# Control of Microgrid

Ramya
Department of Electrical and Electronics
PES University
Bengaluru, India

Sangeeta Modi
Department of Electrical and Electronics
PES University
Bengaluru, India

***Abstract*—A Microgrid system having both AC and DC generation, storage and load is said to be a Hybrid Microgrid System. Adaption of microgrid enables maximum utilization of renewable resources allowing more and more usage of Green Energy, hence contributing to the Clean Energy Environment. In this work, test bed for the microgrid and its ratings are chosen based on our requirements. Topology considered has multiple solar panels connected in parallel to a bi-directional converter. Utility Grid is connected on the other side of the converter. This work presents the simulation of the selected microgrid system with PV as renewable source, utility grid and loads in MATLAB/ Simulink under various condition in Grid-connected mode. Five 250W PV Panels are linked to the system at Point of Common Coupling (PCC). Critical and Non-Critical loads are added to verify the performance. It was observed that power demand was not met as per the requirement. To improve performance with regards to power sharing, Decoupled Vector Control method is implemented. Result reveals that Utility grid and PV panels deliver power to loads continuously without interruption.**

***Keywords*— *Hybrid Microgrid, Bi-directional Converter, MPPT***

## I. INTRODUCTION

At the present time, environmental issues such as deforestation, pollution and global warming are gradually drawing more attention to renewable energy sources. High-voltage transmission over long distances is no longer necessary if electricity can be supplied entirely by local renewable sources.

To save energy and reduce carbon emissions, dc loads such as LED lamps and electric vehicles are connected to power systems [1]. A hybrid AC/DC microgrid has been proposed to facilitate connection of renewable energy sources to traditional AC systems [3][5].

A microgrid is a distributed network of power supplies built to provide electricity to a local community. This consists of Distributed Generation (DG), loads, Energy Storage (ES), and Control devices. Unlike traditional power system, these have on-site generation which reduces losses [4] occurring due to transmission of power. Promoting microgrid system aids in onsite generation, rural electrification, power exchange between customers which helps in economic growth of a country.

In this paper, a hybrid microgrid system with PV panel, Utility grid, AC and DC loads are considered. To convert AC to DC power or DC to AC power, Bidirectional converter of centralized topology is chosen. Simulation has been carried out for different load conditions, PWM signal for inverter and addition of battery as backup under different irradiation conditions. Result reveals that the system does not meet the required level of performance.

Decoupled-Vector Control method has been implemented to ensure power sharing between grid and PV panels in Grid-connected mode. DC voltage, AC side voltage and current is taken as reference to generated reference signals to generate gate signals for inverter. Simulation results verify that the system is able to deliver and share power between them in order to meet AC and DC load demand.

This paper is organized in VII sections. Section I will contain Introduction. Literature review of the work carried out in Section II. Section III explains about the system that is considered in this paper. Section IV and V of the paper discusses about the technique used for power sharing and simulation in MATLAB/SIMULINK. Section VI and VII discusses about and its results and conclusion derived from the simulation carried out. References are included at the end of this paper.

## II. LITERATURE REVIEW

[1] analyses the bidirectional converter for power transfer to AC loads and DC loads. Dual modes of DC-DC converter, i.e. boost and buck modes are developed and verified for the results. It was observed that power sharing between AC and DC bus is regulated by maintaining the PCC voltage.

[2] describes the microgrid system with two inverter-based sources. The system is modelled as constant P and Q in grid connected mode using the current regulation of the d-q axis. When the system is in islanded mode, it is modelled using droop control by selecting droop constants. Results are observed for different load conditions and switch-over from grid-connected mode to islanded mode or vice-versa. Also output feedback compensator is designed and verified.

[3] discusses the integration of renewable sources to the grid under grid connected mode of operation. Renewable sources used for this system are PV Panel and Wind turbine. Battery is used for energy storage. Energy is managed by using Decoupled vector control for centralized microgrid system. Results are observed by connecting AC and DC loads.

[4] discusses the mathematical model of PV Cell based on certain parameters. Simulation is carried out in MATLAB/Simulink Software. Power-Voltage (P-V), Current-Voltage (V-I) characteristics are plotted for various temperatures and irradiances. Results are compared with Solar Cell model available in MATLAB/Simulink Software to verify the accuracy.

