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MPPT CONTROLLER FOR HYBRID PV AND WIND ENERGY SYSTEM BY USING CUK-SEPIC CONVERTER

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ABSTRACT

Sustainable energy sources also called a non-conventional type of energy are continuously available from natural. As the vitality request expands, then vitality failure also expands. So, sustainable energy sources can be utilized to give steady loads. Here, a hybrid PV and wind vitality system combine with another converter topology is proposed which makes use of CUK and SEPIC converters in the design. This arrangement enables the two sources supply to the load individually or simultaneously accessibility of the vitality sources. Maximum vitality is a concentrate from PV and wind vitality sources by utilizing the Maximum power Point Tracking (MPPT) algorithm. Simulation is done in MATLAB/SIMULINK programming and the results of the Cuk converter, SEPIC converter, and the hybrid converter are shown.

Keywords - Sustainable Vitality, SEPIC Converter, CUK Converter, Hybridized Converter, MPPT algorithm.

INTRODUCTION

A Sustainable vitality source is vitality that is gathered from inexhaustible assets, which are normally recharged on a human timescale, for example, Sunlight, Wind, Rain, Tide and so on. Hybrid renewable energy System is getting well known as a remain solitary vitality system for giving vitality in remote zones because of advances in sustainable vitality source innovations and ensuing ascent in the costs of oil-based goods. A hybrid vitality system generally comprises of at least two feasible vitality sources utilized together to provide increased system efficiency as well as greater balance in vitality supply. A hybrid vitality system is a photovoltaic exhibit combined with a wind turbine. This would make more output from the wind turbine throughout the winter, whereas during the summer, the solar panels would produce their peak output. Hybrid vitality systems often yield greater economic and environmental returns than wind, solar, geothermal or regeneration stand-alone systems by themselves. The main drawbacks of RES are uncontrollable and unpredictable. Thus, it is difficult to generate a required quantity of Vitality to meet the load demand and also the generated Vitality contains a lot of variation in frequency and voltage [1]. The above problems are solvable by integrating two or more sustainable vitality sources along with a storage system. Mostly PV and wind Vitality sources are integrated because of its abundance in nature and both are complemented to each other to a certain extent

[1]. A few hybrid Wind/PV vitality systems with Maximum Power Point Tracking (MPPT) have been proposed before [2].

Many DC-DC converter topologies are proposed for the reconciliation of various Vitality sources lately [3]. The hybrid vitality system infuses high-frequency current harmonic into the system. This may expand the warming issues and diminish the generator life cycle and effectiveness of the system. This can't be wiped out by the normal DC-DC converter. Thus, it requires separate input passive filters to diminish this harmonic current, which expands the expense and makes the cumbersome system [2]. .

In this paper, another converter topology of coordinated CUK-SEPIC is proposed for the combination of wind and PV systems. The benefit of the proposed converter is to dispose of the need for input filters to decrease the high-frequency harmonics and it will work in both individual and synchronous methods of activity. The PV vitality system is controlled by the CUK and wind vitality is directed by the SEPIC converter with the P and O method to extract maximum power. The significant preferred position of the proposed system is the point at which one of the sources isn't accessible and afterward, the other source will supply the important capacity to satisfy the load demand. Because of the alternative nature of sources, the normal output voltage of the hybrid system is the entirety of PV and wind output voltages [5].

DC-DC CONVERTERS

A DC to DC converter is an electronic circuit or electromechanical gadget that changes over a source of direct current (DC) starting with one voltage level to next. It is a kind of electric vitality converter. Vitality levels extend from extremely low (little batteries) to exceptionally (high-voltage Vitality transmission). The regulation is regularly practiced by PWM at a fixed frequency and the switching gadget is generally BJT, MOSFET or IGBT.

A. CUK Converter

The CUK converter is a type of DC-DC converter that has an output voltage magnitude that is either more than or less than the input voltage magnitude.

