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A soft switching dual flyback DC-DC converter for renewable energy applications

Reshma R
reshu.leela@gmail.com
MVJ College of Engineering, Bengaluru, Karnataka

Sankar Vijaya Selvakumar
vs.sankar95@gmail.com
MVJ College of Engineering, Bengaluru, Karnataka

Swasthik. B
swasthik.bannadi@gmail.com
MVJ College of Engineering, Bengaluru, Karnataka

ABSTRACT

The world's total energy consumption is higher than its production. With respect to the efficiency, it is known that the conventional energy sources say fossil fuels, is used much more than the non-conventional energy sources. Due to the over-consumption of energy from fossil fuels, after few years it may extinct and thousands of years are needed to produce fossil fuels. Hence, non-conventional energy sources must be used as an alternative source of energy production. One of the renewable energy sources which are available in bulk is solar. But the energy production from solar is not as efficient as that of fossil fuels. Hence, a DC-DC converter has to be built to enhance the solar power. A DC-DC Flyback converter with soft-switching is been built which increases the output voltage of the solar power depending upon the Flyback transformer ratio.

Keywords: *DC-DC Flyback converter, PV panel, Soft-Switching, MATLAB/Simulink.*

1. INTRODUCTION

As the pool of available non-renewable energy resources is being exhausted, the demand for resources that are everlasting and eco-friendly is increasing day by day. One such form is the solar energy. It does not pollute the air by releasing harmful gases such as carbon dioxide, nitrogen oxide, sulphur oxide which may lead to global warming. Hence solar energy can be an alternative to fossil fuel as it is non-polluting, clean and reliable.

One of the major advantages is that solar energy is easily available from the sun. Unlike wind power and hydro energy, solar energy spreads out more evenly in the world. The world's solar energy potential clearly indicates that most part of the world could efficiently utilize the solar energy as one of the primary energy resources.

There are also other advantages of using solar energy, such as no disposal method necessary, less space required and relatively low cost and high efficiency. Therefore, solar energy can be used advantageously instead of using non-renewable energy sources like fossil fuels, etc. Considering the importance of the use of solar cells and efficient use of solar energy, let us study about the solar-based energy systems.

2. PHOTOVOLTAIC CELLS

The word "Photovoltaic" combines two terms – "photo" which means light and "voltaic" which means voltage. There are several types of PV panel based on generation such as (First Second & Third generation) Monocrystalline Solar Cell Polycrystalline Solar Cell Cadmium Telluride (CdTe) Solar Cells etc. The proposed system uses Polycrystalline PV panel as the input voltage source. In the proposed converter, the input voltage is obtained from the solar panel. The polycrystalline solar panel is been used in the proposed system to get the required input voltage. The process used to make polycrystalline silicon is simpler and cost less. The amount of waste silicon is less compared to monocrystalline. Polycrystalline solar panels tend to have slightly lower heat tolerance than monocrystalline solar panels. The efficiency of the polycrystalline solar panel is around 13-16%.

3. DC-DC CONVERTER

A dc-dc converter is an electronic circuit or electromechanical device that converts a source of direct current (DC) from one voltage level to another. It is a type of electric power converter. Power levels range from very low (small batteries) to very high (high-voltage power transmission). Basically, there are two types of DC-DC converter

a) Non Isolated DC-DC Converter: The input and output terminals of a non-isolated dc-dc converter share the common ground. Non-isolated DC-DC converters are more widely used since they are of lower cost, they are used in a most negative ground application in vehicles for various DC powered appliances and equipment. E.g. Buck Converter, Boost Converter, Buck-Boost Converter etc.

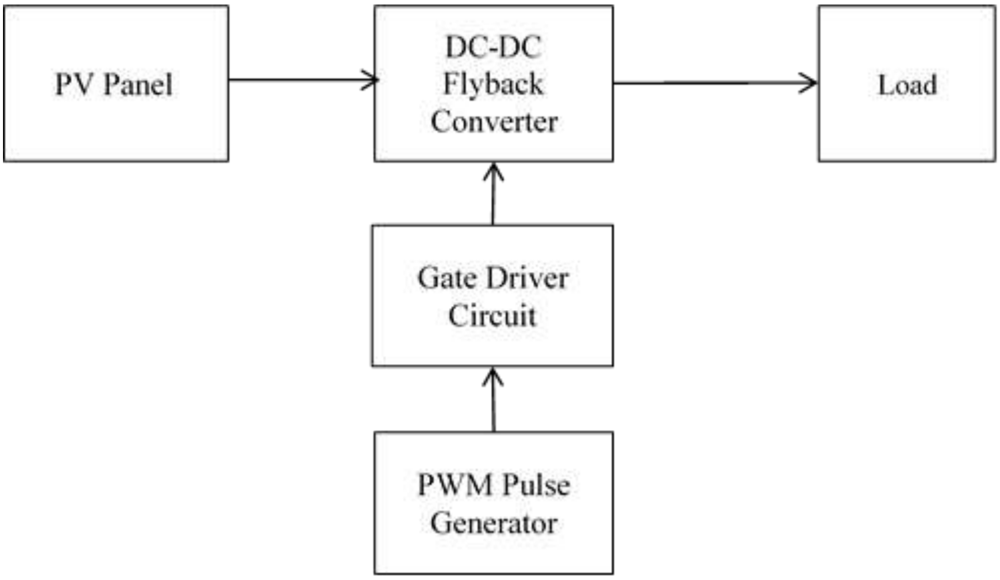
b) Isolated DC-DC Converter: The isolated DC-DC converter is electrically separated between the input and the output terminals. Isolated DC-DC converters have high isolation (barrier) voltage from several hundred to thousand volts depending on the type of standard. They can be used as negative grounded or positive ground or floating ground for various equipment. E.g. Flyback Converter, Push-Pull Converter, Forward Converter etc.

