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POWER QUALITY IMPROVEMENT WIND/PV HYBRID SYSTEM BY USING CONVERTERS

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Abstract:

This paper proposes a modified converter topology for the wind and solar hybrid system. For the hybrid system, extracting as much energy from the wind and solar as possible, and feeding the load with less distorted sine wave are the two main targets. In this topology instead of using separate converters for two sources it uses combined DC-DC converter for wind and solar source i.e. both converters are made to share the single inductor and capacitor on the output side. So those numbers of passive components get reduced. By this configuration two sources can supply the load separately or simultaneously, depending on the availability of the sources. The implicit nature of this converter is that additional input filters are not necessary to filter out high frequency harmonics, as TCSC and SEPIC converters can filter out harmonic contents in a better way and can produce efficient outputs. Performance of separate and combined systems is analyzed by using MATLAB /Simulink.

Key Words: TCSC, SEPIC Converter & Solar- Windhybrid System

1. DC-DC Converters:

(a). Thyristor Controlled Series Compensation (TCSC):

TCSC is the type of series compensator. The structures of TCSC are capacitive bank and the Thyristor controlled inductive brunch connected in parallel as shown in Fig. 2. [7] The principle of TCSC is to compensate the transmission line in order to adjust the line impedance, increase load ability, and prevent the voltage collapse.

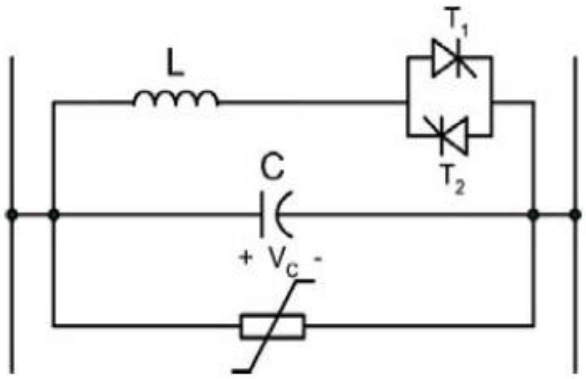


Figure 2: Basic Structure of TCSC

The characteristic of the TCSC depends on the relative reactances of the capacitor bank and thyristor branch. The resonance frequency (ω_r) of LC is express as:

$$X_c = -\frac{1}{\omega_n C}$$

And

$$X_L = \omega L$$

$$\omega_r = \frac{1}{LC} = \omega_n \sqrt{\frac{-X_C}{X_V}} \tag{1}$$

The principle of TCSC. in voltage stability enhancement is to control the transmission line impedance by adjust the TCSC impedance. The absolute impedance of TCSC. which can be adjusted in three modes:

- Blocking mode : The thyristor is not triggered and TCSC. is operating in pure capacity which the power factor of TCSC is leading.
- By pass mode: The thyristor is operated in order to XL=XC. The current is inphase with TCSC. voltage.
- Capacitive boost mode: XC > XL, and then Inductive mode: XL>XC, respectively.

B. SEPIC Converter:

Single Ended Primary Inductor Converter (SEPIC) is a type of converter, performs DC-DC conversion and it makes the voltage magnitude at its output to be exceeding, fewer, or same as its input. Its operation is similar to a buck boost converter. It has the capability to operate in step up and step down modes [12]. The output polarity of the SEPIC converter is positive with respect to its common terminal.

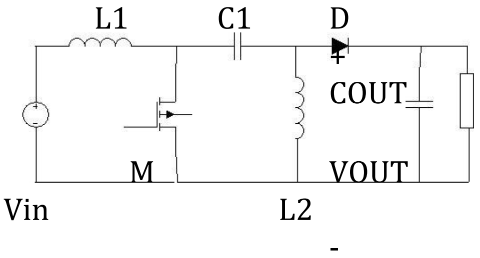


Figure 2: SEPIC Converter

The capacitor C1 blocks any DC current path between the input and the output. The anode of the diode D is connected to a described potential [16]. When the switch M is turned on, the input voltage Vin appears across the inductor L1 and the current IL1 across that inductor rises. Energy is also stored in the inductor L2 as soon as the voltage across the capacitor C1 appears across L2. The diode D is reverse biased during this period. But when switch M turns off, D will conduct. The energy stored in L1 and L2 is delivered to the load and C1 is recharged by L1 for the next cycle of operation. The voltage conversion ratio M_{SEPIC} of the SEPIC converter is given by:

