REACTIVE POWER SHARING IN MICROGRID USING DROOP CONTROL

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Abstract - *In recent years, due to increasing the demand of electricity as well as rapid depletion of fossil fuels, and the government policies on reduction of greenhouse gas emissions , renewable energy technologies are more attractive and various types of distributed generation sources, such as wind turbine generators and solar photo voltaic panels are being connected to low-voltage distribution networks. Micro grid is an integrated system that containins distributed generation sources, control systems, load management, energy storage and communication infrastructure capability to work in both grid connected and island mode to optimize energy usage. The paper presents a advanced control technique for a micro grid system which works efficiently under a decentralized control system.*

Key Words: *Microgrid, Renewable energy resource, Distributed generation, Droop control*

1. INTRODUCTION

Fossil fuel reserves are going to vanish in the near future, so human beings will need to find alternative energy sources to avoid this disaster. Increased concerns of rising price of conventional energy (e.g. fossil fuel) and environmental impacts are fast shifting the focus to the use of renewable and sustainable energy sources. The use of renewable energy sources is becoming popular along with fossil fuels depletion. The unpredictable and intermittent nature of renewable energy sources have kept them from integrating with the utility grid. However, the concept of micro grid has opened up the scope of incorporating renewable energy sources into the conventional grid, without a direct coupling with the conventional grid components. This is possible due to the unique feature of a micro grid, which allows both synchronized grid connected operation and islanded operation in case of instabilities or power outages in the main grid.

Nowadays, a variety of studies and investigations are converging to evolve the electric model to implement micro-grids. It has become clear that the fundamental architecture of the 20th century electricity grid based on a unidirectional power flow is obsolete. Between now and 2015, over 3.1GW of new micro-grid capacity is projected to be implemented worldwide. As shown in the Fig -1, the United States is the current leader, with exactly 626 MW operating at 2010, and that capacity is expected to increase to 2,352 MW by 2015. At 2009, in the United States, 322 MW of college campus micro-grids were up. In the U.S, 40% of future micro-grids will be developed in this market segment, adding 940 MW of new capacity valued at $2.76 billion by 2015.
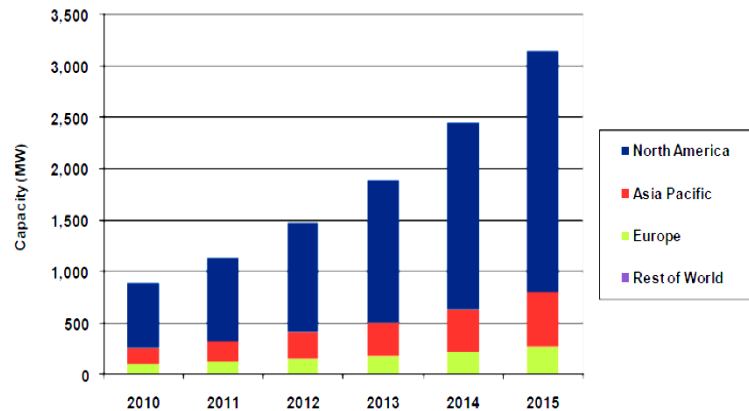

Fig-1 World capacity of micro grid

2. MICROGRID

The micro grid concept acts as a solution of integrating large amounts of micro generation without disrupting the operation of the utility network. With intelligent coordination of loads and micro-generation, the distribution network subsystem would be less troublesome to the utility network, than conventional

micro generation. The net micro grid could even provide ancillary services such as local voltage control. In case of disturbances on the main network, micro grids could potentially disconnect and continue to operate separately. This operation improves power quality to the customer. From the grid's perception, the benefit of a micro grid is that it can be considered as a controlled entity within the power system that can be functioned as a single aggregated load. Customers can get benefits from a micro grid because it is designed and operated to meet their local needs for heat and power as well as provide uninterruptible power, enhance local reliability, reduce feeder losses, and support local voltages. In addition to generating technologies, micro grid also includes storage, load control and heat recovery equipment. The ability of the micro grid to operate when connected to the grid as well as smooth transition to and from the island mode is another important function.
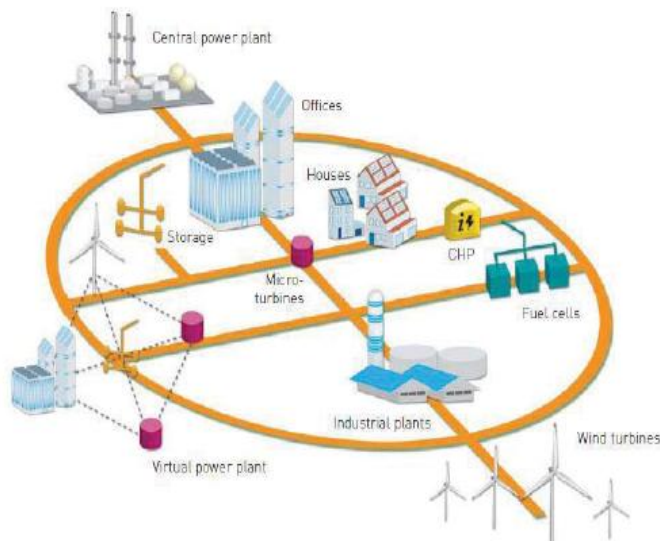

