PV BASED BATTERY LESS COOLING AND LIGHTING SOLUTION

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Abstract. Increase in usage of renewable energy has become mandatory as the world is moving towards green energy. Developing nations like India and many others aid the revolution as it has abundant solar energy to harness. A solar powered flyback converter with an inverter is presented in this paper. This system is of great use at street side vending shops and food trucks where variable loads like fan and incandescent lamp can be connected. Flyback converter provides galvanic isolation to protect the load from the source and minimal usage of circuit components which adds to the advantage. The proposed system has no battery and the power of the load changes as the solar radiation changes. A prototype with 35V DC input and 230V AC output was developed and tested to verify the performance of the proposed system. The efficiency of the system was found to be 81%.

Keywords: Flyback converter, Inductors, Capacitors, Rectified sinewave, MPPT.

1. INTRODUCTION

Renewable energy sources are becoming more and more popular due to their various technical, economical and ecological advantages. Solar Photovoltaic and Wind turbine based power generation have become two of the most used renewable energy power generation due to the abundance of source power[1] and has been under research for various configurations of the converters [1-2], controllers [3-6] and configurations to improve the efficiency of the system.

Flyback converters have more advantages compared to other high gain converters and more suitable for various power levels of solar PV based systems [7-8]. Flyback converter has a galvanic isolated flyback transformer so the source is separated by primary winding from the secondary side of the converter. To achieve the desired high gain in flyback converter the turns ratio of flyback transformer and duty ratio of flyback converter are varied. Flyback converter is mainly used in domestic applications, DC micro grids, Switched Mode Power Supply (SMPS), micro inverter and battery charging applications.

In this paper, the flyback converter based microinverter coupled PV system is used for low power applications ranging from 200W to 250W. The load used here is resistive and inductive type like incandescent lamp and fan, etc. The advantage of such a system is that it is easy to configure to operate in grid tied and islanded mode, as it offers a simple plug and play style of operation [9] which is really good for a developing country like India which is boosting usage of Solar PV based power generation[10].

Some of the recent research topics regarding the renewable energy penetration and optimisation of their amount of real and reactive power generation are discussed in [11-20]. This shows that whether the amount of renewable energy, whether small or large, is really good not just for our power system but also for our environment as they help in reducing the pollution overall.

The system is simulated in PSIM with resistive and inductive loads representing incandescent lamps and fans and the simulation results show successful operation of the flyback converter based PV system. This configuration is smaller in size, easily portable and most importantly suitable for small power applications like small shops on the streets, which require very low power and investing in solar panels is better than investing in batteries as long as they’re only open during day time.
2. SYSTEM MODEL

![Block diagram](image1)

Fig. 1 illustrates that input is fed by PV panel which is a 35V DC. The 35V DC is directly given to the flyback converter connected with an inverter. Here sine wave modulated pulses are used to operate the power converter switch. Due to sine wave modulated pulse the output of the converter is a rectified AC output. This method is used here because to get exact AC output in the inverter side without using LC filter. The maximum power of the solar PV panel is tracked by using MPPT method.

3. PROPOSED CIRCUIT

![Circuit Diagram](image2)

The fig. 2 represents the flyback converter which is connected with a single phase inverter. The source is fed by a 250W solar panel. T₁ represents flyback transformer, S₁ represents MOSFET switch, D represents diode, C represents capacitor and with this capacitor converter circuit completes. The output of flyback converter is connected to a single phase inverter.

3.1 Mode 1 (Q1 on)

When switch ‘Q1’ is on, the primary winding of the transformer gets connected to the input supply with its dotted end connected to the positive side and gets charged. At this time the diode ‘D’ connected in series with the secondary winding gets reverse biased due to the induced voltage in the secondary (dotted end potential being higher). In this time the capacitor delivers voltage to the load. Thus the capacitor gets charged in the previous mode.
3.2 Mode 2 (Q1 off)

In this mode the switch ‘Q1’ turns OFF and due to collapsing magnetic field the polarity of transformer reverses. Due to this the diode gets forward biased and the secondary side voltage gets stored in capacitor and energy gets transferred to load. This activity continues until the core is depleted of energy or the power switch is once again turned on. The primary and secondary windings of the fly-back transformer don’t carry current simultaneously. The fly-back transformer works differently from a normal transformer.

![Fig. 5. Operation of mode 2](image)

![Fig. 6. Equivalent circuit during mode 2](image)

4. SIMULATION RESULTS

The proposed system is simulated using PSIM software. PSIM is a simulation software developed by Powersim Inc. PSIM is designed for power electronics, motor control, and simulation of dynamic systems.

