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# , Design of an Efficient Controller for an Enhanced Gain DC-DC Converter Using APICs for Microgrid

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**Abstract**

The fuzzy logic controller (FLC) for a non-isolated high voltage gain DC-DC converter operating in continuous conduction mode is described in this article (CCM). Active-passive inductor cells (APICs) improve the gain of this converter and aid in providing a high gain with low duty cycles. During large line and load variations, the output voltage of a conventional proportional integral controller is not regulated. A FLC is being designed for this converter to address these issues. The converter's performance with FLC is validated under various operating conditions such as line and load variations. The outcomes are presented in relation to the efficiency of the designed controller for the same converter. It's better suited to microgrids and renewable energy sources. The main benefits this converter has huge gain, low switching losses and small current/voltage stresses.

**Keyword:** DC-DC converter, Microgrid, Fuzzy Logic Controller, PI controller, MATLAB.

## 1. Introduction

The incorporation of renewable energy sources into grid infrastructure, as well as the growing emphasis on microgrids and their economic and environmental importance, have created a demand for new topologies in converters for high gain applications. This is primarily due to the low output voltage derived from these sources, which has always been the primary limitation in their use. [1] Presents an extendable converter based on APICs. The introduced DC-DC converter is based on a three-state switching technique [2]. The converter is theoretically analyzed and experimentally validated using a laboratory prototype. Several other topologies are examined in order to understand their limitations and to demonstrate the benefits of the proposed topology.

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Because of the design structure with power switches, diodes, inductors, and capacitors, conventional boost converters cannot provide high gains [3]. The proposed structure is based on inductors being charged in parallel during the switch ON period and discharged in series during the switch OFF period. The converter provides a high step-up voltage within a narrow duty ratio range. Active switched inductors and passive switched capacitors are used in the converter. Aside from being able to achieve high gain, the topology also achieves high efficiency and reduces voltage stress as the number of elements in the circuit increases [4].

Cuk converter family with transformerless active switched inductor and switched capacitor low voltage and current stress is provided by the high gain capability. Conduction losses are reduced by using semiconductor devices with low voltage ratings [5]. Grid-connected PV systems, for example, necessitate a high step-up voltage. The use of traditional boost converters in such scenarios is restricted. The paper [6] introduces hybrid switched inductor converters for high gain conversion.

Andrade et al.[7] propose a hybrid transformerless converter with two inductor boost converters consisting of a voltage multiplier and switched capacitor cells. The structure's key features include improved voltage gain and efficiency, low current and voltage stress, and ease of operation. The difference in two inductor currents can be compensated for in the two inductor high gain converter topology by increasing the inductor current of the corresponding path.

The proposed method has no effect on the voltage transfer gain of the converter [8]. There are described switching structures that use two capacitors and two-three diodes or two inductors and two-three diodes. These are either ldquostep-downrdquo or ldquostep-uprdquo. When these structures are combined with converters such as buck, boost, buck-boost, Cuk, zeta, and sepic converters, they produce a step up function that can increase or decrease the gain more than traditional converters [9].

High gain DC-DC converters with voltage RE-Lift and Super RE-Lift Luo converters have supplied enough solar energy to grids. High voltage gain and high power efficiency are advantages of the topology, in addition to high efficiency. The output voltage is increased in geometric progression. The voltage gain produced by most of the converter structures is limited by losses [10]. Melo de Andrade et al. prepare an assessment based on Cuk and SEPIC converter topologies by targeting series connection of DC-DC converters [11]. From these literatures, it is found that proposed converter has less components with high voltage gain dc-dc converter for microgrid.

