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Modeling And Simulation Of Novel Topology For Dc-Dc Boost Converter For Solar Pv Applications

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---ABSTRACT---
Renewable energy systems offer environmental and economic advantages in producing energy compared to the conventional fossil fuel systems. However, the renewable energy generated by these sources such as photovoltaic cells has a low-voltage output characteristic, and for most potential applications, a high boost DC-DC converter is required. The selection of an appropriate converter topology is an important and fundamental aspect of designing a photovoltaic cell system as the converter alone plays a major role in determining the overall performance of the system. A number of modified high step-up converter topologies have been proposed in order to increase the voltage conversion ratio. However, the converter efficiency is quite low because of the leakage inductance energy stored in the auto-transformer and the coupled inductors. Therefore, this research develops a converter topology which is based on the incorporation of the voltage multiplier module and the conventional boost converter in order to achieve a high voltage gain. The develop topology of the DC-DC boost converter has been modelled and simulated using MATLAB/SIMULINK software package. A novel topology for DC-DC boost converter, with new switching techniques; higher efficiency and improve performance in term of duty ratio and output voltage is presented. The simulation result shown to demonstrate the effectiveness of the developed high step-up single-switch DC-DC converter for low-input and high-output voltage systems. The results also show that incorporation of the voltage multiplier module to the conventional boost converter, step-up voltage-conversion ratio yields a maximum efficiency of 96%.
KEYWORDS - *About five key words in alphabetical order, separated by commas.*

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I INTRODUCTION

Renewable energy systems offer environmental and economic advantages in producing energy compared with the conventional fossil fuel systems. The renewable energy sources such as photovoltaic (PV) arrays have received increasing attentions due to energy shortage and environmental contamination [1]. Such renewable energy systems typically generate low voltage output. Therefore, high step-up DC-DC converters are widely employed in many renewable energy system applications. The output voltage generated from a single PV panel is about 15V to 40V [2]. This voltage level is not sufficient for the dc-link voltage of a single-phase inverter to generate the ac power with 220V grid voltage. However, to step up the low output voltage up to the higher level, a conventional boost converter is commonly used because of its simple structure and control. Unfortunately, it cannot achieve a high step up conversion with high efficiency due to the extreme duty cycle operating limitations. Many researchers proposed modification to the DC-DC boost converter topologies in order to increase the voltage conversion ratio [3]. The modified single-ended primary inductance converter (SEPIC) with the combination of an auto-transformer and the coupled inductors is introduced to photovoltaic application in order to increase the voltage gain of the converter [4].

The DC- DC converter input is an unregulated DC voltage and the output is a constant or regulated voltage. The regulators can be mainly classified into linear and switching regulators. All regulators have a power transfer stage and a control circuitry to sense the output voltage and adjust the power transfer stage to maintain the constant output voltage. State space analysis is typically used to develop a small signal model of a converter and then depending on the type of control scheme used, the small signal model of converter is modified to facilitate the design of the compensation network [5].

From the above, a number of step-up converter topologies have been proposed by researchers in order to increase the voltage conversion ratio. Advances in semiconductor switching capability combined with the desire to improve the efficiency and performance of converter is very important. The electronic device used for the switch will not be perfect and will have losses. However, the efficiency of the converter can still be quite high (more than 90 percent). The inductor resistance also has an effect on the power efficiency of converters. Efficiency is the ratio of output power to output power plus losses. In [6], a current source is added for the control purposes at the output of the converter to represent a load disturbance in the model. In [7], the averaged model of the power electronic switch and diode are replaced by the combination of controlled current and voltage sources. However, the converter efficiency is very low (90%) as a result of the leakage inductance energy stored in the auto-transformer and the coupled inductors. Clearly, these reported topologies do not provide required efficiency and high voltage gain. Therefore, this research develop a converter topology which is based on the incorporation of the voltage multiplier module and the conventional boost converter in order to achieve efficiency (high voltage gain) of approximately 96%.

