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Research Article

Self Sustaining Hybrid Renewable Energy DC Micro grid with Ideal Energy Superintendence for AC Load Operation

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Abstract

Renewable Energy applications requires high voltage gain converters and thus the paper proposes a converter for the requirements of sustainable operations . The proposed circuit is designed by integrating the standard SEPIC with a magnifying module. Thus the converter benefits from advantages that of the specific converter has, like continuous input current. The other benefits include high voltage gain and input current continuity which makes the converter suitable for sustainable energy sources. The SEPIC converter provides higher voltage gain compared in Continuous current mode and Discontinuous current mode to the existing Converters with single-controlled switch and also the THD levels are reduced when comparing with the existing converters.

Keywords: Sepic, DC Microgrid, High Voltage Gain, AC load operation

1. Introduction

The usage of fossil fuels is rapidly increased in the last decade leading to environmental pollution and increased cost. This creates lot of opportunities to the researchers in various areas of Renewable Energy Resources (RES) like (I) Photovoltaic (II) wind turbine (III) fuel cells. Among this, Photo voltaic is abundant and has various qualities such as environmental friendly, easily available. etc., The output voltage from the PV modules is so low and also mainly depends on the various atmospheric conditions. Therefore, it is necessary to increase the PV voltage. Series and parallel combinations of PV panels can be a solution to meet the demands of various loads , subsequently leading to lower efficiency, increased cost and larger size of the system. A high voltage gain DC-DC converter can be used to boost the low voltage from PV.

The smart grid PV and fuel cell integrated with Dc grid system is shown in Fig 1 .To meet the high voltage demand of DC home, electric vehicle, DC micro grid high voltage gain converter is used as intermediate stage. The conventional converters like Buck Boost, CUK or Sepic when used for high voltage gain leads to reduction in efficiency [2] [3]

Reactive components may be used to boost he voltage gain in DC –DC converters. [4][5] For higher efficiency PV applications non isolated DC –DC converters are used.

The input voltage may be boosted by High Frequency Transformers if the converters are isolated by changing the turns ratio [6][7]. Increased ripple in the input current and high voltage stress across the secondary side are the issues in the isolated converters. On the other hand weight of the transformer, with many conversions and the raised leakage energy are the other main disadvantages [8]. The output is guide by altering turns ratio of inductor coil in the coupled inductor based converters. The leakage inductance of the coupled inductor will generate a spike in switch current and hence a clamping circuit is needed to reduce this current [10]

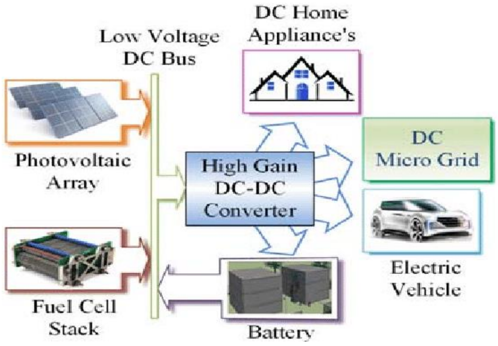

FIG 1 Smart Grid Architecture

2. Proposed Sepic converter for High Gain

For voltage applications of higher levels an increased gain SEPIC converter is of much use. The converter consist of single input-output port of a SEPIC is as shown in Fig. 2(a). Fig. 2(b) shows the power circuit of SEPIC converter. This consists of three inductors (L_x, L_y and L_z), three capacitors (C_1, C_2 and C_3) and three diodes (D_1, D_2 and D_3) which are effectively controlled by a single switch S with switching frequency (*fs*). In this converter, inductor L_Y and capacitor C_1will be voltage-boosting element along with two diodes. The various advantages of this converter are as follows

1) Continuous input current operation
2) Improved voltage gain
3) Single switch
4) Utilization of maximum Input source