[5] describes the control strategy of bidirectional converter used in hybrid microgrid system. Improved droop control strategy is applied for better performance. Simulation is carried out in PSCAD/ EMTDC Software. A stable DC bus voltage is maintained in grid-connected mode and AC and DC bus power sharing is ensured in islanded mode of operation. These results show that proposed control method is stable and efficient.

[6] analyses the microgrid system where two inverters are connected in parallel. Loads are connected at the end of transmission line. Decentralized control method is used for the inverters to operate. Simulation is carried out in MATLAB/Simulink. Average power calculated using two methods and compared. It was observed that power sharing using droop control method by the application of enhanced average power calculator shows better dynamic response than the classical power calculator.

[7] presents an overview of hybrid microgrid. Various issues and types in islanding detection techniques, different control strategies, protection methods, stability issues of hybrid microgrid is addressed. Also, important issues and challenges for development are highlighted. Techniques for islanding detection, control strategy, protection and stability analysis used at present have been reviewed.

## III. SYSTEM UNDER CONSIDERATION

In this work five renewable sources $RS_1$, $RS_2$, $RS_3$, $RS_4$, $RS_5$ of PV System are considered along with Utility Grid Supply[16]. Boost converter is used to step-up the voltage to the desired level. Maximum Power point tracking (MPPT) is used to extract maximum power from the PV panel. DC bus is maintained at 280V and AC bus is maintained at 230V, 50Hz. AC and DC loads are given supply from AC and DC bus respectively. Bi-directional Converter is used to directly link AC and DC sides of the system. Figure. 1 shows the block diagram of the considered microgrid system.

A 2KVA inverter is used to convert AC power to DC power or vice-versa. Loads are categorized as Critical and Non-Critical loads. Critical loads are those which are always connected to the system irrespective of system condition. Non-Critical loads are those loads which can be curtailed if necessary. AC Critical load of 700W, 525Var, AC Non-Critical load of 300W, 225Var and DC load of 250W is considered in this system.

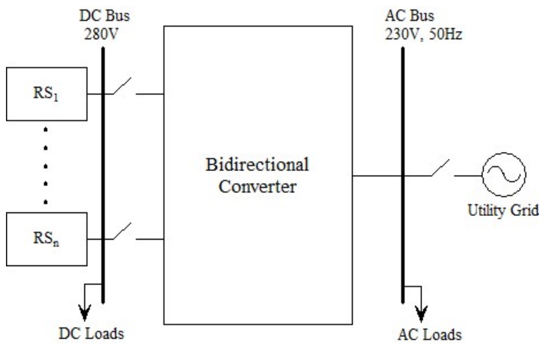

Figure. 1 Block Diagram of the selected Microgrid System

## IV. PROPOSED SYSTEM

Conventional microgrid system as shown in Figure. 1 does not employ any power sharing strategy to control the power flow between DC bus and grid. For centralized control of inverter which is connected to multiple PV panels, Decoupled Vector Control method is used. This method controls active and reactive power in the inverter. Figure. 2 shows block diagram of proposed system. Components included in this Microgrid System in this work are Utility Grid, Solar PV Panel, Boost Converter with MPPT Algorithm Technique, Inverter, Loads and Controller to control power flow between these components.

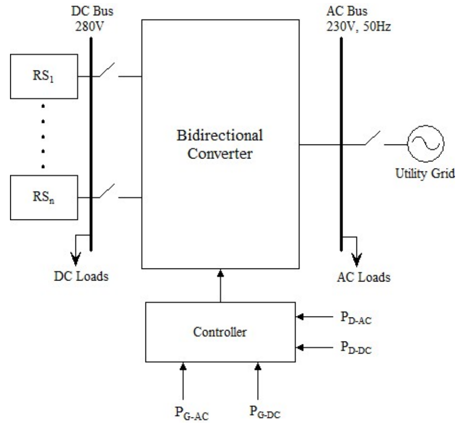

Figure. 2 Block Diagram of proposed system

Power sharing is a crucial task in a microgrid system. In order to match the load demand, a proper control method must be adopted. In this work Decoupled Vector Control method is implemented for power sharing. This method makes use of Park's transformation and Inverse-Park's transformation. Park's transformation converts rotating space vector to stationary axis making any problem simple to solve. Figure. 3 shows block diagram of this control method.

