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THINNED-OUT MPPT WITH L TYPE RESONANT SWITCH

A. Karafil N. Genc

Department of Electrical and Electronics Engineering, Yalova University, Yalova, Turkey
akif.karafil@yalova.edu.tr, naci.genc@yalova.edu.tr

Abstract- High switching loss is one of the most fundamental problems in converters. The occurrence of high switching losses reduces the efficiency of the converters and causes the operating frequency to be low. Zero current switching (ZCS) and/or zero voltage switching (ZVS), which are soft switching techniques, are used to overcome these problems. In this study, a simulation study was carried out in the PSIM program by analyzing L type half wave (HW) and full wave (FW) mode ZVS quasi resonant boost converter with 360 W photovoltaic (PV) panel input power. In the study, maximum power was transferred from the PV panels to the load by using the thinned-out control method.

Keywords: ZVS, Quasi Resonant Boost Converter, MPPT, Thinned-Out Control, PV Systems.

1. INTRODUCTION

The direct conversion of sunlight into electrical energy is provided by PV panels. Depending on the change in solar radiation intensity during the day, the energy obtained from PV panels also changes. In order to extract maximum power from the PV panels, dc-dc converters are widely used as an interface between the PV panel and the load in the system. In order for the dc-dc converter to adapt to changes in the PV panel output power, an appropriate converter topology must be determined. The structure of the converter to be used in the system is determined by the difference between the input voltage obtained from the PV panels and the output voltage of the converter. Conventional dc-dc converters are basically divided into three as boost, buck and buck-boost type [1-5].

The most basic problem encountered in conventional power converters is high switching losses. High switching losses limit the operating frequency of power converters as well as causing low efficiency. In addition, this situation causes the passive circuit elements and the size of the heat sinks to increase; that is, it causes the size of the circuit to increase. All these factors increase the cost of the circuit. Moreover, high values of inrush current and inrush voltage that occur during the switching process cause high-value electromagnetic interference (EMI) noise.

This noise disrupts the signals of all electronic devices operating simultaneously. Soft switching techniques should be used to eliminate all these problems encountered in hard switching [6-8].

The sections of the study are as follows: In section 2, L type HW and FW mode ZVS quasi resonant boost converter is analyzed. In section 3, thinned-out controlled maximum power point tracker (MPPT), which is a novel method, is presented. In section 4, simulation results are given for both HW and FW mode, and in the last section conclusions obtained in the study are mentioned.

2. ANALYSIS OF L TYPE HW AND FW MODE ZVS QUASI RESONANT BOOST CONVERTER

2.1. Resonant Switches

Soft switching techniques are generally grouped under two categories as ZCS and ZVS. ZCS is defined as the limitation of the current when the switch is turn-on with the inductor connected in series with the power switch whereas ZVS is a soft switching technique that is achieved by limiting the voltage occurring at the switch ends when the switch is turn-off with a capacitor connected in parallel to the power switch. Figure 1 shows current mode resonant switches, and Figure 2 shows voltage mode resonant switches [9, 10].

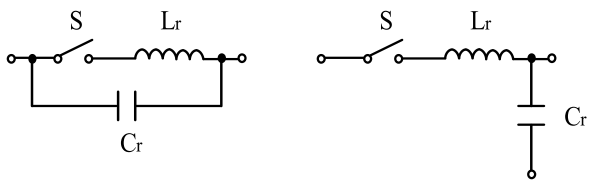


Figure 1. Current mode resonant switches [10]

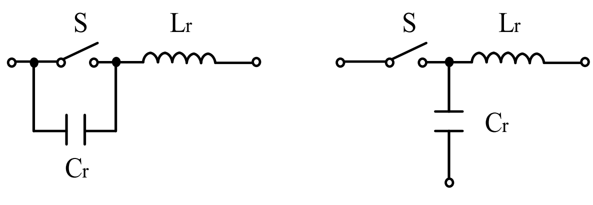


Figure 2. Voltage mode resonant switches [10]

Soft switching conditions are realized with resonant and quasi resonant converter topologies. Quasi resonant converters are obtained when the switch is replaced in conventional converters with one of the resonant switches in Figures 1 and 2. These converters are between conventional converters and resonant converters. A resonant switch consists of a power switch and an inductor and a capacitor, which are resonant elements. Due to the resonant elements, the current or voltage passing through the switch oscillates in the form of a sinusoidal curve, and zero voltage or zero current switching is realized. In general, one of the most important advantages of quasi resonant converters is that high efficiency is provided by the switching element by reducing the conduction loss. In Figure 3, HW voltage mode resonant switches are presented. In Figure 4, FW voltage mode resonant switches are presented [11-13].

2.2. Modeling of L Type HW and FW Mode ZVS Quasi Resonant Boost Converter

The L type HW and FW mode ZVS quasi resonant boost converters are shown in Figures 5 and 6, respectively.