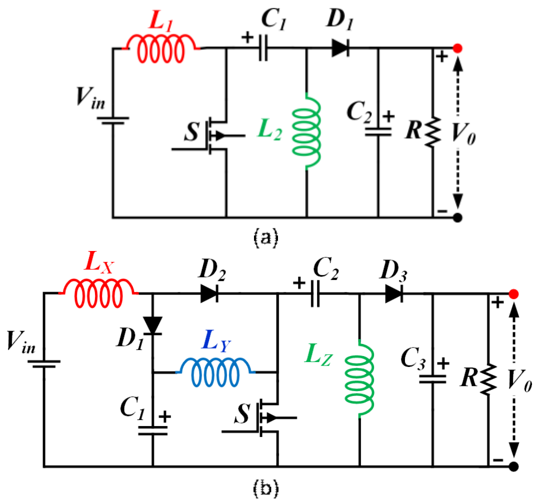

FIG2. a) Power circuitry of SEPIC and b) Modified SEPIC Converter

3. Analysis of SEPIC converter in CCM mode

For the analysis of converter the capacitors are considered in higher values and all the other components are considered ideal. There are two modes of operation from 1) Mode 1 & 2) Mode 2

Mode 1 Operation

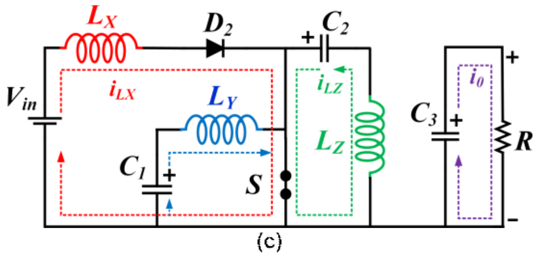

FIG 2.C) Mode I Operation of Sepic Converter

In mode-I, three inductors are polarized with current path as given. Inductor L_X from input supply (Vin $-V_{LX}$ -D2 - S-Vin), inductor L_Y from capacitor C_1 (VC_1-V_{LY} –S-V_{C1}) and inductor L_Z from capacitor C_2 (V_{C2} -S $-V_{LZ}$ $-V_{C2}$). Capacitor C_3 reverse bias the diode D_3 and thus it transfer energy to the load as shown in Fig. 2(c). The characteristic waveforms of each component in mode-I are Presented in Fig. 3.

2) MODE-II Operation

In mode-II, three inductors are demagnetized as

Inductor L_X along with input voltage (Vin) as it charges the capacitor C_1(Vin $-VL_X$ - D_1 $-C_1$ - Vin). The inductor L_Y and capacitor C_1 charges to capacitor C_2 through the path VC_1 $-VL_Y$-VC_2 – D_3 -VC1. In the meanwhile, inductor L_Z discharges through the load with following the path (VL_Z $-D_3$ $-V_O$) as shown in Fig. 2(d). The characteristic waveforms of each component in mode-II

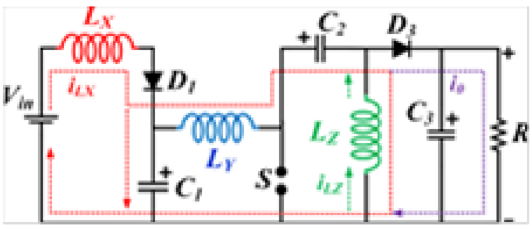

FIG 2d) Mode II operation of SEPIC Converter

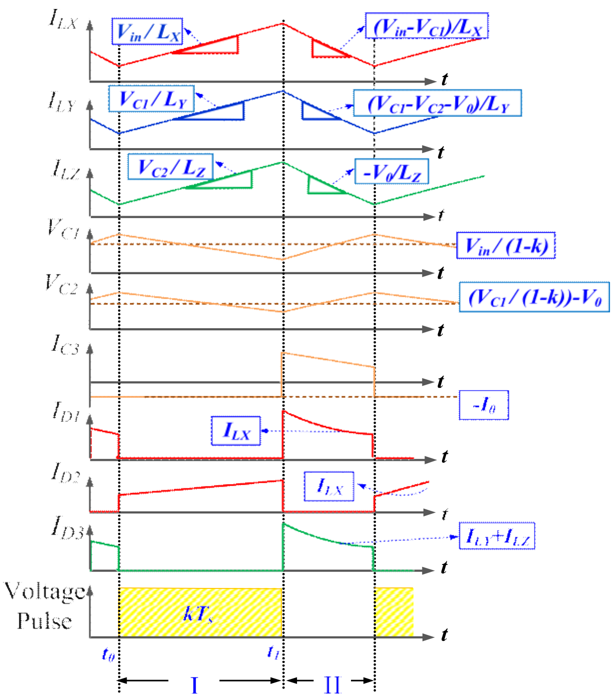

FIG 3 Characteristic component in mode 1

$V_{LY} = V_{C1} - V_{C2} - V_O$ - (1)