In this research the high step-up DC-DC converter with a single power switch will be proposed for photovoltaic system applications. A new topology for the proposed high step-up boost converter will be developed that has higher efficiency; high power output compared to conventional boost converter which delivers constant output voltage for solar photovoltaic applications. In order to boost the low output voltage of PV system to a higher level, a conventional boost converter is commonly used because of its simple structure and control. Unfortunately, it cannot achieve a high step up conversion with high efficiency due to the extreme duty cycle operating limitations. A number of modified high step-up converter topologies have been proposed in order to increase the voltage conversion ratio. However, the converter efficiency is quite low because of the leakage inductance energy stored in the auto-transformer and the coupled inductors. This research will develop a new topology for DC-DC converters that has higher efficiency; high power output and gives constant output voltage for solar photovoltaic applications.

II MATERIAL AND METHOD

A novel high step-up DC-DC converter topology is developed as shown in Fig. 1. In order to achieve the high boost conversion ratio, the developed converter configuration is basically based on two parts; the voltage multiplier module in the first stage and the conventional boost converter in the second stage. As it can be seen in Fig 1, the developed converter consists of only one switch, the input inductor L_1, the output diode D_O, the filter capacitor C_O, the inductor L_2, the dc-link capacitor C_3. The voltage multiplier cell is configured from two identical capacitors, C_1 and C_2, and three diodes, D_1, D_2 and D_3. The blocking diode D_4 is between the voltage multiplier module and the boost converter.

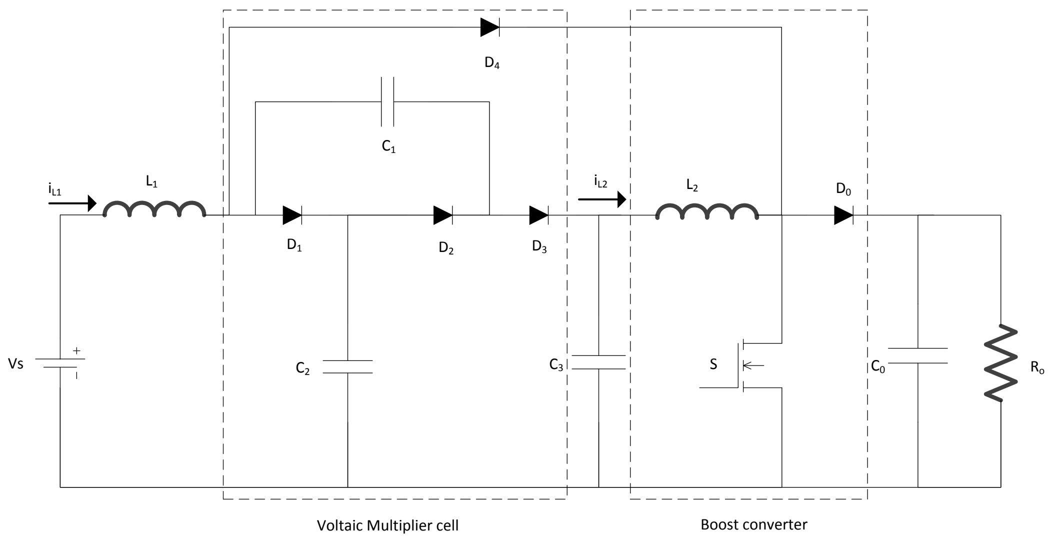


Fig. 1 the developed high boost DC-DC converter configuration The operation of the converter during one switching period can be basically divided into four modes. The operating principle of the developed converter can be described briefly as follows:

Mode 1: the switch S and the diode D_3 are turned on. The remaining diodes are all OFF. V_s and C_1 deliver energy to L_1 and L_2. Thus, during this operation mode, both i_{L1} and i_{L2} increase linearly to store energy in L_1 and L_2, respectively. The capacitor C_3 is charged. The output power is supplied from capacitor C_O.

