Control Strategy of Microgrid during Grid-Connected Mode

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***Abstract* - There has been a keen interest on Distributed Generation (DG) due to their restricted goals of meeting local loads and improving reliability of the overall system. Microgrids (MGs) are connected to the main grid through a Point of Common Coupling which separates the former from the latter. At the time of an intentional islanding or fault at the grid level, a microgrid is able to disconnect itself from the rest of the grid and operate by itself. A microgrid may contain both directly connected and inverter interfaced sources with different control configurations. When disconnected or islanded from the main grid there are various approaches to share the load, one of them being master-slave control where a storage device may become the reference DG to set the nominal voltage and frequency. When the main grid is brought back to normal operation, the microgrid is able to resynchronize itself to the main grid only when it meets certain conditions so as to avoid transients. All the microsources, power electronics and their control with power management were developed in Matlab/Simulink.**

***Index Terms* - Introduction, literature survey, control strategy, PQ control, MATLAB/SIMULINK**

I. INTRODUCTION

IEEE Std 1547.4-2011 states Distributed Resource (DR) island systems or microgrids as electric power systems (EPS) that: (1) include DR and load, (2) include the ability to disconnect from and parallel with the area EPS, (3) include the local EPS and may include portions of the area EPS, and (4) are intentionally planned. A report by SBI Energy states that the world market for microgrids had reached over $4 billion in 2010 and is expected to continue through this decade spurred by growth in renewable energy and energy storage as well as new standards under development in the general area of smart grids. Another report by Pike Research forecasts that more than 2,000 microgrid sites will be operational worldwide by 2015, up from fewer than 100 in 2010. These include:

- Institutional/campus microgrids (single owner)
- Commercial/industrial microgrids (multiple owners)
- Community/utility microgrids tied to the larger utility grid infrastructure
- Remote off-grid systems (commonly in developing countries)
- Military microgrids (to support remote base operations without a fuel supply) [1].

A MG can operate in grid connected mode or in islanded mode. In grid-connected mode MG supplies or draws power to the utility grid depending on the generation and load demand. In case of an emergency and power short age during power interruption the MG shifts to island mode of operation. The essential features of MG are: i) Provide good independent solution in islanded mode of operation, ii) Plug and play function, capability to synchronize safely connected MG to the main grid, iii) Provide V & f protection during islanded operation and capability to resynchronize safely connected MG to main grid, iv) Ensure stable operation during fault & various network disturbances [2].

II. LITERATURE SURVEY

In (Lasseter et al., 2003) the microgrid is defined as an aggregation of loads and microsources operating like single system providing both power and heat. In (Barnes et al., 2007) the microgrid concept is proposed to integrate large amounts of microgeneration without disrupting the operation of the utility network [3]. The MicroGrid concept assumes a cluster of loads and microsources operating as a single controllable system that provides both power and heat to its local area. This concept provides a new paradigm for defining the operation of distributed generation. When the customers are too far from the main grid, small power sources (typically diesel generators or renewable power sources) are used to produce the local needed energy. Generally, such small-scale electrical grid can operate isolated or interconnected with a main grid and is called microgrid (MG). It is mainly composed by one or several micro-sources, multiple loads and potential energy storage systems connected together [4].

Today there is much interest in microgrid due to the environment protection and energy sustainable development. B. Lasseter., first put forward a review of the microgrid example in 2001. Then CERTS (Consortium for Electric Reliability Technology Solutions) [5] and European Commission Project Micro grids respectively proposed the concept of microgrid. Now the concept of microgrid has been accepted in many organizations and laboratories [6]. In a typical microgrid, the microsources may be rotating generators or Distributed Energy Resources (DER) interfaced by power electronic inverters [7]. The installed DERs may be biomass, fuel cells, geothermal, solar, wind, steam or gas turbines and reciprocation internal combustion engines. The overall efficiency may be improved by using combined heat and power sources (CHP) The connected loads may be critical or non-critical. Critical loads require reliable source of energy and good power quality. These loads are supported by their own microsources because they require an uninterrupted supply of energy. Noncritical loads may be shed when required decided by the microgrid operating policies. Since the power level of utility grid is higher than that of the microgrid, the same is dominated mainly by the existing power grid. But the actual performance is judged when the microgrid works in islanded mode. [8]. The real world microgrids are **American Microgrid**s (AEPCERTS, Mad River, BC Hydro Boston Bar, and GE Microgrid), **Asian Microgrids** (Shimizu's Microgrid, Hachinohe Project, Kyoto Eco-Energy Project, Aichi Project, Sendai Project, Hsinchiang in China), and **European Microgrids** (Kythnos, Labein Experimental Centre, EDP Feeder, CESI, Continuon Holiday Park, Demotec, MVV Energie Projects) [9].