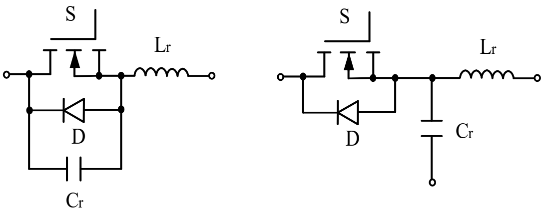


Figure 3. HW voltage mode resonant switches [11]

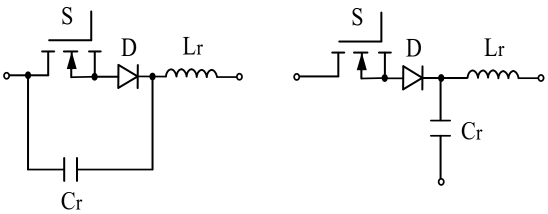


Figure 4. FW voltage mode resonant switches [11]

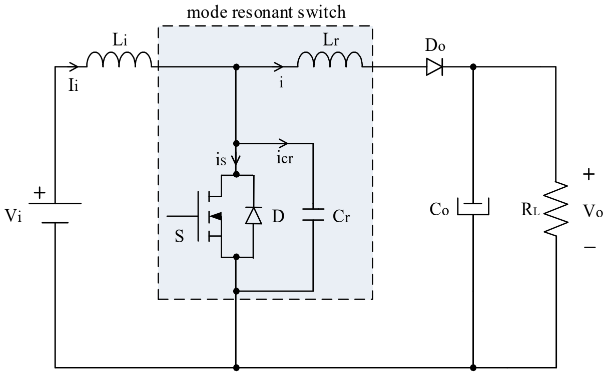


Figure 5. L type HW mode ZVS quasi resonant boost converter [15]

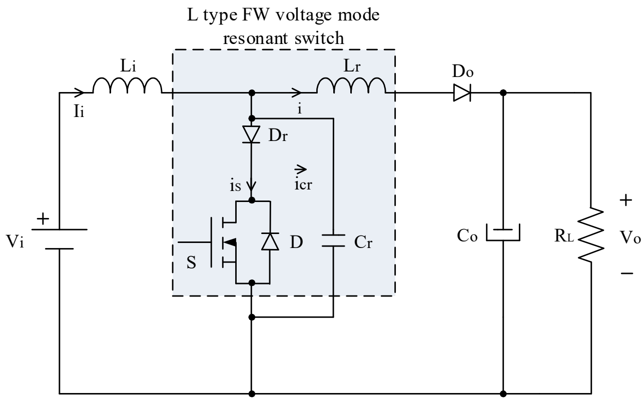


Figure 6. L type FW mode ZVS quasi resonant boost converter [15]

In order to perform a simple equivalent analysis of the L type HW mode ZVS quasi resonant boost type converter circuit, the L_i inductor value must be much higher than the L_r value of the resonant inductor (L_i>>L_r). Likewise, the C_o output capacitor value should be much higher than the C_r value, which is the resonant capacitor value (C_o>>C_r). In this case, input voltage (V_i) and filter inductor (L_i) can be modeled as constant current source (I_i), and output capacitor (C_o) and load resistor (R_L) can be modeled as constant voltage source (V_o). The simple equivalent circuit of the HW mode ZVS quasi resonant converter circuit, which is designed under above-mentioned assumptions, is given in Figure 7 [14, 15].

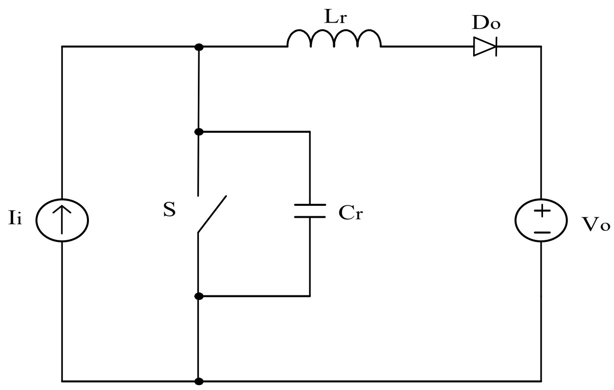


Figure 7. Simple equivalent circuit of HW mode ZVS quasi resonant converter circuit [15]

The resonant parameters L_r and C_r values determine the operation and characteristics of the converter. The equations to be used in the analysis of the converter are as follows: voltage conversion ratio (M), characteristic impedance (Z_n), and resonant frequency (f_r) [14].

$$M = \frac{V_o}{V_i} \tag{1}$$

$$Z_n = \sqrt{\frac{L_r}{C_r}} \tag{2}$$

$$f_r = \frac{1}{2\pi\sqrt{L_r.C_r}} \tag{3}$$

2.3. Operating States

L type HW and FW mode ZVS quasi resonant boost converter has four operating ranges depending on the state of the power switch and D_0 diode. The waveforms of the gate-source voltage of the switch (V_{gs}), the voltage of the resonant capacitor (V_{cr}), the current passing through the resonant inductor (i), the current passing through the switch (I_{MOS}) and the current passing through the resonant capacitor (I_{Cr}) related to these time intervals are given in Figures 8 and 9 [10].

