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KY CONVERTER FOR RENEWABLE ENERGY SYSTEMS

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Abstract

Renewable energy is the energy that is collected from renewable resources and due to the rising depletion of fossil fuels, renewable energy is the source that humanity turns to for harnessing electrical power. The power so obtained often needs DC- better DC conversion for supplying the load properly. The boost converter are used currently for the chopper control in wind and solar power systems that provides a response characteristics that can be improved, by implementing a KY converter in place of the boost converter. The KY converter is a step up DC-DC converter with transient response operating in CCM always with low voltage ripple, non pulsating current and the KY converter provides a larger voltage gain than the conventional boost converter. In this topology where it is combined with buck boost converter but in this topology DCM is also possible. Simulation of conventional boost converter and KY converter by MATLAB software is done for comparing the operation of the converters. KY converter is implemented in hardware to study the operation practically and to verify the feasibility of using the converter in renewable energy systems.

Key Words:KY converter, comparison of boost converter, renewable energy system

1 INTRODUCTION

In the modern society, DC-DC converters were widely used in portable electronic devices such as: mobile phones, laptops and digital still cameras (DSC). In order to converts the battery voltage into different voltage domains. For power supply applications using low voltage battery, in most instances, it is necessary uplift from low voltage to high voltage, thus a boost converter is usually applied, but with a pulsating output current leading to a large voltage ripple [2].

Moreover, the boost converter consists of a right hand plane zero, which deteriorates the converter stability and transient response performances. Recently, a voltage-boosting converter has been proposed, named as KY converter. When this converter is operating in continuous conduction mode (CCM), it has a lot of advantages such as non-pulsating current, low output ripple, and good load transient response [2], [3], which can eliminate the problems exhibited by the boost converter thus a KY converter can be used instead of boost converter which will have better output response comparing with the traditional boost converter. Hence this KY converter can be employed for delivering power to the grid. A solar panel is being used for delivering the DC supply and this DC voltage is stored in the battery. The voltage thus stored in the battery is then given to the KY converter for boosting its voltage level. Then the output of KY converter circuit is given directly to the load. By this a continuous output can be obtained with reduced ripple counts. The circuit of KY converter can be designed which consists of a diode, capacitors, a resistor and inductors.Thus a better transient response can be obtained by using KY converter. Hence a ripple free output with comparatively high efficiency can be obtained which can be implemented for low power applications as mentioned above.

2 KY CONVERTER

Fig. 1 shows the KY converter, taking the output inductor copper resistance rL and output capacitor series equivalent resistance rC into account.

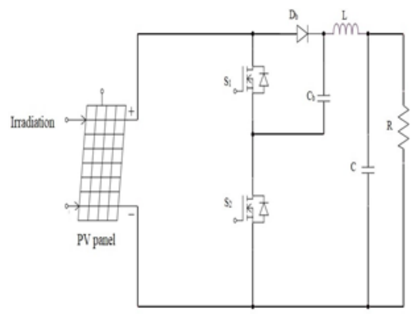

Fig. 1. KY converter considering parasitic elements

The input voltage and output voltage are denoted by vi and vo, respectively. Since the voltage across Cb follows the input voltage vi entirely, the voltage across Cb can be defined as vi [1]. The voltage across C is represented by vC. Moreover, the input current is signified by ii. The currents flowing through Cb, L and C are denoted by ib, iL and iC, respectively.

The basic operating principle of KY converter and the second-order derived KY converters [5] are discussed here which always operate in CCM. As shown in Fig. 2(a), here only one cell in the structure of the KY converter consists of two MOSFET switches S1 and S2 along with diodes D1 and D2 , respectively, one diode Db , and one energy transferring capacitor Cb ; so the corresponding operating principle rule is that the turn-on type of these two switches is (D, 1 D), where D and 1 D are for S1 and S2, respectively, and D is the duty cycle of the PWM control signal for S1.

