International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-8 Issue-4, November 2019

Voltage Regulation in Microcontroller fed Bidirectional Converter Based on Genetic Algorithm using PV

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Abstract: ***The grid connected Bi-directional Converter based on Photo-Voltaic (PV) uses a genetic algorithm (GA) to reduce the settling time of DC link voltage, and to increase voltage gain. The BDC meets load demand and regulates the energy flow from various sources. Problems in the existing system have Total Harmonic Distortion (THD), DC link voltage and its settling time is high. This paper presents a microcontroller based voltage regulation in bidirectional converter using solar power generation. The solar, battery and grid has used to generate the power, to improve output power quality, a Sliding Mode Controller (SMC) in the inverter is used. To improve the voltage regulation operation using genetic algorithm based PID controller. The bidirectional converter and inverter utilize solar, battery and grid power generation hybrid. The battery functions as a charge based on two-way converter operation and electricity generation modes. The power quality improvement in bidirectional converter has power factor correction, harmonics elimination and voltage regulation at AC mains. This paper proposes the analysis of genetic based PID control a process that effectively reduces the bidirectional converter harmonics; this aim is attained and shown in both MATLAB/Simulink and experimental results.***

Keywords: ***Bidirectional power flow; Genetic algorithm; Sliding Mode Control.***

I. INTRODUCTION

In recent days, in many countries there is demand for energy production, so renewable energy consumption is increased to satisfy the requirements [1]. Population growth in urban areas is increasing and environmental problems are also high. The production of hybrid power is ideal for meeting demand. The clean power source is the generation of PV and the energy supply is battery [2]. In [3-4] solar power is generated and transferred through a bidirectional converter to the grid. The solar produces electricity and is distributed to the grid system during the day. The battery is used during the night without the sun to generate electricity and transport to the mains. Increase the uses of bidirectional converter, such as electric vehicles, houses and grids [5] [6].

The transformer uses bi-directional action in the existing converter and also increases and decreases voltage with a fuzzy control. Various transformer switches lead to higher cost and failure of switching. In [7-8] used to achieve high voltage ratio, fly back converters also require a transformer to increase the voltage gain. It is highly complex and less effective. If solar is not available the battery is used and even stores electricity from the grid if the opposite direction is used. In electric vehicle application the bidirectional converter has been used in power flow direction [9]-[11]. This BDC converter works as a buck as well as a boost. The converter increases the forward voltage and reverses the opposite direction of the reverse operation. In [12-14] PI and Fuzzy controller in BDC has high settling time. In [15] SMC is performed in a 3ϕ, converting the DC to AC. Inverter current and THD control, existing MPCs are used and are high compared with SMCs. The grid-connected power converter transfers the power from source to load.

The proposed method involves the bidirectional converter based on grid system using genetic PID control. The main objective is to regulate the voltage of the DC link using an advanced control method. When the reverse energy flow grid is used to supply the PV and the battery acts as source in the reverse direction. The power of the battery is used when PV, wind and grid are required for some other operation. The genetic algorithm-based PID regulation improves voltage gain and reduces settling time. The SMC have been developed to lower harmonics in inverter current.

This paper is organized as follows. Photovoltaic and bidirectional converter has explained in Section 2. In section 3 describes the control system of genetic algorithm based PID and SMC is used in inverter side. Simulation results and evaluation of power flow between battery and grid are illustrated in Section 4. In section 5 shows the experimental results and discussion. Conclusions of the proposed bidirectional converter fed grid system are given in section 6.

II. MATERIALS AND METHODS

Fig. 1 represents the proposed grid connected system. To increase the voltage gain and DC link voltage settling time using GA based PID.