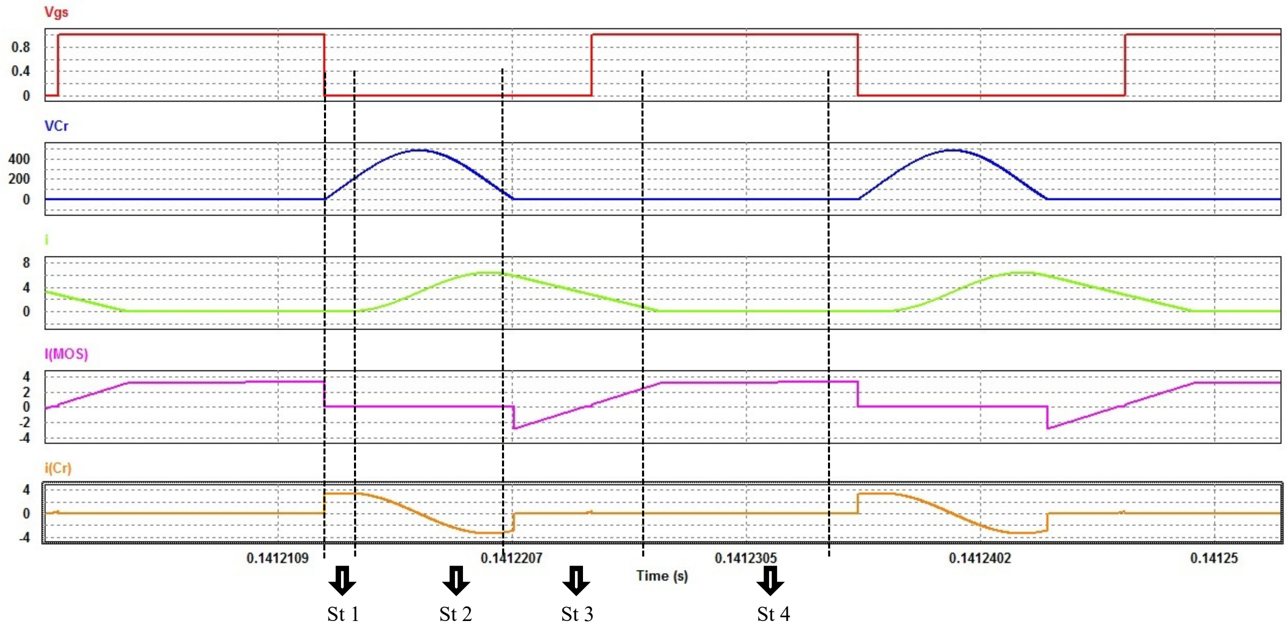


Figure 8. Wave forms of L type HW mode ZVS quasi resonant boost converter [10]

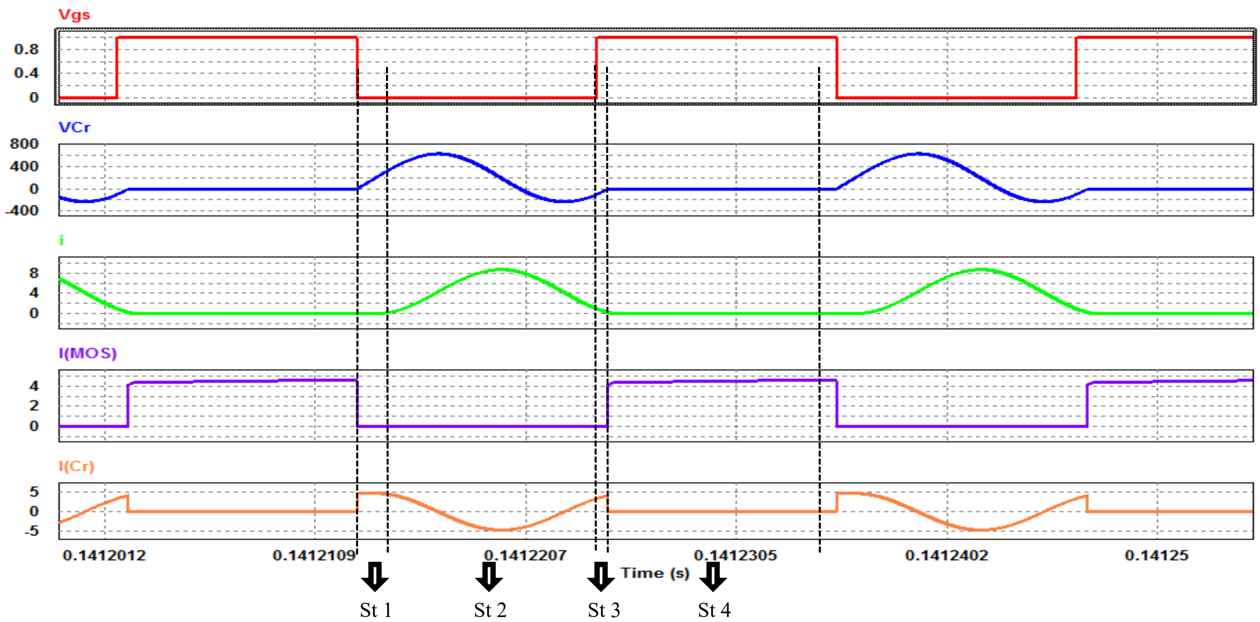


Figure 9. Wave forms of L type FW mode ZVS quasi resonant boost converter [10]

2.3.1. State 1

This operating state starts when the power switch and diode D_0 are off. The equivalent circuit for State 1 is given in Figure 10. As the resonant capacitor, whose initial value is zero, is charged in this operating range, and the voltage at its terminals increases.

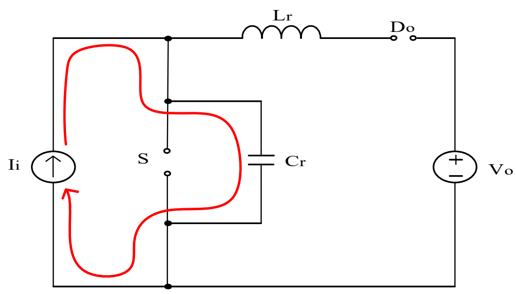


Figure 10. Equivalent circuit of State 1 [10]

2.3.2. State 2

In this operating state, Diode D_0 is on. The inductor and the capacitor work together. In Figure 11, the equivalent circuit for State 2 is presented.

