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Voltage regulation of DC micro grid system using PV and battery coupled SEPIC converter

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ABSTRACT

This paper deals with the voltage regulation of DC micro grid system using photovoltaic and battery coupled single-ended primary-inductor converter (SEPIC) converter. SEPIC converter is a DC-to-DC boost converter, it can produce non pulsating DC current with less ripples when compared to buck and buck boost converters. Non pulsating DC current is the demanding condition required in maximum power point tracking (MPPT) applications and battery charging. This paper presents the simulation of the converters for both open and closed loop systems. Firstly, the proposed PV coupled SEPIC converter and the battery coupled buck boost converters are integrated to regulate the voltage in micro grid, and it is compared with the conventional methods in terms of output voltage, ripple voltage and power. The ripple voltage has been reduced to 0.1 V from 0.3 V in the proposed method. Secondly, PI and PID controllers are employed individually to SEPIC and buck boost converter for the voltage regulation of the DC micro grid system. The performance of the closed loop analysis is done in terms of time domain specifications, and it reveals that PID controller has the better response. The proposed system is simulated using MATLAB/Simulink and the prototype has been developed to verify the simulated results.

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1. INTRODUCTION

Nowadays, grid connected photovoltaic systems are very popular due to constant demand of energy. Many countries are encouraging PV fed power generation systems by funding it. The efficiency of the PV panels to convert electrical power from sunlight is always less than 20%, and even less efficiency in case of load conditions and panel temperature. In order to improve efficiency, maximum power point tracking (MPPT) technique with power point tracker is employed to improve the efficiency. PV coupled single-ended primary-inductor converter (SEPIC) converter can able to generate or track more power from the solar panels using PWM controlled DC-DC converter [1]–[3]. The extraction of maximum power from PV panel without using microcontroller is given in [4]. The maximum power can be extracted from PV panels under all atmospheric conditions and the efficiency can be improved with controlled PWM technique [5]. The power range of low power and residential applications using grid connected single phase inverter are 10 KW and less than that. More switching losses, interference level and acoustic noise are due to high switching at three level inverters [6]. P-V and V-I characteristics of PV due to non-uniform insolation with partial shading was proposed in [7]. PV panels, interfacing circuits with load can extract maximum power from the PV panels [8]–[17]. DC microgrids is the integration of local loads and generators operated in DC. The different advantages of DC microgrid over AC microgrid are i) efficiency of DC power system as it operates with fewer converters, ii) requirement of less components, so it is reliable, iii) low cost due to requirement of the lesser components, and iv) High survival and less complex when subject to disturbances [18]–[25]. The two different modes of DC microgrid are island mode and grid connected mode. In grid connected mode, it can supply the power to the grid in demand and absorbs the power from the grid in excess condition. The above literature has not discussed PV fed SEPIC converter system. System configuration and DC microgrid model is presented in section 2. Section 3 deals with the comparison of conventional and proposed DC microgrid system. PI and PID controlled Closed loop system are also discussed in this section. Hardware implementation of the proposed system is explained in the subsequent sections 4. Section 5 concludes the results.

2. SYSTEM DESCRIPTION

Figure 1 illustrates the schematic of the proposed system. The schematic diagram represents the PI and PID controlled SEPIC and buck boost converter. MPPT technique employed PV source is given to the SEPIC converter and source from battery is given to the buck boost converter through filter is integrated with the DC grid. Figure 2 shows the Integration of conventional buck boost and boost converter employed to the DC grid. The main objective of the buck boost and boost converter is to provide voltage regulation to the DC Microgrid. The modified and proposed SEPIC and buck boost converter is shown in Figure 3. Non pulsating DC current is the demanding condition required in MPPT applications and battery charging. The proposed PV coupled SEPIC converter and the battery coupled buck boost converters are integrated to regulate the voltage in microgrid.