Mode 2: the switch *S* remains conducting and diode D_3 is off. The diodes D_1, D_4 and D_O remain reversely biased but D_2 is forward biased. The energy stored in C_3 is released through L_2. The capacitors C_1 and C_2 are now in charging and discharging stages, respectively.
Mode 3: the switch *S* is turned OFF but D_2 becomes reversely biased. The diodes D_1, D_3 and D_O are in forward biased state. The inductor L_1 releases energy to C_2 while C_1 delivers energy to L_2 through D_3. In addition, the output filter capacitor C_O is supplied from the energy stored in L_2 through D_O.
Mode 4: the switch *S* is still in turned-OFF state and D_1 becomes reversely biased. The diodes D_3 and D_O remain in forward-biased state. The energy stored in L_1 and C_1 is transferred the boost converter side charging the output capacitor filter C_O via diodes D_3 and D_O.

III MODELING OF THE HIGH STEP-UP DC-DC CONVERTER

The high step-up DC-DC converter circuit consists of following components as shown in Fig. 1: inductor, diode; electronic switch and output capacitor. The converter generally has two modes of operation; that is, the continuous conduction mode (CCM) and discontinuous conduction mode (DCM). In CCM, which has been used in this research, the inductor current is constantly greater than zero. The converter switching always occurs at a constant frequency f_s.

By its nature, the high step-up DC-DC converter is a nonlinear system. To transform it into a linear form, the state space averaging method is used to approximate it to a continuous nonlinear system and the linearization is used to approximate the resulting nonlinear system to a linear model as reported in [6]. The initial step in the state space averaging technique is the formation of the state equations that describe the first and second intervals.

IV SIMULATION RESULTS AND DISCUSSIONS

To verify the effectiveness of the developed high boost DC-DC converter, simulation has been presented using MATLAB/SIMULINK. The developed high boost DC-DC converter scheme is modelled in Simulink as shown in Figure 2. The model parameters of the developed converter shown in Fig. 2 is designed as L_1, L_2 = 15 mH because selecting a very large inductor and capacitors will greatly decrease ripples but also inductor resistance directly affect power efficiency so it should be as low as is practicable, C_1, C_2 = 100μF and C_3 = 150 μF, while C_O = 100 μF and R = 20Ω. Here the situation where the load changes suddenly from one value of load resistance to another is considered. This is particularly interesting because it is a typical problem for power electronics, where the power supply is supposed to compensate quickly for the load variation.

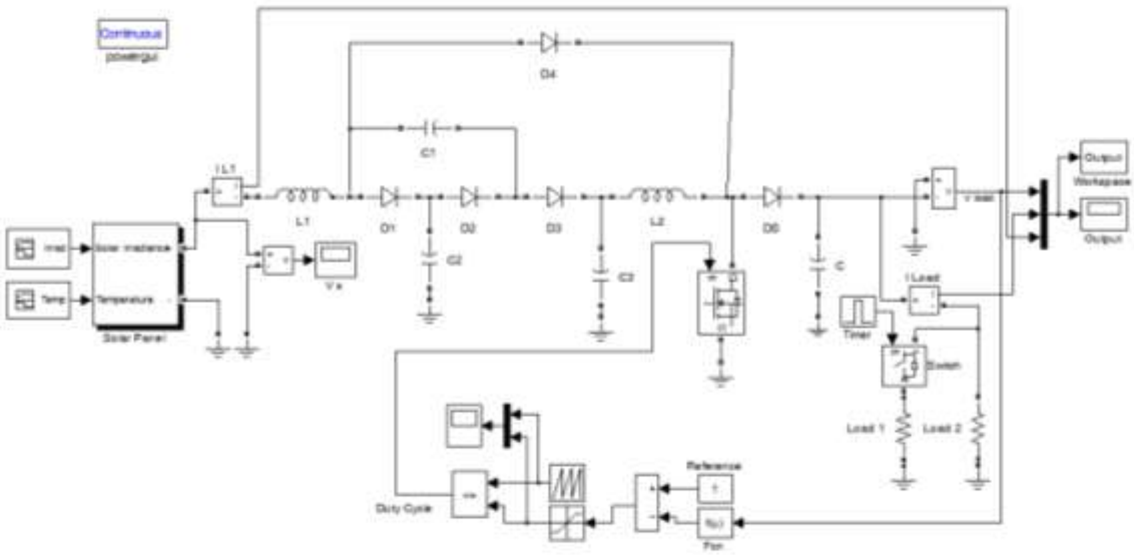


Fig. 2 MATLAB SIMULINK model of the proposed system with DC source.