4.1. System Specification

| Specification                      | Value  |
|------------------------------------|--------|
| Maximum PV Power                  | 250W   |
| PV Voltage at Maximum Power       | 35V    |
| PV open circuit Voltage           | 45V    |
| Input Voltage                     | 35V    |
| Output Voltage (converter)        | 325V   |
| Switching Frequency               | 100KHz |
| Duty cycle                        | 0.45   |
| Power                             | 250W   |
| Load                              | Fan and Incandescent lamp |

4.2. Schematic Diagram

The fig. 7 shows the simulation of proposed project. Here we can see that input source is PV panel and capacitor is connected across the PV panel. And inductor is connected parallel to capacitor. The reason behind this input inductor is that it will reduce the high frequency component from the input current, the discharge path for this inductor is given by input capacitor itself. So that we can reduce the high frequency component in input current. In practical the input current ripple is given by input capacitor which will be accepted by switch for normal
operation, and in practical we don’t need the inductor to be connected in between input source and input capacitor. This is because the wire we connect from panel (source) to the converter will create some parasitic inductance and parasitic capacitance.

4.3. Flyback converter block

The flyback transformer is the main part in flyback converter, whose operation is different from a normal transformer. In normal transformer the current will simultaneously flow in both the primary and secondary side, but in flyback transformer energy transfer from primary to secondary is not simultaneous due to the presence of diode in the secondary side.

![Flyback converter block in PSIM](image)

When switch turns ON the energy gets stored in primary winding and no secondary side voltage is there. During this output capacitor delivers the voltage for load. When switch turns OFF the energy in primary winding starts discharged to the secondary winding due to reverse polarity of these windings and this secondary voltage is a product of input voltage and turns ratio. This block will work as same as the flyback converter.

4.4. Rectified sine wave gate pulses

Rectified sine wave gate pulses are used instead of normal PWM pulses. Rectified sine wave is compared with triangular wave to get gate pulses and this gate pulse is given to the MOSFET switch.

![Rectified sine wave block in PSIM](image)

The fig. 9 shows the sine wave generator which is connected with rectifier circuit to get rectified sine wave. This rectified sine wave is now compared with triangular wave to get rectified sine wave gate pulses.

![Rectified sine wave in PSIM](image)  ![Triangular waveform in PSIM](image)

Fig. 10 shows the rectified sine wave. The frequency of the rectified sine wave is 50Hz. Fig. 11 is a triangular wave which is compared with the rectified sine wave.
Fig 12. Rectified sine wave gate pulses

The fig. 12 is the gate pulse which is given to the switch and this is obtained by comparing rectified sine wave with triangular wave. And duty cycle of this gate pulse is 0.45 (max). To get maximum duty (D=0.45) the comparison of two waves should be in this form.

\[(\text{Peak of the sine wave}) / (\text{peak of triangular wave}) = D_{\text{max}}.\]

In this case peak of sine wave = 0.8 and D_{\text{max}} = 0.45.

Therefore \(0.8/X = 0.45\)

\(X = 0.8/0.45 = 1.77\)

And the peak of triangular wave is 1.77.

Rectified sine wave with 0.8 peak and triangular wave with 1.77 peak are compared to get gate pulse with 0.45 D max.

4.5. MPPT

For MPPT the MPPT algorithm block will gives the value (not D, gate pulse value) based upon radiation in the panel. In this paper the rectified sine wave and triangular wave are given as input to the comparator, so rectified sine wave is embedded to the MPPT block. This method enables the gate pulses to be varied according to the MPPT value.

Fig. 13. MPPT value for MI = 0.44 in PSIM

4.6. MPPT based input power, panel power

Fig. 14. MPPT dependent input and panel power for different radiations
Fig. 14 shows the input power and panel power which is MPPT dependent. Radiation values are changed to check whether the MPPT block is working properly. Here the panel power is changing due to change in radiation (blue graph) and based on panel power input power (red graph) also gets changed which is due to MPPT tracking. From this it is ensured that the MPPT block is working properly.

![Fig. 15. Input voltage varies depends on MPPT tracking](image)

The fig. 15 shows that the input voltage (red graph) changes due to change in input power due to MPPT tracking.

4.6. Converter output

![Fig. 16. Flyback converter output](image)

![Fig. 17. Flyback converter output (zoomed)](image)

The fig. 16 shows the converter output according to input voltage. The fig. 17 is the converter output (zoomed) and you can see that the output is rectified AC due to the usage of rectified sine wave compared with triangular wave. Now it is easy to convert rectified AC to single phase AC just by connecting inverter at the output of converter. The main advantage of using this kind of method is that no filter circuit is required in the output of inverter.

4.7. Inverter output

The inverter output is shown in the fig. 18 and the output of the inverter is an exact sine wave and no ripples are present in the output. For this reason only rectified sine wave gate pulses are used to get rectified AC as output in the converter.

![Fig. 18. Inverter output](image)

![Fig. 19. 230V RMS inverter output(zoomed)](image)

The fig. 19 shows magnified output of the inverter and the RMS value of inverter output is observed to be 230V.
5. CONCLUSION

A PV based cooling and lighting system with a flyback topology is presented in this paper. The proposed system is simulated in PSIM software and the simulated results were obtained for the considered resistive and inductive loads. The operation of the proposed system with the given topology and control is found satisfactory. Because of the simplicity it is easier to implement in hardware and because the proposed system is not having a battery, the size, cost and maintenance of the system will be lesser relative that with a battery. Also, the life of the system is higher as there is no need to replace the battery and it is a good one-time investment for smaller shops or low power applications in homes that are utilizing solar photovoltaic energy.

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