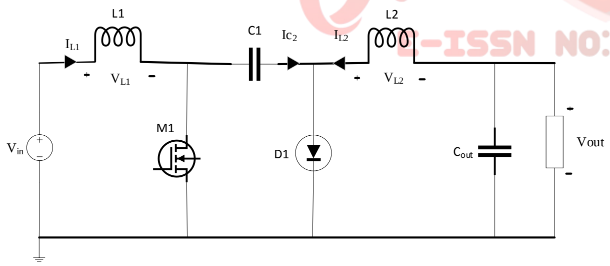

Fig. 1 CUK Converter

In Fig. 1, when switch M1 is turned ON, diode D1 is reverse biased and the current through inductor L1 and inductor L2 increment step by step and conveys the capacity to the load. At the point when switch M1 is OFF, the diode gets forward biased and the capacitor C1 begins releasing for the next cycle. The Cuk converter DC output voltage as far as the duty cycle ratio is given as follows in Eq. (1) [9,10]. The voltage conversion ratio M_{CUK} of the CUK converter is given by,

$$Vcuk = \left(\frac{d_1}{1-d_1}\right) Vpv \text{-----------} \ (1)$$

SEPIC Converter

The rectified wind vitality system output voltage is given as a contribution to the Single Ended Primary Inductor Converter (SEPIC) for getting wanted voltage to fulfil the load demand as appeared in Fig. 2. Essentially, the SEPIC converter is a chopper; it gives either more than or less than the input voltage. The here step-up mode is considered to coordinate the load profile. The DC output voltage of the SEPIC converter as far as the Duty Cycle proportion is given as follows in Eq. (2) [9,10].

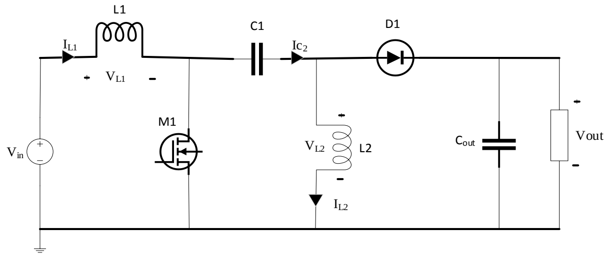

Fig. 2 SEPIC Converter

In Fig. 2, when switch M_2 is turned ON and diode D_2 is reversed biased then the current through inductor L_1 and inductor L_2 builds step by step and conveys the capacity to the load. At the point when switch M2 is OFF, the diode gets forward biased and capacitor C2 begins releasing for the next cycle. The voltage conversion ratio M_{SEPIC} of the SEPIC converter is given by;

$$Vsepic = \left(\frac{d_2}{1-d_2}\right) Vwind \text{ ------ (2)}$$

PROPOSED HYRBID SYSTEM

In this paper, new converter topology for hybridizing the PV and wind vitality sources has been proposed. In this topology, both PV and wind vitality sources are fused together utilizing a blend of CUK and SEPIC converters, so that on the off chance that one of them is inaccessible, at that point the other source can make up for it. The DC link voltage, Vdc of the proposed converter is the entirety of two converters output as appearing in Eq. (3) and it is kept up consistent by differing the Duty Cycle D1 and D2 of Cuk and SEPIC converters which are gotten from the Eq. (1) and Eq. (2) separately by utilizing duty ratio control.

$$Vdc = \left(\frac{d_1}{1-d_1}\right) Vpv + \left(\frac{d_2}{1-d_2}\right) Vwind \text{---------- (3)}$$

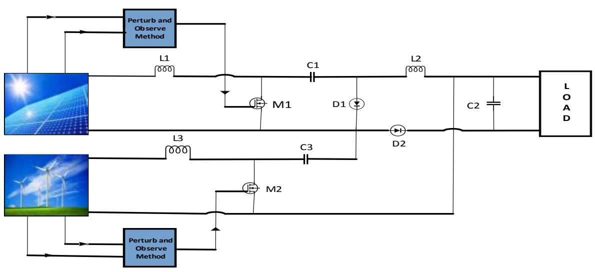

Fig. 3 Converter Topology for Hybrid System

MPPT control algorithms assume an indispensable job in sustainable vitality sources application to acquire maximum power and efficiency. There is a tremendous measure of maximum power control algorithms and they vary from one another depending on the sensor's necessity, unpredictability, cost, intermingling speed, adequacy extent, the conduct of the algorithms when input parameter changes and usage of hardware [8-9]. For the proposed system P & O control methods are used for extracting the maximum power [13].