Figure 3 and 4 shows the simulation result with the voltage multiplier and constant load. The input voltage is a photovoltaic source. At time 0.5 ms, maintain a constant voltage output of 34.1 V and the input voltage varies between 1 V to 17.3 V. From this result one can say that the converter regulate the output voltage at a steady-state voltage of 34.1 V. It means that the converter completely reduced the effect of the ripple disturbance in the input voltage.

Figure 5 shows the simulation result with the voltage multiplier and constant load. The input voltage is a photovoltaic source. At time 0.5 ms, maintain a constant current output of 7.1A and the input current of 1.2 A. From this result one can say that the converter regulate the output current at a steady-state voltage of 7.1A.
The high step-up boost DC-DC converter developed which can step-up a low input voltage to a high level without an extremely large duty cycle, is really suitable and applicable in the PV system since it is capable of achieving optimal operation regardless of the load value and better performance efficiency.

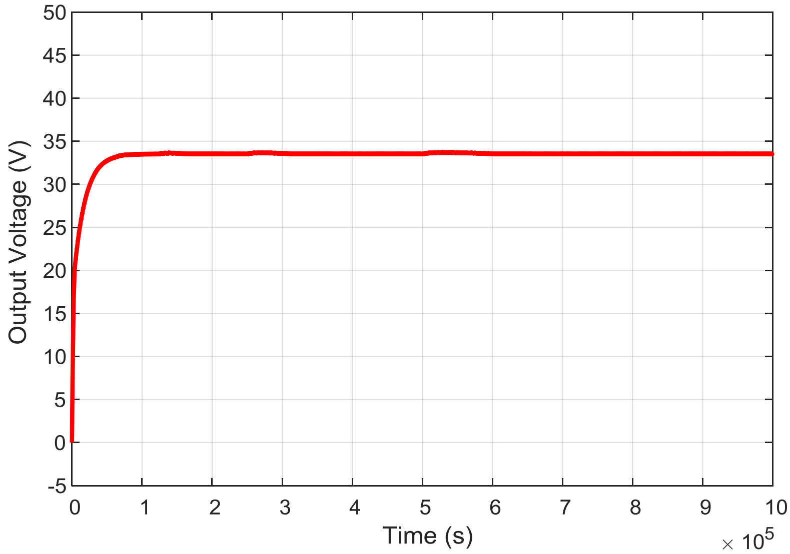


Figure 3 Simulation result of output voltage with voltage multiplier

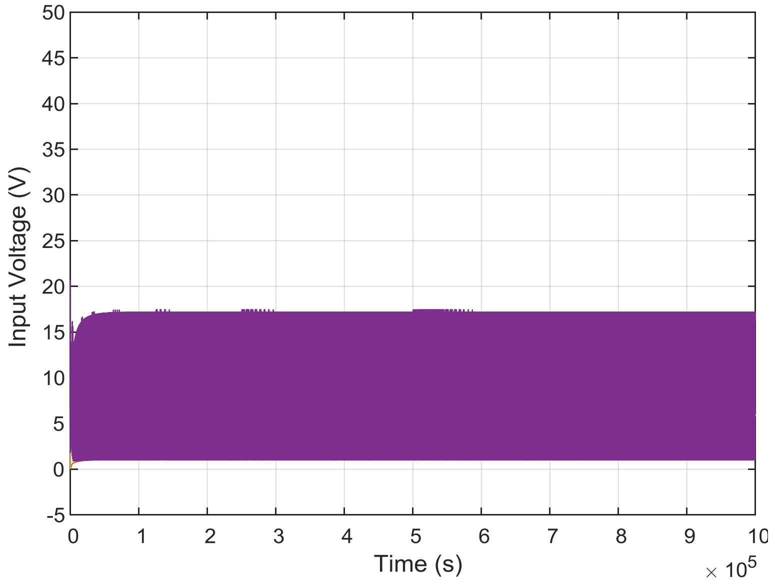


Figure 4 Simulation result of input voltage with voltage multiplier

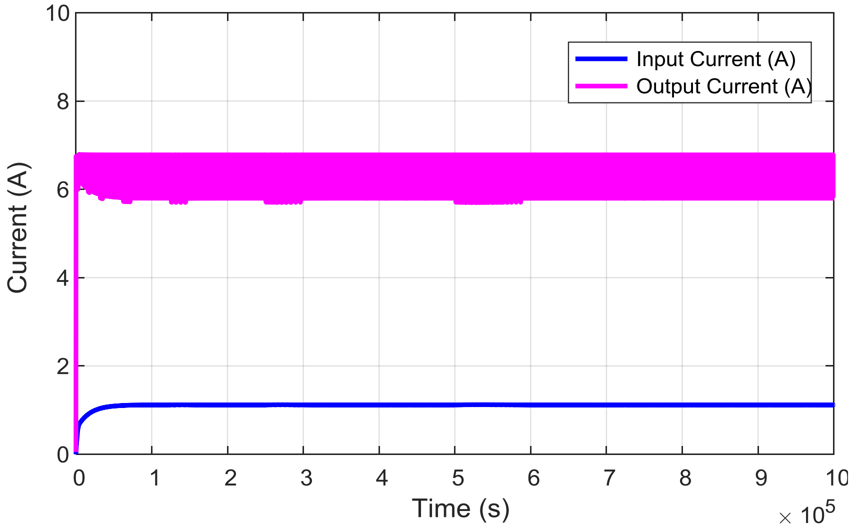


Figure 5 Simulation result of current with voltage multiplier

Figure 6 and 7 shows the simulation result under step load change with photovoltaic source. The input voltage varies between 1V to 17.3V. At time 4.2 ms, a step load change occurs, the load resistance changes from 20Ω to 10Ω. As a result of this change, it is shown that the inductor current 6.8A. The drop in the regulated output voltage went down by 18 V and it took about 0.2 ms for it to attain constant again. From this result one can say that the converter accomplish to regulate the output voltage at a steady-state voltage of 34.1V. It means that the converter completely reduced the effect of the ripple disturbance in the input voltage.

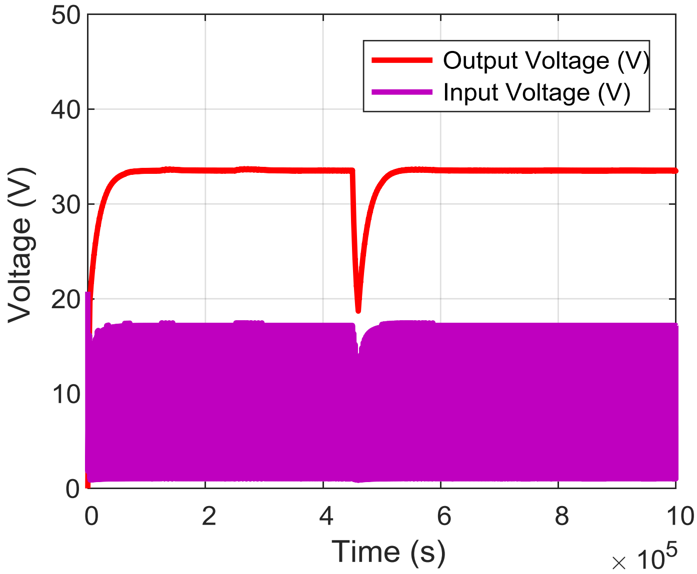


Figure 6 Simulation result of voltage with voltage multiplier under load variation