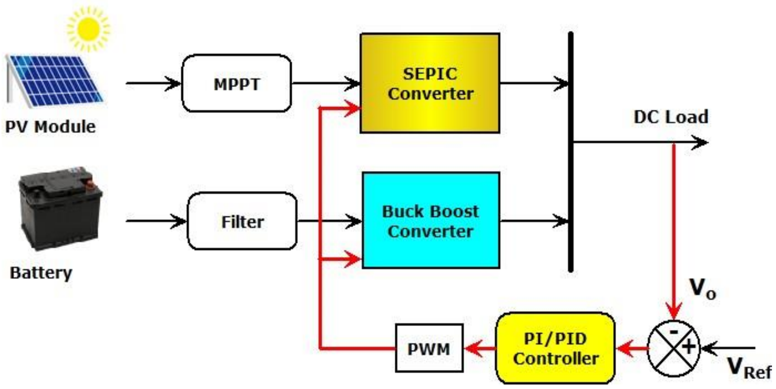

Figure.1. Schematic illustration of proposed system

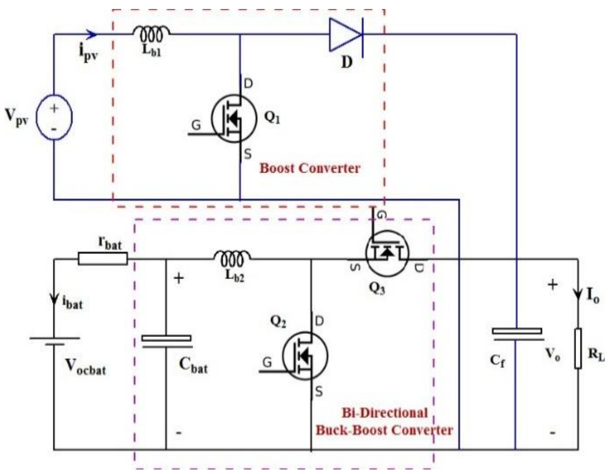

Figure 2. Conventional circuit diagram

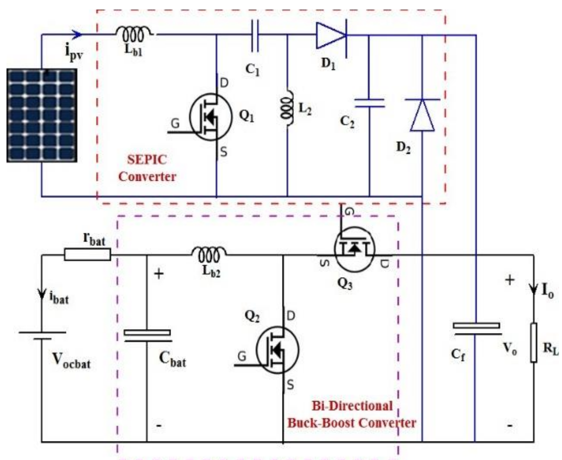

Figure 3. Circuit diagram of proposed system

3. MATLAB/SIMULINK SIMULATION RESULTS

In the circuit diagram of DC micro grid-based boost and buck boost converter is depicted in Figure 4. Output voltage of 70 V with 1 V ripple voltage is obtained across RL are depicted in Figure 5 and Figure 6. The output current of 0.7 A through R-L load is as depicted in Figure 7. The output power of 47 W is obtained from the R-L load of the converter is delineated in Figure 8.

