Improvement of Voltage Profile and Reduction of Losses INDC Micro Grid using Bus Voltage Control Method

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Abstract— The reduction of fossil energy and environmental concerns, accompanied by technical and economic reasons, gave rise to increase the interest in penetration of Distributed Generations (DG) which consists of renewable energy sources such as wind generator, Photo Voltaic (PV) generator and fuel cell. As the integration of DG, energy storage systems, e.g. battery, super capacitor and flywheel energy storage and novel loads such as heat pumps, electric vehicles, and the concept of the micro-grid was proposed for improving the utilization efficiency of renewable energy. In order to improve voltage profile and to reduce the switching frequency losses between Source and Load, DC bus voltage control method is proposed using MATLAB/SIMULINK software.

Keywords: DC Grid, voltage profile, micro grid, photovoltaic generators

I. Introduction

A developing country like India has more energy demand compared to other countries. Nowadays, most of the energy comes from fossil fuels such as coal, diesel, petrol and gas, which is 80% of our current energy production. This energy demand is expected to rise by almost half over the next two decades. Possibly this is causing some fear that our energy resources are starting to run down, which has very serious disturbing consequences on the global quality of life and global economy. This increasing demand of energy has two major impacts like energy crisis and climate changed. Also the greenhouse gas production related to energy increases due to rise in energy demand.

Globally it is a challenge to reduce the CO_2 emission and offer sustainable, clean and affordable energy. Energy saving is one of the best cost effective solution for the worldwide increasing energy demand but does not tackle perfectly till now. For that issue, renewable energy is a good option because it gives a green and clean energy free of CO_2 emission.

Renewable energy is defined as the energy that comes from resources which are naturally generated like sunlight, wind, rain, tides, waves and geothermal heat. In recent years, the development on alternative energy sources has become a global priority which giving rise to intensive research about these available renewable energy technologies such as Photovoltaic (PV), hydroelectric, wind, geothermal and tidal systems.

So due to the growing problem of environmental pollution and decrease of conventional energy sources, the utilization and research of the renewable energy sources, such as solar energy, wind energy has concerned with more and more attention. And among all renewable energy resources solar power is very much popular for its environmental-friendly features and plug-N-play operation. Solar energy has become a promising, popular and alternative source because of its advantages such as abundance, pollution free, renewability and maintenance free. PV system requires less maintenance as compared to wind, hydroelectric and tidal systems because all these systems require rotating instrument for energy conversion which is not required for conversion of solar energy to electrical energy.

II. Voltage Droop Control

The block diagram of the voltage droop control scheme is shown in the Fig. 1. Each droop controller emulates an impedance behavior reducing the converter output voltage with the increase of the supplied current [5, 9]. This strategy promotes the current sharing between paralleled converters connected in the DC micro grid without the need of a central control. A low-pass filter is used to cut-off harmonic frequencies and fast oscillations of the DC bus voltage. Based on Fig. 1 it is possible to calculate P_{ref} as follows,

$$P_{ref} = G(s)\left[V_{ref} - \left(\frac{W_{LP}}{S+W_{LP}}\right)V_{dc}\right]V_{dc} \quad (1)$$

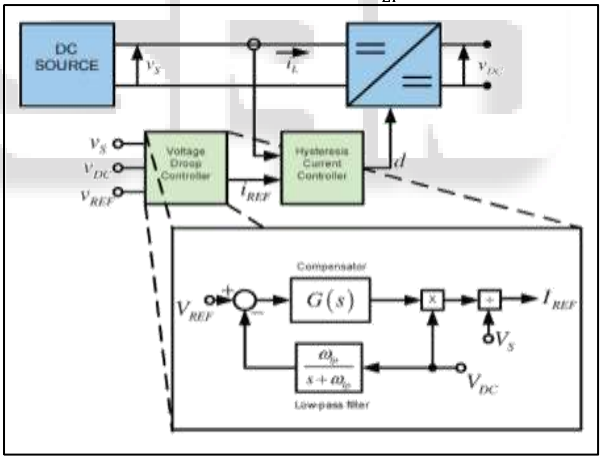

Fig. 1: Voltage control scheme of the DC-DC converter

Where G(s) is the transfer function of the compensator, V_{ref} is the reference voltage, ω_{LP} is the cut off frequency of the low pass filter, and V_{dc} is the DC grid voltage at the point of the converter coupling. From equation (1) the reference current for each converter can be calculated as follows,