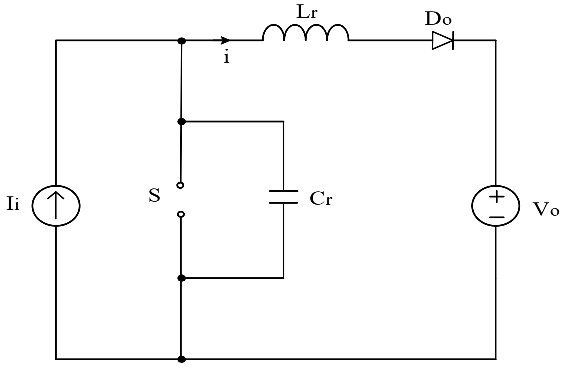


Figure 11. Equivalent circuit of State 2 [10]

2.3.3. State 3

This operating state starts when the capacitor voltage drops to zero. In Figure 12, the equivalent circuit for State 3 is presented. In this operating state, at the end of the period, the inductor current decreases and drops to zero.

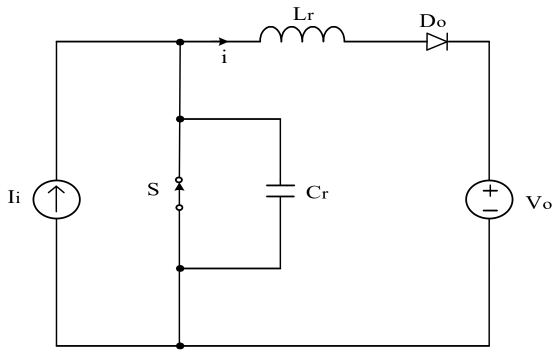


Figure 12. Equivalent circuit of State 3 [10]

2.3.4. State 4

The circuit diagram of State 4 is shown in Figure 13. In this operating state, the D_0 diode is off while the power switch is on. This operating state continues until the switch turns off [10, 15].

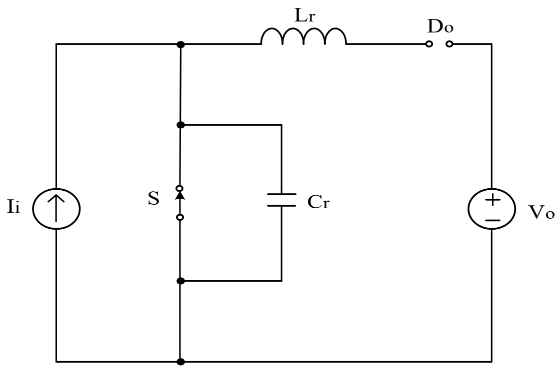


Figure 13. Equivalent circuit of State 4 [10]

3. THINNED-OUT CONTROLLED MPPT

The main drawbacks of PV energy systems are that the efficiency of PV panels is low, atmospheric conditions change during the day and accordingly the power values obtained from PV panels constantly change. Therefore, it is desired that the output power obtained from the PV panels is constantly at the maximum level. In such systems, maximum power point tracker (MPPT) algorithms are used, which continuously tracks the PV panel power and obtains the maximum power [16-18]. In the study, incremental conductance (IC) algorithm, which has a high maximum power tracking efficiency, was used. In this study, power control was provided by thinned-out pulses depending on the change of solar radiation. The proposed thinned-out control structure is shown in Figure 14. The block diagram of the thinned-out controlled MPPT system is given in Figure 15.

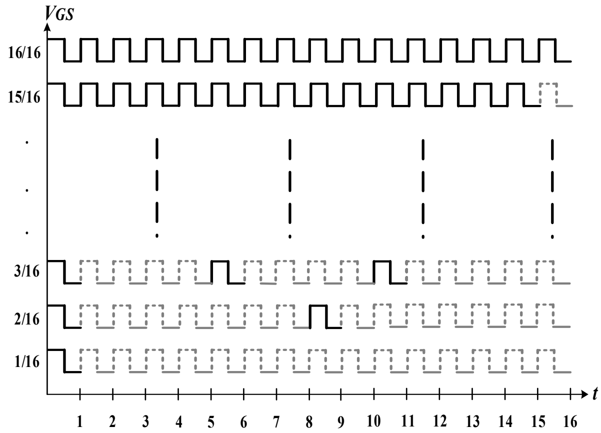


Figure 14. The proposed thinned-out control structure [16]

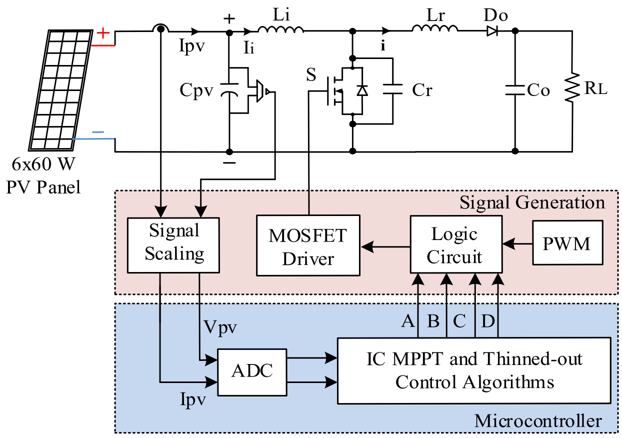


Figure 15. Thinned-out controlled MPPT system

4. SIMULATION RESULTS

The simulation of the L type HW and FW mode ZVS quasi resonant boost converter was carried out in the PSIM program and is shown in Figure 16. IC MPPT and thinned-out control algorithms were written in C block. Additionally, for the proposed thinned-out control structure shown in Figure 14, the logic circuit design of the 16-pulses was made and its representation as a sub-circuit in the simulation was realized.