## 2. Working of Enhance High Gain DC-DC Converter Using APICs

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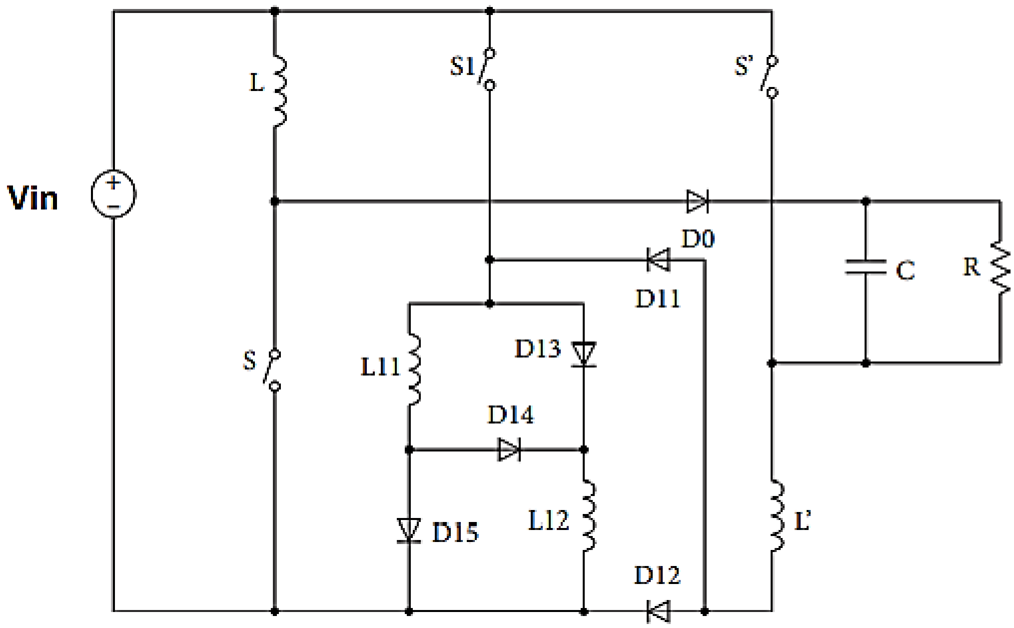
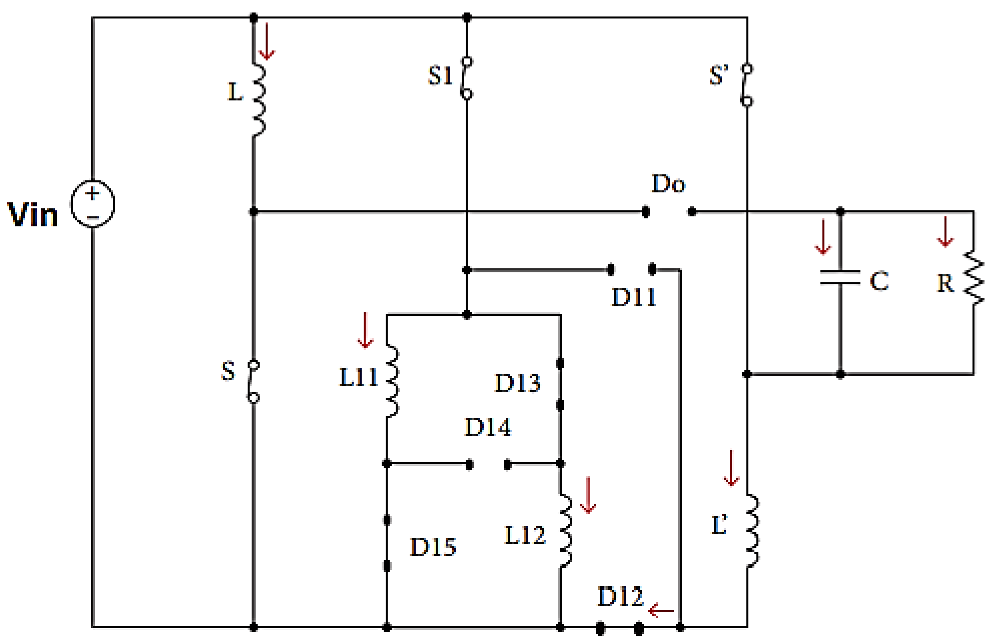
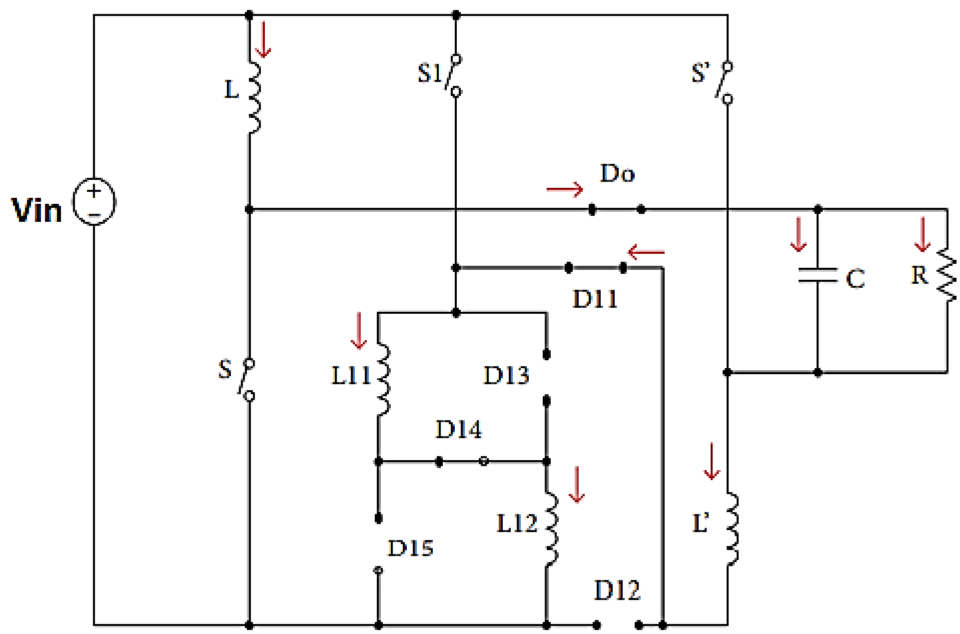