The Consortium for Electric Reliability Solutions Testbed (CERTS) microgrid provides an example of an effective microgrid implementation. The CERTS microgrid is comprised of two primary components: a static switch and DERs [10]. The static switch serves as the gatekeeper for interconnection with the utility grid. The CERTS microgrid relies on a control scheme that is local to each DER, thus eliminating the possibility of catastrophic failure of a central coordinating controller. Additionally, this arrangement allows DERs to "plug and play" without requiring dynamic restructuring of the microgrid architecture; however, this capability would be feasible with a centralized controller, as well. Each local controller operates by sensing DER output voltage and current, converting these signals to real and reactive power quantities, and utilizing voltage versus reactive power (V-Q) and frequency versus real power (f-P) droop methods for appropriate control. The governing control principal for droop methodology is power balancing. While it has been shown to be very effective in the CERTS case, this scheme does not currently consider other competing objectives within its power management and control strategy [11].

III. CONTROL STRATEGIES FOR MICROGRID OPERATION

According to the integral control strategy, microgrid control can be divided into master-slave control and peer-to-peer control [12]. There is a main control unit in master-slave control to maintain the constant voltage and frequency. The main control unit adopts V/F control while other distributed generations adopt PQ control to output certain active and reactive power. Master-slave control is composed of upper master control and sub-layer slave control. The upper master controller send control command towards sub-layer slave control. Peer-to-peer control, based on the idea of "plug-and-play", contain a number of equal-status equipments, one of which changes won't affect the others. The control strategy of DG can be divided into three categories: PQ control, Droop control and V/f control, according to the control method of DG. Droop control is a common control strategy in peer-to-peer control.

The droop control uses the real power out of a generator to calculate the ideal operating frequency. This relaxing of a stiff frequency allows the microgrid to dampen the fast effects of changing loads, increasing the stability of the system [13]. This section deals with the hierarchical control of microgrids, consisted in three control levels. UCTE (Union for the Co-ordination of Transmission of Electricity, Continental Europe) have defined a hierarchical control for large power systems [14].

IV. MICROGRID CONTROL DURING GRID-CONNECTED MODE

PQ Control

Fig.-1 is the PQ control schematic for the three-phase grid-interfacing inverter. If the DG needs inverter to connect to the conventional distribution system and the capacity of power and energy storage device is enough, each feeder in Fig.-2 can be equivalent to the part above the dashed line of Fig. 2.3.2 [15].

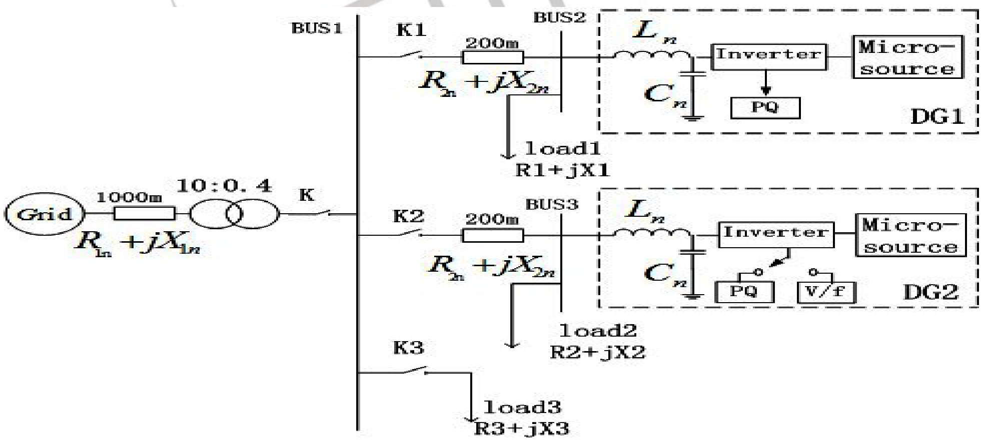

Fig.1 Microgrid modeling [15]