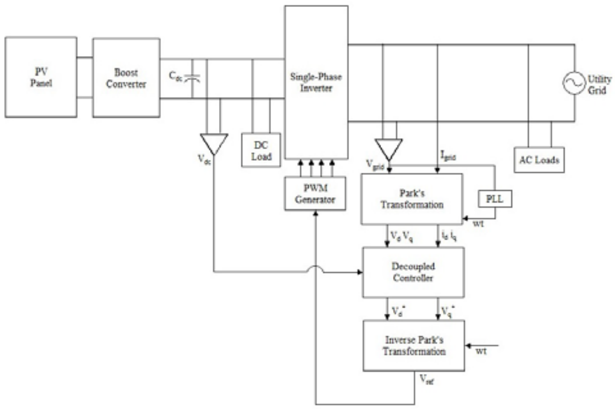

Figure. 3 Block Diagram of Decoupled Vector Control

In the first stage grid voltage ($V_{grid}$) and current ($I_{grid}$) is measured. Park's transformation is applied to these to get *d* and *q* components. Phase Locked Loop (PLL) is used to obtain phase angle (ωt) from grid voltage.

$$\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \begin{bmatrix} \cos\omega t & -\sin\omega t \\ \sin\omega t & \cos\omega t \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix}$$

$$\begin{bmatrix} V_d \\ V_q \end{bmatrix} = \begin{bmatrix} \cos\omega t & -\sin\omega t \\ \sin\omega t & \cos\omega t \end{bmatrix} \begin{bmatrix} V_\alpha \\ V_\beta \end{bmatrix}$$

Where,

$i_d$, $V_d$ are direct axis components of grid current and voltage;

$i_q$, $V_q$ are quadrature axis components of grid current and voltage;

$i_\alpha$, $V_\alpha$ are components of grid current and voltage;

$i_\beta$, $V_\beta$ are components of grid current and voltage phase shifted by 90º.

In the next stage, decoupled vector controller is adapted. This controller will control the active (P) and reactive power (Q) based on $i_d$, $i_q$, $V_d$, $V_q$ and DC link Voltage $V_{dc}$. Using a PI controller, the error between reference current and actual current is brought to zero. d-q components of inverter outputs are given by,

$$V_d^* = V_d - k_p e_d - k_i I_d + \omega L i_q$$

$$V_q^* = V_q - k_p e_q - k_i I_q - \omega L i_d$$

Where,

$V_d$ and $V_q$ are d-q aspects of parks transformation of grid voltage

$k_p$ and $k_i$ are proportional and integral constants in PI controller

$e_d$ and $e_q$ are errors in d and q components

$I_d$ and $I_q$ are d and q components of grid current.

Third stage is to apply inverse park's transformation to get the reference voltage from which PWM signals are generated for inverter.

Inverse Park's Transformation,

$$\begin{bmatrix} i_\alpha^* \\ i_\beta^* \end{bmatrix} = \begin{bmatrix} \cos\omega t & \sin\omega t \\ -\sin\omega t & \cos\omega t \end{bmatrix} \begin{bmatrix} i_d^* \\ i_q^* \end{bmatrix}$$

$$\begin{bmatrix} V_\alpha^* \\ V_\beta^* \end{bmatrix} = \begin{bmatrix} \cos\omega t & \sin\omega t \\ -\sin\omega t & \cos\omega t \end{bmatrix} \begin{bmatrix} V_d^* \\ V_q^* \end{bmatrix}$$

## V. MATLAB SIMULATION

A microgrid system consisting of 5 PV panels integrated at the PCC of bidirectional converter and AC side connected to Utility grid is simulated in MATLAB/SIMULINK Software. Input parameters used for the simulation are given in Table. I.

Given that the system is unable to supply loads with the required power, Decoupling Vector Control is used for power sharing. Figure.4 shows the simulation diagram of microgrid system which employs decoupled vector control method for power sharing using MATLAB/SIMULINK.

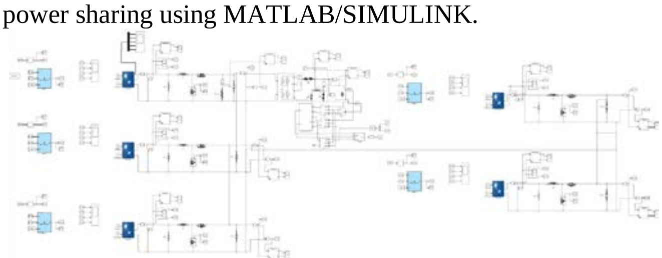

Figure.4 Simulation diagram of Microgrid System

## VI. RESULTS AND DISCUSSIONS

Results of the simulated microgrid system is analyzed using MATLAB/SIMULINK Software. Results of the conventional system is compared to the proposed system in which decoupled vector control is applied.

