IMPLEMENTATION OF HIGH GAIN DC-DC CONVERTER FOR DC MICRO-GRID

[1]Jais Joseph, [2]Neetha John, [3]Kiran Boby
[1]PG Scholar, [2]Professor, [3]Professor
Department of Electrical & Electronics
Mar Athanasius college of engineering, Kothamangalam, Ernakulam, India

Abstract: *DC micro-grids are popular due to the integration of renewable energy sources such as solar photovoltaic and fuel cell.* ***The solar energy may be varying time to time so MPPT algorithms are necessary because PV arrays have a nonlinear voltage-current characteristic with a unique point where the power produced is maximum. This point depends on the temperature of the panels and on the irradiance conditions. Both conditions change during the day and are also different depending on the season of the year. The irradiation can change rapidly due to changing atmospheric conditions such as clouds.*** *Owing to the low output voltage of the DC power generators, high efficient high gain DC-DC converters are in need to connect the DC micro-grid. In this paper, a non-isolated high gain DC-DC converter is proposed* ***along with a bidirectional converter and a battery in order to connect the DC micro-grid.*** *The operation of switches with two different duty ratios is the main advantage of the converter to achieve high voltage gain without using extreme duty ratio.* ***Power from PV and Battery for different irradiance is measured and results are tabulated. The simulation of implementation of high gain DC-DC converter for DC micro-grid is done by using MATLAB/ SIMULINK software. dsPIC30F2010 is used for generating control pulses for the switches. The prototype of proposed converter is setup and verified its performance.***

IndexTerms - DC-DC Converter, PV array, High Gain converter , Lead Acid Battery, Bidirectional Converter.

I. INTRODUCTION

Renewable-energy-based micro-grids have appeared to be a better way of exploiting renewable energy and reducing the environmental risks of fossil fuels. In the view of the fact that most renewable energy sources (RES), such as photovoltaic (PV), fuel cell (FC) and variable speed wind power systems, generate either DC or variable frequency/ voltage AC power, a power–electronics interface is an indispensable element for the grid integration. In addition, modern electronic loads such as computers, plug-in hybrid electric vehicles and even traditional AC loads such as induction motors, when driven by a variable speed drive require DC power. DC micro-grids have shown advantages in terms of efficiency, cost and system that can eliminate the DC/AC or AC/DC power conversion stages required in AC micro-grids for the integration of RES and loads. Nowadays, high gain DC-DC converters are used in many applications other than the renewable energy conversion, such as battery backup systems for uninterrupted power supplies, high intensity discharge lamp ballasts for automobile headlamps, electric tractions and some medical equipment [2].

In the recent past, conventional DC-DC boost converter is used to step up the voltage. However, the voltage stress on the switch is equal to the output voltage. Hence, high rated switch is selected to meet the voltage stress on the switch that results in high conduction loss [1]. In addition, selection of large duty ratios to achieve high voltage gain not only increases the conduction losses and high voltage spikes, but also induces serious diode reverse recovery problem. The isolated converters such as forward, fly-back, push-pull, half-bridge, and full-bridge types can adjust the turns ratio of the transformer to achieve high step-up voltage gain. However the main switches of these converters will suffer a high voltage spike and high power dissipation from the leakage inductor of the transformer [3]. To reduce these drawbacks, the non-dissipative snubber circuits and active-clamp circuits are employed. However, the cost increases accordingly due to the extra power switch and high side driver. Theoretically, the non-isolated converters can be adopted to provide high step-up voltage gain with extremely high duty cycle. However, the step-up voltage gain is limited by the effect of the power switches, rectifier diodes, and equivalent series resistance of the inductors and capacitors. The extreme duty cycle operation may also result in serious reverse-recovery problem and electromagnetic interference problem. To improve the conversion efficiency and achieve high step up voltage gain, many topologies have been proposed [3]. High step-up gain can be achieved by the use of the switched capacitor technique. However, the main switch will suffer high transient current, and the conduction loss is high. Another method for achieving high step-up gain is the use of the voltage-lift technique. However, it has the same drawback.