MODES OF OPERATION

i) MODE-1 (M_1-ON, M_2-ON)

In MODE-I, both PV and wind systems together generate power to meet the load demand. The equivalent circuit for both the switches M1 and M2 are ON is shown in Fig (4). In this mode, D1 and D2 are in reverse bias. Inductor L1is charged by PV source, L3 is charged by Wind source and the vitality stored in capacitors C1 and C3 starts discharging to the capacitor C2 through the inductor L2.

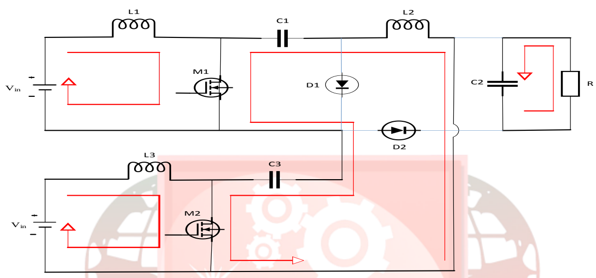

Fig. 4 MODE-1: Equivalent Circuit

ii) MODE-2 (M_1-ON, M_2-OFF)

In MODE-II, only a PV source is available to generate vitality to meet the load demand. The equivalent circuit for both switches M1 ON and M2 OFF are shown in Fig (5). In this mode, D1 is reverse bias and D2 is in forwarding bias. Inductor L1 is charged by PV source, the capacitors C1 starts discharging the stored Vitality to the inductor L2. Diode D2 provides the closed path to discharge the stored Vitality in L3 and C3 to the capacitor C2.

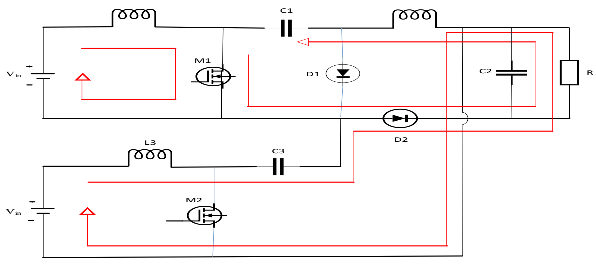

Fig. 5 MODE-2: Equivalent Circuit

iii) MODE-3 (M_1-OFF, M_2-ON)

In MODE-III only wind source is available for vitality generation. The equivalent circuit for switches M1 OFF and M2 ON is shown in Fig (6). In this mode, D1 is forward bias and D2 is in reverse bias condition.

Inductor L3 is charged by Wind source and the L1 is charged by the capacitors C1. Diode D1 provides the closed path to charge the L2 by discharging the capacitor C3.

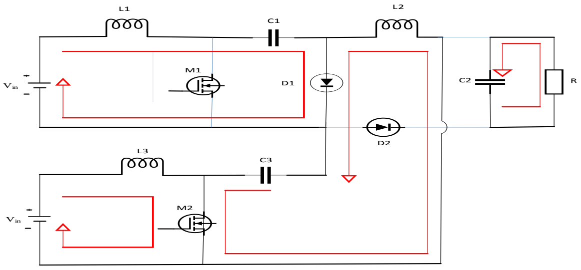

Fig. 6 MODE-3: Equivalent Circuit

iv) MODE-4 (M_1-OFF, M_2-OFF)

In MODE-IV both sources are not available, this is a very rare case because both PV and wind systems are complemented nature. So, this case is not considered in the analysis of the proposed converter. The equivalent circuit for both switches M1 and M2 is OFF is shown in Fig (7). In this mode, D1 and D2 are in forwarding bias conditions. Diode D2 provides a path for charging the L3 by the capacitor C3 and D1 provides a path for charging the L1 by the capacitors C1 and the Vitality stored in the inductor L2 is transferred to the capacitor C2.