3 OPERATION OF KY CONVERTER

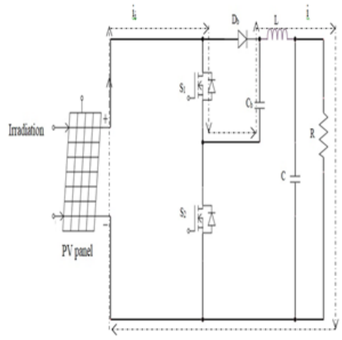

Fig .2 (a) Equivalent circuit of Mode 1

The above figure shows the equivalent circuit of mode 1 where switch S1 is turned on. In both modes the load is supplied.

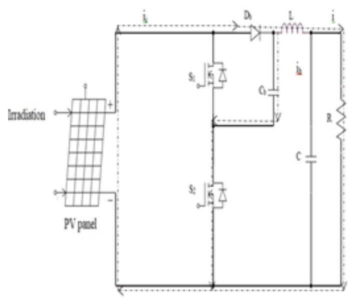

Fig .2 (b) Equivalent circuit of Mode 2

Mode 1: S1 is turned on and S2 is turned off, the voltage across L is the input voltage vi plus the voltage vi across Cb minus the output voltage vo, thereby causing L to be magnetized. Also, the current flowing through C is equal to the current i flowing through L minus the current flowing through R. Besides, in this mode, Cb is discharged.

Mode 2: As soon as S1 is turned off and S2 is turned on, the voltage across L is the input voltage vi minus the output voltage vo, thereby causing L to be demagnetized. Also, the current flowing through C is equal to the current i flowing through L minus the current flowing through R. Besides, inthis mode, Cb is abruptly charged to vi within a very short time, which is much less than Ts. The voltage gain is given as

V_0/V_{in}= 1 + D (For 1st order) =2+D and 1+2D (For2nd order)

where, D is Duty cycle.

4 DESIGN OF INDUCTANCE AND CAPACITANCE VALUES

The design specifications of the KY converter are given as follows:

V_{IN}=12V

V_{OUT}=18V

operating frequency of the switch (mosfet here) = 195KHz Gain formula of converter = 1+D

OUTPUT CURRENT

$I_{OUT} = P_{OUT}/V_{OUT}$= 50W / 18V = 2.77A

INPUT CURRENT

Assume that the converter efficiency is about 100%

$P_{OUT} = P_{IN}$

$I_{IN} = P_{IN}/V_{IN}$ = 50W/12V= 4.16A

VOLTAGE GAIN CALCULATION

Gain =V_{OUT}/V_{IN} = 18V / 12V = 1.5

DUTY CYCLE CALCULATION

Voltage gain of converter = (1+D)

1.5 = (1+D)

D = 0.5= 50

INDUCTOR VALUE CALCULATION

In mode 1 when the switch s1 is on and s2 is off, voltage across the inductor

$V_L = 2V_{IN} - V_{OUT}$ =2* 12V - 18V =6V

for an inductor voltage current basic relation is

$V_L = L * dI/dt$

then, $L = V_L * dt/dI$

Here dt = duty cycle / frequency

Assume that operating frequency of the switch (mosfet here) =195 kHz and di is the ripple current of inductor

$I_L = I_{IN} * 2$ = 4.16*2=8.32 A

From the industrial viewpoint,the output inductor is generally designed to have no negative current when the output current is above 20%∼40% of the rated output current . Therefore, in this paper, the boundary between the positive current and the negative current is assumed to be at 40% of the rated output current. Hence, the value of Lo can be obtained as follows:

Assume that inductor ripple current = 40% of inductor current

$dI = 40\% * I_L$

dI =40% * 4.16A *2 = 3.328 A

$L = V_L * dt/dI = V_L * D/(F * di)$

= 6V * 0.5 / (195000 Hz * 3.328 A) =4.6μH

charge pump capacitor value for a capacitor voltage current basic relation is

I = C * dV / dt

dV is output ripple voltage. Assume that output ripple voltage is about 0.05% of output voltage

dV = 0.1% * 12V

dV = 0.012V

$C = I_{IN} * dt/dV$

We have dt = duty ratio/frequency

$C = I_{IN} * D/(F * dV)$

= 4.16A * 0.5/ (195000 Hz* 0.012 V)