Manuscript published on January 30, 2020.
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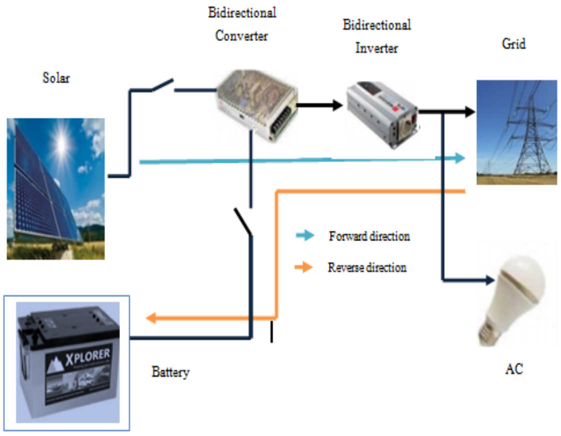

Fig. 1. Proposed Grid Connected System

A. Photovoltaic Power Generation

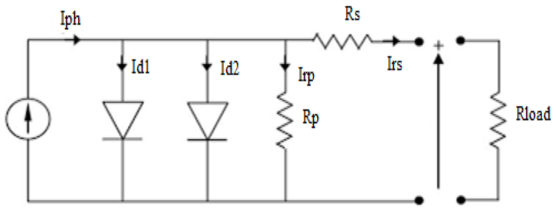

Fig. 2.Two diode PV cell equivalent circuit

Fig.2. shows the two diode model PV equivalent circuit. The simulation of two diode photovoltaic will generate PV and VI curves with different irradiation and resistance values. The expression of non ideal single and two diode of PV cell in below equation.

$$I = I_{photo} - I_{series}\left(\exp\frac{V + R_{series}I}{V_t} - 1\right) - \frac{V + R_{series}I}{R_{shunt}} \quad (1)$$

$$I = I_{Photo} - I_{Diode1} - I_{Diode2} - I_{shunt} \quad (2)$$

$$I_{Photo} = I_{ShrtCrt} + K_I\left(T_{Cell} - T_{ref}\right)G \quad (3)$$

$$I_{Diode1} = I_{01}\left[e^{\left(\frac{V+IR_S}{\alpha 1 V_T}\right)} - 1\right] \quad (4)$$

$$I_{Diode2} = I_{02}\left[e^{\left(\frac{V+IR_S}{\alpha 2 V_T}\right)} - 1\right] \quad (5)$$

$$I_{Shunt} = \frac{V + IR_S}{R_p} \quad (6)$$

Input voltage and power is decoupled by increased current and voltage stress. PV is developed with a passive capacitive filter. Use of electronic power equipment, namely UPS, transmitter, Air Conditioner (AC), etc. connected to the contact point is enhanced. Non-linear load increases device harmonics and losses. The transformer and shunt capacitor load, heating effect will be affected. Shunt active filter connected to the inverter will remove the harmonics. In intermittent energy resource the two diode PV cells have more accurate characteristics. Power electronics converters are used for maintaining voltage and current on the load side and for controlling the power flow in a micro grid.

B. Bidirectional Converter

The bidirectional converter is a Buck boost converter, based upon the switch configuration in both front and reverse directions. The circuit of BDC is displayed in Fig. 3. The switch design is based on the switch which uses the genetic algorithm based PID control to control the voltage of the BDC converter over the output. The bidirectional application is the industrial, electric, auxiliary, battery charging and discharge converters in UPS.

Photovoltaic or battery in forward drive mode is used as a source and power supply to bidirectional converters.

The grid is used to generate the power supplied to the battery in the reverse conduction mode. The 3ϕ inverter is operated with a buck converter and a converter that acts as a buck converter. The battery has increased the state of charge (SOC) and the battery is charged for further use.

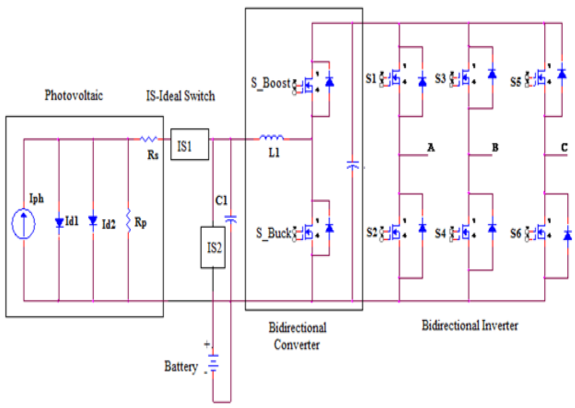

Fig. 3. Circuit diagram of BDC fed 3ϕ inverter

III. METHODS OF CONTROL SYSTEM

The PID control based on genetic algorithms has been used in the proposed grid connected photovoltaic bi-directional converter. Bidirectional inverter has controlled by using the SMC for improve the efficiency. Utilization of optimization technique the characteristic of PID control is evaluated easily.