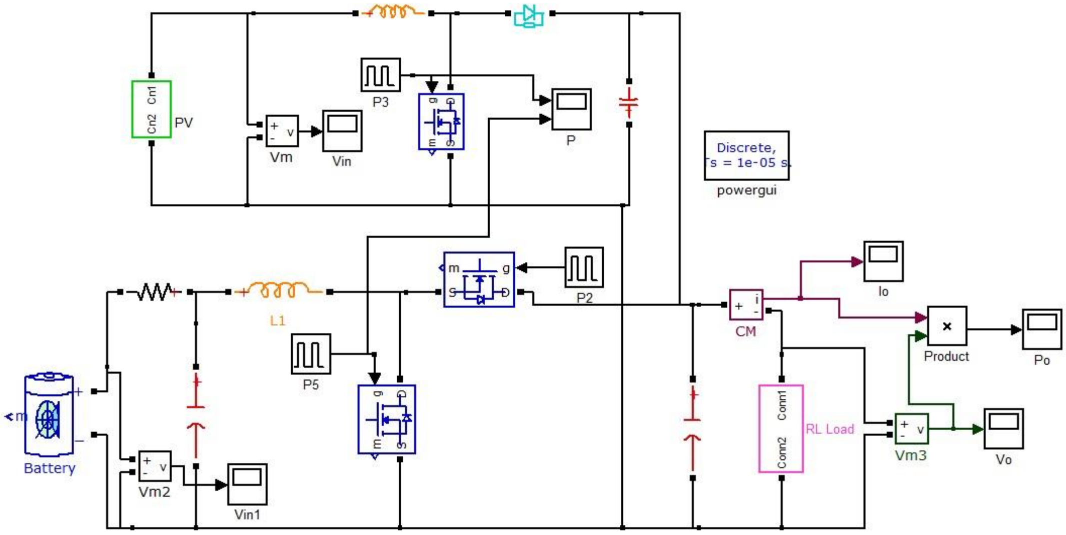

Figure 4. Schematic diagram of boost and buck boost converter for DC microgrid

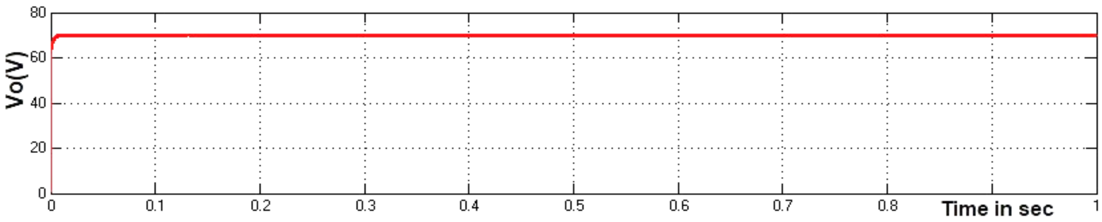

Figure 5. Voltage across RL-load of the converter

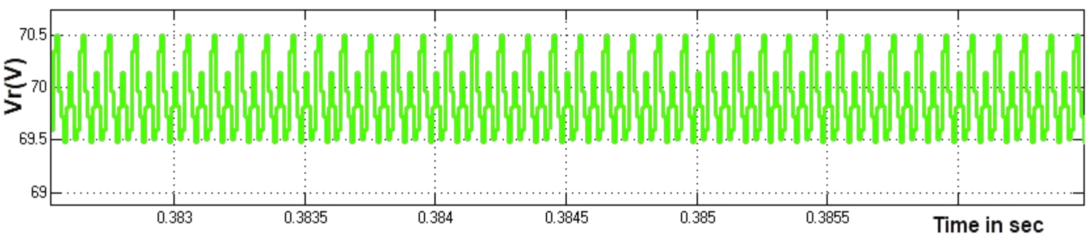

Figure 6. Ripple voltage across RL-load

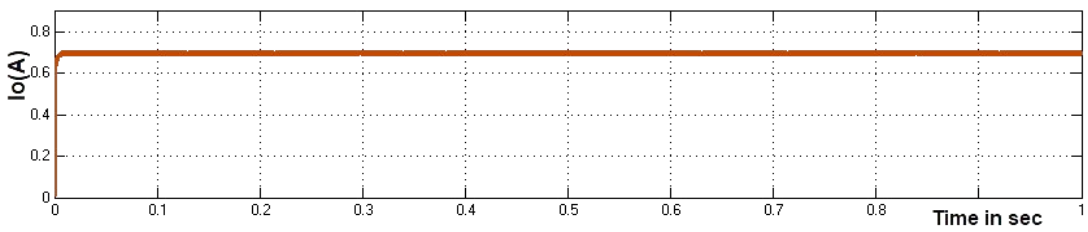

Figure 7. Current through R-L load

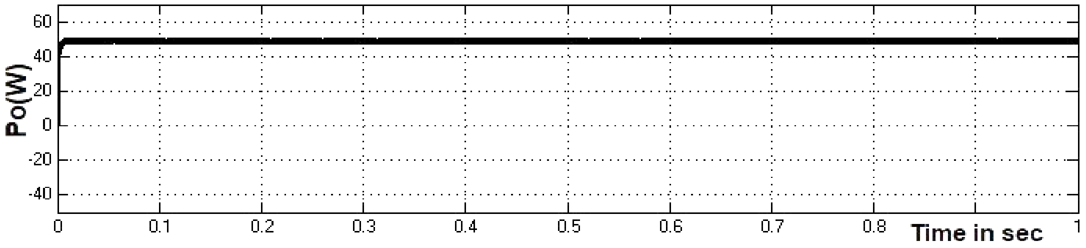

Figure 8. Output power of the converter

The Simulink circuit diagram of DC micro grid-based buck boost and SEPIC converters is depicted in Figure 9. Figure 10 and Figure 11 depict the output voltage of 95 V with 0.3 V ripple voltage across the RL. Figure 12 depicts the 0.98 A output current through RL-load of the converter and Figure 13 depicts the 90 W output power across the RL-load of the converter.

