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CONTROL OF PARALLEL CONNECTED BIDIRECTIONAL AC-DC CONVERTER

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Abstract — *This paper present control of parallel connected single-phase Bidirectional AC-DC converter for Microgrid application. Depleting layer of fossil fuel with increasing demand of electricity renewable energy sources plays vital role in existing environment. Smart grid is a newly immersing technology which drawback of existing power grid with additional future. Microgrid is a part of smart grid used to supply small community such as residential areas, universities etc. Bidirectional AC-DC converter plays important role for connecting renewable energy sources to microgrid. This paper deals with the parallel connected single-phase Bidirectional PWM AC-DC converter which operates in rectification and inversion mode. Double loop PI control is used to control the converter in either mode of operation. The parallel connected single-phase Bidirectional AC-DC converter is simulated using MATLAB/Simulink.*

Keywords- *Renewable energy sources, Distributed Generation (DG), Microgrid, PWM (Pulse Width Modulation), Bidirectional converter, PI(Proportional-Integral) .*

I. INTRODUCTION

Now a day, the increasing demand of electrical energy with depleting layer of fossil fuel is major problem around the world. As a result renewable energy sources plays vital role in modern energy system. The existing electricity grid converts only one third of fuel into electricity and 8% of its output is wasted across the transmission line therefore smart grid is newly immersing technology basically derived from traditional power grid with additional feature such as reliability, efficiency, and sustainability. Due to increasing concern over energy shortage and environmental pollution, the concepts of distributed generation (DG), smart grid system, dc nano grid system, and ac/dc hybrid power system have all become progressively more popular with decreasing cost of various clean renewable sources such as solar, wind, bio-mass, fuel cell. Distribution Generation(DG) concept is decentralize flexible technology, located near to the load center, having capability less or equal to 10MW . Hence the transmission losses are reduced and number of power line is also reduced. Distributed hybrid power system consist ac and dc subsystem connected to various types of load, where DG resources either ac or dc.[1]

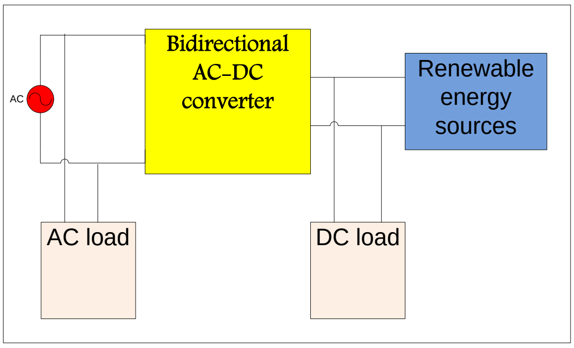


Figure 1 The Distributed Generation system

Power electronics plays important role for connecting renewable energy sources to microgrid system. Bidirectional converter operates in rectification and inversion mode by utilizing ac and dc renewable sources. It uses voltage source PWM converter. Bidirectional converter improves power quality issues such as Total Harmonic Distortion (THD), low power factor, ac voltage distortion, ripple in DC current and DC voltage pulsation. Parallel converter provides many advantages such as high reliability, high power, distributed power, high performance, enabling technology for emerging application.

Advantages of Parallel operation:

- It operates with high power low lost application
- It provides system redundancy and improving reliability of system
- No external communication between axes is needed which improves performance of load sharing

- Equal sharing of linear and non-linear load can be made by using droop control technique

1.1 Control principles for converter

Different control principles for converter are as below:
(1) AC/DC converter with current and DC voltage control
(2) AC/DC converter with AC voltage control
(3) AC/DC converter with current and power control allowing bidirectional power flow
(4) DC/DC converter with current and power control allowing bidirectional power flow

1.2 Bidirectional AC-DC converter

Bidirectional converter for Microgrid system operates in following modes:

Stand Alone Mode (SAM): When grid is lost the converter regulates the AC bus voltage and frequency while drawing energy from DC side renewable sources. The renewable energy sources on AC side act as a current source.

Grid Connected Mode (GCM): When grid is present the converter injecting or sinking power from grid which are classified as:

(a) Inverter Mode: In inverter mode DC side renewable energy is available and converter operates as inverter feeding power to AC load and DC load directly get power from renewable energy sources and filter is used to get sinusoidal output**.** AC source regulates power flow between DC and AC system while DC source regulates DC bus voltage.