$$Iref = \frac{P_{ref}}{V_s} \quad (2)$$

Where V_s is the voltage of the DC source.

III. Hysteresis Current Control for the Generation of Pulses

With a view to generate gate signals or pulses so as to turn on the MOSFET/IGBT, HHCC technique is exercised. The supreme utility of this control scheme is that it can be digitally implemented. Hysteresis controller incorporates a feedback loop which is nonlinear along with hysteresis comparator [6].

In this technique hysteresis comparator includes two levels: Lower Hysteresis Band (LHB) and Upper Hysteresis Band (UHB). These bands actuate the steady state error. The actual current and the reference current are compared so as to produce any error in the current. This error is then passed to the hysteresis comparator. If the error current reaches UHB, the under most switches are turned ON and the inductor current decrements thereby lessening the error current. In a similar way, if the error current reaches LHB the uppermost switches are turned ON and the inductor increments which regulate the current not beyond the limits. This process repeats. Switches work up ON and OFF randomly to trace the reference current and maintain the error current within pre-determined band width.

Here inputs are I_{ref} and I_L and after performing relational and logical operations we are collecting outputs in X1, X2, X3 and their complements are represented as cX1, cX2 and cX3, Fig. 2 shows the Simulink diagram of Hysteresis Current Control. The switching signals are obtained through logic reported below:

1) If $|I_{ref}| \leq \Delta I_L\_ripple$ the output X1 is one, otherwise cX1 $(X1)$ is zero.
2) If $I_{ref} <- \Delta I_L\_ripple$ the output X2 is one, otherwise cX2 $(X2)$ is zero.
3) If $I_{ref} > \Delta I_L\_ripple$ the output X3 is one, otherwise cX3 $(X3)$ is zero.

Therefore, the Table 1 truth table, representing the different situations for the inductor current, is obtained:

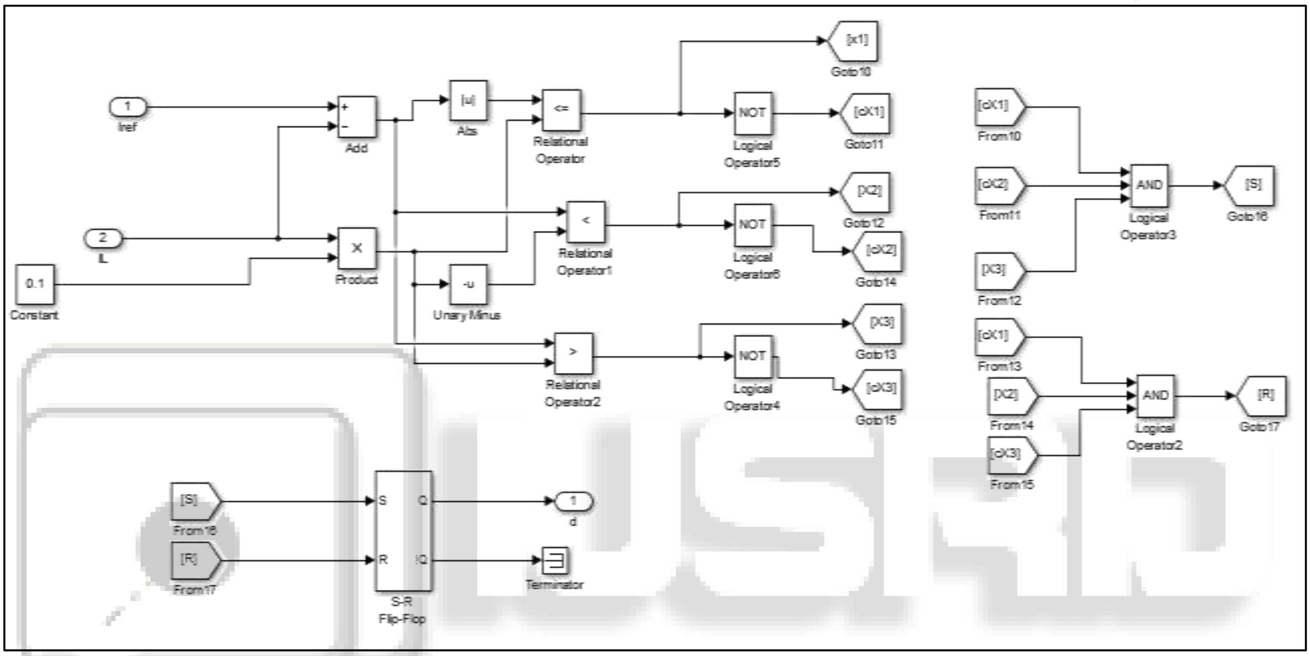

Fig. 2: Simulink Diagram of Hysteresis Current Control

X1	X2	X3	Converter configuration state (N=Not Possible, Y=Possible)
0	0	0	N
0	0	1	Y
0	1	0	Y
0	1	1	N
1	0	0	Y
1	0	1	N
1	1	0	N
1	1	1	N

Table 1: Truth table for inductor-current control

The hysteresis block compares two current signals. In this model the actual variation of the inductor current I_{ref} of the converter is compared with the maximum allowed ripple (10%) of the current of the inductor (ΔI_L_ripple) which represents the tolerance band around the reference value of the inductor current. The hysteresis is thus used to keep the actual variation of the inductor current within the tolerance band defined here by the ripple current. This means we have only three possible configuration for the inductor current. However, the last possible configuration (1 0 0) simply means that the actual inductor current variation is inside the inductor the tolerance band, and hence it does not need any control.

At the end only two states are possible and the input signals S and R for the flip-flop device can be calculated as:

$$S = \bar{X}_1 . \bar{X}_2 . X_3 \tag{3}$$

$$R = \bar{X}_1 . X_2 . \bar{X}_3 \tag{4}$$

S	R	Q	$\bar{Q}$
0	0	Q_{n-1}	$\bar{Q}_{n-1}$
0	1	0	1
1	0	1	0
1	1	0	0

Table 2: Truth table for the generation of gate signals through S-R flip-flop logic

From the Table 2, it is clear that the first inductor current state to control (0 0 1), will correspond to S=1 and R=0, and it leads to Q=1 and $\bar{Q}$=0. The second inductor current state to control (0 1 0) will correspond to S=0 and R=1, and it leads to Q=0 and $\bar{Q}$=1.

In this way the desired control signals Q and $\bar{Q}$ to the gate of the two switches can be generated in according to the different inductor current states. The pulses produced from S-R flip-flop that is Q is given to boost converter as a duty cycle. Based on this signal voltage is boosted and output of a boost converter is controlled.

IV. SIMULATION RESULTS

In order to verify the performance of the proposed model, numerous simulation and experimental case studies are carried out in this section using the MATLAB/Simulink R2017a Software package.