Fig-2: Microgrid system

2.1 Operation Modes of Micro grid

The micro grid should not only operate at grid-connected mode, but also operate at islanded mode and continuously supply power to critical loads when grid faults are detected. In addition, after the clearance of grid faults, the micro grid has to get resynchronized with the utility for reconnection.

A. Grid-Connected Mode

In grid-connected mode, the microgrid frequency is fixed to the utility frequency. The DG units supply their rated active and reactive power at rated frequency and voltage. When the load requirement is less than the rated capacity of the DGs, the excess power flows to the utility. On the

other hand, when the load requirement is greater than the rated capacity of the DGs, more power would be imported from the utility.

B. Islanded Mode

In islanded mode, the static transfer switch (STS) disconnects the microgrid from the main grid, the total power demand of the load is supplied by the DGs. With any load change, each DG must regulate its frequency and magnitude of output voltage to meet the new load requirement in a predetermined droop characteristic.

C. Seamless Transfer

A smooth transfer between grid-connected and islanded mode is essential for the reliability of a microgrid. When grid faults occur, in order to protect the power electronic devices and some sensitive loads, the STS disconnect the microgrid from the grid. At the same time, DGs must immediately increase their power output in a predetermined manner so as to continue supplying power to critical loads. On the other hand, when the clearance of faults takes place, the voltage at ac common bus should track that of the grid, in terms of frequency, magnitude and phase, in order to achieve smooth and fast resynchronization.

3. MICROGRID CONTROL

Micro grids have been designed with the objective to add more reliability and robustness to the conventional grid system. Advanced controller design and control strategy has facilitated the integration of a large number of renewable energy sources to the utility grid, which has encouraged distributed supply demand. Moreover, the capability of the distributed generators (DG) to meet considerable amount of load demand has greatly reduced the stress on the centralized grid system. Therefore, micro grids consisting of these DGs are now able to maintain an uninterrupted power supply for its loads, even during grid outage. By the virtue of this unique feature, micro grids can now maintain optimal grid connectivity in order to provide a disturbance free supply to its loads.

Micro grid in islanded mode maintains the same load demand as when connected to the grid, but with limited resources supplying power. Loss of a micro source, increase in load demand or presence of a non-linear or unbalanced load makes it even more difficult to maintain the stability of the microgrid. Conventional control strategies can be applied in order to counteract the stability issues. However, due to the presence of varied stability issues, control strategies specific to each issue needs to be developed. In order to do so, the affected

parameters (e.g. voltage, frequency etc.) and the control challenges need to be identified.

3.1. Droop Control

To achieve good power sharing and wireless communication between DGs, one of the most popular approaches is to employ droop control for active and reactive power regulation. The DGs can meet the new load requirements in a manner determined by its frequency and voltage droop characteristics. Another significant feature of microgrid is the resynchronization for smooth reconnection to utility, which means that a microgrid not only can disconnect from the utility when grid fault is detected, but also reconnect to the utility when the fault is cleared, and these operation mode transition should not cause negative effects on the utility and critical loads . This paper focuses on a control strategy that is used for the operation of a parallel inverters based microgrid. First, the power flow in a network system is investigated, based on which the droop control method for microgrid is presented .The basic equation of voltage and frequency droop control method for microgrid can be defined as