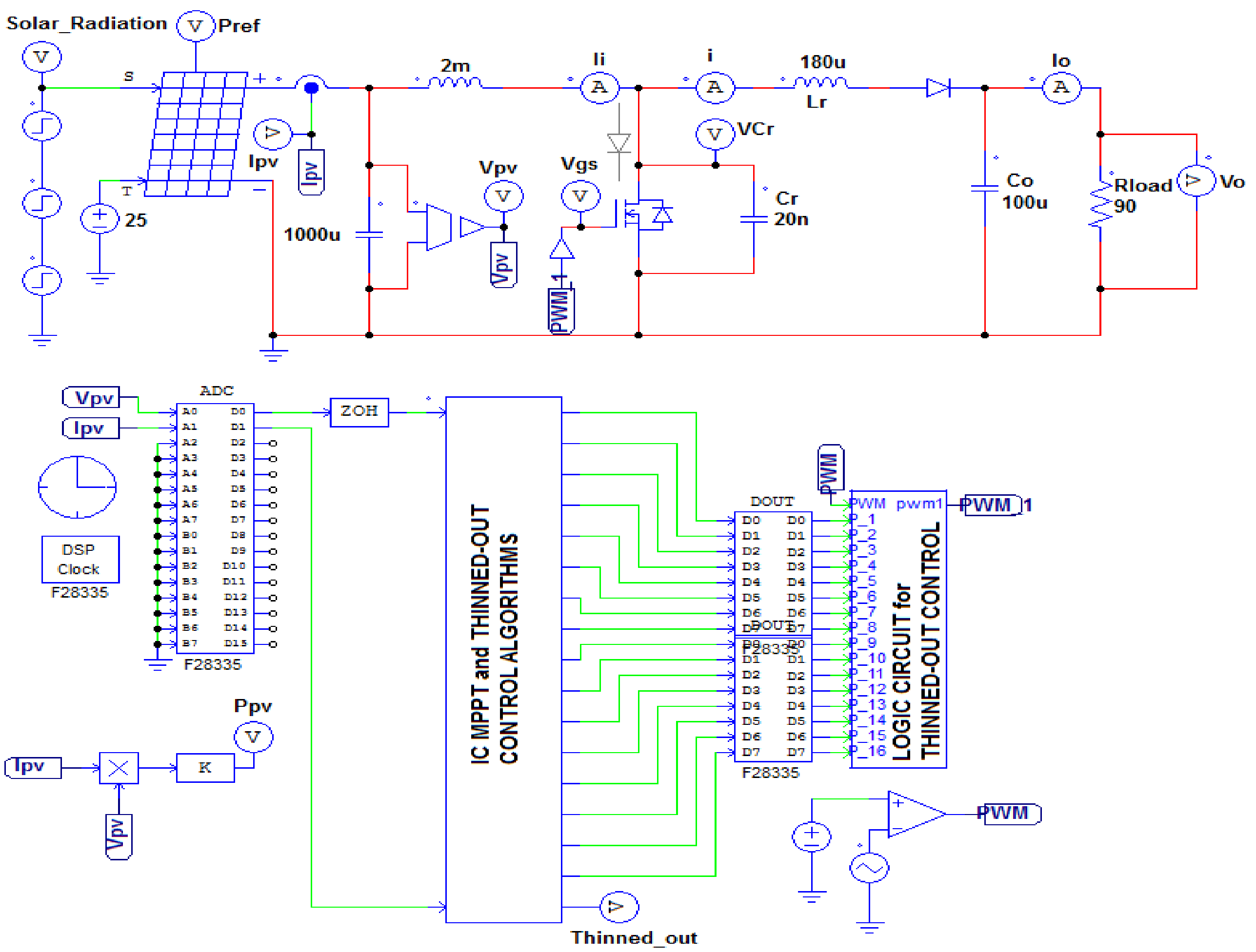


Figure 16. Simulation of L type HW and FW mode ZVS quasi resonant boost converter

In the study, the power of one PV panel is 60 W, and six panels are connected in series. The maximum input voltage is 102 V. The MPPT efficiency was investigated by changing the solar radiation level of the PV panels to 500-750 and 1000 W/m^2. The switching frequency of the circuit is 45 kHz.

Other parameters of the circuit were determined by calculating as C_{pv}=1000 µF, L_i=2 mH, L_r=180 µH, C_r=20 nF, C_o=100 µF and R_L=90 Ω [19]. The MPPT efficiency of the system is shown in Figure 17. ZVS conditions at values of 500 and 1000 W/m^2 solar radiation are given in Figures 18 and 19 for HW and FW mode operating situations, respectively.