Fig.1 Circuit diagram of the modified high gain converter using APICs

The circuit diagram of the modified high gain DC chopper with APICs is illustrated in Fig.1. It consist of three switches, APICs cell (n=1) , output capacitor (C), input voltage ($V_{in}$) and load resistance (R).




(a)




(b)

Fig.2Working of the modified high gain converter using APICs, (a) during on time period of switches and during off time period of switches

**Time Interval of $T_{ON}$**: All the switches are turned ON (Fig.2a). , The voltage across the inductor during this period is expressed as (1)

$$V_L=V_{in} \quad (1) ,$$

The inductor current is expressed as (2)

$$i_L= V_{in}/ L\, t + I_{LV} \quad (2)$$

In this interval, the inductors get charged therefore the inductor current increases and reaches its maximum value at t = DT. Applying t = DT in equation (2) the maximum inductor current can be derived as (3)

$$I_{LP}=V_{in}DT/ L + I_{LV} \quad (3) ,$$

The capacitor is discharged by the interval end, and the capacitor voltage decreases to $V_{CV}$.

**Time Interval of $T_{OFF}$:** All the switches are OFF (Fig.2b). The voltage across the inductor can be arrived as (4)

$$V_L=V_{in}– Vo/ 2n + 2 \quad (4)$$

Where, n is the number of APICs.

Voltage Gain Calculation: Considering equations (1) and (3), the voltage gain can be derived as(5)

$$V_o / V_{in} = 1 + D(2n + 1) / (1 - D) \quad (5) ,$$

The converter is designed considering minimum output voltage ripple. Least OVR is obtained in CCM operation. , the value of the inductor is greater than the critical value. The voltage gain as well as the output ripple of the converter is independentof the inductance value. Simulation specifications of the converter are cataloged in Table 1.

Table 1. Specifications of the modified high gain DC-DC converter with APICs for microgrid

| Simulation parameter | Value |
|---|---|
| Output voltage, ($V_0$) | 400 V |
| Switching frequency, (F) | 50 kHz |
| Load resistance, (R) | 50–100 Ω |
| Capacitance, (C) | 200 mF |
| Output power, ($P_0$) | 2 kW |
| Input voltage ($V_i$) | 20 V–40 V |
| Inductance, ($L_c$) | 11.3 μH |

## 3. Simulation Results and Discussions

This section deals about the open loop simulation study of the modified high gain DC-DC converter with APICs for microgrid. The MATLAB/Simulink model of the proposed converter is depicting in Fig.3.