$$\omega = \omega^* - m\,(P - P^*) \qquad (1)$$

$$E = E^* - n\,(Q - Q^*) \qquad (2)$$

Where, P^* and Q^* are the desired active and reactive power, ω^* and E^* are the inverter normal output frequency and voltage amplitude, m and n are the slopes of the droop characteristics. Fig-3 depicts the $P\text{-}\omega$ droop characteristics. In droop control method, the changes in load can be taken up by the DGs in a predetermined manner and the wireless control of parallel inverters is achieved with the utilization of system frequency as a communication link within a microgrid.
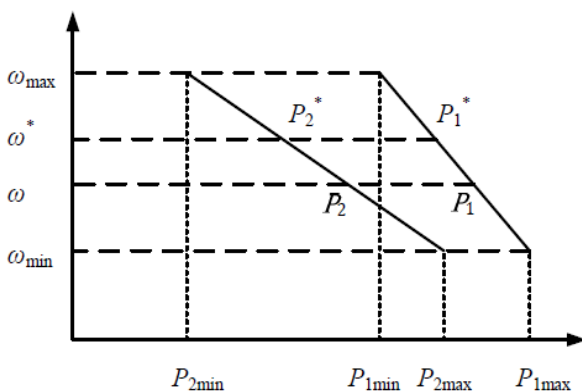

Fig -3: Active power and frequency droop characteristics

4. SIMULATION RESULTS

The performance of the control strategy has been tested in simulation using Matlab/Simulink. A micro grid with a single DG unit, as shown in Fig-4 is employed. In this simulation, there is one local load connected to a DG unit and one common load connected to ac common bus, the microgrid is connected to utility through a STS. For the sake of simplicity, voltage and current feedback control is utilized to regulate the inverter output voltage.
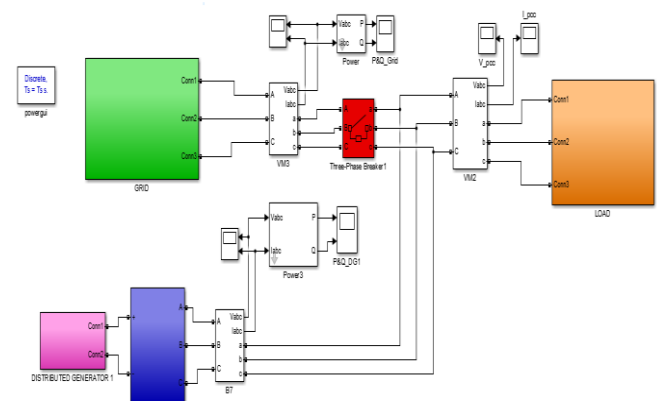

Fig -4: Model of microgrid with a single DG

At the beginning, the microgrid operates at islanded mode. Fig-6 shows the active and reactive power sharing within the microgrid. *P* denotes the active power output from DG1 and the active power flowing from the utility. On the other hand, *Q* denotes the reactive power output from DG1 and the reactive power flowing from the utility, respectively. In islanded mode, DG1 will supply all the active and reactive power required by the local loads and the common load according to their frequency and voltage droop characteristics. It can be seen that DG1 carries a larger share of active power since it has a stiffer slope while $P_g = 0$ W and $Q_g = 0$ Var. At 0.1 s-.25s, the STS will be active and the utility will connected to the load and the system is said to be operated in grid connected mode. At 0.1s, the microgrid starts to synchronize, the increase in both active and reactive output power of DGs can be observed during the process of synchronization. After reconnection (0.25 s) of the microgrid and utility, it is seen that the output powers of DG drop back to their referenced dispatched values (*P* and *Q*) because part of the power flows from the utility in grid-connected mode.