In this paper, a novel high gain DC-DC converter is developed to overcome the issues mentioned above [1]. The proposed converter has high voltage gain by selecting appropriate duty cycle for the three switches. It has the following advantages: (i) the three power switches in the proposed converter operates with two different duty ratios to attain high voltage gain; (ii) the stored inductor energy is supplied to the load without additional clamping circuit; (iii) the voltage gain achieved by the proposed converter is greater than the conventional boost converter and the converter presented in [4, 5]; (iv) reduced voltage stress on the diodes and switches based on the percentage output voltage.

II. HIGH GAIN DC-DC CONVERTER FOR DC MICRO-GRID

There are PV panel, high gain converter , bidirectional converter and a battery. The system uses a bidirectional converter which gives an output voltage of 200V. For PV panel the rated voltage is 17V and 100W.

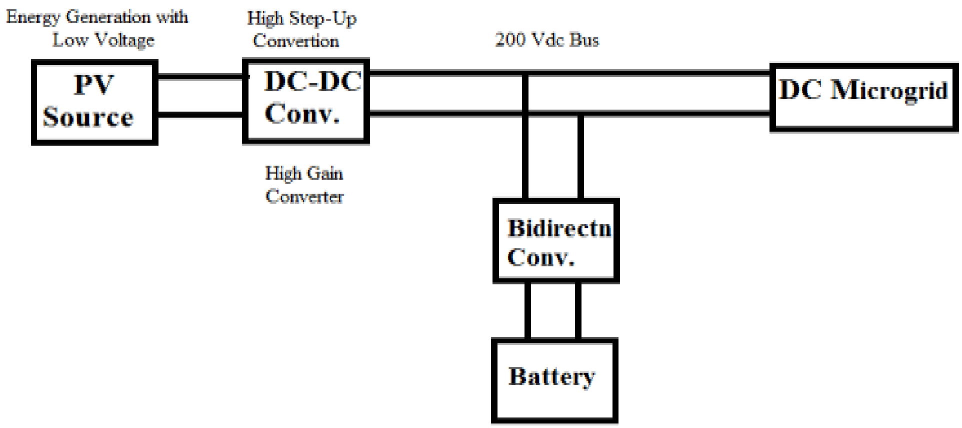

Fig.1. block diagram for DC micro-grid

Block diagram for the implementation of high gain DC-DC converter in DC micro-grid is shown in Fig. 1. The advantages of distributed power generation over conventional centralized systems are well known. Environmental benefits can be also achieved with the use of renewable energy sources such as photovoltaic (PV) and wind. However, because of the stochastic nature of these sources, high penetration levels require energy storage units as well as controllable loads to balance supply and demand with reduced impact on the utility grid. The concept of micro-grids has been developed in this context for feeders and neighborhoods. They can optimize the energy use in the micro-grid and also present a more predictable profile for the utility in cases of grid connected micro-grids.

Output of PV cell is given as the input of high gain DC-DC converter. Apart from this converter, there is a bidirectional converter and a battery. If the power from the PV cell is less, the required power is taken from the battery and at this time battery gets discharged. When the power from PV is excess it is given to the battery using a bidirectional converter. At this time the battery gets charged. Power from the battery is taken only when, the power from PV cell is not enough to produce the output voltage. So a natural resource is preferable here.

2.1 High Gain DC-DC Converter

The proposed high gain DC-DC converter shown in Fig.2 consists of three active switches S_1, S_2 and S_3, two inductors L_1 and L_2, two diodes D_1 and D_2 and one output capacitor Co. The switches S_1, S_2 and S_3 operate at a switching frequency of f_s. The duty ratio of the switches S_1 and S_2 is d_1 and the third switch S_3 is d_2.