$$Vo = Vin[D/(1-D)] \qquad (2)$$

2. Renewable Energy Sources:

A. PV Array:

In PV system the output voltage is a constant DC and its magnitude depends on the composition in which the solar cells/modules are coupled. On the same way, the current outputs of the PV system mainly lean on the available solar irradiance [7]. The main concern of power electronic interfaces for the PV systems is to convert the generated DC voltage into a suitable AC for consumer use and utility connection.

The characteristic equation of a solar module is relying on the number of cells connected in parallel and number of cells connected in series [6]. It is ascertained from experimental results that the current variation is less subordinate on the shunt resistance and is more relying on the series resistance.

$$I = Iph - Io[\exp\{qV/kT\} - 1] \qquad (3)$$

Where,
Iph = photocurrent,
Io = saturation current,
q = electronic charge 1.6x10-9,
KB = Boltzmann's gas constant (1.38x10-23), T = cell temperature,

I = cell current, V = cell voltage.

B. Wind Energy System:

Wind turbines novitiate kinetic energy in the wind into mechanical power that can be again converted into electrical energy by using generator. Power is ordinarily generated either with an induction generator or with a synchronous generator [3]. Induction generators are normally employed on standalone systems and Synchronous generators are typically used where grid connection is possible through power electronics converters [11].

The basic equation for the power of the wind is given by:

$$P = (\rho ACpV3)/\lambda \quad (4)$$

Where

P is the power,

ρ is the air density,

V is the wind speed and, Cp is the power coefficient, which describes the fraction of the wind captured by a wind turbine.

3. Design of Proposed System:

A hybrid wind-solar energy system is shown in Fig.3. The design incorporates two converters at an output side of the sources [15], where one of the converter inputs is connected to the output of the wind generator and the converter input is connected to the output of a PV array. An unification of the two converters is rendered by reforming the two existing diode from respective converter and the shared utilization of the inductor on the output side [16] of the CUK converter by the SEPIC converter.