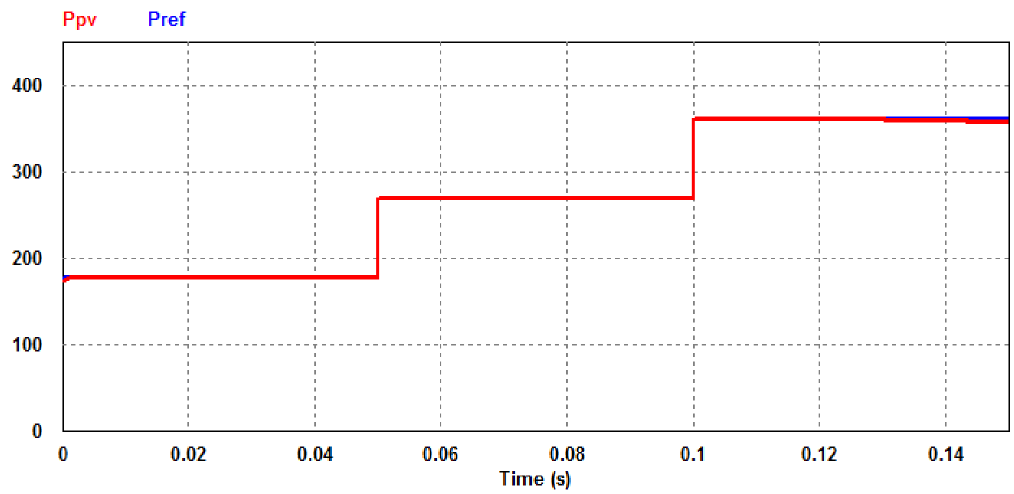
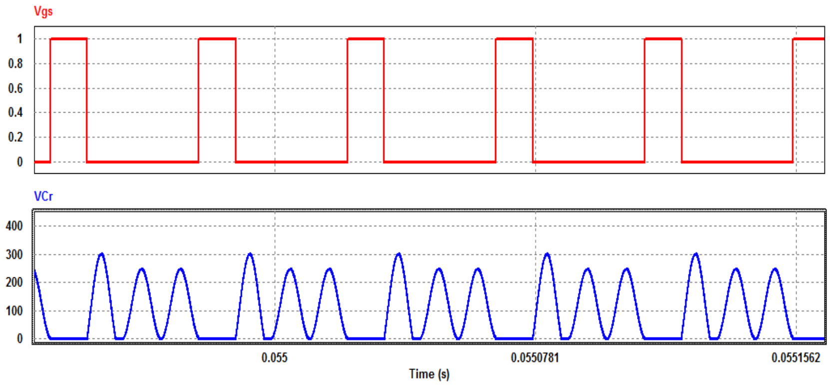
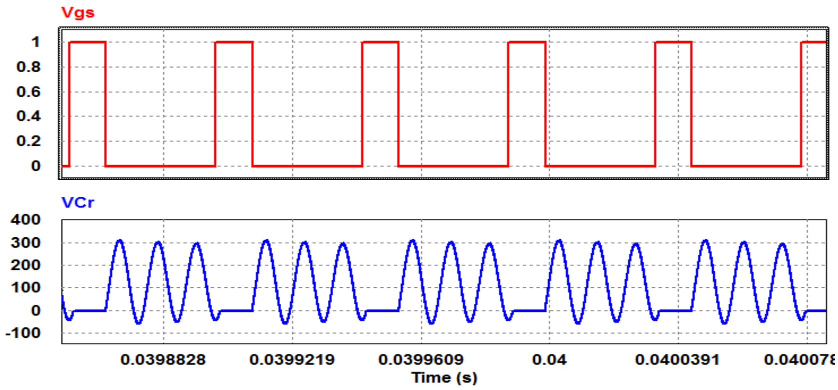


Figure 17. Maximum power tracking

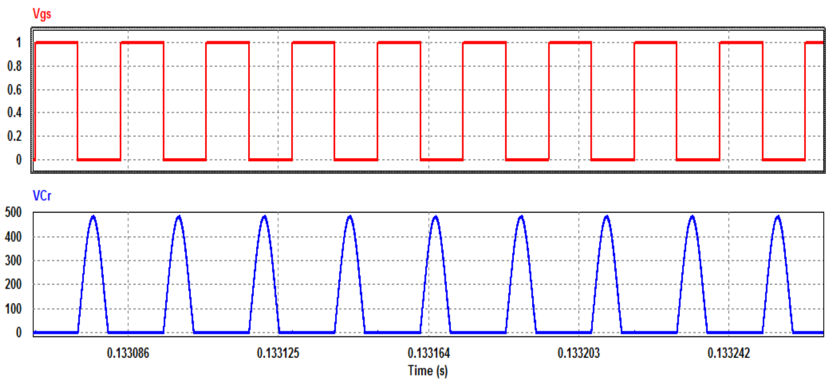


(a)

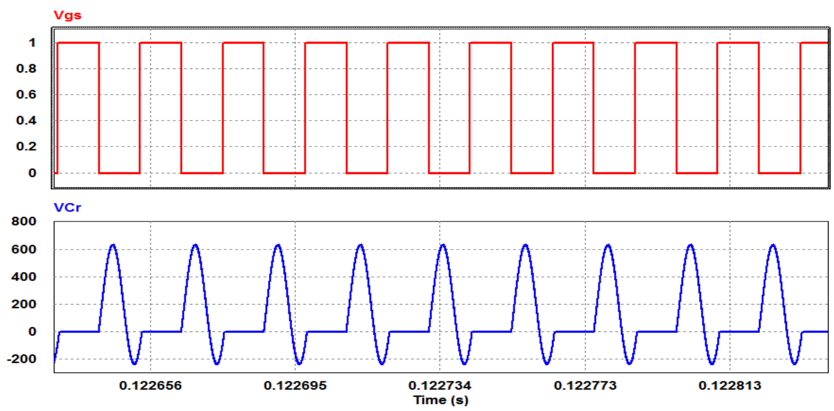


(b)