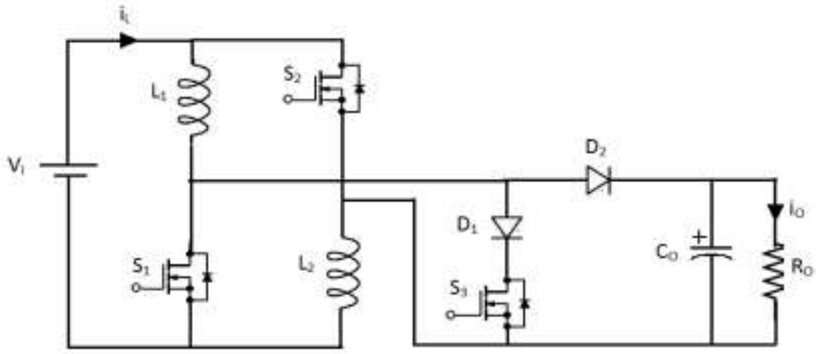

Fig.2. High Gain DC-DC converter

2.1.1 Modes of Operation

In this section, the operating modes of the proposed converter in continuous conduction mode (CCM) are discussed. There are three modes of operation for a single switching period with two different duty ratios. Fig.3 shows the waveforms of the proposed converter in CCM.

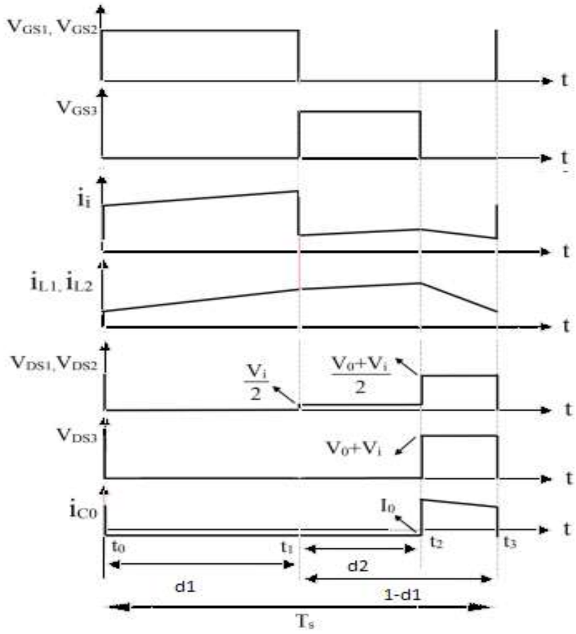

Fig.3. CCM operation of the converter

2.1.1.1 Modes 1

During the time interval [t_0, t_1], S_1 *and* S_2 are turned *ON* and S_3 is turned *OFF*. The current path in the circuit is shown in Fig. 4(a). The source energy is transferred to the inductors L_1, L_2 and the energy stored in the capacitor Co is discharged to the load. In this mode, inductors are parallel to the source.

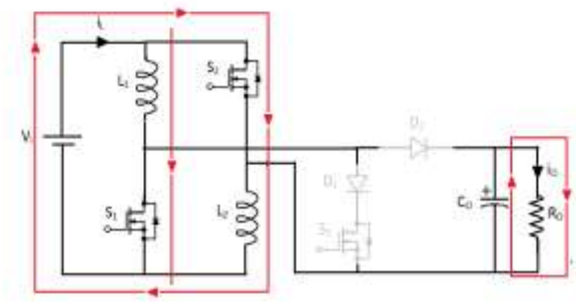

Fig 4(a) CCM operation of mode 1

2.1.1.2 Modes 2

During the time interval [t_1, t_2], S_1 and S_2 are turned OFF and S_3 is turned ON. The current path during this period is depicted in Fig.4(b). The source energy is transferred to the inductors and the current flows through L_1, D_1 and L_2. The stored energy in the capacitor Co is delivered to the load. In this mode, the inductors are in series to the source.