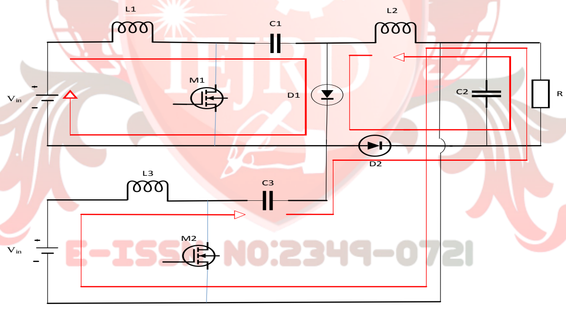

Fig. 7 MODE-4: Equivalent Circuit

MODELLING OF PV PANEL

A. PV Cell Characteristics

A cell is involved in a P-N junction semiconductor material like Si, Ge etc., which produces current by using the electrical wonder sway. When light-weight Vitality strikes the photovoltaic cell, the electrons zone unit thumped free from the particles inside the semiconductor material. If an electrical conductor is associated with the positive and negative terminal, shaping partner electrical gadget, the electrons will be caught inside the sort of an electrical current. This power will at that point be wont to control a load. Many PV cells are associated in series (for high voltage) and in parallel (for high current) to make a PV module for wanted output [11]. An equivalent circuit diagram of PV Cell as shown in fig (8).

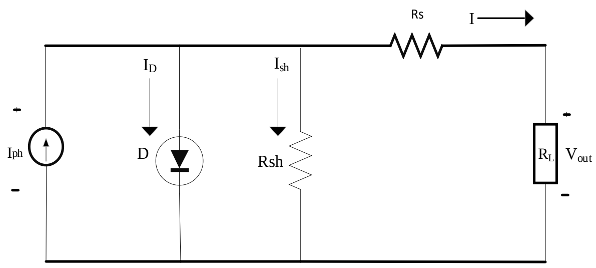

Fig. 8 PV Cell equivalent Circuit

A PV cell might be depicted by a current supply associated in parallel with a diode since it creates current once it's well-lit and goes about as a diode once it isn't. The equivalent circuit model moreover incorporates a shunt and series inside resistance. Rs is that the intrinsic series resistance. Rp is the equivalent shunt resistance which has a high value. The current-voltage equation of a PV cell is given by,

$$I = np\ Iph - np\ Irs\ (\exp\left(\frac{qv}{KTAn}\right) - 1) \quad \text{-----------} \ (6)$$

Where I: Cell output current, np: Number of parallel solar cells, K: Boltzmann's Constant ($1.38X10^{-23}$J/K), T: the ambient temperature in kevin, q: Electron Charge ($1.6X10^{-19}$ C), V: Cell output voltage, A: P-N junction ideality factor (between 1 & 5), Iph: the Photocurrent, Irs: the reverse saturation diode current, n: The diode quality factor.

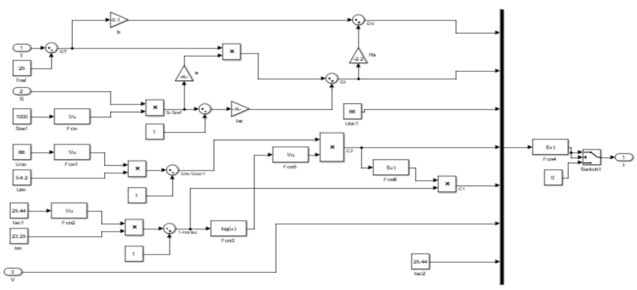

Fig. 9 Simulink model of PV Panel

MODELLING OF WIND TURBINE SYSTEM

In WECS the vitality from wind is used to cause a rotation motion in the turbine. This motion will make the generator produces electrical vitality which can be regulated and controlled by the power interface. The mechanical power produced by a wind turbine can be represented by (1), where ρ is the air density, R is the turbine radius, Vw is the wind speed measured in meters per second (m/s) and Cp is the power coefficient which depends on the tip speed ratio λ and the pitch angle β [6], [7], [8].

