion of three converters is efficient and reliable, comparison in separately connected converter. Output voltage is also greater than in it .Maximum Power Point Tracking is more than separately connected converters in it. This is shown by comparison of " hybrid wind-PV-wind connected with fusion of –zeta-cuk-Sepic converter" versus wind and PV turbine separately connected with one converter.

Parameters of sandwich topology

Input for sandwich topology				**Output for sandwich topology**
Voltage or current given by	**Zeta converter fed wind turbine**	**Cuk converter fed PV**	**Sepic converter fed wind turbine**	
Input voltage	50.23	39.3	4.79	400
Input current	0.2015	11.17	0.04493	0.8089

Other parameters for sandwich topology

Inductor L1	5.371mH
InductorL2	7.1433mH
Resistance	150Ω
CapacitorC1	$3.625*10^{6}$f
CapacitorC2	$1*10^{6}$f
Duty Cycle	0.8691
Switching frequency	20kHz

- This table shown ,maximization of voltage. Sandwich topology has voltage more than all three converters connected separately.

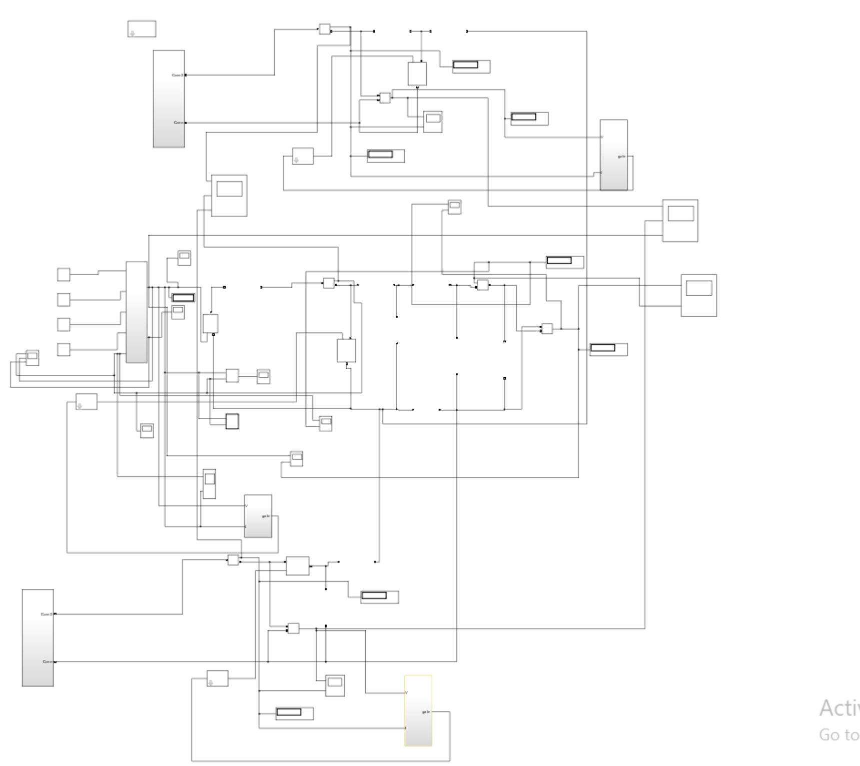

Fig13:Cuk-zeta-sepic fused converter topology for hybrid renewable system

7. Results and Discussion

- **Simulation result of zeta converter fed wind turbine:**

This is waveform of output voltage and output current which is find by zeta converter which is fed by wind turbine and connected to MPPT for maximum power point tracking.

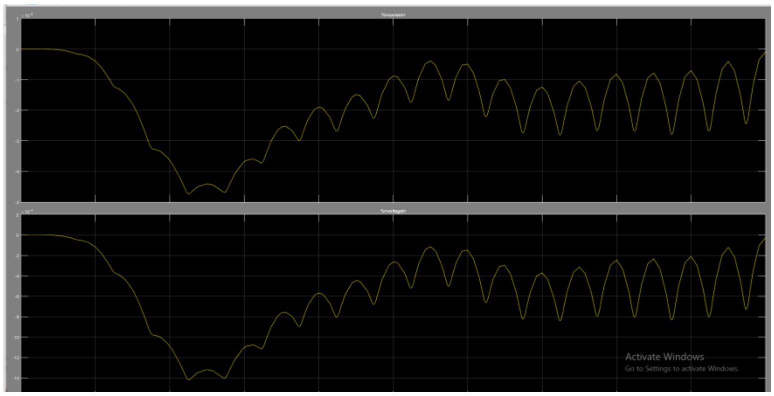

Fig 14: zeta converter fed wind turbine

- **Simulation result of Cuk converter fed PV panel:**

This is waveform for output current and output voltage of Cuk converter fed PV panel which is connected to MPPT for maximum power point tracking and has switching frequency 20khz.