### A. *Conventional Microgrid System*

Here, PV Panels will be having an input irradiance of 1000W/m$^2$ and ambient temperature of 25ºC. Figure.5 shows PV power generated by each of the PV panels. Figure.6 and Figure.7 shows the power supplied to AC and DC loads respectively. Only AC active power delivered to the AC load was meeting its requirement. Whereas, DC Power and AC reactive power required by the loads were not supplied properly.

TABLE I. PARAMETERS USED FOR SIMULATION

| Parameters | Value |
|---|---|
| Utility Grid | 230V, 50Hz |
| PV Panel Output | 250W |
| Maximum Power Point Voltage | 30.23V |
| Maximum Power Point Current | 8.27A |
| Open Circuit Voltage | 37.6V |
| Short Circuit Current | 8.8A |
| Inverter Rating | 2KVA |
| AC Critical Load | 700W, 525Var |
| AC Non-Critical Load | 300W, 225var |
| DC Load | 250W |
| Proportional Constant, $K_p$ | 0.001 |
| Integral Constant, $K_i$ | 0.01 |

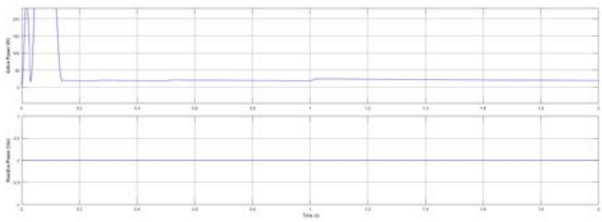

Figure.5 PV Power

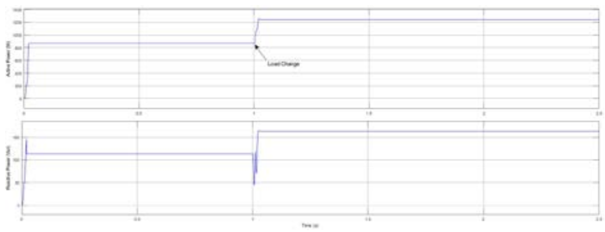

Figure.6 AC Load Power

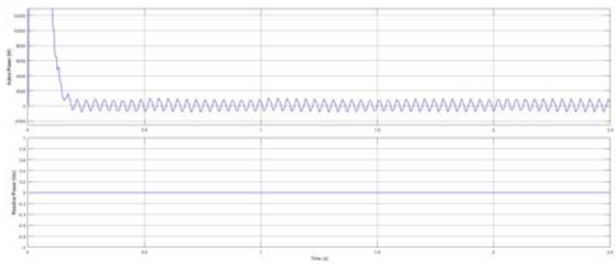

Figure.7 DC Load Power

### B. *Results of Decoupled Vector Control Method*

To improve the system's flow of power between Grid and PV Panel, this method was employed. Simulation results were analyzed based on load condition.

In the first case, DC load is less than total PV Panel capacity (Maximum PV Panel power : 100W, DC load : 50W) Figure.8, Figure.9 and Figure.10 shows the total grid power supplied to the loads, AC and DC load power respectively when DC load is less than PV panel capacity.

Initially, DC load demand of 50W is supplied from the PV Panels and AC load demand of 700W, 525Var is supplied from Utility Grid. At 1s, due to the addition of load, grid will supply additional load thus delivering total of 1000W, 750Var from Utility grid.