$$Pm = 0.5ACp(\lambda, \beta)\vartheta w^3 \qquad \text{--------} \ (7)$$

The tip speed ratio is given by:

$$\lambda = \frac{\omega_r R}{V_w}$$

-------- (8)

Where ωr is the turbine angular speed. The power coefficient *Cp* is normally defined by (7) and (8)

$$Cp(\lambda,\beta) = C_1{}^{\left(\frac{C_2}{\lambda_1} - C_3\beta - C_4\right)} \exp\left(\frac{-C_2}{\lambda_1}\right) + C_6\lambda \quad \text{--------- (9)}$$

$$\frac{1}{\lambda_1} = \frac{1}{\lambda + 0.08\beta} - \frac{0.035}{\beta^3 + 1} \quad \text{--------- (10)}$$

However, the non-linear, dimensionless *Cp* characteristic can be represented by (5). Constants *c1* to *c6* are obtained through experimental tests. The maximum value of Cp is 0.48 at β = 0 and λ = 0.16. The wind turbine model is associated with a squirrel cage asynchronous generator. The mechanical Vitality got from the wind turbine is supported by the generator, which converts it to electrical vitality.

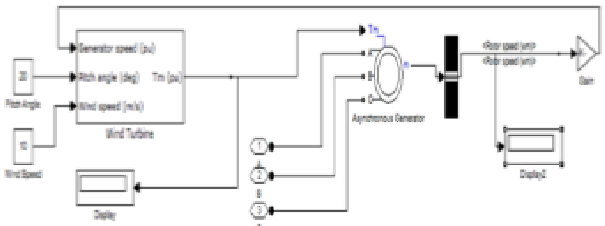

Fig. 10 Simulink model of Wind Turbine

MPPT ALGORITHM

MPPT or Maximum Power Point Tracking is an algorithm that included in charge controllers used for extracting maximum available power from the PV module under certain conditions. The Perturb and Observer (P&O) based MPPT method is most ordinarily utilized controller to follow the maximum available power from the PV system, on account of its plain structure, fewer parameters and simple to actualize [15]. The P and O algorithm express that the when working voltage of the PV panel is perturbed by little augmentation, if the consequent change in power ΔP is positive, by then we are going toward Mpp. In case ΔP is negative we are leaving from the Mpp. The pictorial portrayal of the P&O algorithm is showed up in Fig (11) and the maximum power point is gained by perturbing the PV array terminal voltage concerning PV output power. At whatever point output Vitality is extended, by then the following cycle, the terminal voltage will be moved a positive way and a different way. MPPT intensity of PV cell encouraged with CUK converter, Wind turbine sustained with SEPIC converter and the proposed hybrid system is exhibited using MATLAB/SIMULINK programming.

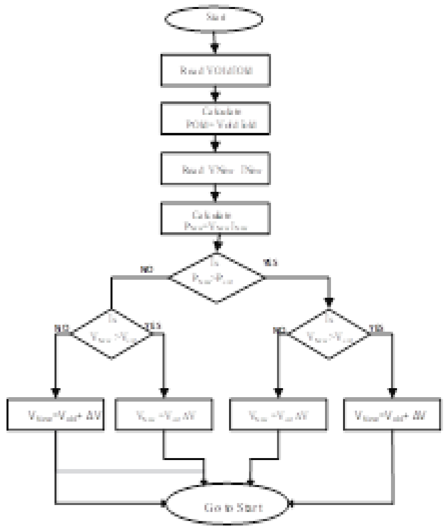

Fig. 11 Flow chart for P & O Algorithm

SIMULATION MODELS

MPPT Vitality of PV cell with CUK converter and Wind turbine with SEPIC converter and the proposed hybrid system is modeled by using ng MATLAB/SIMULINK software.

A. Simulink Model of MPPT Power of PV Cell Fed CUK Converter

PV cell is given as the input to the CUK converter. It is intended for an input voltage of 34V to get an output voltage of 200V. Fig. 12 shows the Simulink model of the MPPT power of PV cell bolstered CUK converter.

