Single Phase Bidirectional PWM Converter for Microgrid System

C.Kalavalli[#1], K.ParkaviKathirvelu[*2], R.Balasubramanian[#3]
Department of Electrical & Electronics Engineering, SASTRA UNIVERSITY
Tirumalaisamudram, Thanjavur – 613 401, INDIA
[1]kalavallichn@gmail.com
[2]to_Parkavi@eee.sastra.edu
Department of Electrical & Electronics Engineering, SASTRA UNIVERSITY
Tirumalaisamudram, Thanjavur – 613 401
[3]rbalu@eee.sastra.edu

***Abstract*—Smart grid is a newly flourishing research area because of its viable applications and expected to address the drawback of existing grid. Microgrids are the part of the Smart grid and they are designed to supply electricity for a small community such as residential areas, universities or industrial sites. Power electronics plays a vital role for connecting the renewable energy sources to Microgrid system. This paper deals the Microgrid connected single phase Bidirectional PWM converter which operates in Rectification and Inverting mode. This converter helps to connect renewable energy sources to loads as well as excess power are given to power grid. Double Loop PID control technique is used for controlling the converter for both modes. The designed Converter is simulated in MATLAB/Simulink software and results are verified using the Hardware.**

Keyword —Renewable energy resources, Microgrid, PWM, Bidirectional converter, PID

I. INTRODUCTION

The existing electricity grid converts only one-third of fuel into electricity and 8% of its output is wasted across the transmission lines. Smart grid technology basically derived from traditional power grid with some additional features such as reliability, efficiency and sustainability [1]-[2]. The conventional methods of power generation are burning of fossil fuels which affect the environment, causing an increase in greenhouse gas emissions that leads to global warming. Even though these methods of generations have exceptional scale of economy, it transmits power over long distances [3]. As a result, it has turn into the driving force for the growing interest in alternative energy. Distributed generation is one approach to the manufacture and transmission of electric power. In this generation the power is generated locally (near load) hence the transmission loss is reduced and size and number of power line is also reduced. Therefore Microgrid is an accepted concept that consists of generating units and storage elements and uses the naturally available distributed energy resources such as solar, wind, fuel cell etc., [2].

II. MICROGRID

Fig.1 describes the simple diagram of Microgrid system. Microgrid consists of Distributed generation (DG) resources and interconnected loads. It is a small independent power grid and can be viewed as the building block of Smart grid. It can be operated in parallel with the grid or independently provide power to the load.

Single phase Bidirectional PWM converter is an important component in Microgrid system that connects ac and dc subsystem [1]. It has to operate in Inverter mode as well as Rectifier mode by utilizing dc and ac renewable energy sources [4]-[5]. The Double loop PID control is proposed for controlling the converter. Inner current loop is common for both modes to regulate inductor current and outer voltage loop is separately designed for each mode to regulate ac and dc voltage.

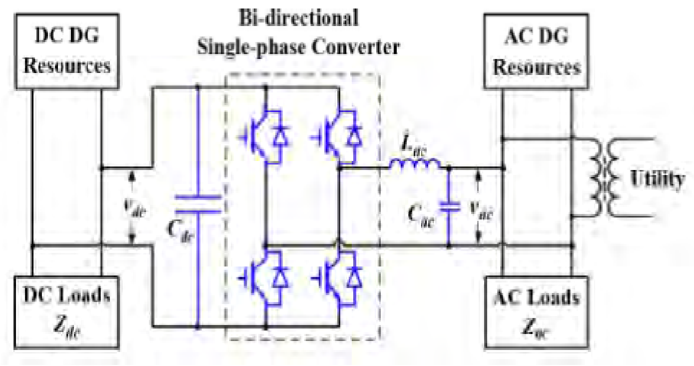

Fig.1. Microgrid System

The bidirectional converter should operate in the following modes:

1) *Inverter Mode*

If the dc side renewable energy is available converter operates as the inverter feeding power to the ac loads and dc loads directly get power from renewable energy sources. In this mode the converter act as a full bridge inverter and LC filter is used to get the sinusoidal output.

2) Rectifier Mode

If the dc side renewable energy is not available converter operates as the rectifier feeding power to dc loads and ac side renewable energy resources provide power to ac loads. In this mode the converter act as a rectifier and provide dc output with less ripple factor by using filter capacitor C_{dc}.