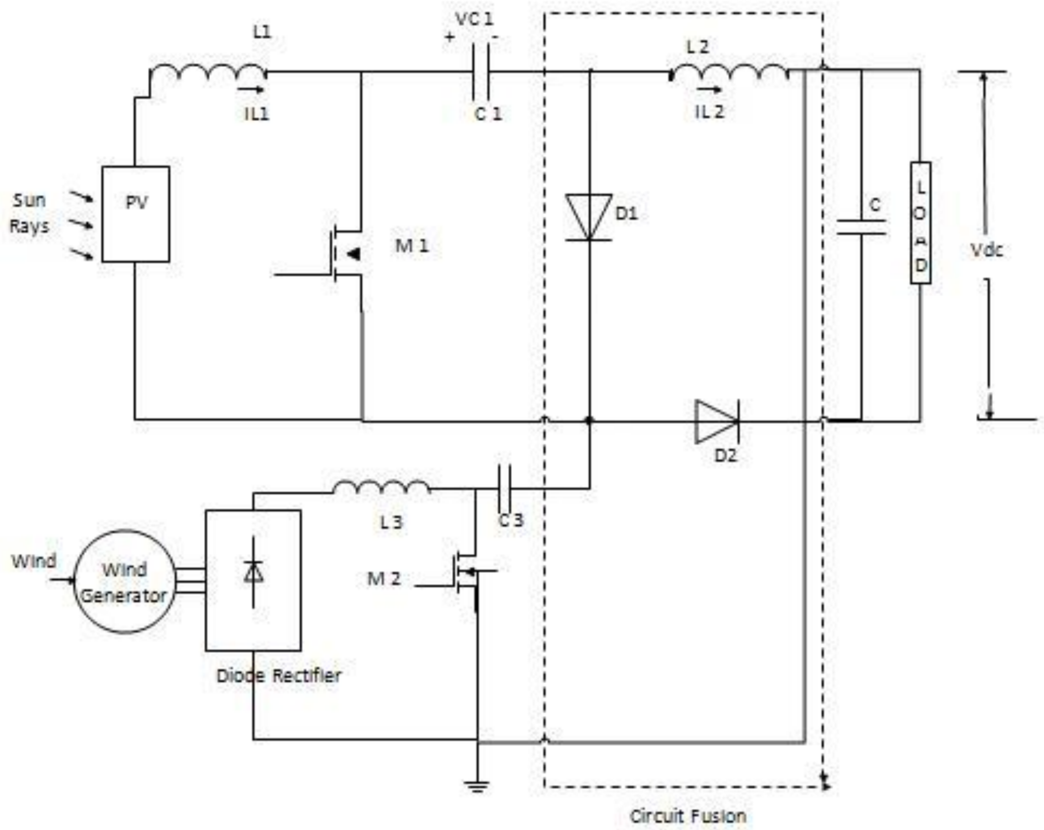


Figure 3: Circuit configuration with integrated converter

A. State II (M1 on, M2 off):

If only the PV source is available, then diode D1 turns off and D2 will be on [16].

In this case the circuit becomes a Cuk converter as shown in Fig. 1. The input to output voltage relationship is given by equation (1). In this case, both step-up/down operations are possible.

B. State III (M1 off, M2 on):

IL1=IPV+((VPV-Vc1)/L1) t (d1Ts < t < d2Ts) (10)

C. Model of Proposed System:

If only the PV source is available, then diode D1 turns off and D2 will be on. Above two circuits are combined likewise in the fig.3. to get the hybrid system with integrated Cuk converter and SEPIC converter[12]

IL2 = Idc (Vc2/L2) t, (d1Ts < t < d2Ts) IL3= IW+(Vw/L3) t , (d1Ts < t < d2Ts)

D. State IV (M1 & M2 off):

IL1 = Ipv+((VPV- Vc1)/L1) t, (d2 Ts < t < Ts)

IL2 = Idc – (Vc2/L2) t , (d2 Ts < t < Ts)

IL3 = IW +(Vw-Vc2-Vdc)/L3)t ,(d2 Ts< t< Ts)

4. Results:

In this section, simulation results from MATLAB are given to verify that the proposed rectifier stage can support standalone as well as integrated operation. Finally, Insert the TCSC between the bus 6 and bus 2 which the one weak bus and repeat the simulation again. The maximum loading point is increasing at λ=7.69 p.u. The Figure is shown in 9. The ability of TCSC can extend the maximum loading point which the TCSC connected at bus 1 – 4.