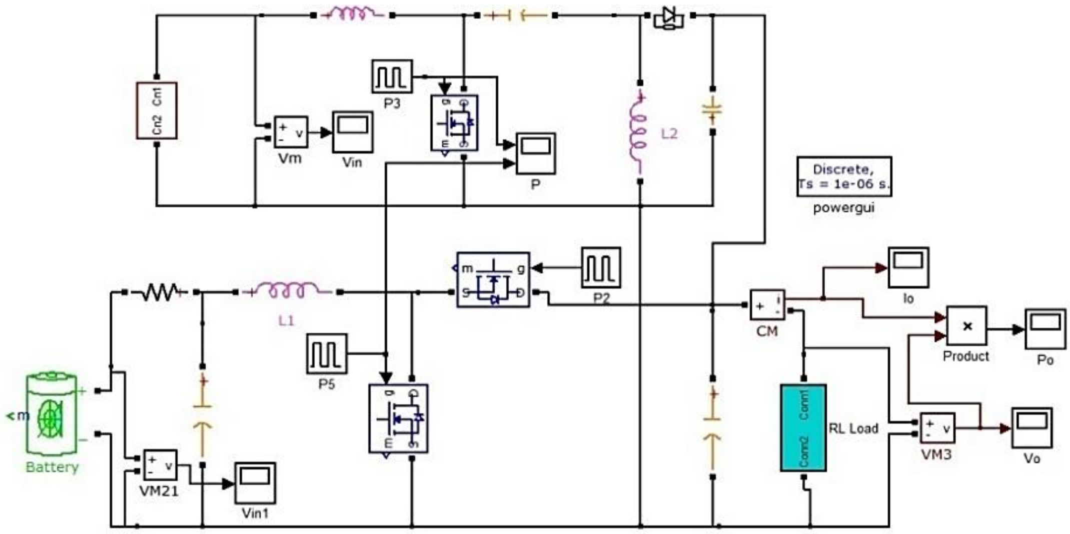

Figure 9. Circuit diagram of integrated SEPIC and buck boost converter for DC microgrid

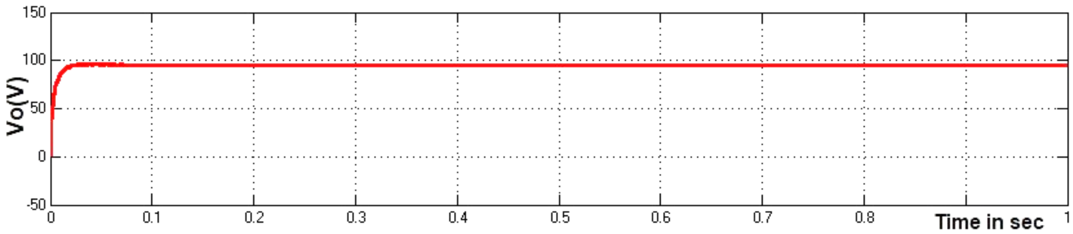

Figure 10. Voltage across RL-load of SEPIC and buck boost converter

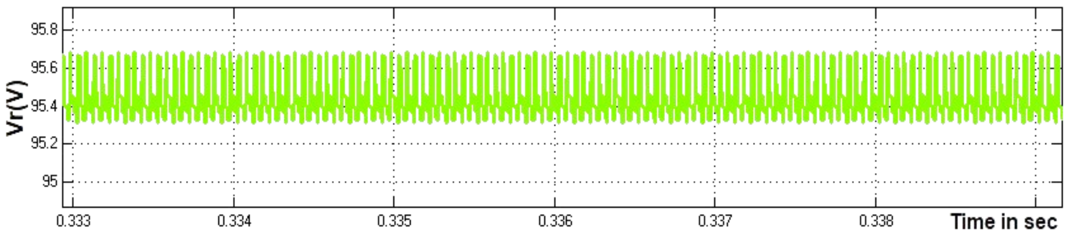

Figure 11. Ripple voltage across RL-load of SEPIC and buck boost converter

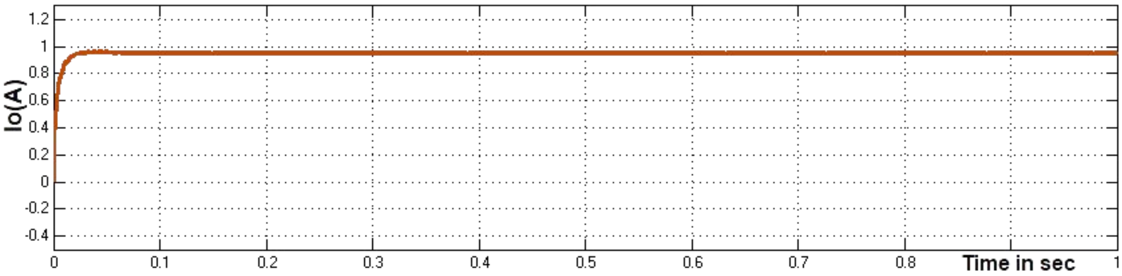

Figure 12. Current through RL-load of SEPIC and buck boost converter

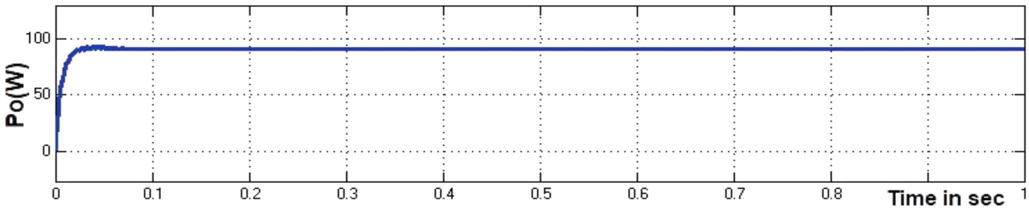

Figure 13. Converter output power

Table 1 shows the comparison of input and output parameters of the converters. The ripple voltage has been reduced to 0.1 V from 0.3 V in the proposed method. The circuit diagram of DC micro grid based SEPIC and buck boost converter with source disturbance is delineated in Figure 14 and its input voltage is 19 V. Output voltage of 110 V and output current of 1.18 A of the proposed converter with source disturbance are shown in Figure 15 and Figure 16 respectively.