(b) Rectifier Mode: In rectifier mode DC side renewable energy is not available and converter operate as rectifier feeding power to DC load and AC load directly get power from AC renewable energy. AC source regulates the DC bus voltage and performs energy balancing to sustain dc bus integrity.[1]

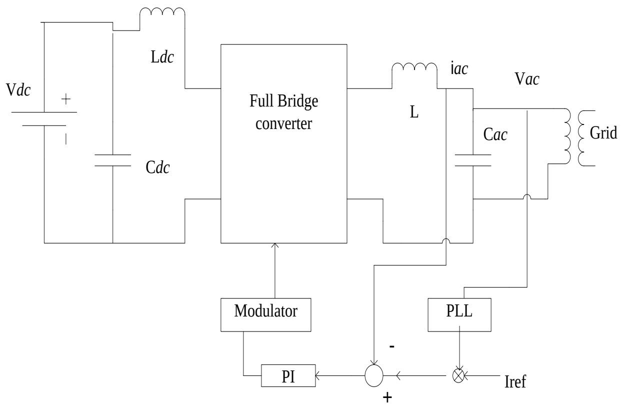


Figure 2 Control structure for grid connected mode operate as inverter

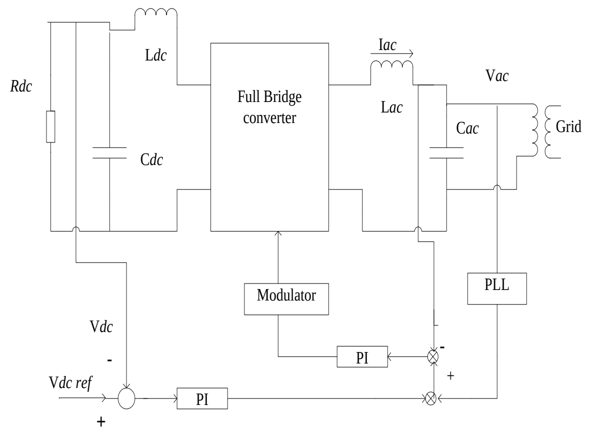


Figure 3 control structure for grid connected mode operate as rectifier

Figure 2 shows control structure for grid connected mode operates as an inverter and figure 3 shows control structure for grid connected mode operates as a rectifier. PLL (Phase Locked Loop) is used for synchronization with grid. Control method consist two control loop inner current loop, and outer voltage loop for individual mode.

II. CONTROL STRATEGY

With development of different new control strategy such as hysteresis control, model predictive control, fuzzy logic control, sliding mode control, neural network control. Each method has different control strategies which increase difficulties in control system design and reduces the reliability of system. Due to this double loop PI control is used which has many advantages simple design, easy to implement, good performance. Tuning of PI controller is obtained by Ziegler-Nicholas method.
The average model of full bridge inverter is given by following equation

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

$$C_{ac}\frac{dv_{ac}}{dt} = i_{ac} - \frac{v_{ac}}{z_{ac}} \quad (2)$$

The current loop regulates inductor current and outer voltage is separately designed for each mode to regulate ac and DC voltage.
Transfer function of current loop,

$$\frac{i_{ac}}{v_{dc}} = \frac{1+sZ_{ac}C_{ac}}{s^2 L_{ac}Z_{ac}C_{ac}+sL_{ac}+Z_{ac}} \quad (3)$$

Transfer function of voltage loop,
For inverter mode,

$$\frac{V_{ac}}{i_{ac}} = \frac{Z_{ac}}{1+sZ_{ac}C_{ac}} \quad (4)$$

For rectifier mode,

$$\frac{V_{dc}}{i_{dc}} = \frac{Z_{dc}}{1+sZ_{dc}C_{dc}} \quad (5)$$

The desired output is obtained by tuning PI gain value.[1]

III. SIMULATION AND RESULTS

Figure 4 show simulation of parallel connected bidirectional AC-DC converter. This is done using MATLAB/Simulink. Different cases are taken for this simulation. Table 1 show parameter used for simulation. Two control loop inner current loop which is common for both mode and outer voltage loop is separately for individual mode. The pulses for inverter and rectifier are generated using sine PWM for individual mode. For closed loop control in inverter mode measured voltage and reference voltage and for rectifier mode measured voltage and reference DC voltage are compared and error signal is given to PI controller. The output signal is again compared with current and current error signal is given to PI controller and output signal of PI controller is compared with triangular wave and at every crossing instant pulse is generated.