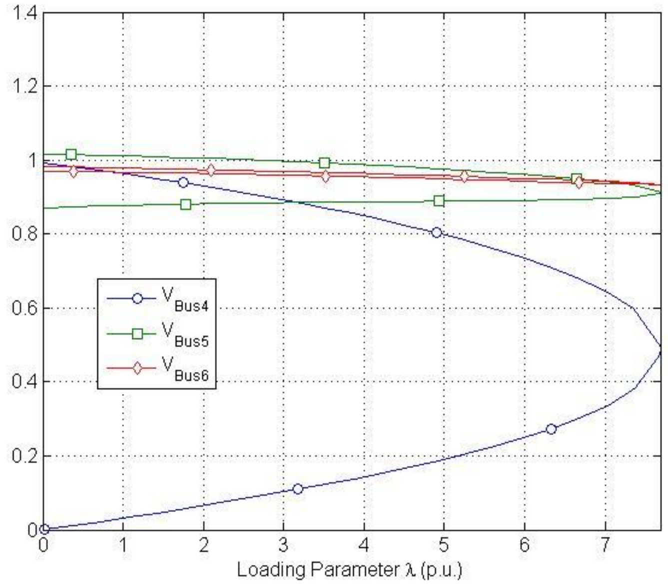


Figure 9: PV curve for 6 bus with TCSC at bus 6 – 2

5. Simulink Models:

A. Simulation result of wind turbine with SEPIC converter

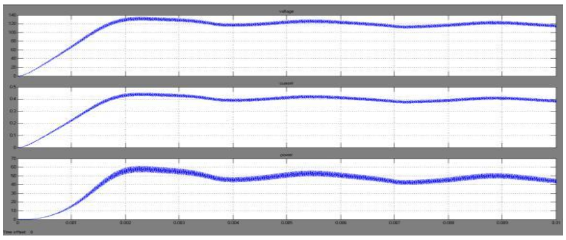
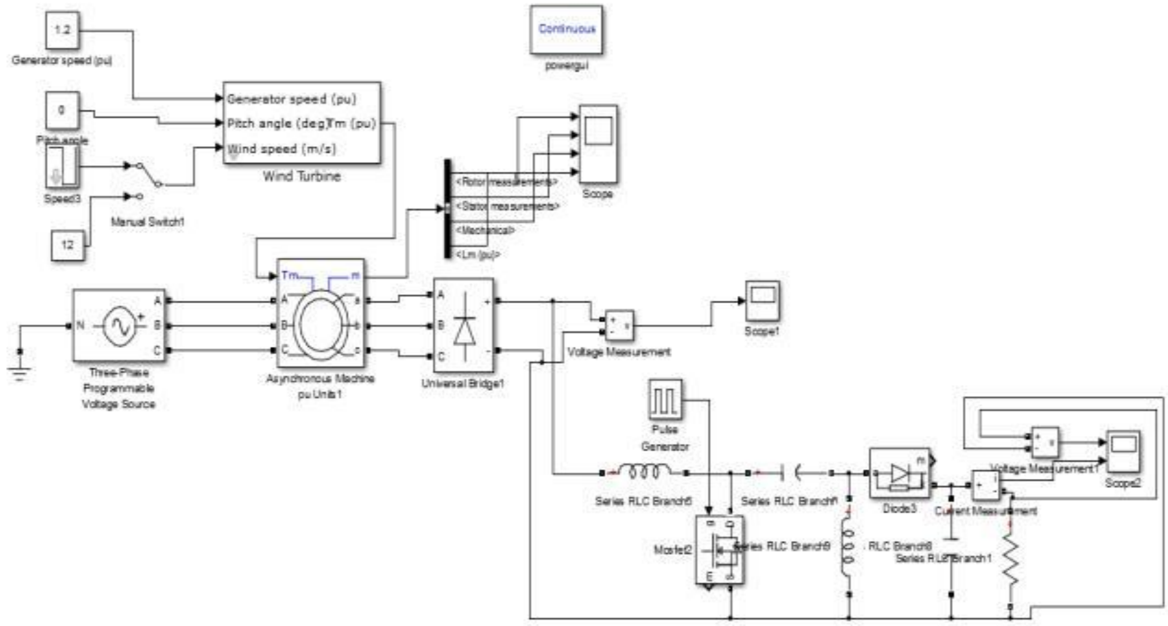


Fig.4. Simulink model of PV array

B. Model of wind turbine with SEPIC converter



C. Simulation result of Integrated Converters:

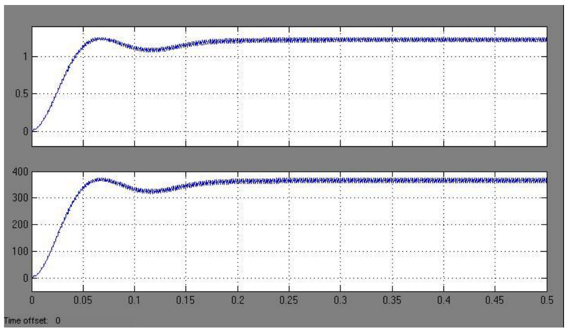


Figure 8: output waveform of integrated converter

Figure 8 manifests the system condition where both sources are available. Here system operates in an integrated mode and both the converter will supply the load[10]. Likewise in standalone mode its output is also high, so that with reduced number of passive elements same output can be obtained.

6. Conclusion:

In this paper hybrid system of solar and wind is implemented with a combination of two converters. These converters made the system more reliable and stable, because most of the renewable systems are unstable ones. Results of the systems are analyzed in both standalone and combined manner, so that it provides better results. Here the main aid is that number of passive components needed for this topology is less, compared to the separate converters. This system finds application in electrification of rural areas and variable speed conversion systems.

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