A. PID Controller

The steady state error has decreased and enhances the dynamic performance by using the PID controller. The transfer function of the PID controller is in equ 7,

$$C(S) = k_p + \left[k_i \int \left(v_{ref} - v_{act}\right)dt\right] + k_d \frac{d\left(v_{ref} - v_{act}\right)}{dt} \quad (7)$$

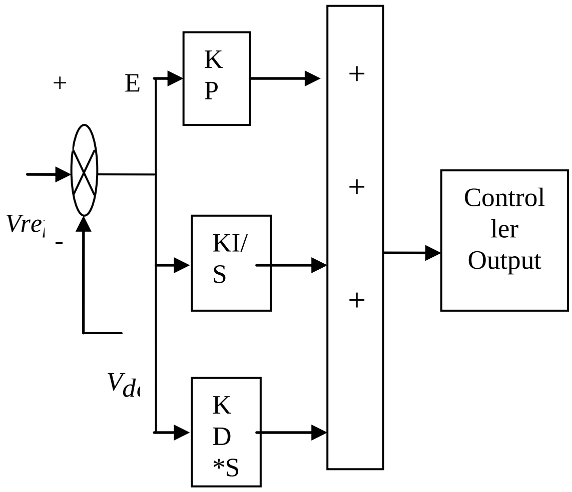

Fig. 4.PID Controller Block

Block diagram of PID controller is displayed in Fig.4. The DC link voltage is regulated and oscillation decreases. The integral and proportional control removes the offset by lagging the device and neglects the delay.

B. Genetic Algorithm

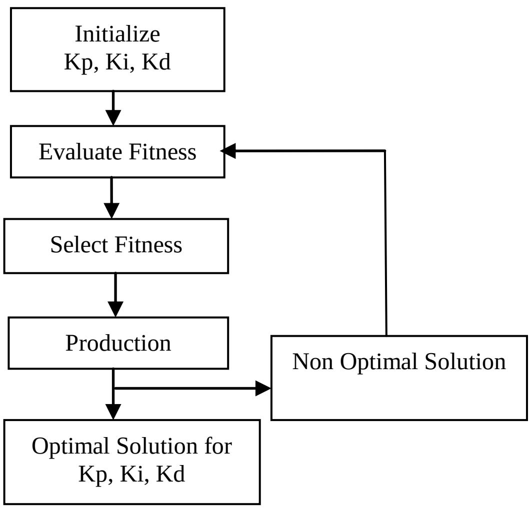

Fig. 5.Flowchart of Genetic algorithm

In industrial application the genetic algorithm has used to eliminate the manual tuning of kp, ki and kd of PID controller and it generates the value of kp, ki and kd. In genetic algorithm has enhance the performance of computational system and they operate with no knowledge of correct solution and it depends on the response from the evolutionary operator such as reproduction, cross over and mutation. This algorithm is search and optimization method by the natural selection and genetics. It solves many prospective problems by the genetic operator such as cross over and mutation.

In genetic algorithm the problem is analyzed and initiates the population, measure and evaluates fitness, select the fitness member of the population, production and finally give an optimum solution. Fig. 5 shows the block diagram of genetic algorithm.

C. Sliding Mode Controller

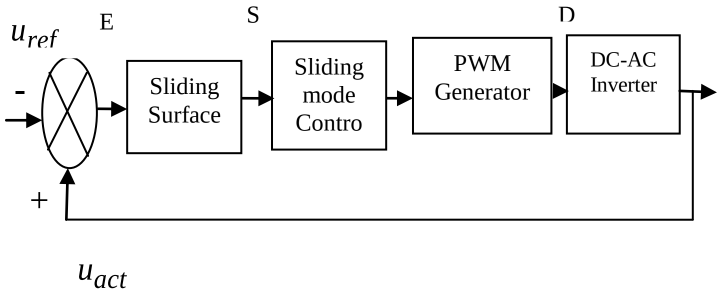

Fig. 6. Block Diagram of SMC

SMC was used in grid-connected BDC inverters to reduce the overall harmonic distortion in inverter current. The sliding mode controller block diagram in the Fig. 6 is shown. Errors are measured and the difference of inverter and reference voltage determined. The SMC must reduce the steady status error because the converter has kept the frequency constant. The error changes the actual voltage of the inverter and the reference voltage. The selected sliding surface S is equated and duty cycle of the SMC is in equ 8, 9, 10. The simulation parameters are given in table 1.