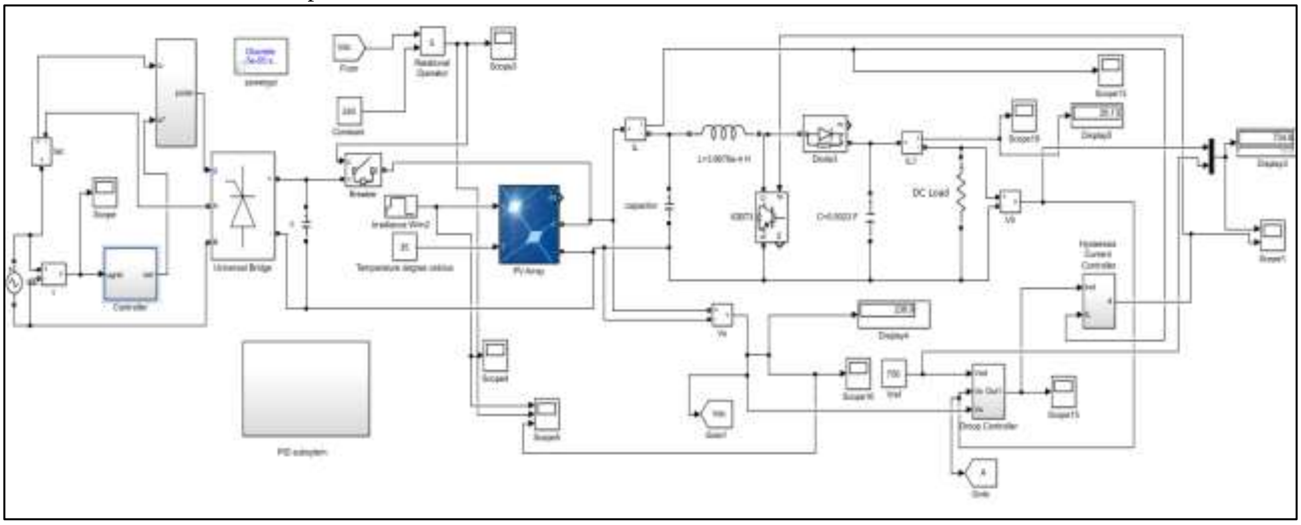

Fig. 3: Simulink DC micro grid model

Simulink DC micro grid model is shown in Fig. 3 which consists of both the modes Grid connected Mode and Islanded mode. A breaker is used to switch the Islanded mode and Grid connected mode. Input voltage given to the boost converter is compared with a constant voltage of 240 V, if the voltage produced from PV array is greater than or equal to 240 V breaker opens and Grid is operated in Islanded mode, otherwise in Grid connected mode.

Circuit from Boost Converter is common to both the modes, it consists of Droop controller and Hysteresis current controller. Hysteresis current control consists of relational operators, Gates and S-R flip-flop. Droop controller consists of Proportional Integral Controller and Low Pass Filter. A PV system and utility Grid system is constructed with the configuration and parameters listed in the Table 3.

S.NO	Parameters	Value
1	Input from utility grid	230 V
2	Reference Voltage	750 V
3	Load	20 kW

Table 3: Parameters of the PV and Utility Grid System

In Islanded mode PV array is operated. Irradiance of 1000 W/m^2 is maintained throughout the Simulink. The output of the boost converter is 732.1 at 0.1 sec. The output from the PV array is shown in the Fig. 4.

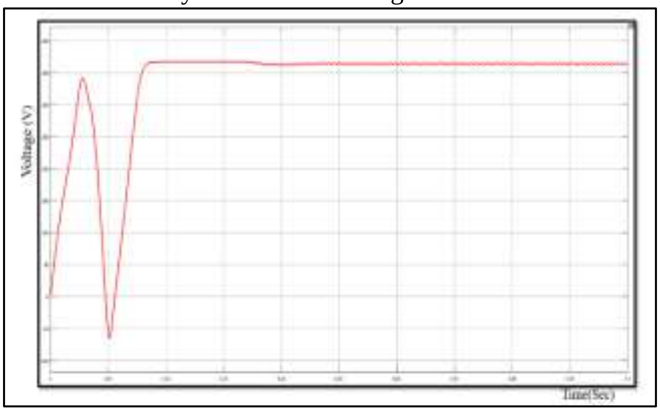

Fig. 4: Output of the PV array

This input is given to boost converter the output of boost converter and source voltage and reference voltage is given to droop controller, the output taken from the droop controller is reference current. Fig.5 shows the inductor current and reference currents.