Figure 18. 500 W/m^2 solar radiation, (a) HW mode, (b) FW mode

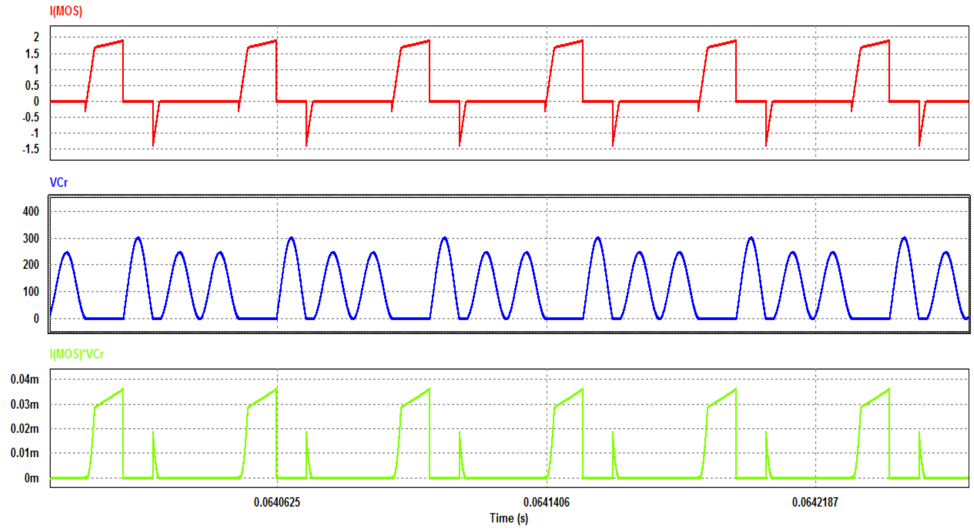


(a)

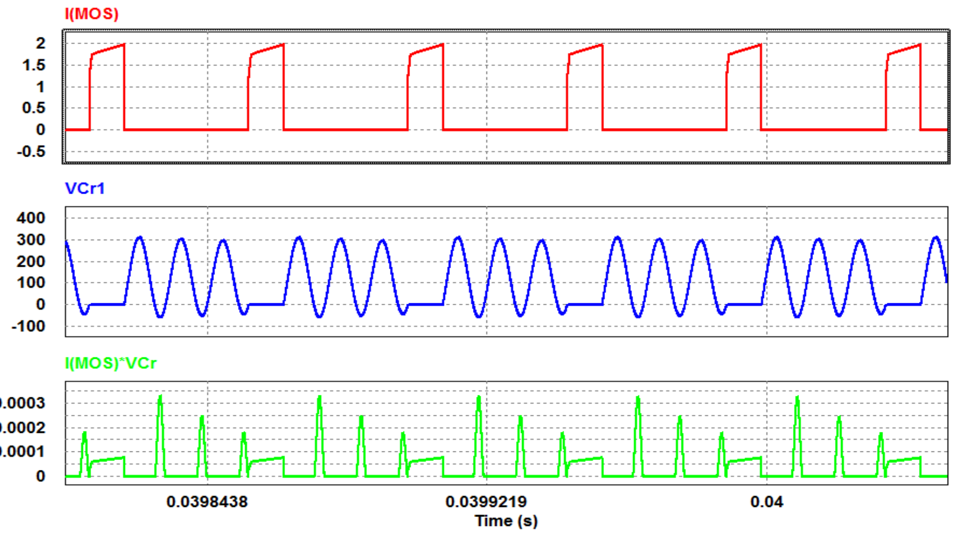


(b)

Figure 19. 1000 W/m^2 solar radiation, (a) HW mode, (b) FW mode

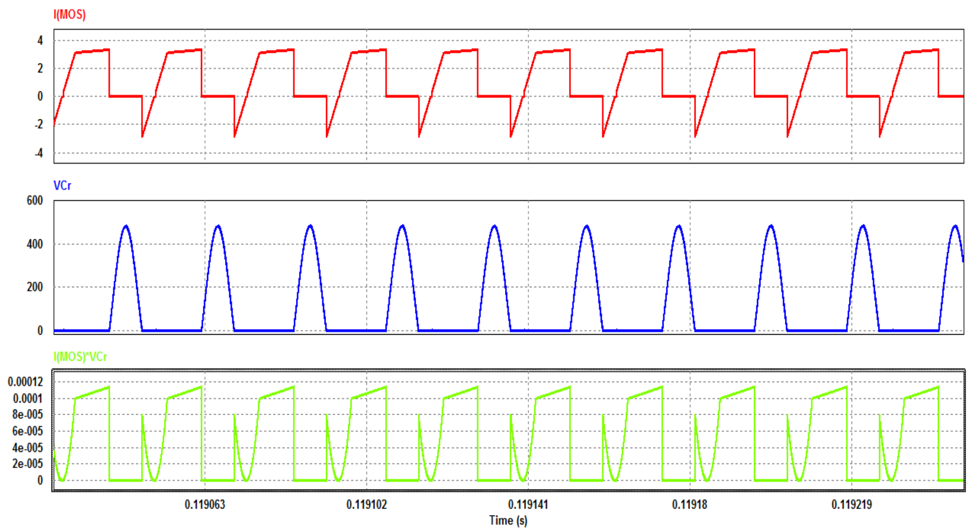


(a)

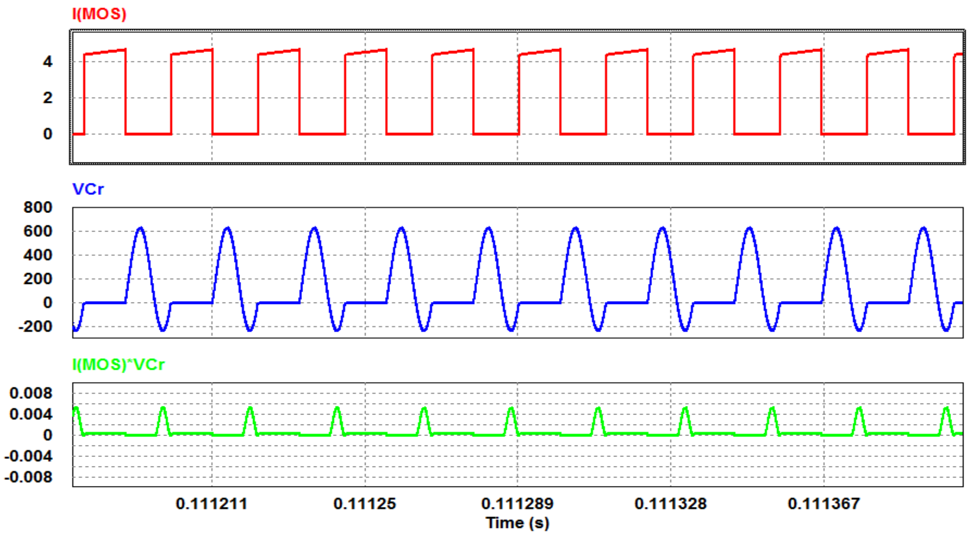


(b)