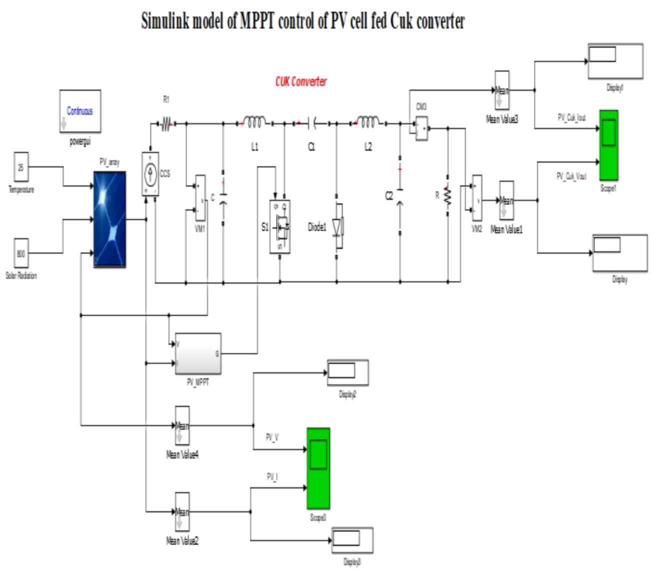

Fig. 12 Simulink Model of MPPT Power of PV Cell

TABLE-1

Parameters of PV Cell fed CUK converter

Parameters	Value
Input Voltage, V_d	34V
Input Current, I_d	14A
Output Voltage, V_o	200V
Output Current, I_o	2A
Switching frequency, f_s	20kHz
Duty cycle, D	0.8692
L1	0.6436mH
L2	5.36mH
C10	2.657μF
C2	1μF
R	100Ω

B. Simulink Model of MPPT Power of Wind Turbine Fed SEPIC Converter

A wind turbine is given as the input to the SEPIC converter. It is intended for an input voltage of 34V to gain an output voltage of 200V. Fig. 13 shows the Simulation model of MPPT intensity of Wind turbines with a SEPIC converter.

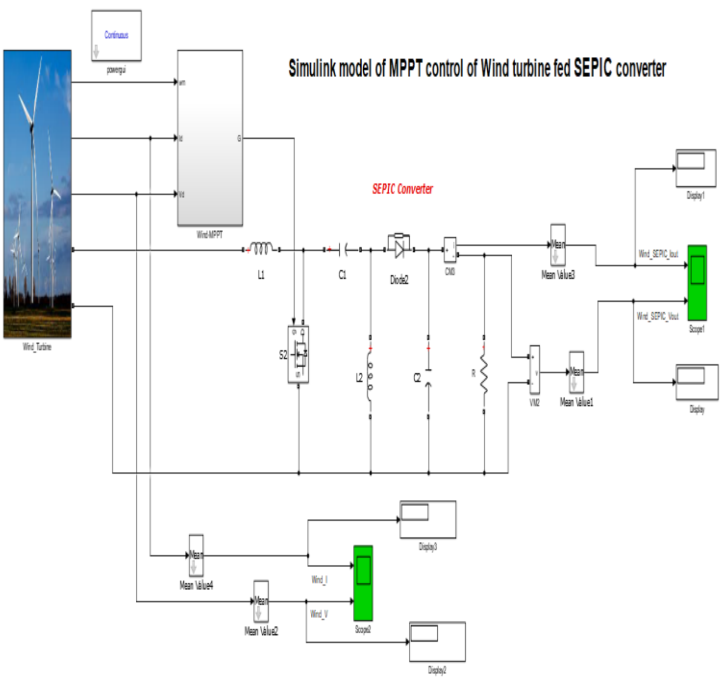

Fig. 13 Simulink Model of MPPT Power of Wind Turbine Fed SEPIC Converter.