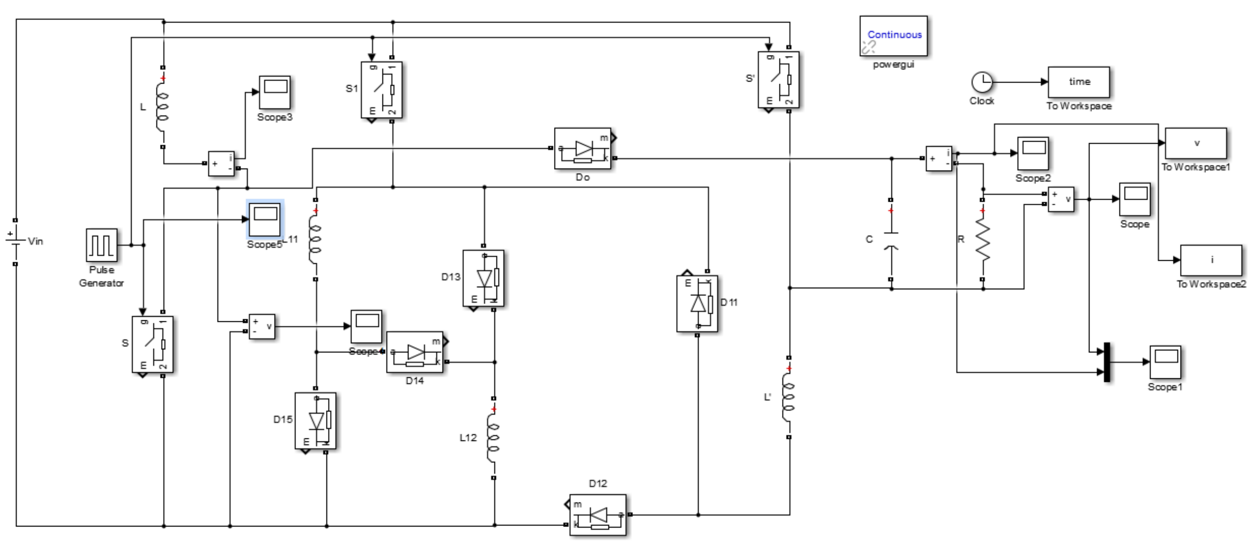



Fig.3 Working of the modified high gain converter using APICs, (a) during on time period of switches and during off time period of switches

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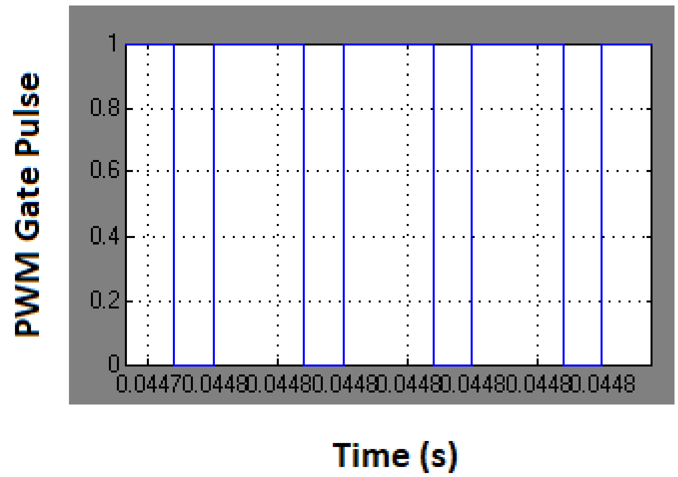


Fig.4Simulated response of PWM gate pulses of switchesfor modified high gain converter using APICs ($V_{in}$=40V, R=50 Ohm)

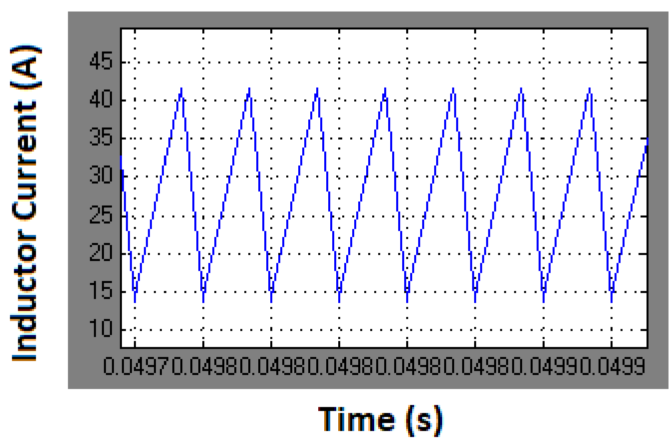


Fig.5Simulated response of inductor current for modified high gain converter using APICs ($V_{in}$=40V, R=50 Ohm)

Figs.4,5,6,7 and 8 show the simulated responses of gate pulse, inductor current, voltage across the switch, output voltage and output current of modified high gain converter using APICsfor input voltage $V_{in}$=40V and load resistance R=50 Ohm. From these results has been matched the theoretical value recorded in Table 1. Fig. 9 and Fig. 10.show the simulated responses of output voltage and output current of modified high gain converter using APICs for input voltage $V_{in}$= 20V and load resistance R=50 Ohm.