Table 1 Simulation parameter

Sr No.	Parameter	Value	Sr No.	Parameter	Value
1	V_{ac} (peak)	230V	6	C_{dc}	420µF
2	V_{dc}	230V	7	Switching frequency	5kHz
3	L_{ac}	266mH	8	R,L(load)	100Ω,500mH
4	C_{ac}	40µF	9	Voltage sensor gain	0.01(Rectifier) 0.03(inverter)
5	L_{dc}	900mH	10	Current sensor gain	0.06

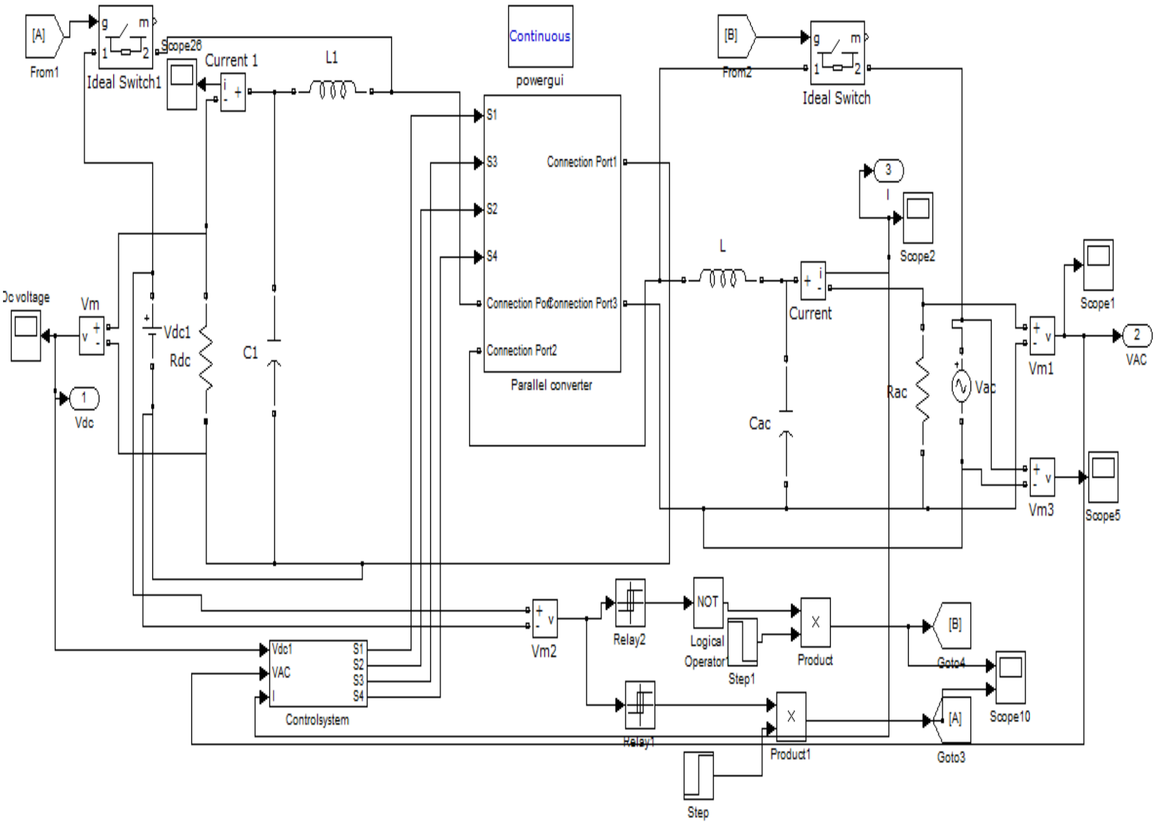


Figure 4 Simulation circuit for parallel connected bidirectional AC-DC converter using MATLAB