$$Error = Actual\ voltage - reference\ voltage \tag{8}$$

$$S = C \cdot Error + \dot{Error} \tag{9}$$

$$D = \frac{1}{2}\left[1 + \frac{L_{ac}C_{ac}}{u_{dc}}\left(\ddot{u}_{ref} + \frac{\dot{u}_{act}}{R_L C_{ac}} + \frac{u_{act}}{L_{ac}C_{ac}} - C\,\dot{Error} - KS\right)\right] \tag{10}$$

Where

$Error$ - Tracking voltage of inverter output,

C - positive constant,

$\dot{Error}$ - Derivative of Error,

K - positive constant.

Table- I: Simulation Parameter

Parameter	Values
Stator Resistance (Rs)	0.7 ohms
Stator Inductance (Ls)	2.72mH
Rotor Speed	500 rpm
Flux Linkage	0.019099 V.s
Poles	4
Torque Constant	0.15279N.m/A
Stator Resistance (Rs)	0.7 ohms
Impedance source inductors (L_1, L_2, L_3)	0.1mH, 1mH, 1mH
Impedance source capacitors (C_1, C_2)	1000μF
DC-Link Voltage (V_{DC})	60v

IV. SIMULATION RESULTS

MATLAB / SIMULINK have been used to simulate the genetic PID control in a bidirectional grid conversion system used to generate photovoltaic power. The Simulink software is usedfor grid-based modeling, simulating and evaluating the performance of bidirectional networks. The SMC control system increases the performance of a bidirectional grid-connected converter.

Retrieval Number: E3122018520/2020©BEIESP
DOI:10.35940/ijrte.E3122.018520
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The simulation results were checked and shown according to: THD and voltage power. Fig. 7 shows the simulink circuit diagram of the proposed system. Simulink model of SMC is representing in fig.8.