=888μF = 1000μF (standard value)

charge pump capacitor value for a capacitor voltage current basic relation is

I = C * dV / dt

dV is output ripple voltage. Assume that output ripple voltage is about 0.05% of output voltage

dV = 0.1% * 18V

dV = 0.018V

$C = I_{OUT} * dt/dV$

We have dt = duty ratio/frequency

$C = I_{OUT} * D/(F * dV)$

C = 2.77A * 0.5/ (195000 Hz* 0.018 V)

$C = 394\mu F = 470\mu F$(standard value)

5 SIMULATION RESULTS

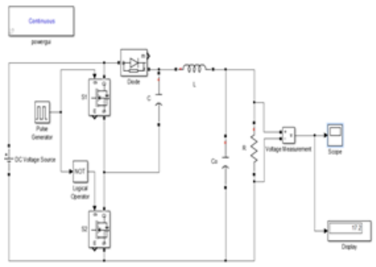

Fig 3(a) Simulink model of KY converter

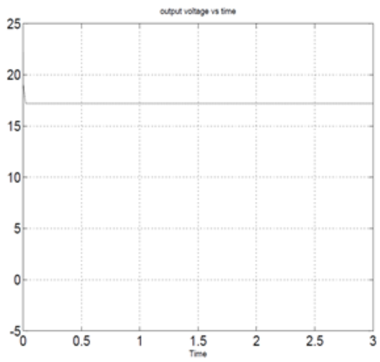

Fig 3(b) V_o of KY converter

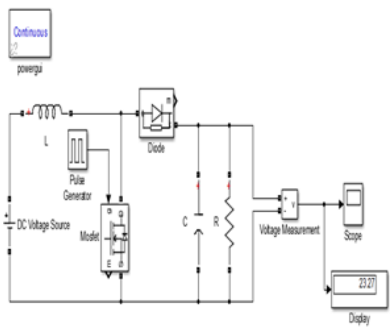

Fig 4(a) Simulink model of boost converter

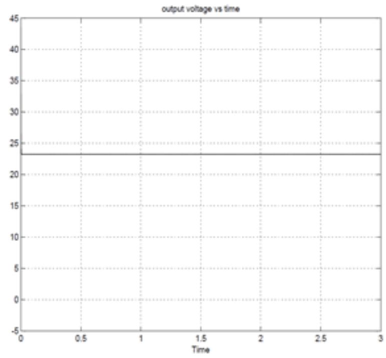

Fig 4(b) V_o of boost converter

From the$V_o$plots (5(a) and 5 (b)) of the two converters it is inferred that the ripple in the KY converter is lower.

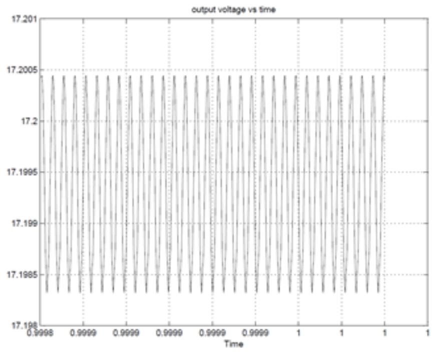

Fig 5(a)V_o of KY converter

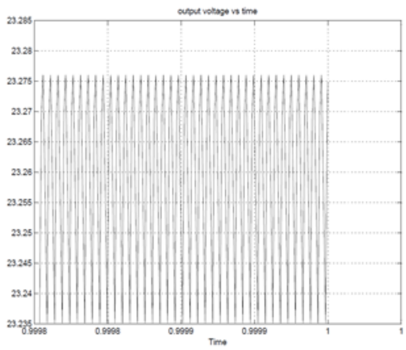

Fig 5(b)V_o of boost converter

The following are the Simulink model of the KY and boost converters with RL load and its output current . The value of inductance is 10μH