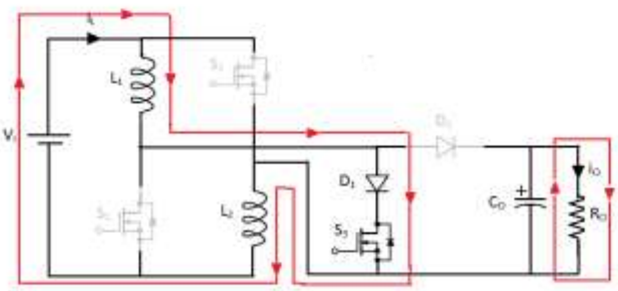

Fig 4(b) CCM operation of mode 2

2.1.1.3 Modes 3

During the interval [t_2, t_3], S_1, S_2 and S_3 are turned *OFF*. The current direction in the circuit is shown in Fig.4(c). In this mode, both source and the inductors supply the load. In addition, the capacitor Co is in charging mode. In this mode, the inductors are in series to the source.

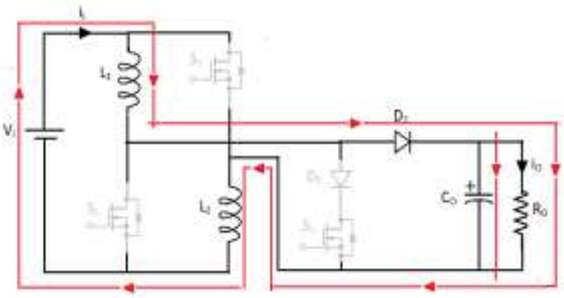

Fig 4(c) CCM operation of mode 3

2.2 *Bidirectional* Converter

The conventional bidirectional DC-DC converter forms an important part in the proposed DC Micro-grid system. Basic DC-DC converters such as buck and boost converters (and their derivatives) do not have bidirectional power flow capability. This limitation is due to the presence of diodes in their structure which prevents reverse current flow. In general, a unidirectional DC-DC converter can be turned into a bidirectional converter by replacing the diodes with a controllable switch in its structure.

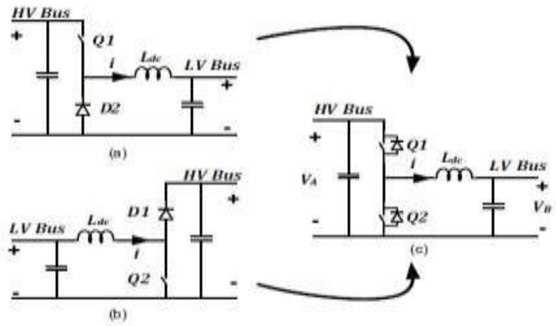

Fig 5: (a) Elementary unidirectional buck converter, (b) elementary unidirectional boost converter and (c) transformation to conventional bidirectional converter by substituting diodes with a controllable switch

Fig.5 shows the structure of elementary buck and boost converters and how they can be transformed into bidirectional converters by replacing the diodes in their structure. It is noteworthy that the resulted converter has the same structure in both cases. In the buck mode of operation, i.e. when the power is transferred from the high voltage (HV) to the low voltage (LV) side, Q1 is the active switch while Q2 is kept off. In the boost mode, i.e. when the power is transferred from LV to HV side, Q2 acts as a controlled switch and Q1is kept off.

2.3 Design of High Gain DC-DC Converter

The selection of inductor depends upon the input voltage *(Vi)*, ripple current *(ΔiL),* switching frequency *(fs)* and duty ratio *(*d_1*)*. The critical value of the inductance to operate the proposed converter in CCM is obtained using

$$L_1 = L_2 = (V_I * d_1)/(\Delta i_L * fs)$$

The value of output capacitor *Co* depends upon the power rating of the converter (*Po*), output voltage (*Vo*), voltage ripple (*ΔVc*) and switching frequency (*fs*) which is obtained using equation,

$$C_o = P_o/(V_O * \Delta V_C * FS)$$

The voltage stress V_{DS1}, V_{DS2} and V_{DS3} on the switches S_1, S_2 and S_3 respectively is given as