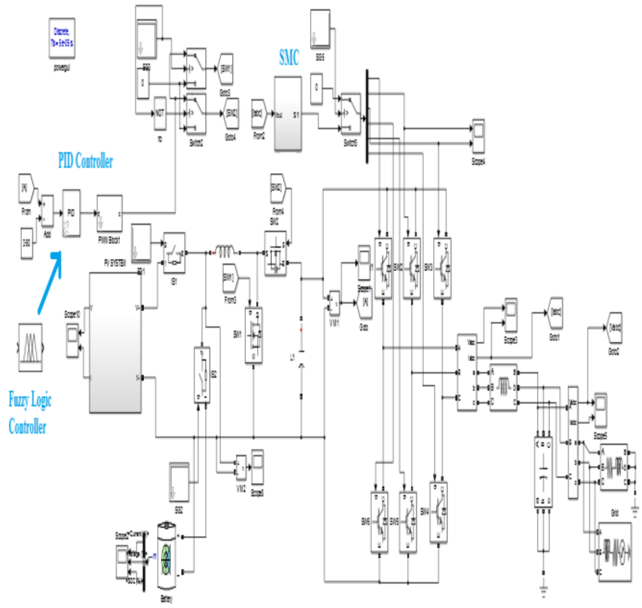

Fig. 7.Simulink Model of grid Connected BDC System

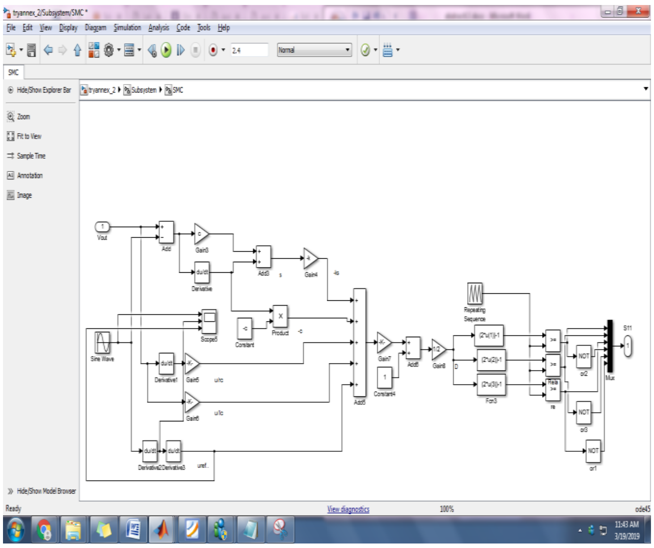

Fig. 8. Simulink Model of SMC

This BDC is designed with the PID controller based on genetics algorithm. Bidirectional converter voltage DC link voltage and Genetic PID control showed in fig 9. In the Fig.10 see the output current and voltage in the BDC. Fig.11 shows the THD of the grid-connected inverter. Table 2 shows the value of proposed PID genetic-based PID control DC-connected voltage and THD.

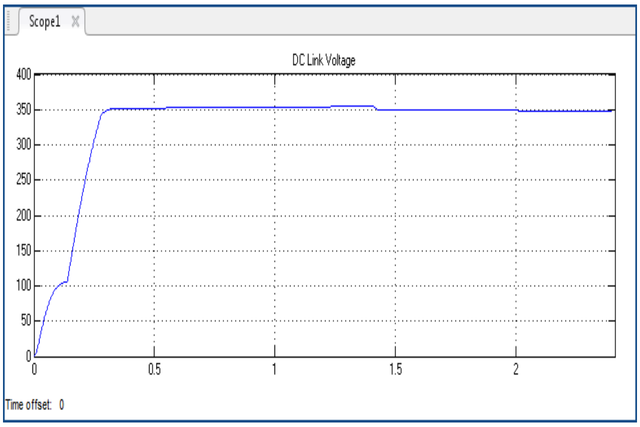

Fig. 9. DC Link Voltage of BDC using Genetic PID Control

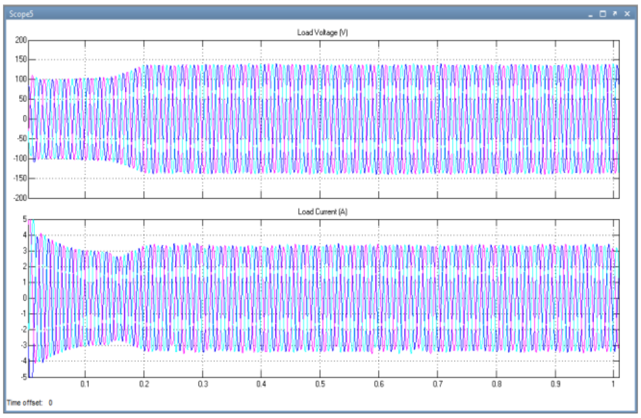

Fig. 10. 3ϕ **Grid Voltage and Current waveform**

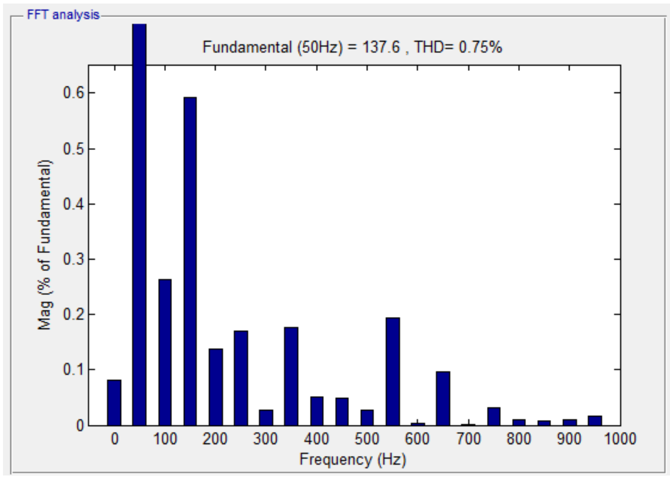

Fig. 11. %THD

Table- II: %THD, DC link of Genetic based PID Control

Parameter	Genetic Based PID control
DC Link Voltage (V)	350
THD (%)	0.75

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DOI:10.35940/ijrte.E3122.018520
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V. EXPERIMENTAL RESULT AND DISCUSSION