Figure 20. Current flowing through the power switch, voltage at the switch ends and switching loss for 500 W/m^2 solar radiation (a) HW mode, (b) FW mode



(a)



(b)

Figure 21. Current flowing through the power switch, voltage at the switch ends and switching loss for 1000 W/m^2 solar radiation (a) HW mode, (b) FW mode

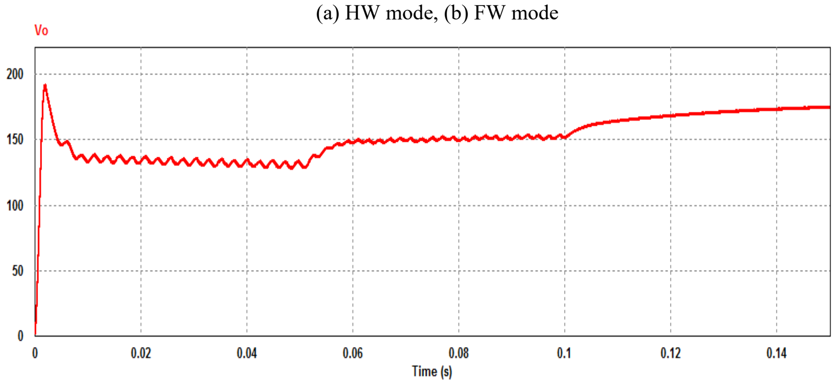


Figure 22. Variation of output voltage

The current passing through the power switch at 500 and 1000 W/m^2 radiation, the voltage at its ends and the switching losses are shown in Figures 20 and 21. As can be seen from the figures, the switching losses were low as the ZVS conditions were met for both HW mode and FW mode in all radiation conditions. At the same time, it can be seen from Figure 17 that high efficiency power tracking is achieved using the thinned-out control method. The variation of the output voltage is given in Figure 22.

5. CONCLUSIONS

In this study, the analysis of the L type HW and FW mode ZVS quasi resonant boost converter circuit to be used in PV systems was carried out. The operating states of the converter were examined in detail and simulation studies were carried out in the PSIM program. In the study, a total of 360 W input power was obtained from the PV panels. The IC algorithm was used as the MPPT algorithm. Maximum power was obtained from the PV panels and transferred to the load by thinned-out of the pulses depending on the change of solar radiation. In the simulation program, both the IC MPPT algorithm and the thinned-out control algorithm were written in the C block. Logic circuit design was made for the thinned-out control method. According to the results obtained, it was seen that while high MPPT efficiency was achieved, switching losses were reduced as a result of ZVS conditions. Reducing the switching losses increases the efficiency of the converter, while at the same time reducing the volume of passive components by providing high frequency operation. It is seen that all these problems encountered in conventional converters are eliminated in the L type ZVS quasi resonant boost converter circuit. For future studies, thinned-out controlled MPPT method, which is proposed as a new method, can be applied to other quasi resonant converter circuits, and the results obtained can be compared with conventional converters. Applications of the studies can be conducted and given together with simulation studies. Moreover, it is possible to carry out different studies by testing different MPPT algorithms and different thinned-out control structures.

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BIOGRAPHIES

Name: **Akif**
Surname: **Karafil**
Birthday: 19.04.1983
Birth Place: Bursa, Turkey
Bachelor: Department of Electrical Education, Faculty of Technical Education, Marmara University, Istanbul, Turkey, 2007
Master: Department of Electrical and Electronics Engineering, Engineering Faculty, Karadeniz Technical University, Trabzon, Turkey, 2011
Doctorate: Department of Electrical and Electronics Engineering, Engineering Faculty, Karabuk University, Karabuk, Turkey, 2018
The Last Scientific Position: Assist. Prof., Department of Electrical and Electronics Engineering, Engineering Faculty, Yalova University, Yalova, Turkey, Since 2020
Research Interests: Resonant Converters, MPPT, PV System Applications
Scientific Publications: 49 Papers, 1 Patent, 7 Projects

Name: **Naci**
Surname: **Genc**
Birthday: 10.10.1977
Birth Place: Erzurum, Turkey
Bachelor: Department of Electrical Education, Faculty of Technical Education, Gazi University, Ankara, Turkey, 1999
Master: Department of Electrical and Electronics Engineering, Engineering Faculty, Van Yuzuncu Yil University, Van, Turkey, 2002
Doctorate: Department of Electrical and Electronics Engineering, Engineering Faculty, Gazi University, Ankara, Turkey, 2010
The Last Scientific Position: Prof., Department of Electrical and Electronics Engineering, Engineering Faculty, Yalova University, Yalova, Turkey, Since 2020
Research Interests: Energy Conversion Systems, Power electronics, Electrical Machines
Scientific Publications: 78 Papers, 3 Books, 14 Projects, 25 Theses