Table 1. Comparison of input and output parameters of the converter

DC Micro grid	Vin(V)	Vo(V)	Vor(V)	Po(W)
Boost and buck boost converter	15	70	1.0	50
SEPIC and buck boost converter	15	95	0.3	90

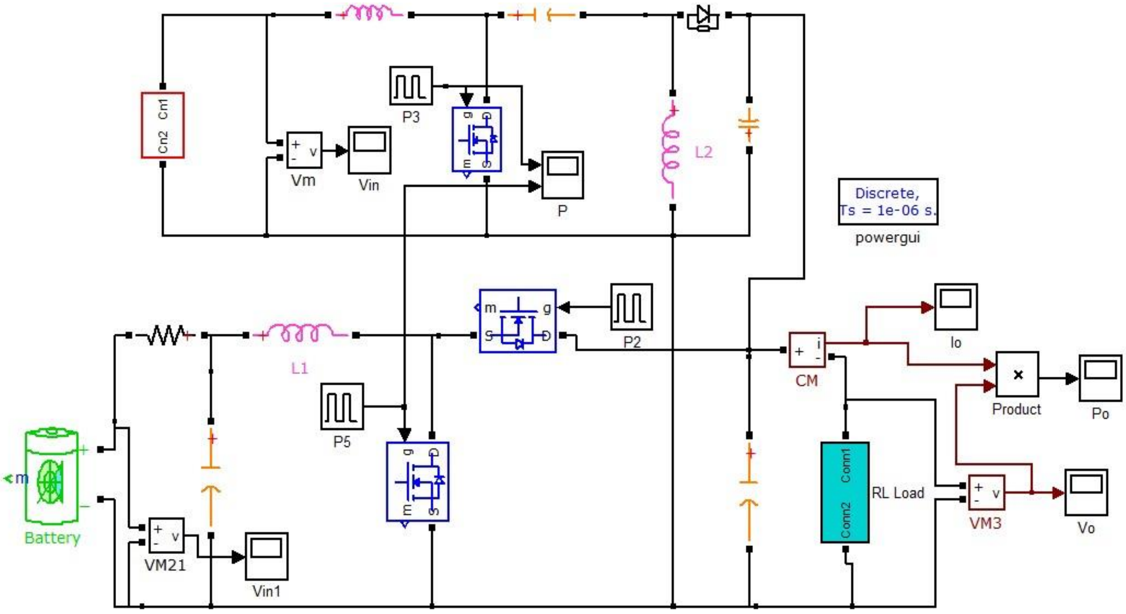

Figure 14. Circuit diagram of proposed converter with source disturbance for DC micro grid

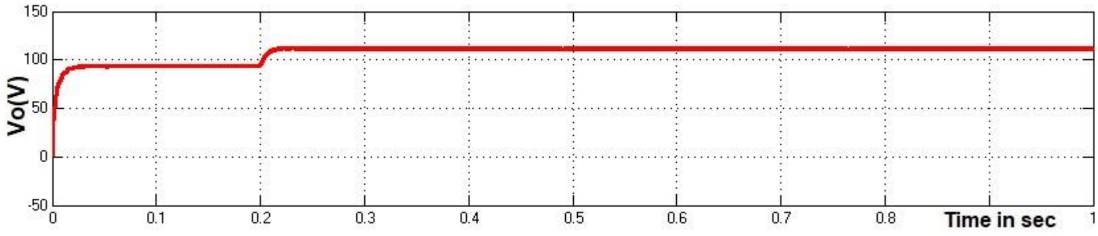

Figure 15. Voltage across RL-load of converter with source disturbance

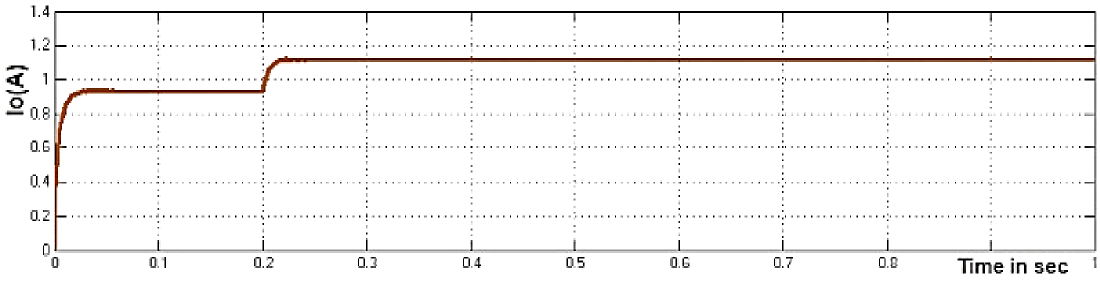

Figure 16. Current through RL-load of proposed converter with source disturbance

The circuit diagram of PI controlled proposed converter for DC micro grid is depicted in Figure 17 and its input voltage value is 19 V. Voltage across R-L load and current through RL-load of SEPIC and buck boost converter with PI controller are depicted in Figure 18 and Figure 19 respectively and its values are 100 V and 0.98 A. Output power is as shown in Figure 20 and its corresponding value is 99 W.