$$V_{DS1} = V_{DS2} = (V_O + V_I)/2$$

$$V_{DS3} = V_o$$

The voltage stress V_{D1} and V_{D2} on the diodes D_1 and D_2 respectively given as

$$V_{D1} = V_i$$

$$V_{D2} = V_o + V_i$$

III. SIMULATION STUDIES

The simulation of high gain DC-DC converter for DC micro-grid is done in MATLAB R2017a/Simulink. The simulation parameters, simulation model and results of implementation of high gain DC-DC converter for DC micro-grid are shown below.

3.1 Simulink Model and Simulation Results

The detailed MATLAB/Simulink model of high gain DC-DC converter is made. Table 1 shows the simulation parameters of the converter for the implementation in DC micro-grid.

Table 1: Simulation parameters for the converter

Components	**Specification**
Inductor (L_1, L_2)	360µH
Capacitor (C_o)	10µF

Output Voltage (V_o)	200V
Switching Frequency (f_s)	50KHz
PV panel	17V, 100W
Battery	48V

The detailed MATLAB/Simulink model of high gain converter for DC micro-grid is shown in Fig.6. There are three switches S_1, S_2 and S_3 are worked on switching frequency 50KHz. A bidirectional converter and a battery is used for the proper operation of micro-grid.

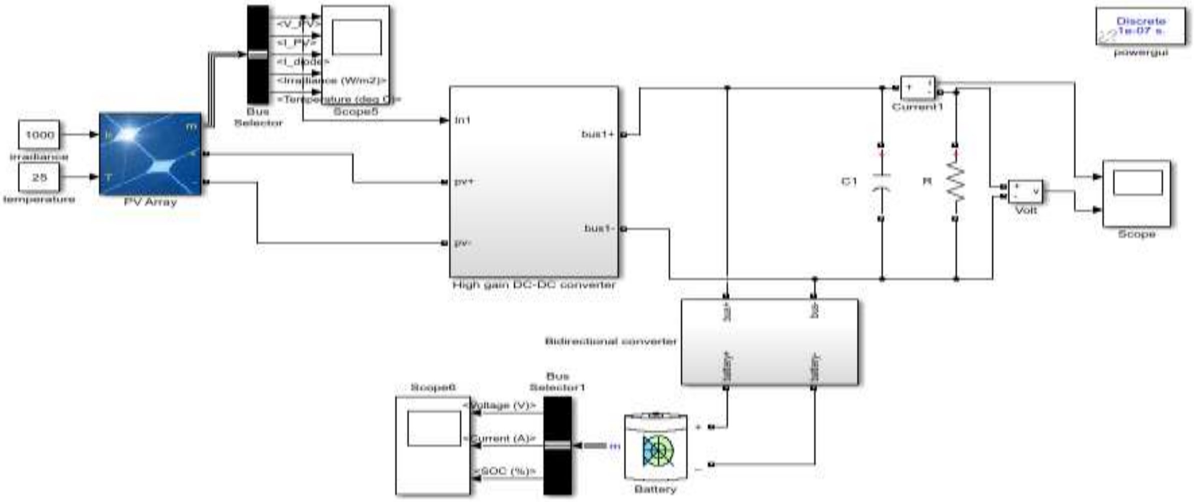

Fig 6. Simulink model of high gain DC-DC converter for DC micro-grid

High gain converter for DC micro-grid is simulated in MATLAB R2017a. The output is measured for different irradiance and is tabulated below. Results are also shown below.