In this section the PV powered bidirectional converter and inverter fed grid system is shown in fig.12 is implemented in hardware for testing and establish of proposed method. Bidirectional inverter is controlled using PIC16F877A digital signal controller Platform and results are presented in this study. The three phase inverter circuit is implemented using power MOSFET IRF 840 and for driving these MOSFET's 8-pin opto coupler TLP-250 IC is used. Power from solar panel will charge a 12 V, 1.3 Ah batteries with the help of a charge controller and acts as a source of proposed circuit.

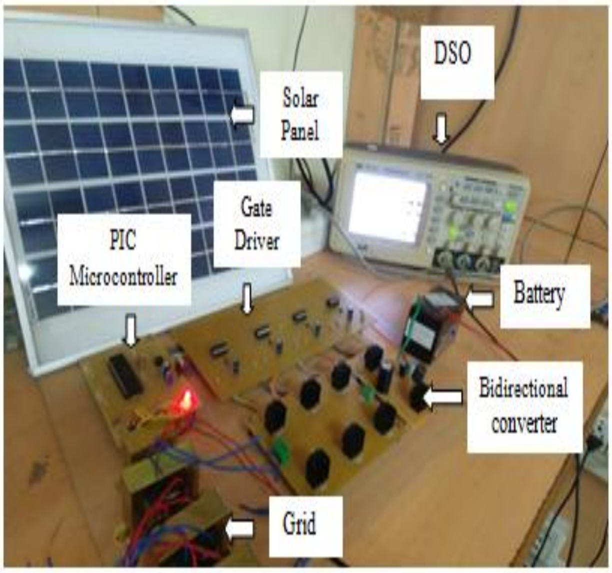

Fig. 12. Experimental setup

Fig.12 shows the experimental set-up of the proposed circuit. Fig. 13 represents the input voltage of the proposed circuit. The DC link voltage of the circuit during forward direction is shown in Fig. 14. Fig. 15 displays the output voltage of 3ϕ inverter.