Voltage gain of the proposed converter is

$$CCM = \frac{V_O}{V_{in}} = \frac{K}{1-k^2} \quad (2)$$

4. Analysis of SEPIC converter in DCM mode

The converter can be worked in Discontinuous Conduction Mode (DCM) as current through inductor/s compasses to zero levels separately or together as individual diode become converse predisposition. The DCM activity of the converter is separated into three modes as mode-I, II and III. Where, mode-I and II have comparable working rule like CCM. Though mode III is the continuation activity of mode II. Concerning the current and individual diode working state, the converter can be work in three various conceivable DCM mode as mode-A, mode-B and mode-C. In mode-A, inductor L_X current (I_{LX}) min separately reach to zero level as diode D1 gets opposite predisposition. In mode-B, diode D1 is forward predisposition and Diode D3 gets opposite inclination because of inductor L_Y and L_Z current (I_{LY}) min,(I_{LZ})min). Also in mode-C, the two diodes D1 and D3 become opposite inclination by the impact of current through inductor L_X, L_Y and L_Z .The force hardware with individual current way in three potential DCM modes is displayed in Fig. 4. In light of the three various potential modes, the converter has three distinctive voltage acquire in DCM. Subsequently, for straightforwardness the MSC is examined with mode-B DCM mode. The particular waveforms of every segment are displayed in Fig. 5