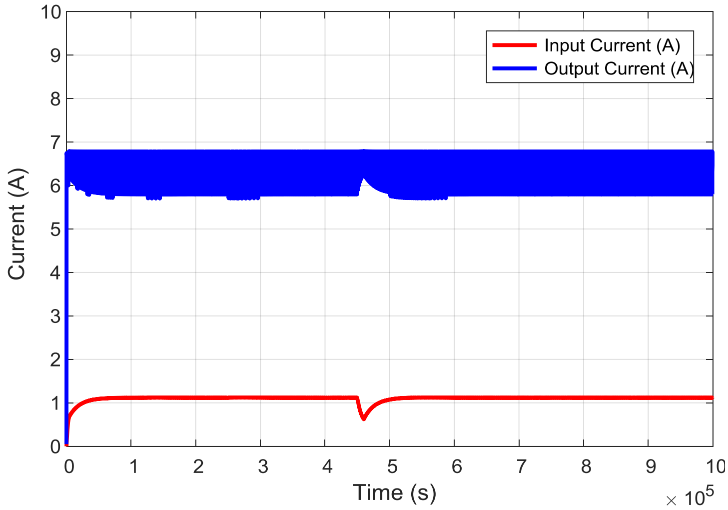
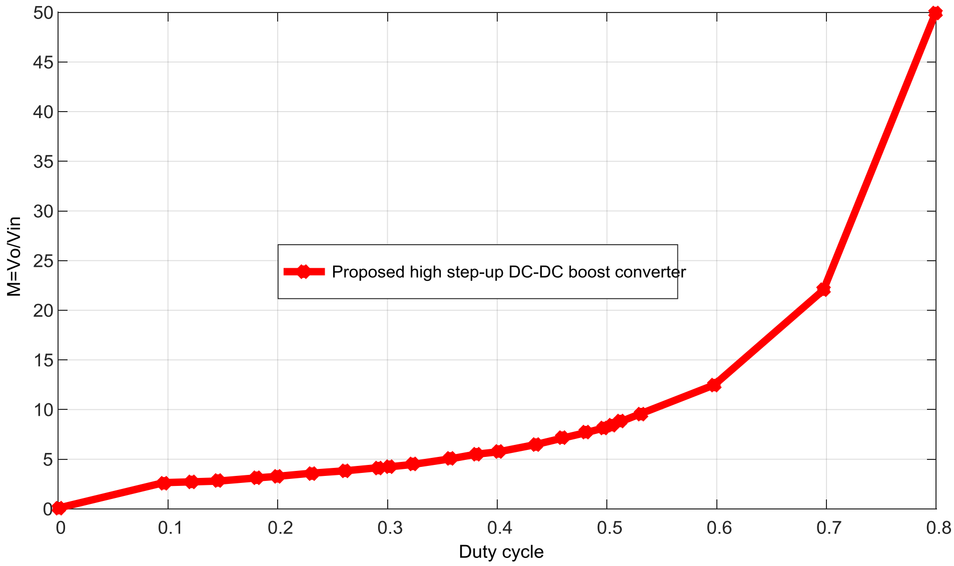


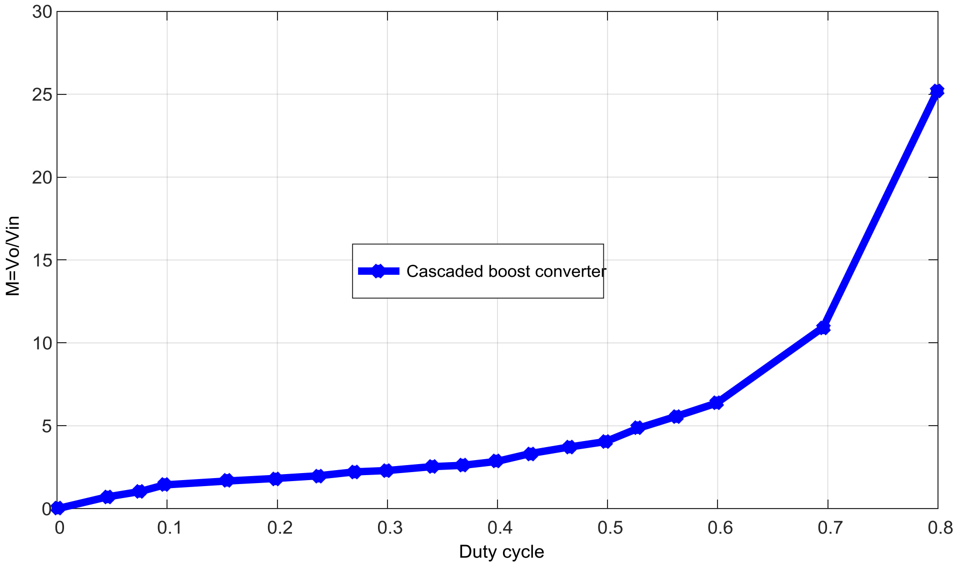
Figure 7 Simulation result of current with voltage multiplier under load variation