The main aim of this project is to increase the output voltage level so that solar energy is used efficiently. In the proposed system, Flyback dc-dc converter is used. Flyback is a buck-boost chopper with the isolated division to configure a transformer. With additional advantage of isolation, the voltage ratio is multiplied. It is used in both alternating to direct and direct to direct transfer with galvanic separation between output and input. With regard to efficiency and energy, fly-back power supplies are substandard than several switched mode power supply circuits but it is easy technique and because of less rate makes it accepted in small output power range. Efficiency is typically 75% to 80

4. COMPONENTS

Sl no.	Component	Specifications	Parameters
1	Solar Panel	Polycrystalline	Voc=20.6V; Pmax=10W; Efficiency=13-16%
2	MOSFET	IRFZ44N	Vdss=55V; Rds(on)=17.5ohms; Id=49A
3	Flyback Transformer	Ferrite Core	N2/N1=3; Lp=20uH; Ls=2uH; Ip=4A; Is=2A
4	PWM	SG3525	Operates at 8V to 35V

5. BLOCK DIAGRAM



6. DESIGN

The supply voltage has been provided and ground has been connected. Also, the V_C has been connected to V_{CC}. A bulk and a decoupling capacitor has been added across the supply pins. The decoupling capacitor (0.1µF) should be placed as close to the SG3525 as possible. We should always use this in all our designs. We should not omit the bulk capacitor either, although a smaller value can be used.

At Pins 5, 6 and 7, a small resistance R_D (between pins 5 and 7) has been added that provides a little dead time. R_T is connected between pin 6 and ground and C_T between pin 5 and ground. R_D = 10 kΩ, C_T = 1nF and R_T = 15 kΩ. This gives an oscillator frequency $f = 1/(10^{-9} * (0.7 * 10000 + 3 * 470)\text{Hz}$ = 118.9 kHz

As the oscillator frequency is 39.3 kHz, the switching frequency is 0.5 * 118.9 kHz = 59.45 kHz and this is close enough to our target frequency of 60 kHz. Now if exact 60 kHz switching frequency needs to be achieved, then the best way would have been is to use a pot (variable resistor) in series with R_T and adjust the pot, or to use a pot (variable resistor) as R_T, although I prefer the first as it allows for fine-tuning the frequency. At pin 8 now a 1µF capacitor is connected from pin 8 to ground and this provides a small soft-start. I've avoided using too large a soft-start as the slow duty cycle increase (and thus the slow increase in voltage) causes problems when using CFLs at the output. At pin 10, initially the switch is kept on, pin 10 is now at the ground and so PWM is enabled. When the supply is given to the converter, the PWM is also switched ON. If needed to switch off the PWM a pull-up resistor can be used to pull it up to VREF. So, we've made use of the SG3525 shutdown option (via pin 10). Thus the switch acts like an on/off switch. Pins 11 and 14 drive the MOSFETs. There are resistors in series with the gate to limit gate current. The resistors from gate-to-source ensure that MOSFETs don't get accidentally turned on.

7. WORKING

An input voltage of 12 V is given from a DC Voltage source - either a battery or a solar panel. A filter is employed to smoothen the waveform from the input voltage. The input filter consists of 4700uF Capacitor and a Diode. The positive end is connected to the center tap of the primary winding of the Flyback transformer. The remaining terminals of the Flyback transformer are given to two pairs of MOSFETs. The PWM SG 3525 provides gate pulses to the MOSFETs at 60 kHz switching frequency, the DC-AC conversion takes place and is given as input to the transformer. Hence, an inverter circuit is not needed for the DC-AC conversion.

For the output of the circuit to be further conditioned (for example stepped up) then the frequency is much higher (20 kHz) for good transformer efficiency, therefore we have taken switching frequency as 60 kHz.The flyback transformer is used to step up the voltage. It has a transformer of ratio 1:3. The center tap of the secondary winding of the transformer is grounded, while the positive and negative is given to the rectifier. The output from the Flyback transformer is AC. Therefore, it is given to the bridge rectifier to convert AC to DC.

8. SIMULATION

The system simulation is been carried out using MATLAB/ Simulink 2014a edition.