III. CONTROL SYSTEM DESIGN

In recent years many control strategies have been developed for example hysteresis and predictive control (current control),fuzzy logic, sliding mode ,repetitive control and neural network (voltage control).In this methods each mode requires different control strategy which results difficulty in control system design and over all reliability of the system is reduced. Therefore the Double loop PID control is proposed because of simple design, easy implementation and excellent performance.

Before designing the control system, converter has to be modeled. The Average model of the full bridge inverter is given by the following equation (1) & (2),

$$L_{ac}\frac{di_{ac}}{dt} = V_{ab} - V_{ac} \quad \text{-----------} \ (1)$$

$$C_{ac}\frac{dv_{ac}}{dt} = i_{ac} - \frac{V_{ac}}{Z_{ac}} \quad \text{-----------} \ (2)$$

Since the double loop control is used, the current loop is used to regulate the inductor current and the voltage loop is used to regulate ac and dc voltage. The current and voltage loop is designed separately. Transfer function for current and voltage loop can be obtained from the average model given by the equation (1) & (2).

Transfer function for common inner current loop,

$$\frac{i_{ac}}{v_{dc}} = \frac{1+SZ_{ac}C_{ac}}{S^2L_{ac}Z_{ac}C_{ac}+SL_{ac}+Z_{ac}}$$

Transfer function for outer voltage loop,

Inverter Mode

$$\frac{V_{ac}}{i_{ac}} = \frac{Z_{ac}}{1+SZ_{ac}C_{ac}}$$

Rectifier Mode

$$\frac{V_{dc}}{i_{dc}} = \frac{Z_{dc}}{1+SZ_{dc}C_{dc}}$$

The desired output for a closed loop system is obtained by tuning PID gain values to the system inherent condition. Several methods are used to tune the PID controller in which Ziegler- Nicholas method is commonly used.

IV. SIMULATION

In this paper the control system is designed and simulated using MATLAB/simulink. This table listed below gives the considered simulation parameters.

Input voltage V_{dc}	230V
V_{rms}	230V
Ac Filter Inductor	100mH
Ac Filter Capacitor	40µF
Dc Filter Inductor	500mH
Dc Filter capacitor	1000µF
Linear load	1000Ω
Switching frequency	25kHz
Voltage sensor gain	0.01(Inv) 0.03(Rec)
Current sensor gain	0.06