V PERFORMANCE COMPARISON OF THE HIGH STEP-UP DC-DC CONVERTERS

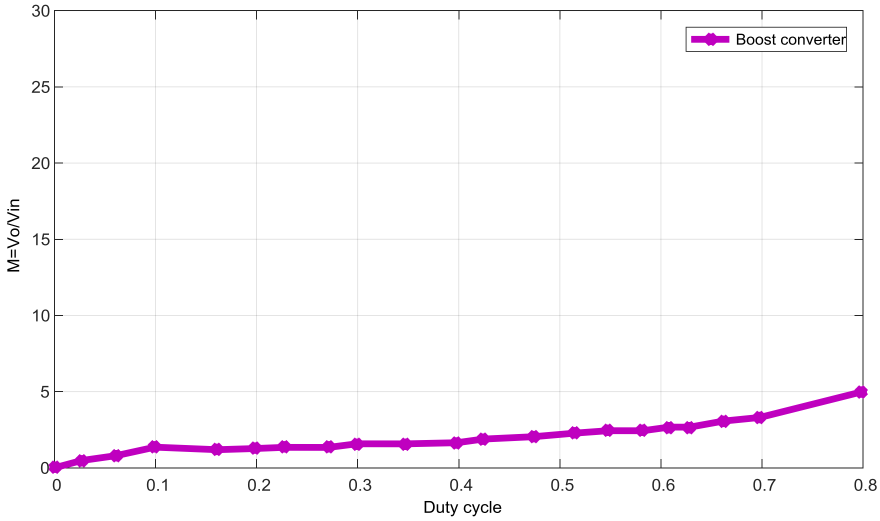
For demonstrating the performance of the developed converter, the developed converter is compared with other high step-up converters introduced in [2] and [8]. The high step-up converter introduced in [2] is also suitable as a candidate for high step-up, high-power conversion of the PV system, and the other high step-up converter introduced in [8], which is an asymmetrical cascaded structure as developed converter is favorable for DC-Microgrid applications. The voltage conversion ratio characteristic of the developed converter as a function of duty cycle is shown in Fig. 8a. As can be seen, a much higher voltage conversion ratio of the developed converter can be achieved than that of the other two boost converters over a range of duty cycle as in Fig. 8b and 8c respectively. In addition, it is clear that the developed converter can provide a high voltage gain without the extreme duty cycle.



(a)



(b)



(c)

Fig. 8 Performances comparison of the developed high step-up DC-DC converter conversion ratio characteristic and other converters.

VI CONCLUSION

A number of step-up converter topologies have been proposed by researchers in order to increase the voltage conversion ratio. In some, a current source is added for the control purposes at the output of the converter to represent a load disturbance in the model or the averaged model of the power electronic switch and diode are replaced by the combination of controlled current and voltage sources. However, the converter efficiency is very low as result of the leakage inductance energy stored in the auto-transformer and the coupled inductors. Clearly, these reported topologies do not provide required efficiency and high voltage gain. Therefore, this research proposes converter topology which is based on the incorporation of the voltage multiplier module and the conventional boost converter in order to achieve a high voltage gain.

The operating principle and steady analysis as well as a comparison with other boost converters are presented. Thus, the proposed converter is suitable for PV systems or other renewable energy applications that need high step-up high-power energy conversion.

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