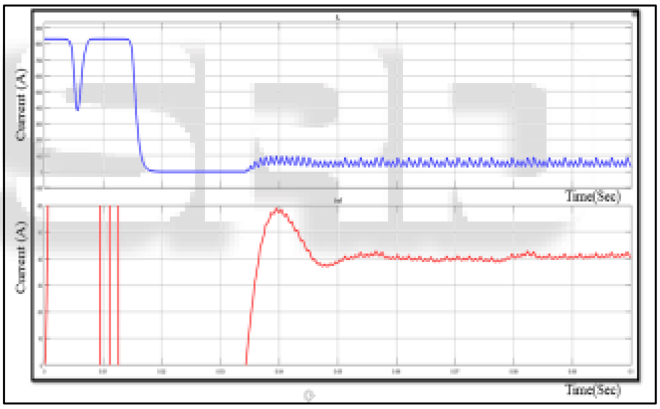

Fig. 5: Inductor current and Reference current

In the Hysteresis current control block both the currents I_{ref} and I_{L_ripple} is compared as $|I_{ref}| \leq \Delta I_L\_ripple$ and the output is shown in the Fig. 6.

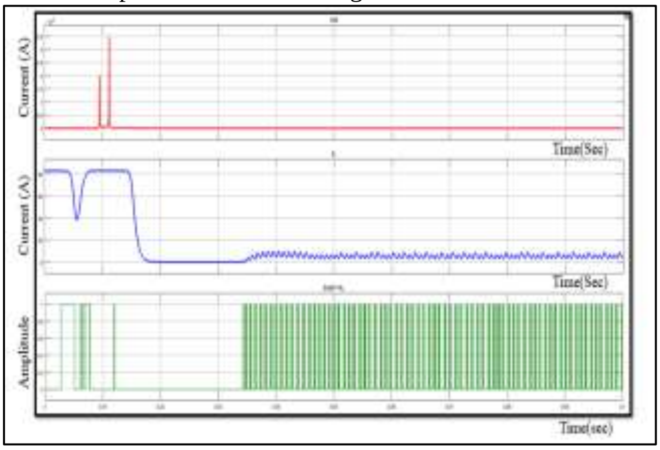

Fig. 6: Output of $|I_{ref}| \leq \Delta I_L\_ripple$

The currents I_{ref} and I_{L_ripple} is compared as $I_{ref} < -\Delta I_L\_ripple$ and the output is shown in Fig. 7.

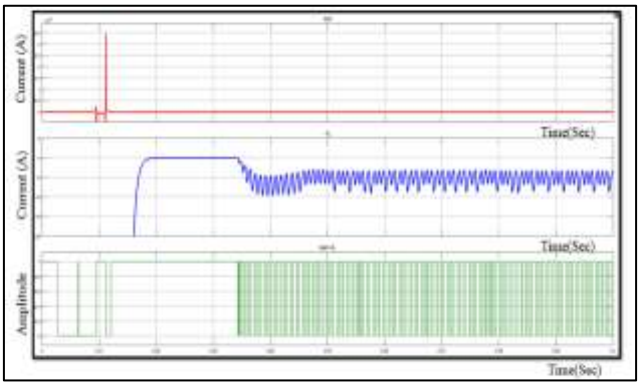

Fig. 7 Output of $I_{ref} < -\Delta I_L\_ripple$

The currents I_{ref} and I_{L_ripple} is compared as $I_{ref} > \Delta I_L\_ripple$ and the output is shown in Fig. 8.