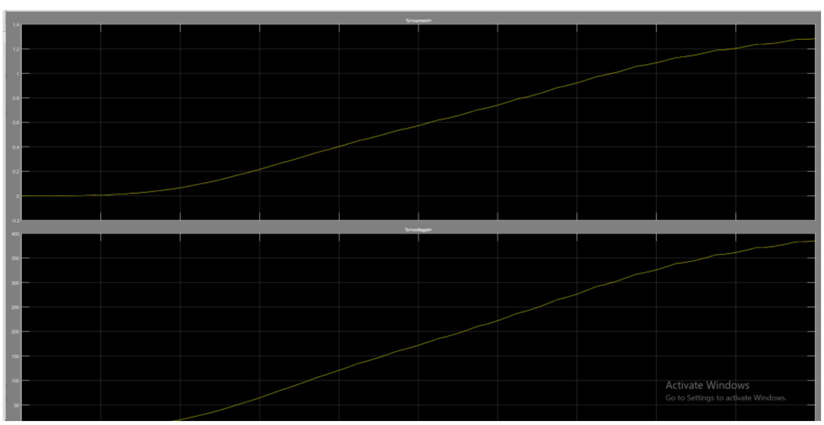

Fig 15: Cuk converter fed with PV panel

- **Simulation result of Sepic converter fed wind turbine:**

This is waveform for sepic converter fed by wind turbine. This is connected to MPPT which is duty cycle of 0.08691 and PWM controller which has switching frequency 20KHZ

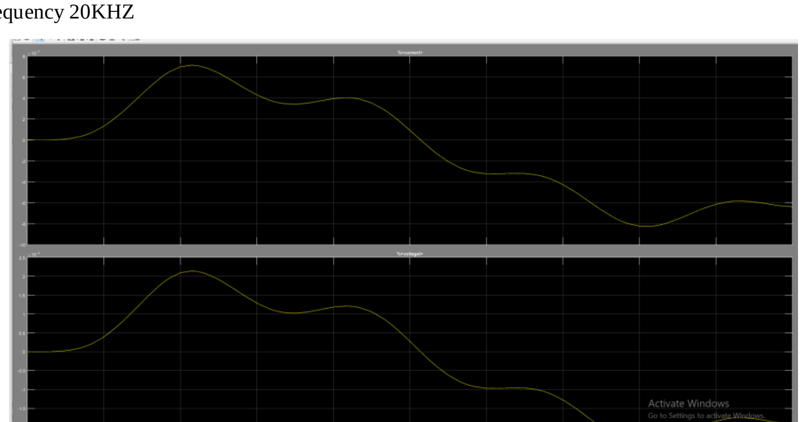

Fig 16:sepic converter fed wind turbine

- **Simulation result for hybrid system:**

It is named as sandwich topology because it have fusion of one solar panel and two wind turbine input sources in it. It also have fusion of three converters. Waveform for output voltage and output current for hybrid system is shown below**:**

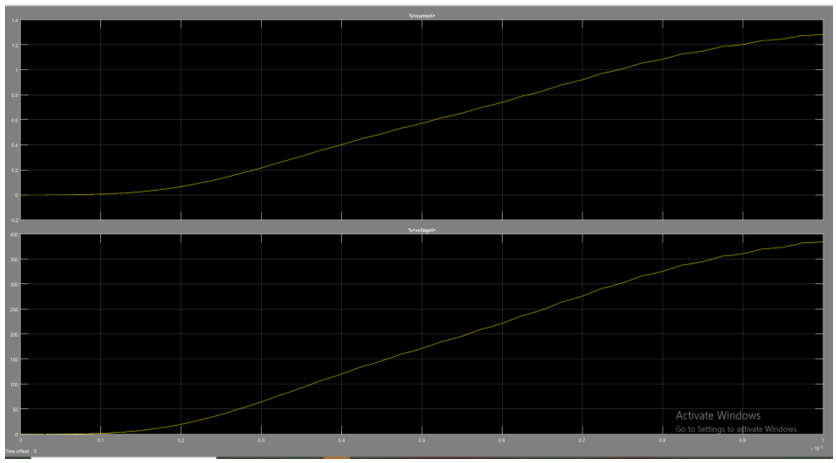

Fig 17 :current and voltage waveform for hybrid system

8. Conclusion

This system is cost effective compare to PV solar and wind system alone,realiability is also increses in this system.By using this system we can provide electricity in rural as well as the areas where transmission lines can not stabilished.Environment pollution is reduced by renewable sources.It provides more energy for people with no input source cost and because these sources are provided by nature so it can't be finished.Cost of generated energy from renewable sources is higher as compared to non renewable cost of electricity generated by wind is higher then solar.But gradually it is reaching almost same price. In this thesis a new topology is proposed for hybrid renewable system,it is called sandwich topology.In this topology fusion of three converters take place. This topology allows the three sources to supply the load separately or simultaneously depending on the availability of the energy sources.For running system more reliably and efficiently and track maximum power MPPT technique is used . Less operating cost is one more advantage of this topology and it is useful in many aspacts like generation of power in remote areas, constant and variable speed also and rural electrification. MATLAB/ SIMULINK software is used to model the PV panel, wind turbine, DC-DC converters, MPPT controller and proposed hybrid system.

Future scope for this model:

- We can use other types of renewable energy sources like hydro,geothermal etc.
- We can take other dc-dc converters for fusion ,like flyback ,boost etc.
- We can use other MPPT technique for extract maximum power.

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