The Circuit diagram of PID controlled proposed converter for DC micro grid is depicted in Figure 21 and its input voltage value is 19 V. Voltage across R-L load and current through RL-load of proposed converter with PID controller are depicted in Figure 22 and Figure 23, and its values are 100 V and 0.98 A. Table 2 gives the comparison of time domain parameters for PI and PID controllers. Table 2 results show that PID controlled SEPIC and buck boost converter has the better performance.

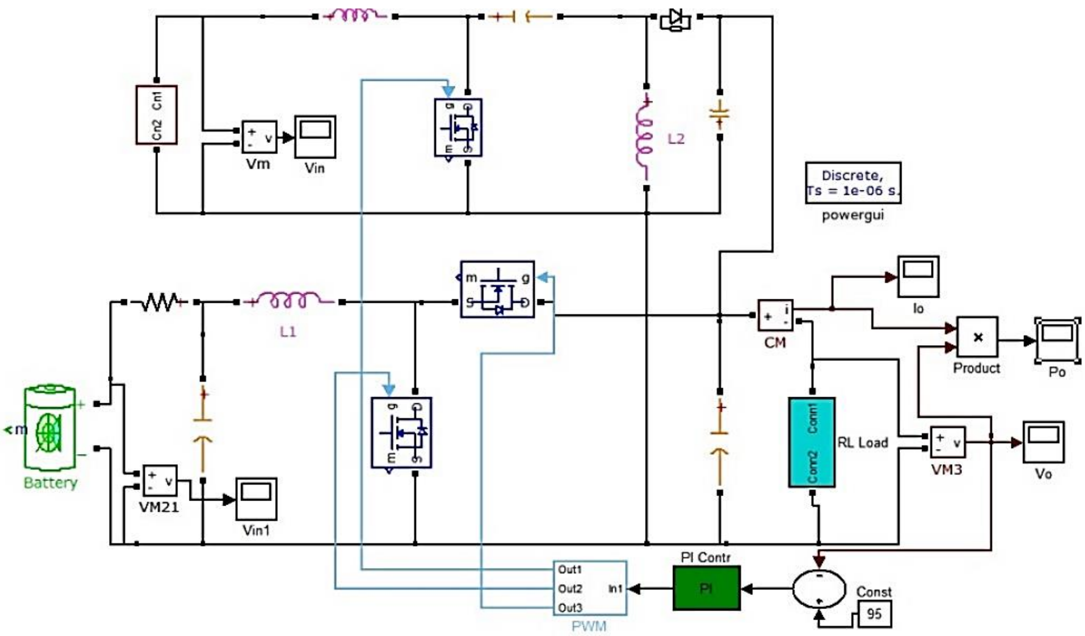