Fig-5 and Fig-7 shows the voltage, current and power response of local Load while the dynamic response of ac common bus voltage and STS current can be found in Fig-5 The ac common bus voltage is very stable during the grid connection process while slight overshoot current can be observed in the STS at 0.1 s.
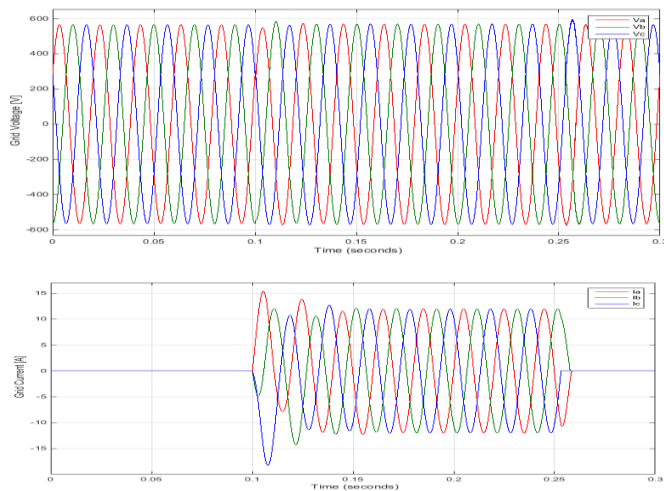
Fig -5: Grid voltage and grid current in Grid connected operation of microgrid
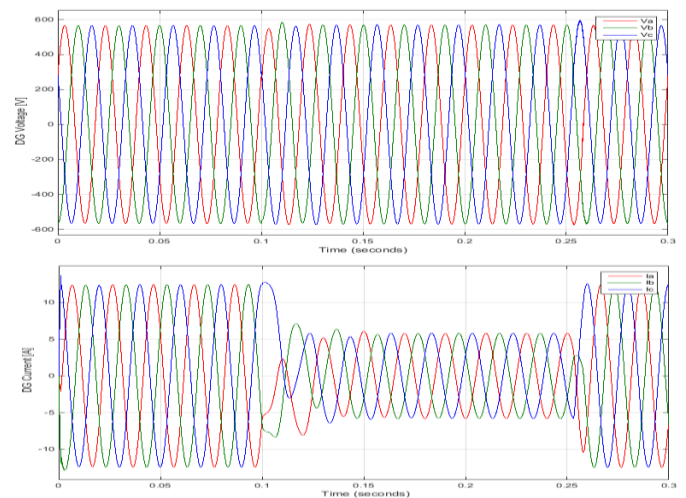
Fig -6: Active power and reactive power in Grid connected operation of microgrid
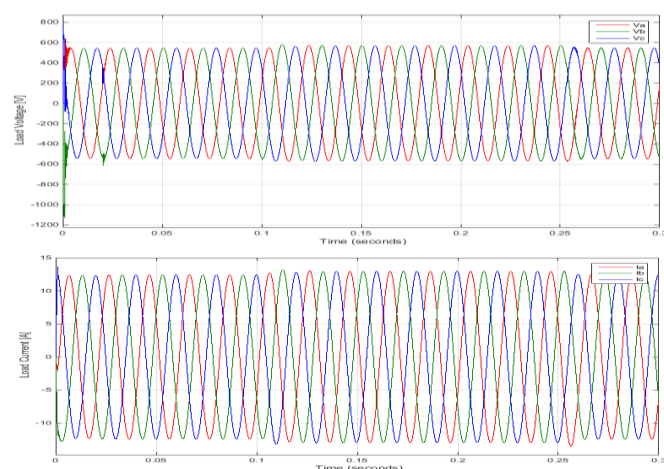
Fig -7: Load voltage and load current in Grid connected operation of microgrid

Fig -8: DG voltage and DG current in Grid connected operation of microgrid

5. CONCLUSIONS

In this paper, a control strategy for parallel connected DG System forming a microgrid was presented. This control strategy combines frequency and voltage droop method and inverter voltage regulation control scheme. In the external power control structure, the referenced frequency and magnitude of inverter output voltage are obtained according to the droop characteristics this specified voltage is then implemented in the inner voltage control structure. The load changes can be taken up by the parallel connected DGs. Moreover, seamless transfer between islanded and grid connected mode is achieved without causing negative influences on both utility and critical loads.

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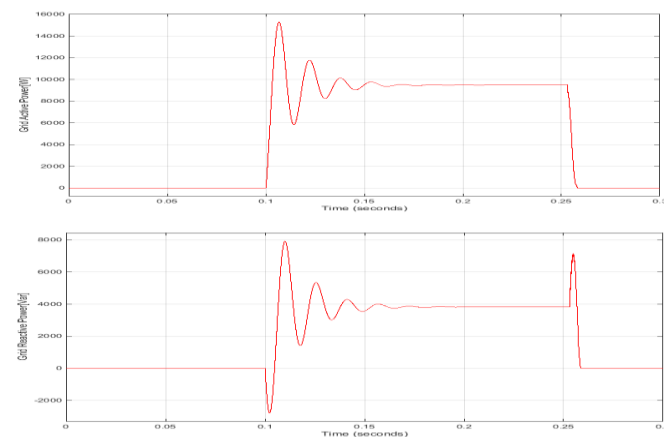
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BIOGRAPHIES

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