TABLE-2

Parameters of Wind Turbine fed SEPIC converter

Parameters	**Value**
Input Voltage, Vd	34V
Input Current, Id	7A
Output Voltage, Vo	200V
Output Current, Io	2A
Switching frequency, fs	20kHz
Duty cycle, D	0.8692
L1	5.371mH
L2	7.1433mH
C10	3.265µF
C2	1µF
R	300Ω

C. Simulink Model of MPPT Power of Proposed Hybrid System

The hybrid system contains a CUK converter and SEPIC converter related together. Fig. 14 shows the Simulation model of the MPPT intensity of the proposed Hybrid System.

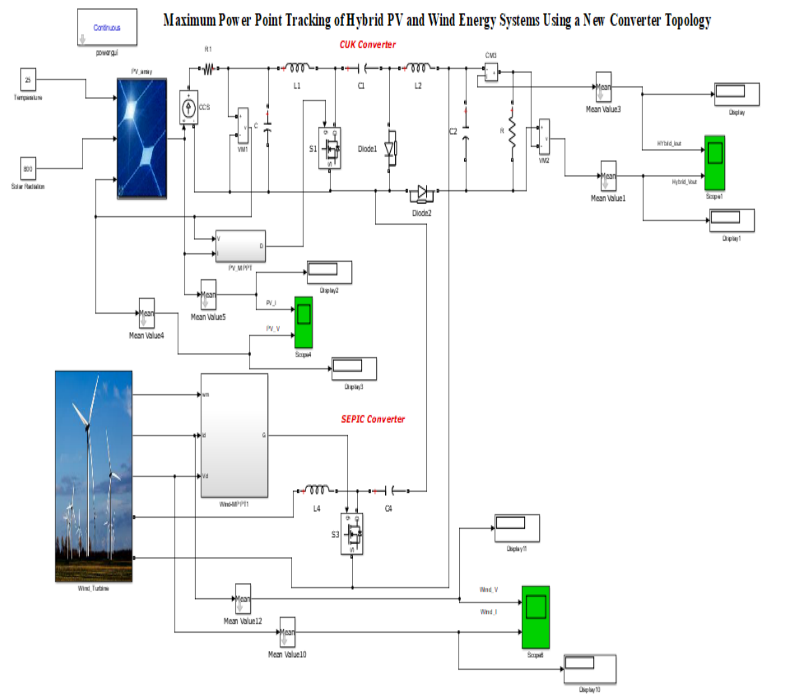

Fig. 14 Simulink Model of MPPT Power of Proposed Hybrid System

TABLE -3

Parameters of Proposed Hybrid System Converter

Parameters	**Value**
Input Voltage (solar), V_d	40V
Input voltage (wind	34V
Input Current (solar), I_d	8A
Input Current (wind	4A
Output Voltage, V_o	400V
Switching frequency, f_s	20kHz
Duty cycle, D (solar)	0.8692
Duty cycle, D (wind	0.8692
Output Current, I_o	2A
L1	0.6436mH
L2	5.36mH
L3	5.371mH
C1	2.657μF
C2	1 μF
C3	3.265μF
R	300 Ω

SIMULATION RESULTS

A. Simulation Result of MPPT Power of PV Cell Fed CUK Converter

The simulation of CUK converter with MPPT power of PV cell fed as input is done separately and the input and output waveforms for current and voltage are obtained as shown in (15) & (16).