Figure 17. Circuit diagram of PI controlled proposed converter for DC microgrid

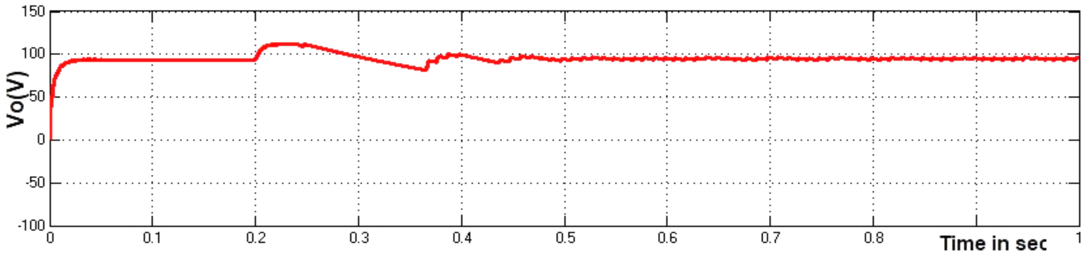

Figure 18. Voltage across R-L load of PI controlled proposed converter

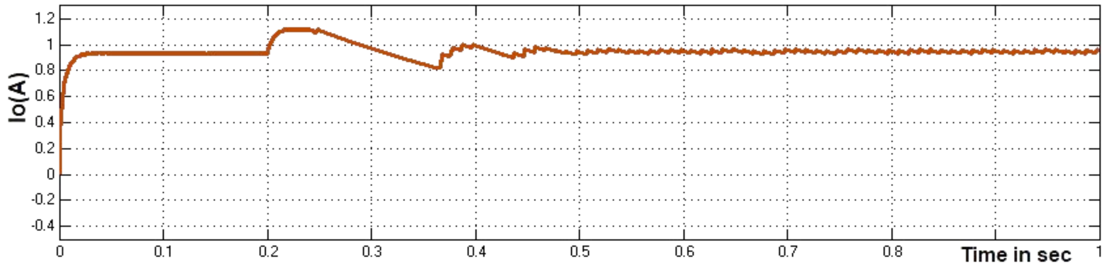

Figure 19. Current through R-L load of PI controlled proposed converter

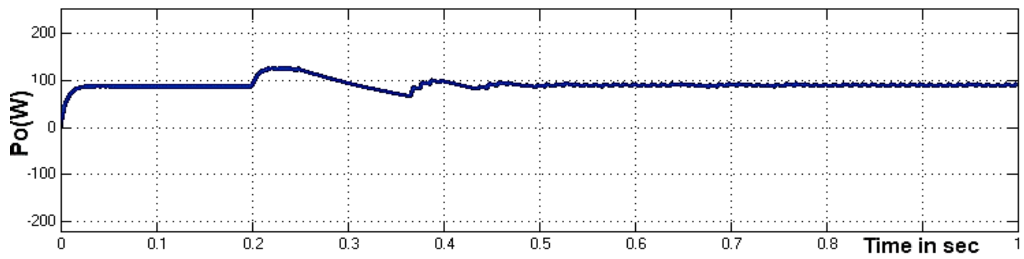

Figure 20. Output power of PI controlled proposed converter

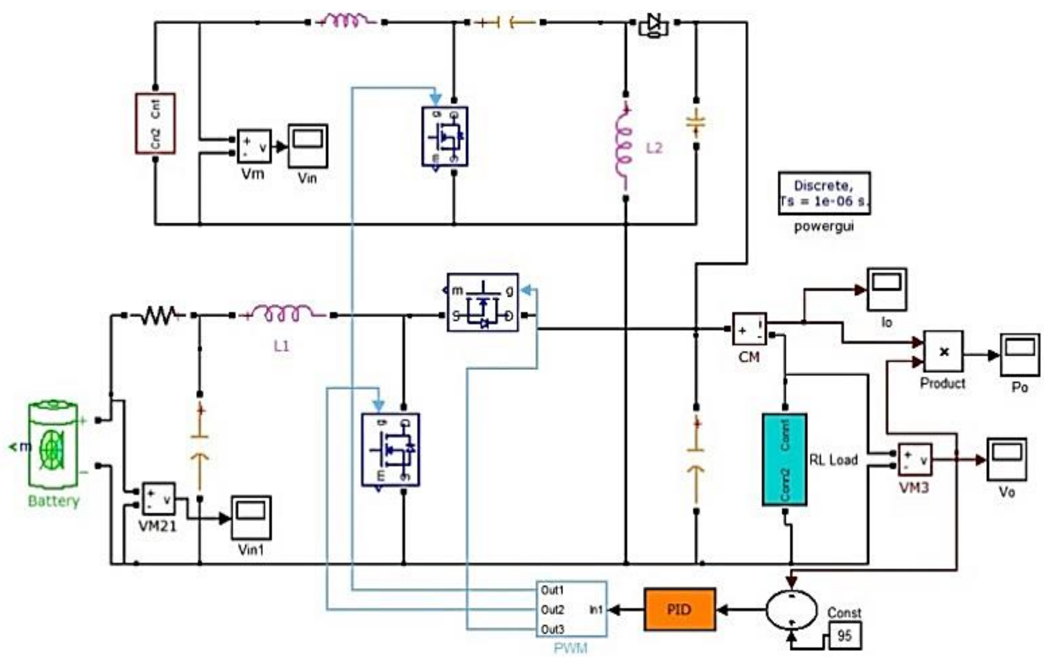

Figure 21. Circuit diagram of PID controlled proposed converter for DC micro grid