TABLE.1 SIMULATION PARAMETERS

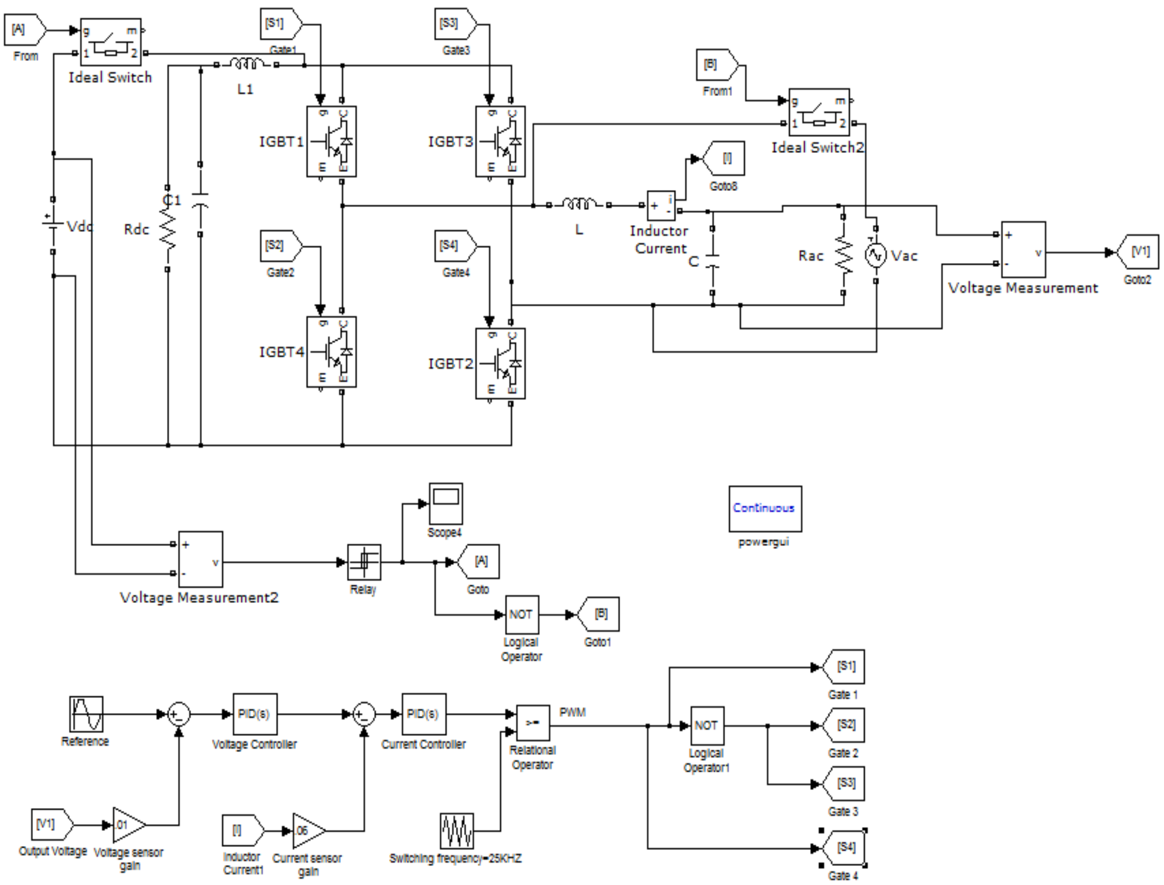

Fig.2. Simulink model for Bidirectional converter in Inverter mode

The MATLAB/simulink model for Bidirectional converter in Inverter mode is given in Fig.2.In this the input dc voltage is continuously sensed by voltage sensor and in turn it operates the relay which is set by the rated input voltage. If dc input voltage is within the set limit the relay gives the pulse to switch A and the converter operates as a inverter and the output is a sine wave with (frequency 50Hz) less THD using LC filter. Otherwise the relay gives pulse to switch B and converter operates as a Rectifier and the output is unidirectional dc with a ripple factor less than 5%.

For closed loop control of converter in Inverter mode the output voltage and sinusoidal reference voltage are compared and the difference is given to PID voltage controller. The output signal is again compared with inductor current; the current error signal is given to PID current controller. This control signal from PID current controller is used as the reference signal for PWM generation. The triangular wave of 25 kHz frequency is compared with reference signal and at every crossing instant the pulse is generated and used to control the switches.