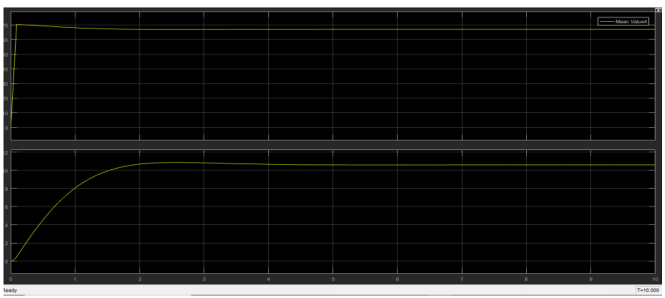

Fig. 15 Input Current and Voltage waveform of CUK Converter

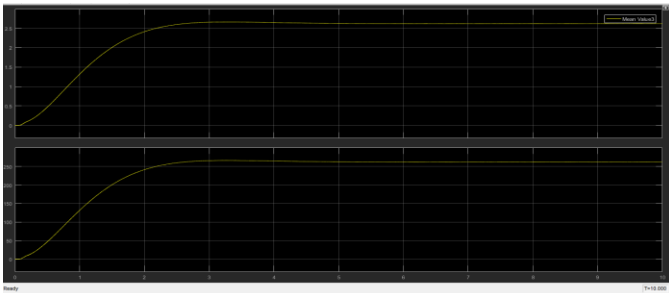

Fig. 16 Output Current and Voltage waveform of CUK Converter

B. *Simulation Result of MPPT Power of Wind Turbine*

Fed SEPIC Converter:

The simulation of SEPIC converter with Wind turbine fed as input is done separately and the input and output waveforms for current and voltage are obtained as shown in (17) & (18).

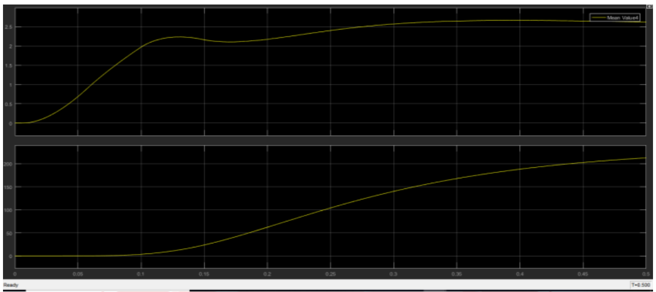

Fig. 17 Input Current and Voltage Waveform of SEPIC Converter

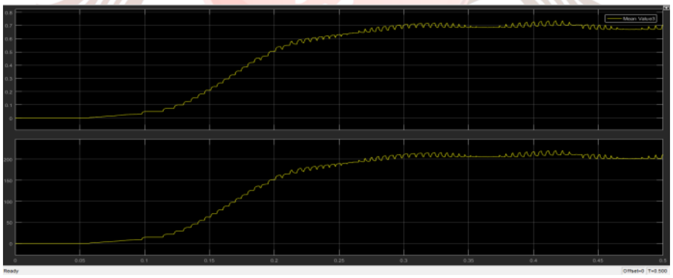

Fig. 18 Output Current and Voltage Waveform of SEPIC Converter

C. *Simulation Result of MPPT Power of Proposed Hybrid System:*

The output current and voltage waveforms obtained from the simulation are shown in Fig. 19.

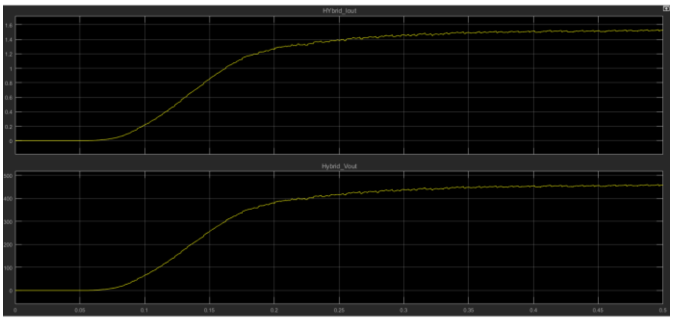

Fig. 19 Output Current and Voltage Waveform of Hybrid System

CONCLUSION

The analysis of the integrated CUK-SEPIC converter with MPPT has been presented for the integration of Hybrid PV and Wind source. In this paper, two separate DC-DC converters are combined to minimize the converter components, size, and complexity. The proposed system does not require any additional input filters for eliminating high-frequency harmonics and to improve the converter efficiency. Since a smaller number of the switching device and passive components are used in this system. MPPT algorithm is used to extracting maximum power from sources. MPPT has been realized for both PV and wind sources by using the P & O algorithm. MATLAB/SIMULINK programming is utilized to show the PV panel, wind turbine, DC-DC converters, MPPT controller and proposed hybrid system.

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