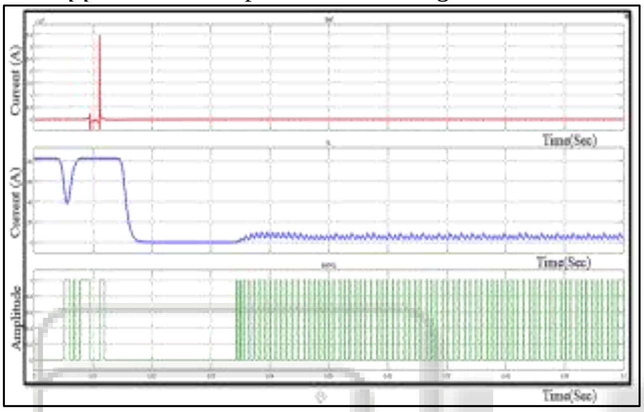

Fig. 8 Output of $I_{ref} > \Delta I_L\_ripple$

Product of cX_1, cX_2 and X_3 is shown in Fig. 9.

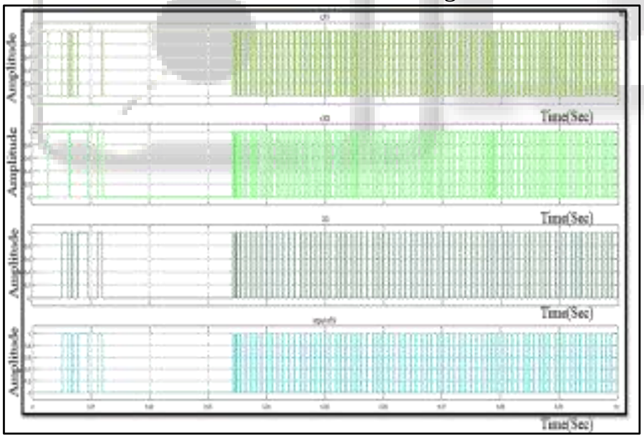

Fig. 9 Input to $S = \bar{X}_1.\bar{X}_2.X_3$

The product of cX_1, X_2 and cX_3 is shown in Fig. 10.

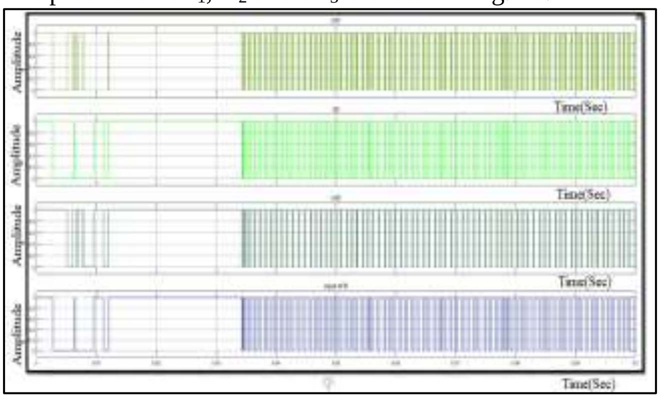

Fig. 10 Input to $R = \bar{X}_1.X_2.\bar{X}_3$

The output of S-R flip flop is shown in the Fig. 11.

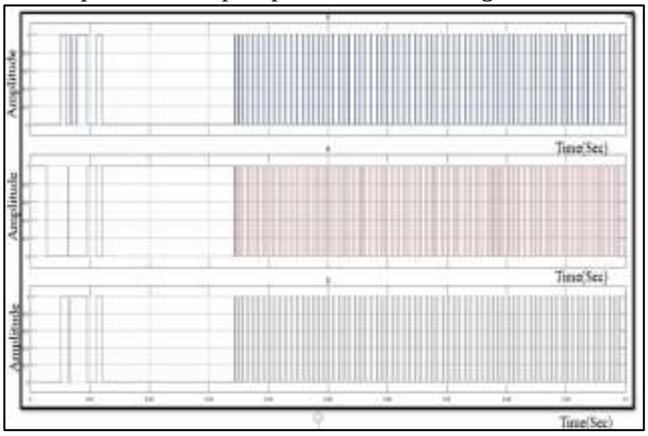

Fig. 11: Output of S-R Flip Flop

Output voltage and Duty cycle for islanded mode is shown in Fig. 12.