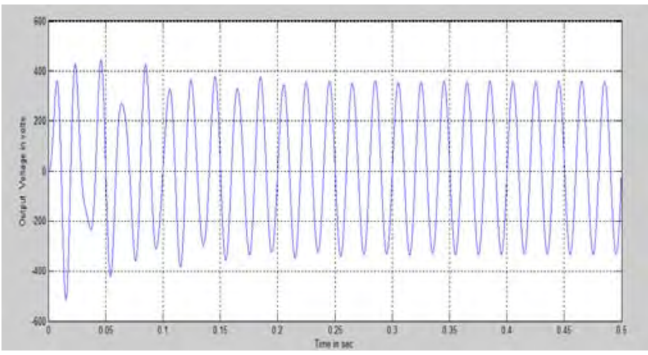

Fig.3. Output voltage from Inverter mode

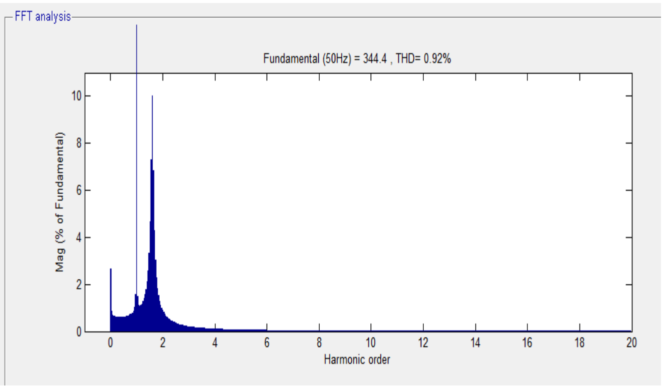

Fig.4. THD analysis for Inverter output

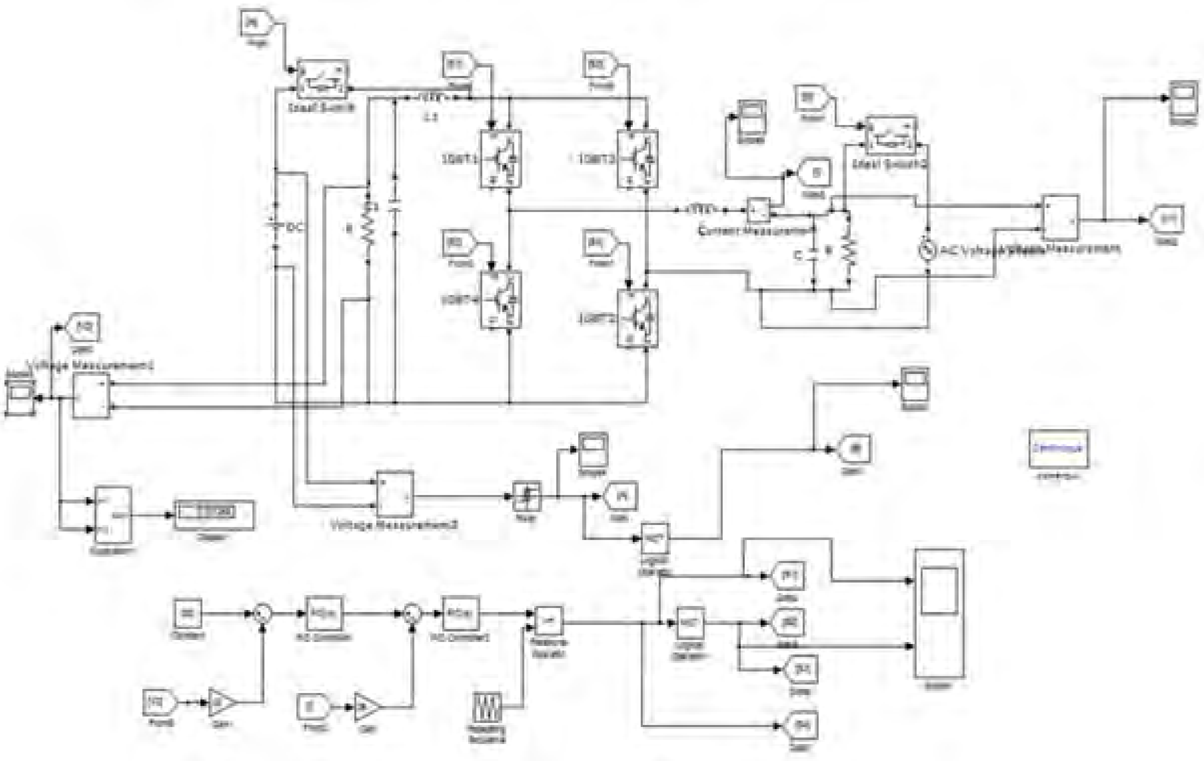

Fig.5. Simulink model for Bidirectional converter in Rectifier mode

The MATLAB/Simulink model for the converter in rectifier mode is given in Fig.5.The output signal and dc reference signal are compared and the error signal is used to generate the PWM pulses and control the switches in the converter.Fig.6 shows the dc output from Bidirectional converter in Rectifier mode.

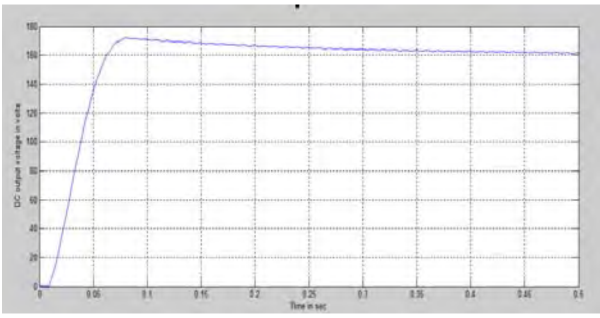

Fig.6. DC output from converter in rectifier mode

V. EXPERIMENTAL RESULTS

The Bidirectional converter is designed using MOSFET (IRF640) and Microcontroller PIC 16f877a is used to control the switches in the converter and driver IC IR2110 is used for amplification and isolation between controller and power circuit. In order to avoid device failure and safety, the fabrication and experiments were done as a scaled down voltage level.