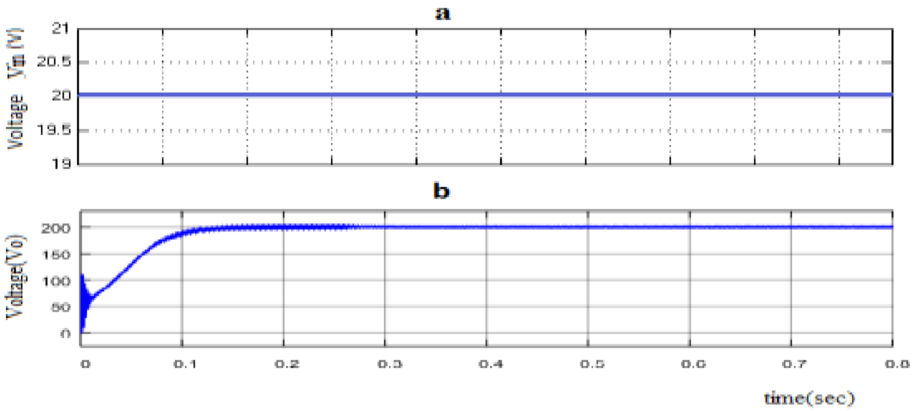

Fig.7 (a)InputVoltage, Vi (b)OutputVoltage, Vo

From the Fig.7 it is clear that the input voltage is 20V. The output voltage(*Vo*) is 200V. Here the output voltage is greater than the input voltage. So this can be used for boost operation.

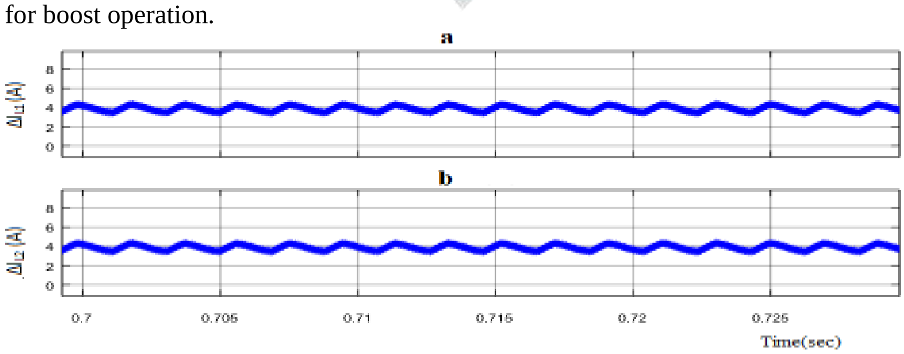

Fig.8 (a) (a)Inductor current i_{L1} (b) Inductor current i_{L2}

The inductor current waveforms is shown in Fig. 8. Inductor current is 3.7 A. Inductor current is same as input current. Both L_1 and L_2 have the same value of current.

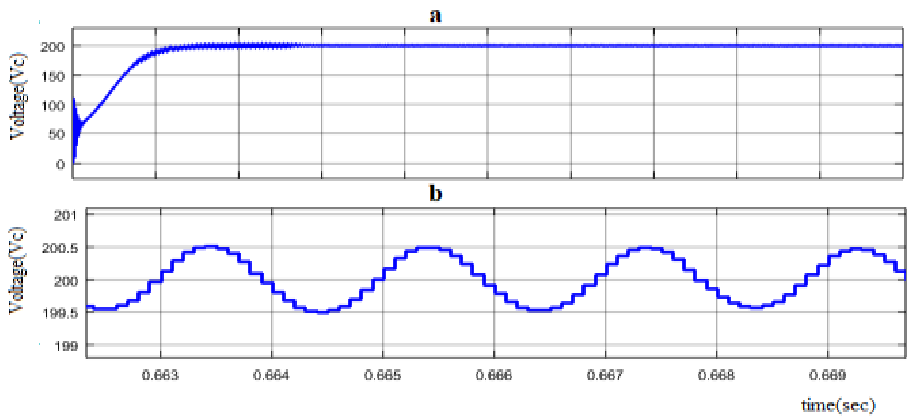

Fig.9 (a) Capacitor voltage V_{c0} (b) Ripple Voltage

Capacitor voltage is given in the Fig. 9. This is same as that of output voltages *Vo*. Capacitor voltage, *Vc* is 200 V. Voltage ripple is 1 V.