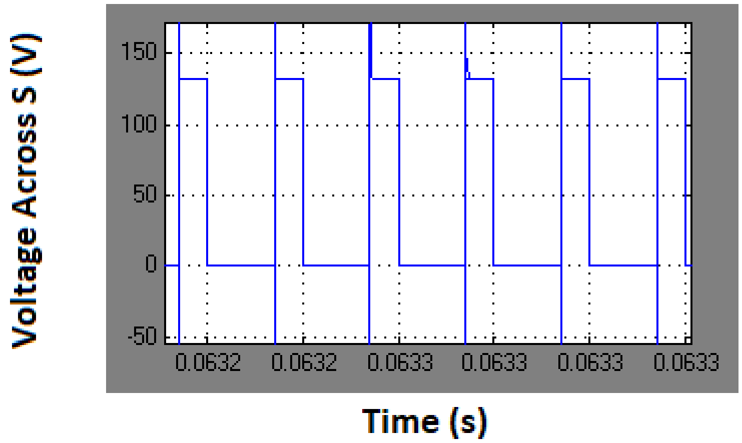


Fig.6Simulated response of voltage across the switch S for modified high gain converter using APICs ($V_{in}$=40V, R=50 Ohm)

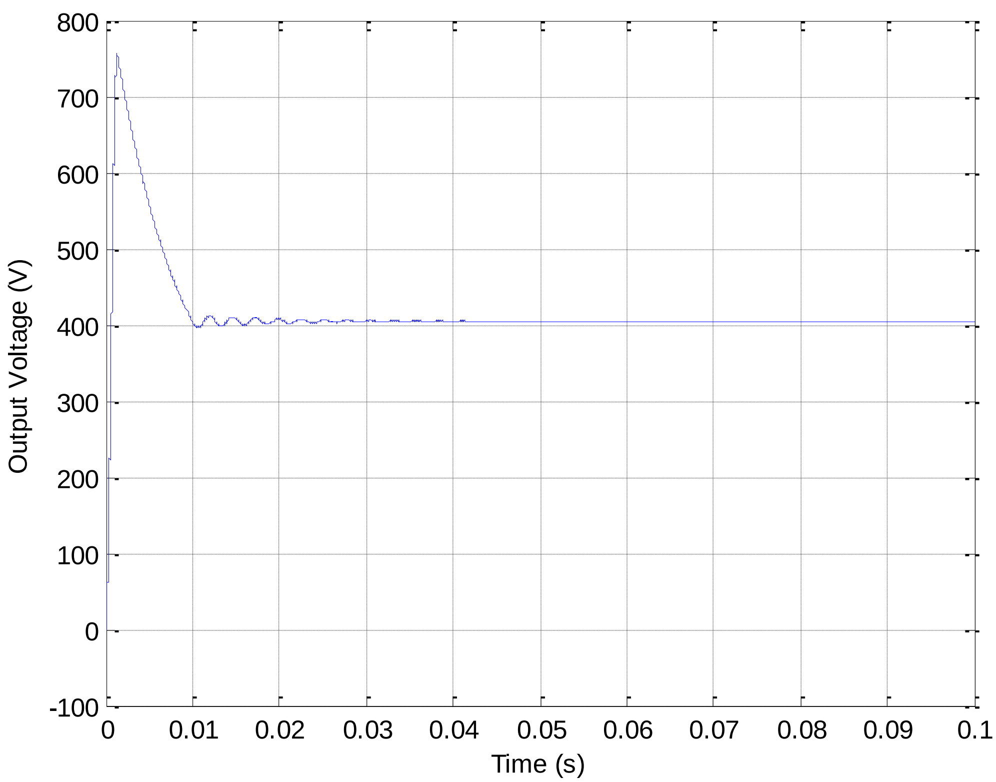

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Fig.7Simulated output voltage response for modified high gain converter using APICs ($V_{in}$=40V, R=50 Ohm)