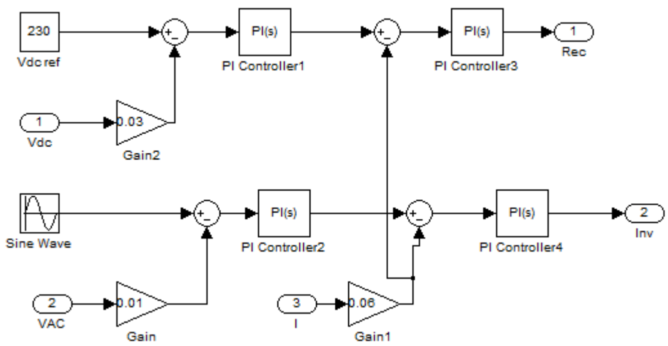
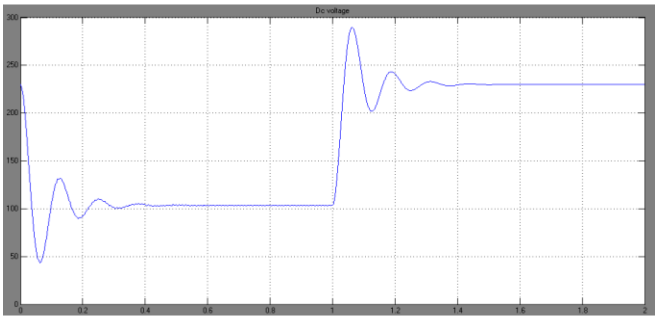
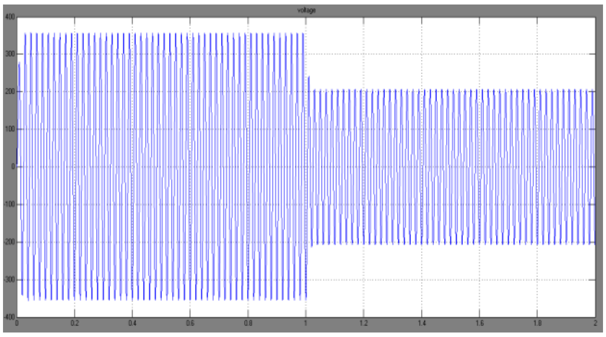