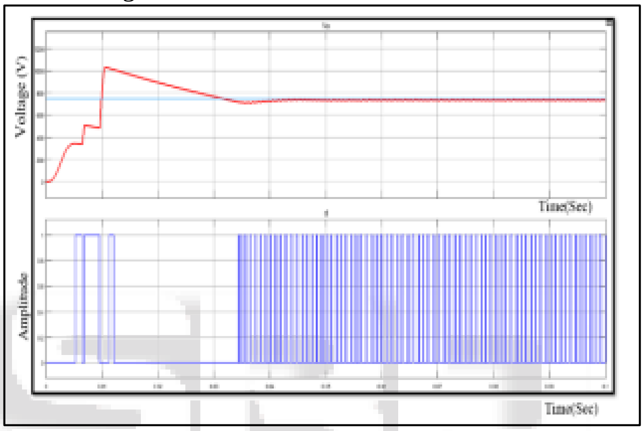

Fig. 12: Voltage waveform of the boost converter and Duty cycle for Islanded mode

In Grid connected mode AC generator is operated with an input voltage of 230 V which is given to the inverter bridge. Input to the universal bridge is shown in Fig. 13.

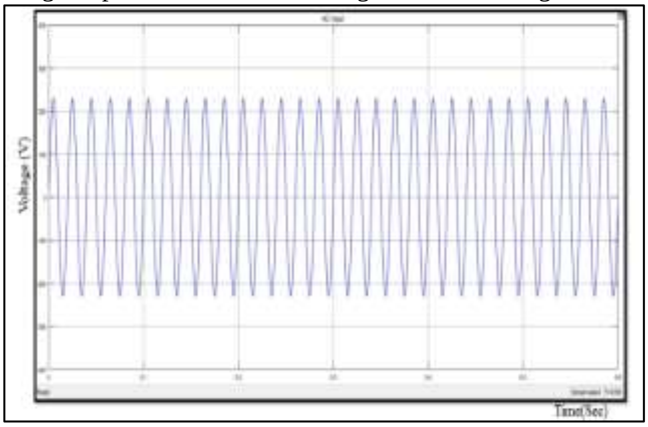

Fig. 13: Input to the Universal Bridge

Universal bridge converts AC voltage into DC voltage with the help of Pulse width modulator. This DC output voltage is given to boost converter and the overall output from the model is shown in Fig. 14.

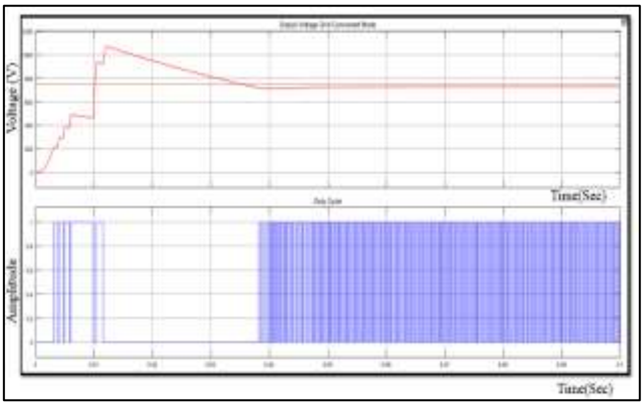

Fig. 14: Output voltage and Duty cycle of Grid connected mode

V. CONCLUSION

This work presented MATLAB simulation results of a DC Micro grid with bus voltage control method. Mathematical modelling of Boost converter is presented. Two types of compensators, with voltage droop, were investigated. The P-controller exhibited a faster response while the PI showed a better power regulation and a zero steady state error. The voltage droop method demonstrated to be a good strategy to share the currents between different converters without the need of a central controller. Hysteresis current controller reduces the switching frequency losses and losses in DC can be reduced by selecting the cable rating more than the maximum current rating. Voltage profile is improved by using current as a feedback parameter both in Islanded and Grid connected modes. If a DC micro grid is extended and another energy storage system is included, it would require a communication line to obtain state information and detect faults.

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