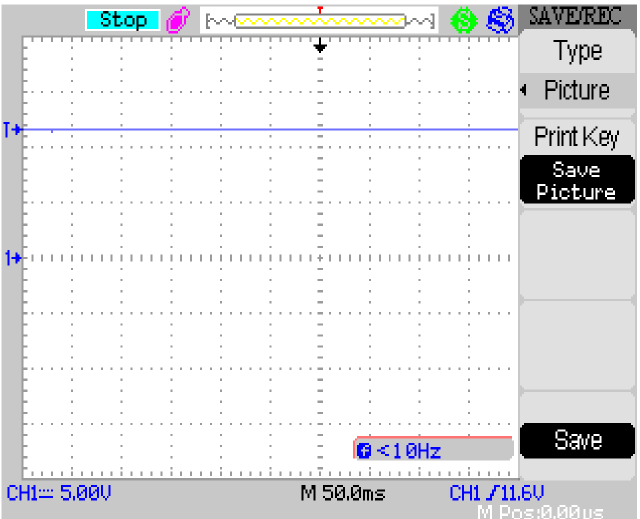

Fig. 13. Input Voltage of Proposed Circuit

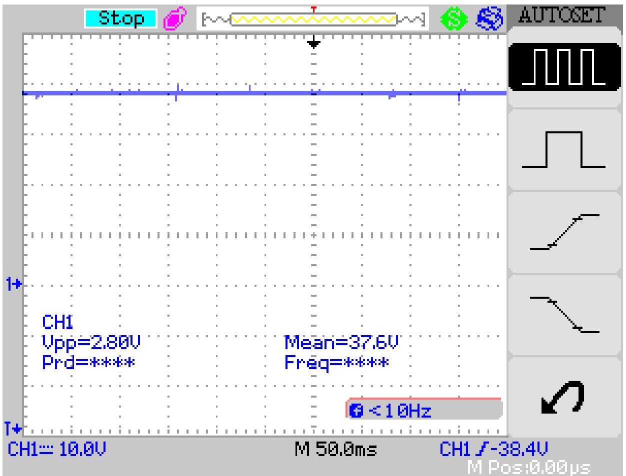

Fig. 14. DC link voltage during Forward Direction

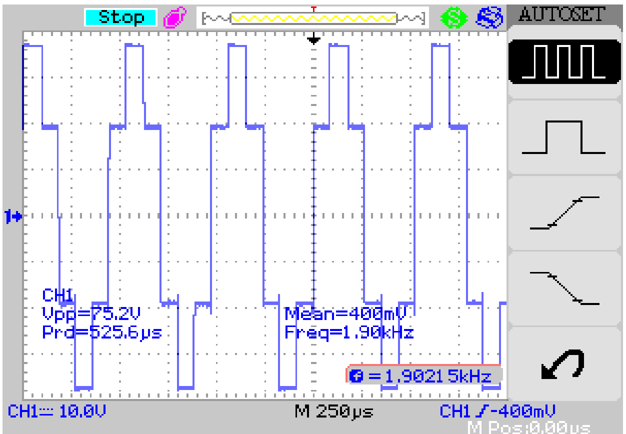

Fig. 15. Output voltage of Bidirectional Inverter

When a BDC converter operates, the grid has a source in the reverse direction and the net voltage is represents in Fig. 16. Fig. 17 represents the DC link voltage of bidirectional converter during reverse direction.

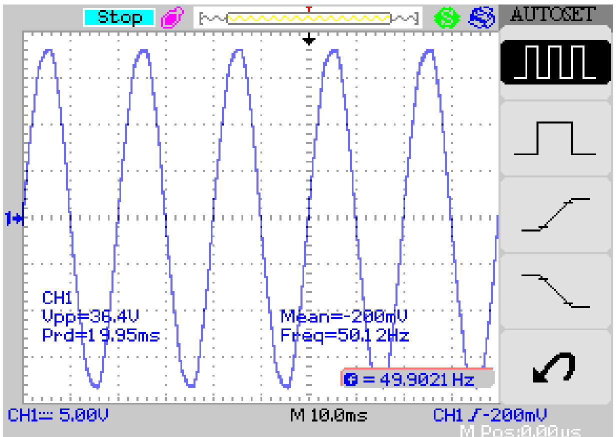

Fig. 16. Grid voltage

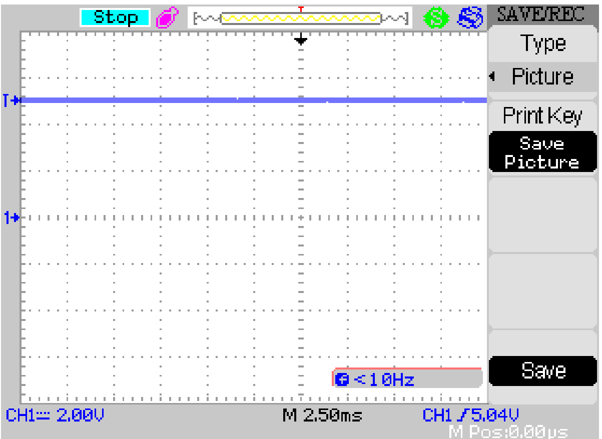

Fig. 17. Output voltage during buck mode

VI. CONCLUSION

A PID based Genetic Algorithm for voltage enhancement is used to decrease settling time, and the THD. The solar and battery are supplied to a bilateral converter and the bidirectional inverter using a genetic algorithm. Genetic based PID control for voltage control and voltage control is applied to converter control methods. The SMC has used the THD in the bi-directional inverter. The system is being analyzed in simulation and experimental results are designed using a microcontroller to generate the pulse and feed into a bidirectional converter with solar panel for power generation. In both reverse and forward power, the proposed bidirectional converter-feed grid system is controlled and tested both in terms of simulation and experimental results.

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