Figure 5 Control scheme for bidirectional converter

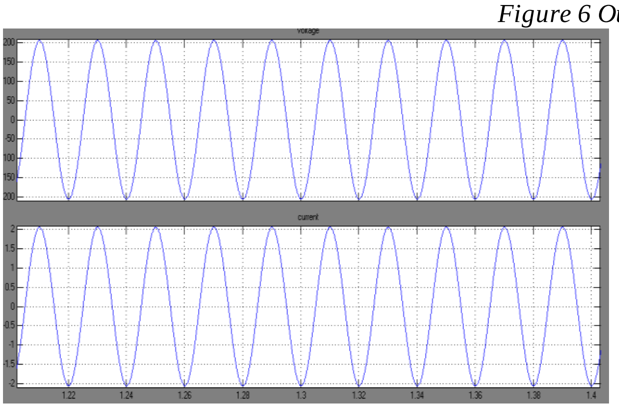


(a) Rectifier output

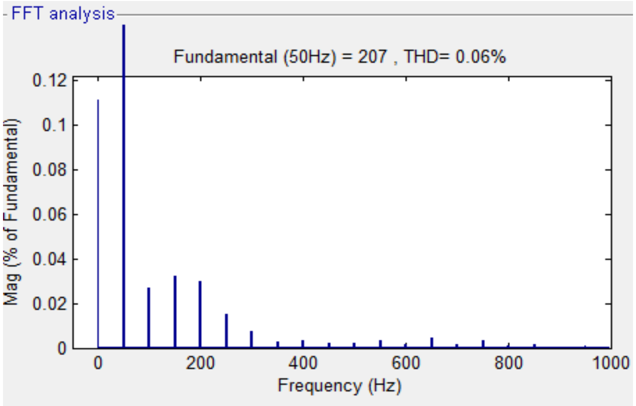


(b) inverter output

Figure 6 Output voltage of bidirectional converter

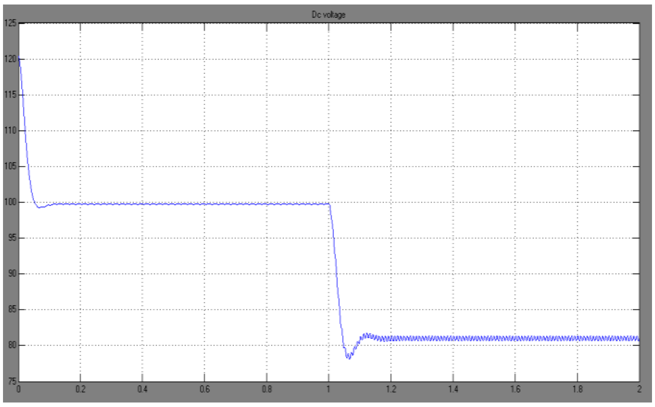


(a) Output voltage and current in inverter mode

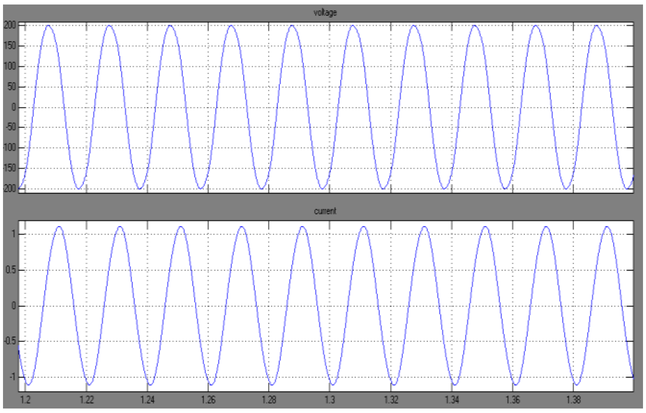


(b) % THD present in output DC voltage

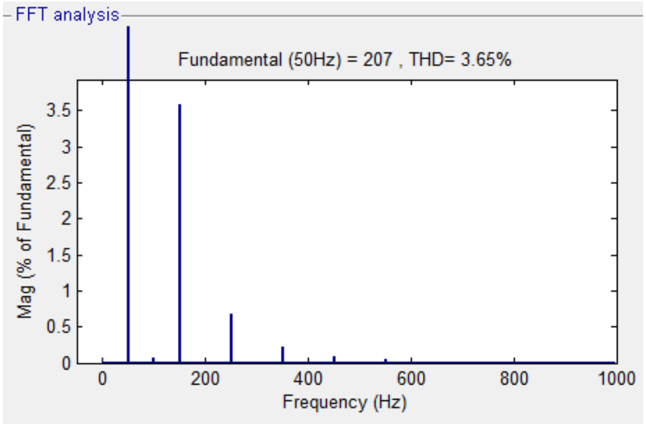
Figure 7 Waveform of voltage current and THD analysis for bidirectional converter operate as inverter



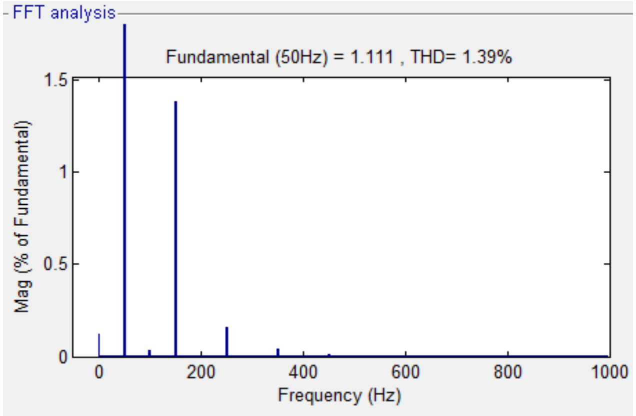
(a) Rectifier output voltage with RL load



(b) Inverter output voltage and current with RL load



(c) %THD in output AC voltage



(d) %THD in output AC current

Figure 8 Results of parallel connected bidirectional AC-DC converter using RL load

Table 2 THD comparison

Sr. no	% THD for voltage	% THD for current
With R load	0.06%	0.06%
With RL load	3.65%	1.39%

IV.CONCLUSION

This paper proposed the control system design of parallel connected single-phase bidirectional AC-DC converter for microgrid application. Microgrid is a newly emerging technology designed to supply small community such as residential areas, university etc. It uses renewable energy sources which available at reduced cost therefore implementation become cost effective. Bidirectional converter plays important role to connect AC and DC subsystem. The double loop PI control is designed for rectifier and inverter mode. The reliability of system is maintained with parallel connection and availability of renewable energy sources. The simulation results shows that the designed control system shows inverter output with THD 0.06% and rectifier output with ripple factor 1.15% using linear load.

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