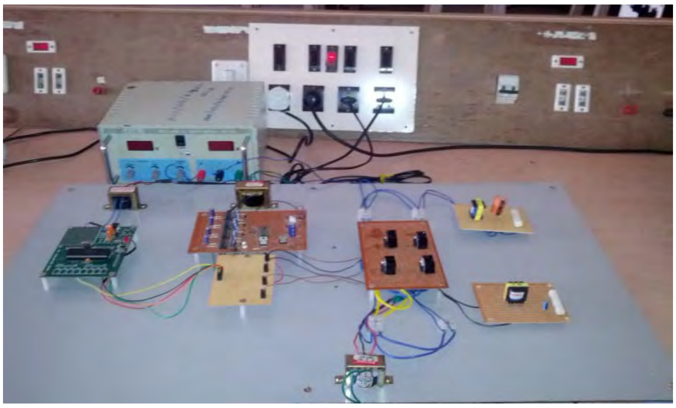

Fig.7. Experimental set up for Bidirectional converter

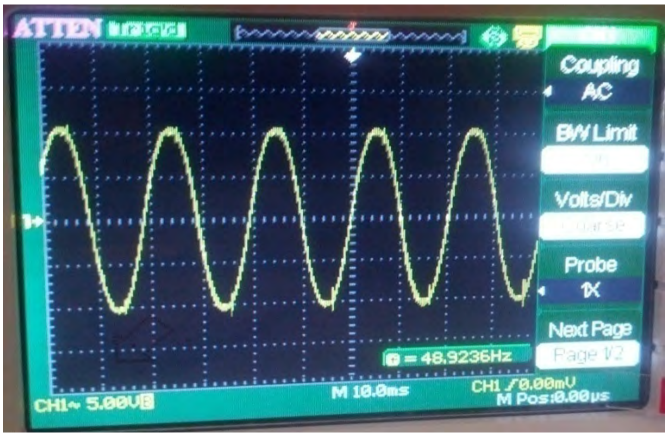

Fig.8. Inverter output voltage

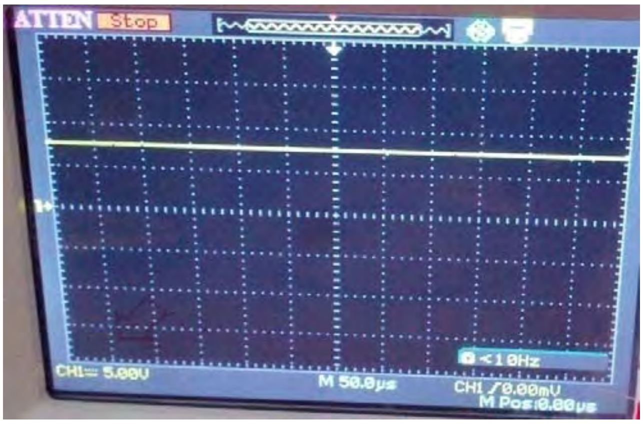

Fig.9. Rectifier output voltage

VI.CONCLUSION

This paper proposed the control system design for Microgrid connected single phase bidirectional PWM converter. Microgrid is a emerging technology provides power locally for a specific region like university, Industries, residential areas etc. It uses the renewable energy resources and is available at a reduced cost therefore the implementation is easy and cost effective. Bidirectional converter is a important component in Microgrid which connect dc and ac subsystem. The reliability of the supply is maintained even with the availability of any one renewable energy resources The Double loop PID control is designed for both mode and simulated using MATLAB/Simulink. The simulation results shows that designed control system produces inverter output with THD 0.92% and rectifier output with ripple factor 0.13%.

REFERENCES

[1] Dong Dong, Timothy Thacker, Igor Cvetkovic, Rolando Burgos, Dushan Boroyevich, FredWang, and Glenn Skutt "Modes of Operation and System-Level Control of Single-Phase Bidirectional PWM Converter for Microgrid Systems" in IEEE Trans. Smart grid., vol. 3, no. 1, Mar 2012

[2] D. Dong, T. Thacker, R. Burgos, D. Boroyevich, F. Wang, and B.Giewont, "Control design and experimental of a multi-function single phase bidirectional PWM converter for renewable energy systems," in Proc. 2009 Eur. Conf. Power Electron. Appl., pp. 1–10.

[3] Cvetkovicetal. "Future home uninterruptible renewable energy system with vehicle-to-Grid technology," in Proc. 2009 IEEE EnergyConv. Congr. Expo., pp. 2675–2681

[4] Naser M.Abdel-Rahim,etc,"Analysis and design of a multiple feedback loop control strategy for single-phase voltage-source UPS inverter",IEEE trans.power electrp.vol.11,July 1996, pp.532-541

[5] H. Gu, Z. Yang, D.Wang, and W.Wu, "Research on control method of double-mode inverter with grid-connection and stand-alone," in Proc.2006 IEEE Power Electron. Motion Control Conf., pp. 1–5

[6] N. Mohan, T. M. Undeland, W. P. Robbins, "Power Electronics, Converters, Applications, and Design", 3th edition, John Wiley & Sons, New York, 2003.