3.2 Simulation Analysis

High gain DC-DC converter for DC micro-grid is simulated for different irradiance. Power from PV, Load and Battery is tabulated here. Table 2 shows power from PV, battery and load for different loads. Here the irradiance is 1000W/m^2 . Table 3 shows power from PV, battery and load for different loads. Here the irradiance is 500W/m^2 .

Table 2: Simulation Analysis with irradiance 1000W/m^2

Load(Ω)	Power(W)			V_{bus}(V)
	PV	Battery	Load	
100	100	336	393	200
300	100	52	132	200
400	100	28	99	200
500	100	-6	80	200
700	100	-29	57	200
1000	100	-45	40	200

Table 3: Simulation Analysis with irradiance 500W/m^2

Load(Ω)	Power(W)			V_{bus}(V)
	PV	Battery	Load	
100	51	377	387	200
300	51	103	130	200
400	51	50	97	200
500	51	34	78	200
700	51	17	56	200
1000	51	-4	39	200

IV. HARDWARE IMPLEMENTATION

The simulation results are verified experimentally by implementing the hardware, due to the lack of PV power supply and other availability of devices, the hardware is done by reducing the parameters of prototype to 17V as the input and for 100W power. The Fig. 10 shows the hardware setup of the high gain converter for DC micro-grid. Here a battery of 24V is used and a bidirectional converter with reference voltage of 80V is given for convenience. Switching pulses obtained from dsPIC30F2010 is given to the driver circuit. Opto-coupler TLP250 provides the isolation between the driver and power circuits. IRF740 is chosen as the power switch.