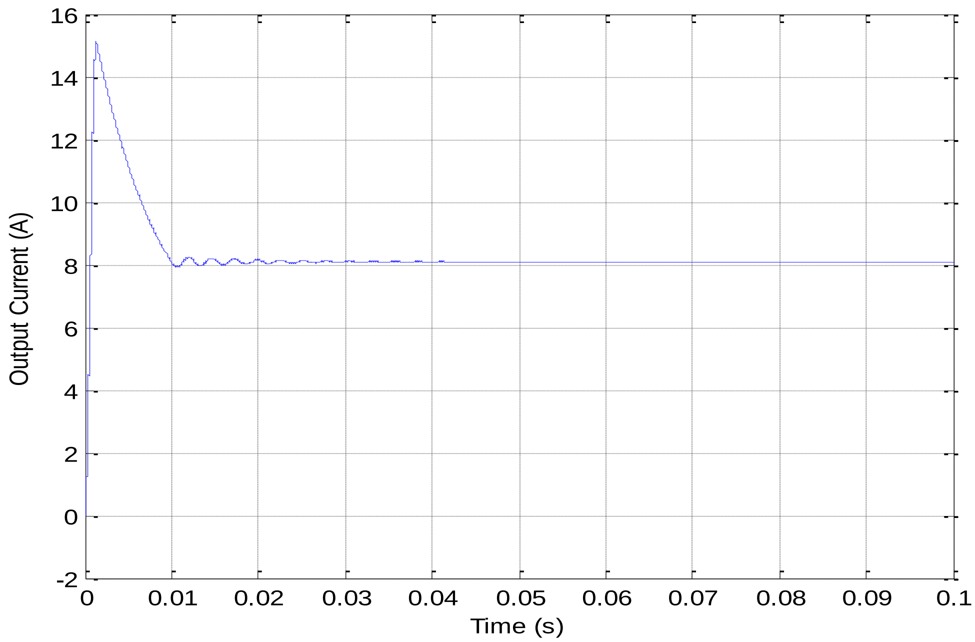


Fig.8Simulated output current response for modified high gain converter using APICs ($V_{in}$=40V, R=50 Ohm)

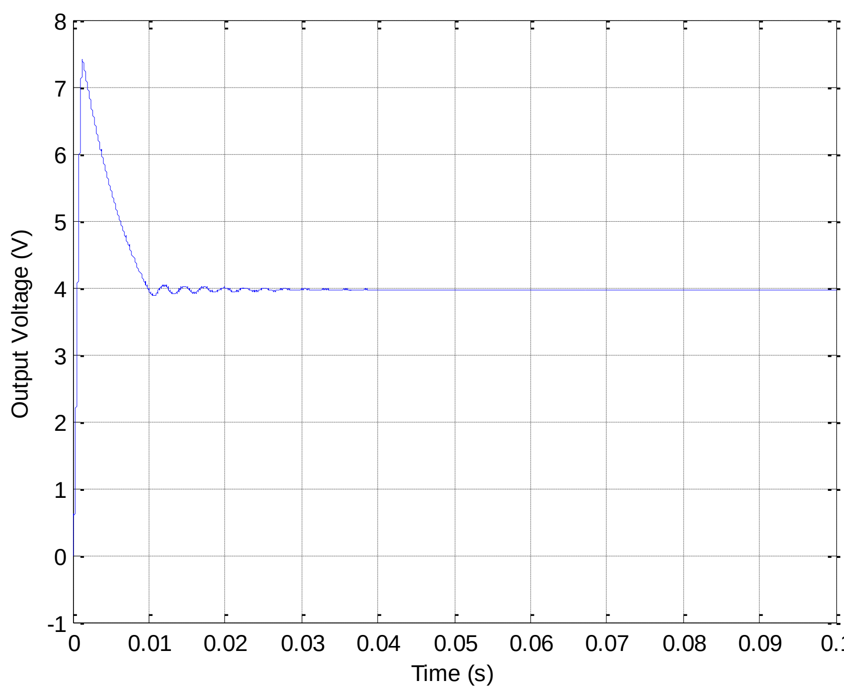

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Fig.9Simulated output current response for modified high gain converter using APICs ($V_{in}$=20V, R=50 Ohm)