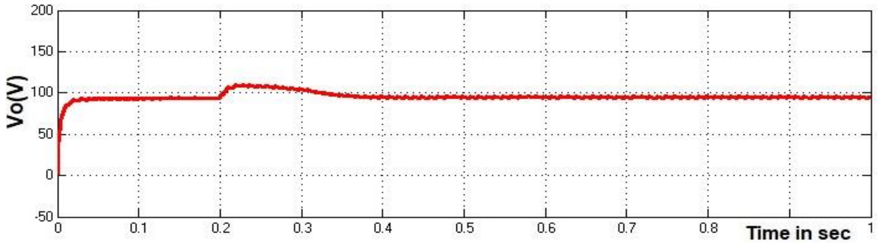

Figure 22. Voltage across PID controlled proposed converter

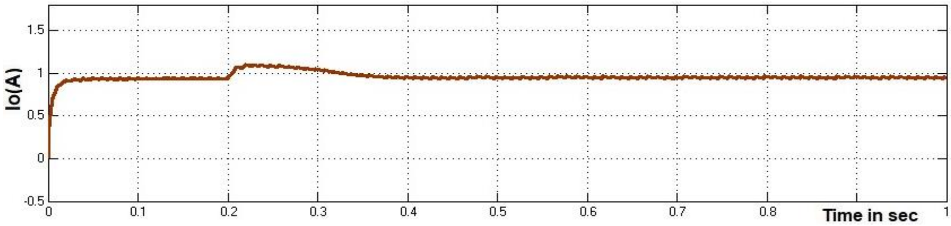

Figure 23. Current through R-L load of PID controlled proposed converter

Table 2. Comparison time domain parameters

Controllers	Tr(s)	Tp(s)	Ts(s)	Ess(v)
PI	0.22	0.26	0.50	1.8
PID	0.21	0.23	0.38	1.3

4. HARDWARE SYSTEM RESULTS

This section Explains the prototype model of the proposed converter for voltage regulation in the DC Microgrid. The hardware protype model of the proposed converter is depicted in Figure 24. The input voltage of the hardware implementation is shown in Figure 25. The output voltage of hardware implementation of SEPIC and buck boost converter are shown in Figure 26. The hardware prototype verifies the simulation results.

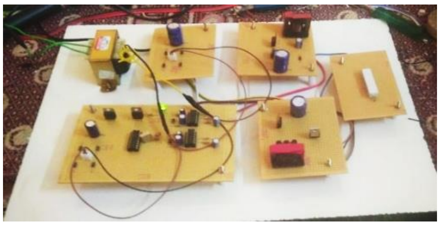

Figure 24. Hardware protype model of SEPIC and buck boost converter

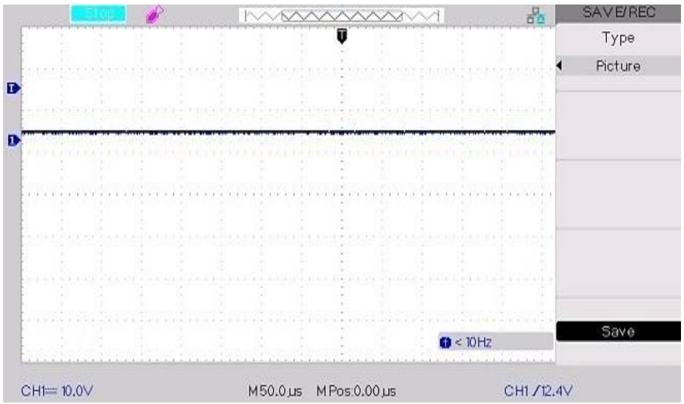

Figure 25. Input voltage of hardware implementation

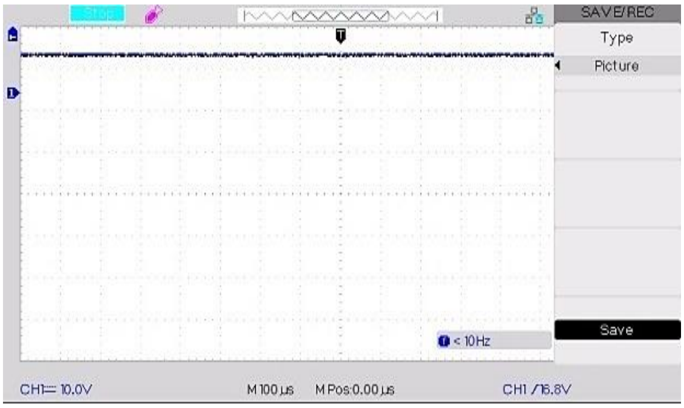

Figure 26. Output voltage of hardware implementation

5. CONCLUSION

The voltage regulation of DC microgrid system using PV and battery coupled SEPIC converter has been designed and simulated using MATLAB/Simulink. SEPIC converter is a DC-to-DC boost converter, it can produce non pulsating DC current with less ripples when compared to buck and buck boost converters. Non pulsating DC current is the demanding condition required in MPPT applications and battery charging. Hence, SEPIC converter in DC micro grid is superior to Buck boost converter in DC micro grid. Closed loop SEPIC converter with PI and PID controllers are simulated, and the comparison reveals that PID controller has better time domain responses in comparison with PI controller. Hence, a closed loop DC micro grid-based SEPIC converter with PID controller is superior to closed loop DC micro grid based SEPIC converter with PI controller.

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