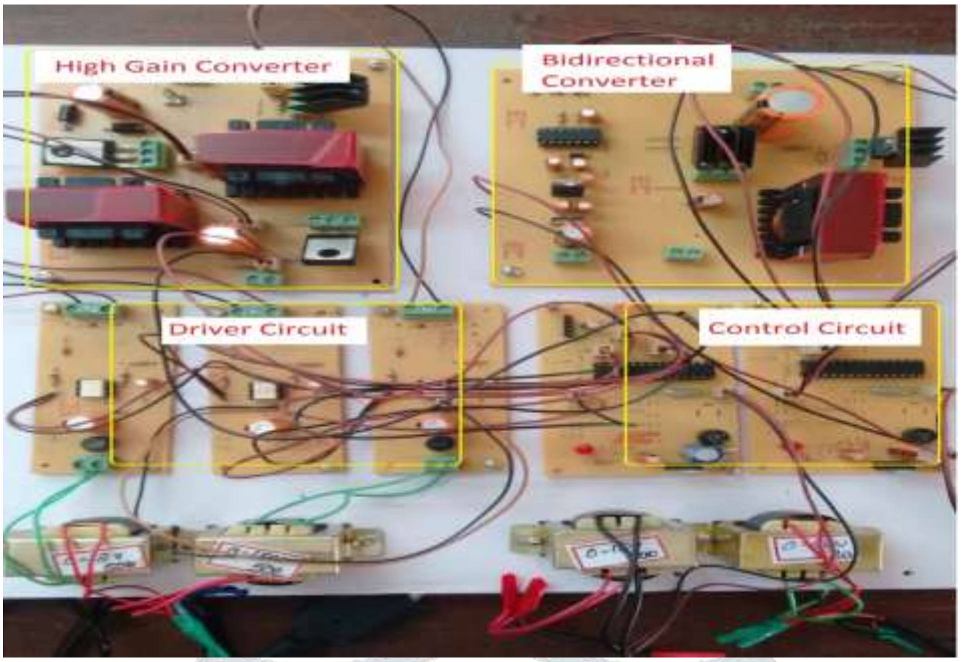

Fig 10. Experimental setup

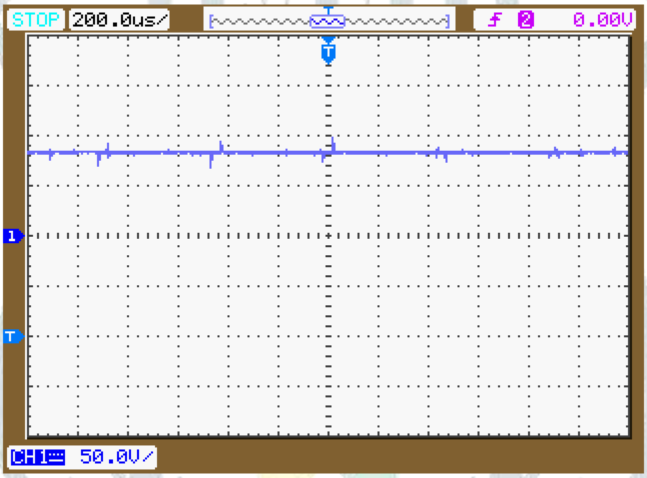

Fig.11 Experimental output V_0

From the experimental setup we can assure that the hardware setup is working and produces the desired output. The reference voltage at the bidirectional converter side is 80V. So the output of the whole system is get as 80V in experimental setup.

V. CONCLUSIONS

The high gain converter system for DC micro-grid has simulated, the simulation results are close agreement with experimental result of the prototype. For any converter that uses single duty ratio D, the extreme duty ratio operation is not reliable. In the high gain converter, the inclusion of switch S_3 and the operation of three switches with two different duty ratios are the main advantages. The maximum efficiency is obtained as 90% at input voltage is 17V and 100W load. The closed loop is applied to the input of high gain converter and output side of the bidirectional converter. The reference voltage at the bidirectional converter side is 80V. So the output of the whole system is get as 80V in experimental setup.

REFERENCES

[1] M. Lakshmi and S. Hemamalini, Non-isolated high gain DC-DC converter for DC microgrids, IEEE Transactions on Industrial Electronics, vol. 4, no. 3, July 2017.

[2] Navid Eghtedarpour and Ebrahim Farjah, Distributed charge/discharge control of energy storages in a renewable-energy-based DC micro- grid, IET Renewable Power Generation, vol. 8, no. 1, April 2013.

[3] Yi-Ping Hsieh and Jiann-Fuh Chen, A Novel High Step-Up DC–DC Converter for a Micro-grid System, IEEE Transactions on Power Electronics, vol. 26, no. 4, April 2011.

[4] J. F. Chen and T. J. Liang, Transformerless DC-DC Converter with High Step-up Voltage Gain, IEEE Transactions on Industrial Electronics**,** vol. 56, no. 8, August 2009.

[5] L. S. Yang and T. J. Liang, Analysis and Implementation of a Novel Bidirectional DC–DC Converter, IEEE Transactions on Industrial Electronics**,** vol. 59, no. 1, January 2012.

[6] T. Kerekes, R. Teodorescu and U. Borup, Transformerless Photovoltaic Inverters Connected to the Grid, 22nd Annual IEEE Applied Power Electronics Conference, USA, 2007.

[7] Hirofumi Matsuo and Pujio Kurokawa, New solar cell power supply system using a boost type bidirectional DC-DC converter, IEEE Power Electronics Specialists conference, vol. 27, no. 8, June 1982.
[8] S. Dwari and L. Parsa, An Efficient High-Step-Up Interleaved DC-DC Converter with a Common Active Clamp, IEEE Transactions on Power Electronics, vol. 26, no. 1, January 2011.
[9] Poonam Mavi and Dr. Ashok Arora, Designing of Transformer less Bidirectional DC-DC Converter, International Journal of Advanced Research in Computer Science and Software Engineering, vol. 4, no. 9, September 2014.
[10]R. Gonzalez, J. Lopez, Transformerless Inverter for Single-Phase Photovoltaic Systems, IEEE Transaction on Power Electronics, vol. 22, no. 2, March 2007.