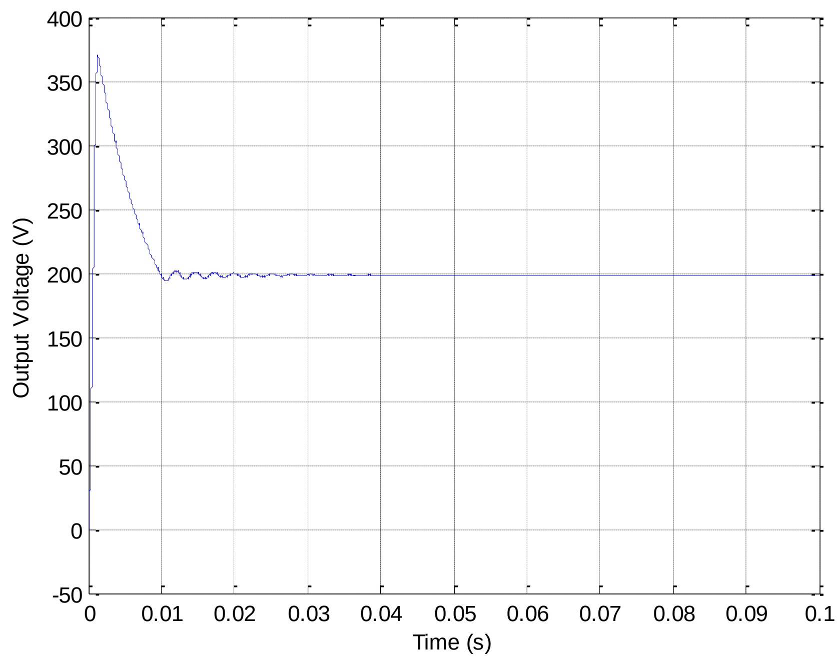
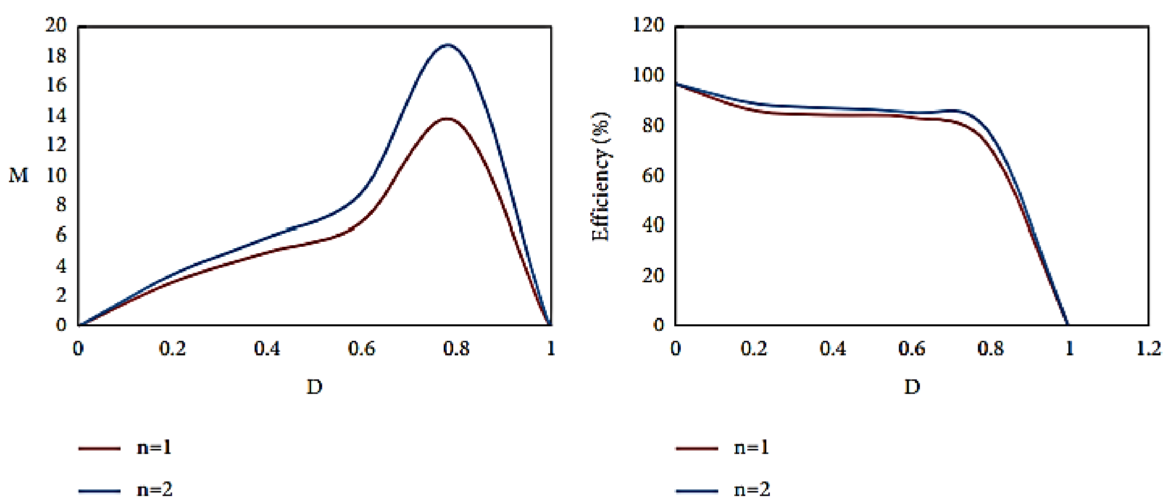



Fig.10Simulated output voltage response for modified high gain converter using APICs ($V_{in}$=20V, R=50 Ohm)

Fig.11 The plot of efficiency versus duty cycle confirms that for a typical duty cycle value, the efficiency of the converter improves as n increases.



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(a) (b)

Fig. 11.(a) Voltage gain versus duty cycle. (b) Efficiency versus duty cycle.

## Chapter-4

## Conclusions and Future Work

For microgrid applications, an extendable high gain DC-DC converter has been proposed. Because the topology uses active-passive inductor cells, it can be extended to provide improved voltage gain. The voltage stress on semiconductor devices is low, reducing losses. The inductors required are small in size. The proposed topology can achieve high gains at lower duty cycle values, which is difficult to achieve with conventional boost converters. Open loop simulation results are presented to proficient of the proposed converter.

Next phase, fuzzy logic control and PI control for modified high gain dc-dc converter with APICs for microgrid is to be implementing.

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