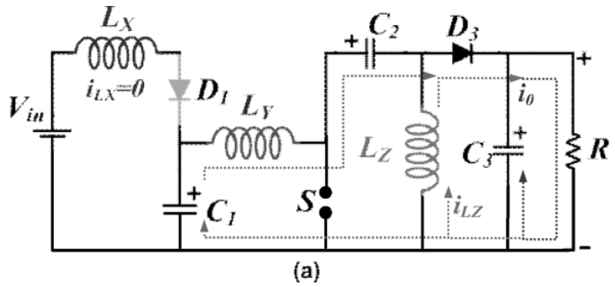

FIG 4 Mode A DCM Operation of Converter

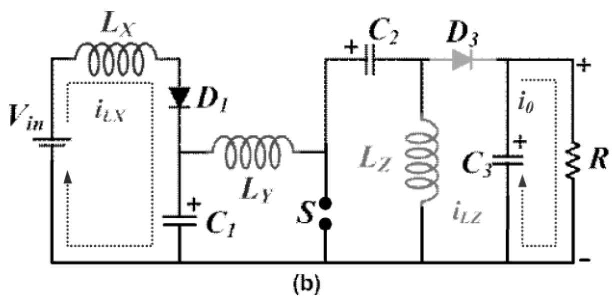

FIG 4 Mode B DCM Operation of Converter

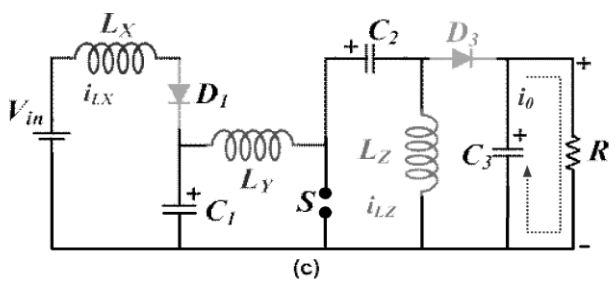

FIG 4 Mode C DCM Operation of Converter

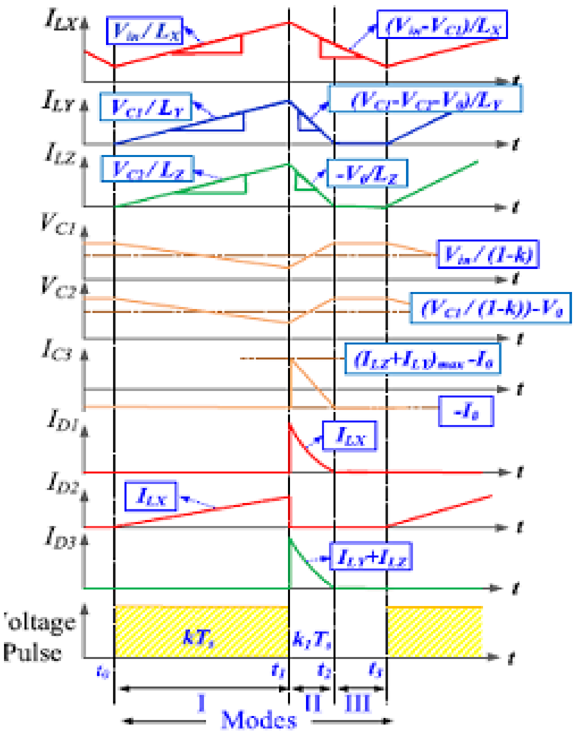

FIG 5 Characteristic of converter in DCM mode

5.Total Harmonic Distortion

The force Converters utilized is having a nature of changing the state of the waveform. Switching power supplies, in which the force component quickly changes between a completely on and a completely off state, can be particularly non-direct. Various strategies, for example, shifting or adding control frameworks to compel current stream to follow a reference signal are frequently used to lessen the impact of the exchanging. At the point when the heap takes absolutely sinusoidal molded current and the voltage structure the stockpile source then it is supposed to be the direct burden. The term of the power factor is the cosine angle difference of the phase voltage and the current in the network .

Because of the switching activity of rectifiers predictable unsettling influence of current happens. The state of current waveform gets decay because of the harmonics present in streaming current in nonlinear burdens which isn't in sinusoidal nature. The amplitudes of various odd sounds of the line current are considerable as indicated by the key recurrence and these can't be disregarded .

Another boundary to quantify the distortion in the power supplies is the absolute Total harmonic Distortion.

There are several factors to be considered for Ac and DC load applications while designing the converters. The harmonics level will be predicted depending upon the different factors of the applications. The modern sepic converter plays a vital role in reducing the harmonic levels. The Hysteresis Current Control method uses a constant off time and turn on time. Hysteresis comparators are utilized to obtain the hysteresis band through the system using predefined reference current so that better dynamic controlling is achieved, because it works quickly on demand. The comparator also issues an intrinsic current limiting proficiency to the system. A narrow hysteresis band is needed to accomplish the smaller amount of ripple content in the input current which is coming from the source. Anyhow the narrowed the hysteresis band, the higher the switching frequency. This control method (HCMC) can also be used in a determined frequency procedure but it might upsurge the complicated issues of the control circuitry. The circuit apparatuses like magnetic components and switching devices are used to improve the hysteresis band.

The converter actually reduces the Total Harmonic Distortion .The waveforms is shown in FIG 6 below. The THD level is reduced with a value of 2.91% for the proposed converter.

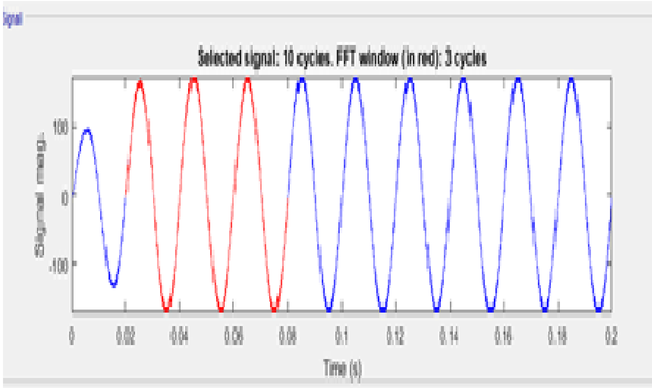

FIG 6 THD waveforms of the converter

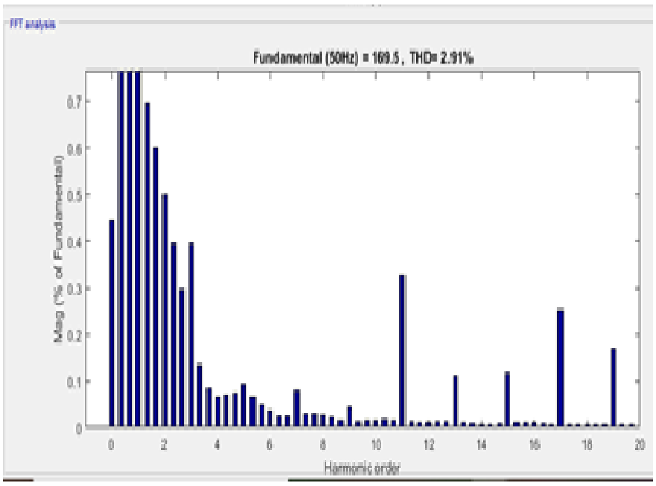

Fig 7 Proposed converter THD

6. Simulation Results

Simulation models of SEPIC converter were built with MATLAB package. For the switching frequency of 20 KHZ the converter is simulated with a input voltage of 24 V and the waveforms are observed. Fig.8 and Fig.9 show the simulation circuit of SEPIC converter ad the output voltage respectively.