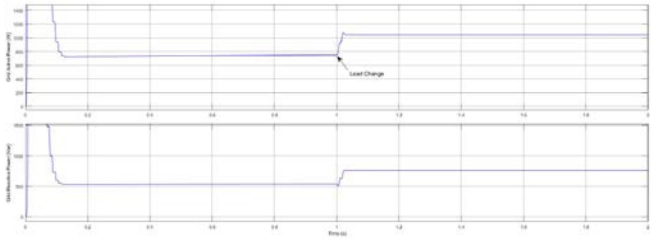

Figure.8 Grid Power

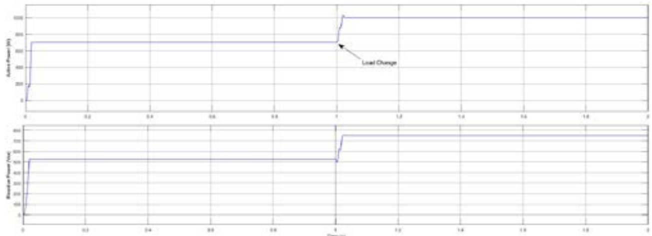

Figure.9 AC Load Power

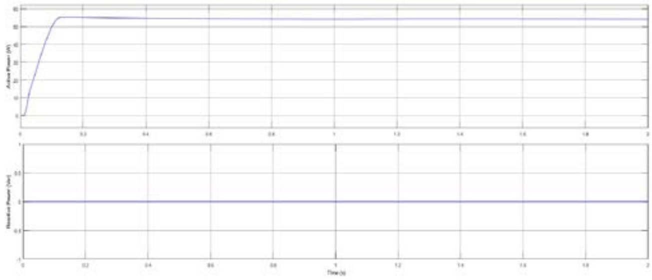

Figure.10 DC Load Power

In the Second case, DC load is made more than total PV Panel capacity (Maximum PV Panel power: 100W, DC load: 250W). Figure.11, Figure.12 and Figure.13 shows the Grid power, AC and DC load power respectively when DC load is greater than PV panel capacity.

Initially, DC load demand of 250W. As PV panels are capable of supplying 100W (20W from each panels), remaining 150W is supplied by the grid. AC load demand of 700W, 525Var is supplied from Utility Grid. Thus, utility grid supplies total of 850W power to AC and DC loads. At 1s, due to the addition of load, grid will supply additional load thus delivering total of 1150W, 750Var from Utility grid.

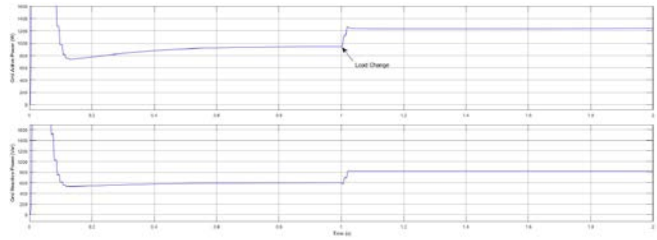

Figure.11 Grid Power

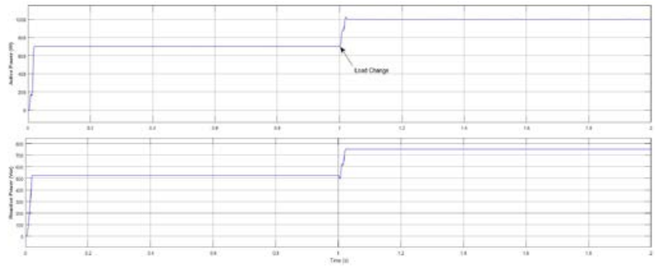

Figure.12 AC Load Power

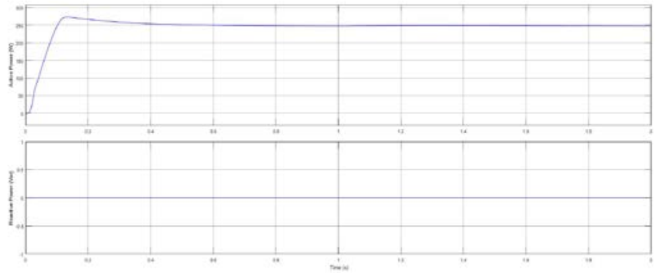

Figure.13 DC Load Power

It is observed that, when DC load is less than PV Power, required DC load demand will be supplied from PV panel and AC load demand will be supplied from Utility grid. When DC load is more than PV Power, additional DC load demand will be supplied from Utility grid and AC load demand will be supplied from Utility grid.

## VII. CONCLUSION

Simulation of selected Hybrid Microgrid is carried out using Solar Panel, Boost Converter and Inverter and results are presented. To enhance the capacity of the system, multiple PV panels are used. MPPT has been employed to extract maximum power from the solar panel. Decoupled vector control method is implemented to meet power sharing requirement. This method adjusts power supply from Grid and PV panel to meet the load demand. Result reveals that total load demand without any interruption is met continuously by implementing decoupled vector method to the system. Power sharing in islanded mode of operation by adding island detection scheme can be taken as future work.

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