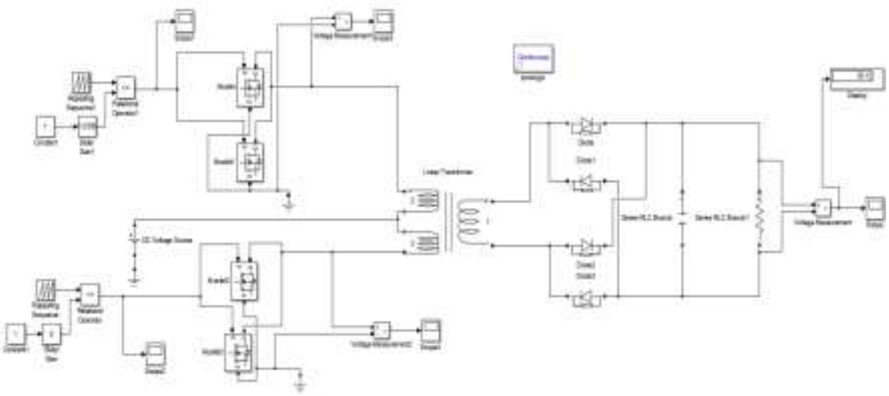


Figure 1: DC-DC Converter Simulation

A DC voltage source of 12V is connected to the center tap of the primary winding. The two pairs of MOSFETs connected in series are connected to the primary winding of the Flyback transformer. It mainly consists of MOSFETs, Flyback Transformer and Capacitor.

The calculation of the capacitance value is same as that of the Flyback converter.

Co = 36 / (3.6*10000*10) = 100uF

The output from the system obtained is 34.3V as it is open loop system.

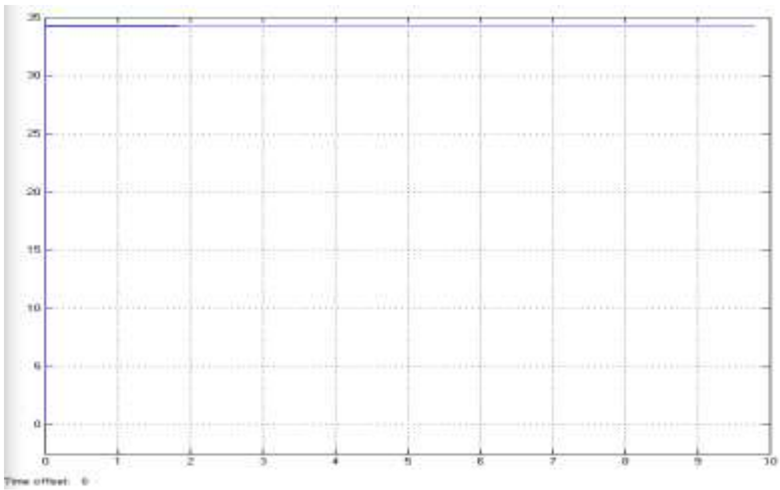


Figure 2: Simulation Output

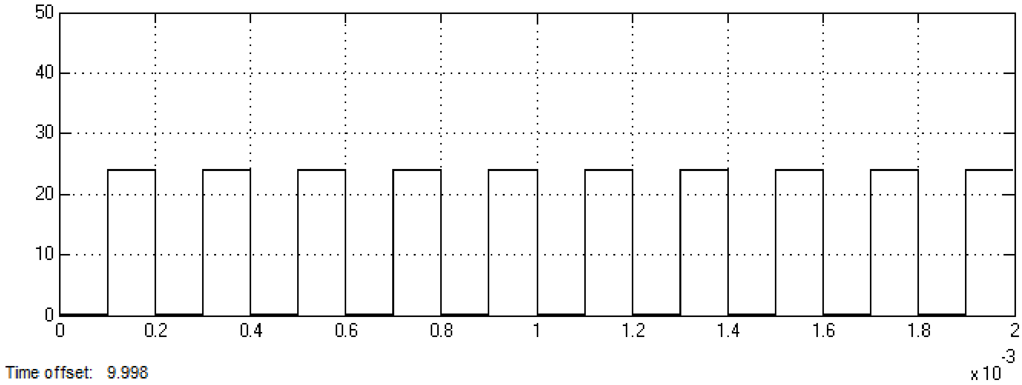


Figure 3: Output for ZVS

9. CONCLUSION

The main aim of this project is to make efficient use of solar power. Using DC-DC Flyback converter the output voltage is thrice the input voltage. The efficiency of Flyback converter is greater than the buck, boost or buck-boost converter. The conversion of DC to AC is done without using any inverter circuit which reduces circuit complexity. The switching loss of the proposed DC-DC Flyback converter is reduced to a minimal value. The usage of hard switching is eliminated. Although the DC-DC Flyback converter has certain advantages when compared to other converters, the switching loss and the conduction loss of this converter was not completely eliminated.

Further modifications can be done to make the switching loss and conduction loss completely nil. Not only ZVS but both ZVS and ZCS can be achieved for MOSFETs switches. With greater transformer ratio, the input voltage from the PV panel can be increased more to make an efficient use of solar power.

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