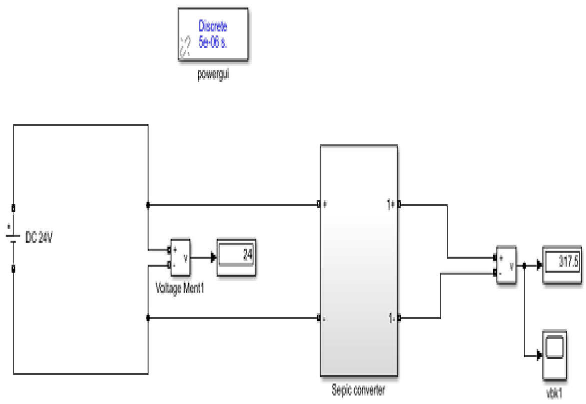

Fig. 8. Simulation circuit of SEPIC converter

For an input voltage of V_{in} = 24V (Switching frequency f_s = 20 KHz,) an output of 170 V is simulated.

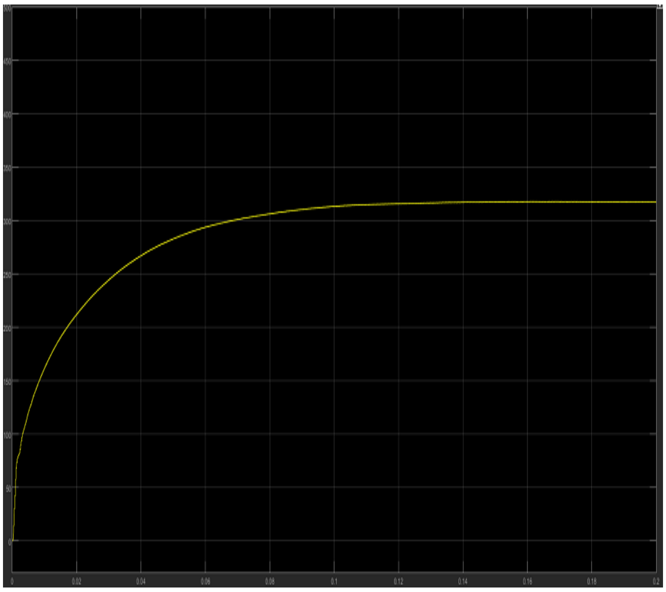

Fig. 9. Output Voltage of SEPIC Converter

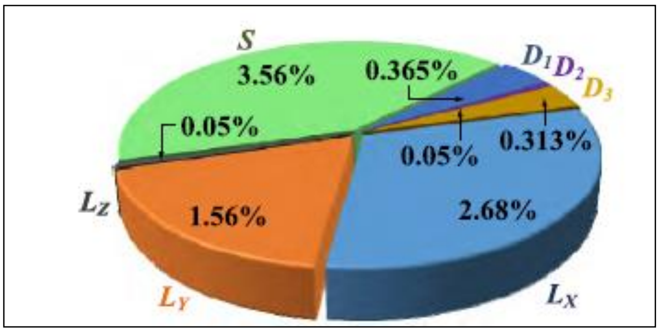

Fig 10. Voltage drop at different components

Fig.10 shows the voltage drop at different components like Diode, Inductor and switch. The Switch has the highest drop at the duty ratio of 0.7

7. Conclusion

DC-DC SEPIC converter has been proposed for renewable energy applications. High voltage gain and continuous input current and the reduced THD are theadvantages of this converter . The working of converter in CCM and DCM mode has been presented.. The analysis of the given converter is tested with numerical simulation and hardware for 100 W prototype model. The results are shown for 170 V output from 24 V input supply with a gain of almost 10.According to the obtained results, it can be concluded that the proposed converter is well suited for high voltage renewable energy applications..

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