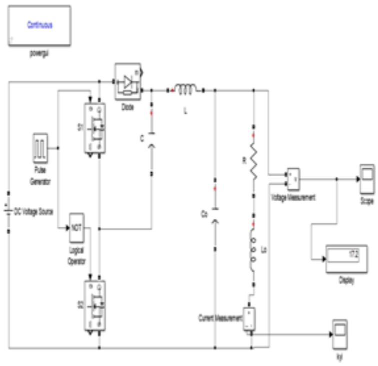

Fig 6 (a) Simulink model of KY with RL load

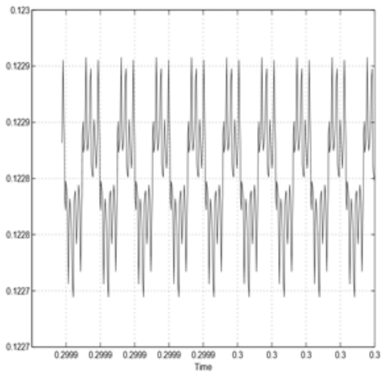

Fig 6 (b)Output current of Simulink model of KY converter with RL load

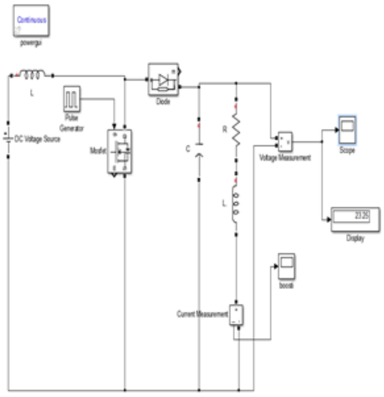

Fig 7 (a) Simulink model of boost with RL load

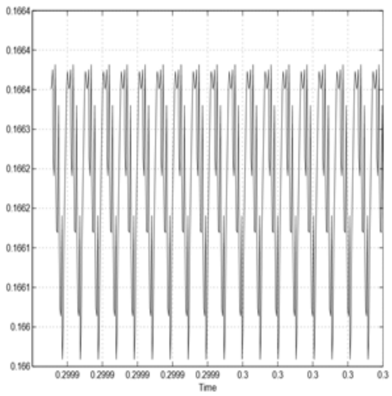

Fig 7(b) Output current of Simulink model of boost converter with RL load

From the above simulated output we infer that the current is more stable in KY converter for RL load.

6 HARDWARE IMPLEMENTATION

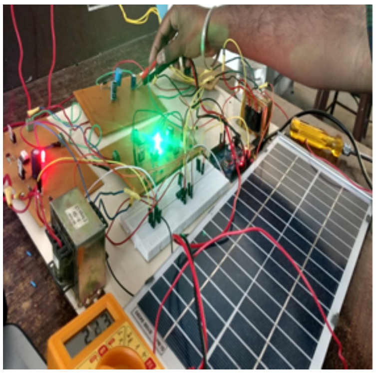

Fig .8 (a) Photograph of hardware

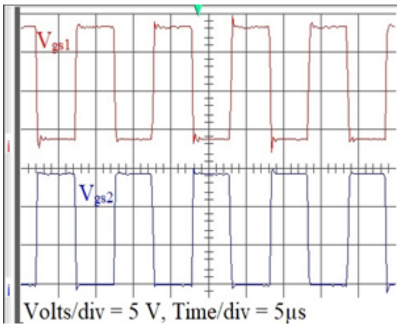

Fig 8(b) Gating pulses ofS_1 and S_2

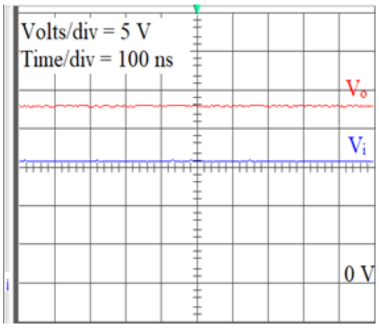

Fig 8(c) V_o and V_i of KY converter

7 CONCLUSION AND FUTURE WORK

In this paper, an attempt has been shown for reducing the output voltage ripple across the capacitor in the KY Converters Unlike the nonisolated DC-Dc converter, these KY Converters are operating in Continuous Conduction mode (CCM) inherently, it possess non-pulsating output current, thereby decreasing the current stress on the output capacitor but reducing the output voltage ripple.

The KY Converter can be used efficiently without the ripple voltages in the Converter. Thus a DC-DC Converter is converting one DC voltage level to another DC voltage level with a minimal loss of energy.

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