The microgrid in [16] contains both directly connected and inverter interfaced microsources, their control scheme also varies. All the controllable inverter interfaced microsources are operated with a PQ control strategy when grid-connected. In the PQ control of an inverter as shown in Fig. 2.3.3, Park's transformation is used to convert the three-phase voltages and currents at the grid side into the rotating reference frame components [16, 17].

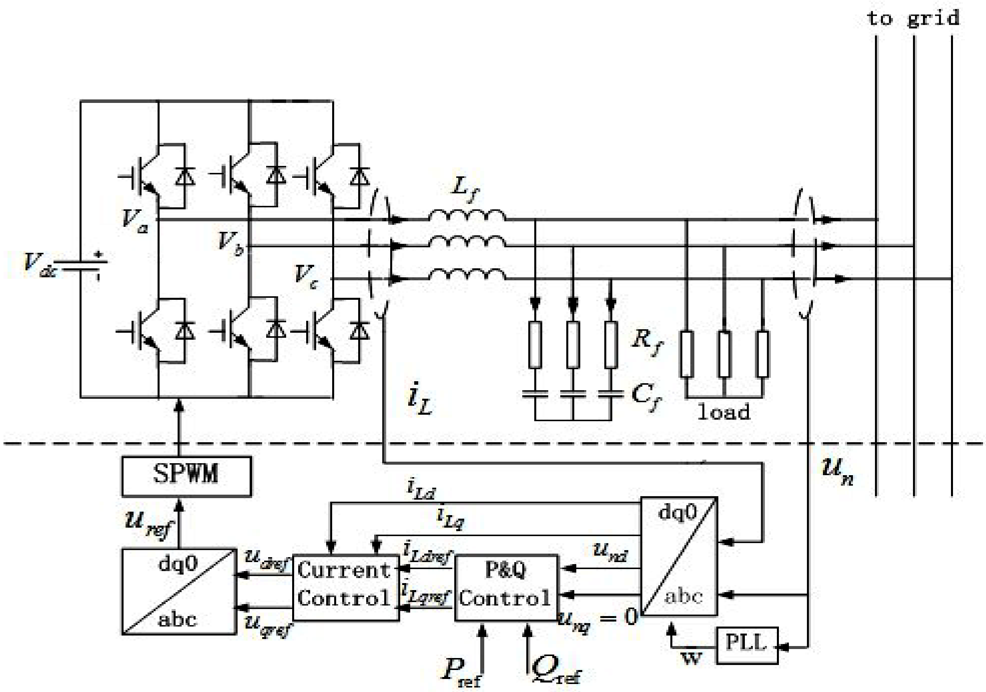

Fig.2 PQ control schematic [15]

I is the output current of inverter, *Ldi* and *Lqi* are currents of d axis and q axis of *Li* by dq transformation, respectively. Assuming that the output active power and reactive power of inverter are *ref P* and *ref Q*, respectively, and due to

$$u_{nq} = 0$$

Then,

$$i_{Ldref} = \frac{P_{ref}}{u_{nd}}$$

$$i_{Lqref} = \frac{Q_{ref}}{u_{nd}}$$

the above two equations represent the P&Q Control module in Fig. 3 and show that there are an external power control and inner current control. The tracking of the reference active power *ref P* and reactive power *ref Q* is to track the reference current *Lrefi*. P is determined by *Ldi* and Q is determined by *Lq i*. Thus, control of P and Q is decoupled. Fig.-3 shows the MATLAB/SIMULINK diagram. Table-1shows Simulation Parameter Of PQ Control.

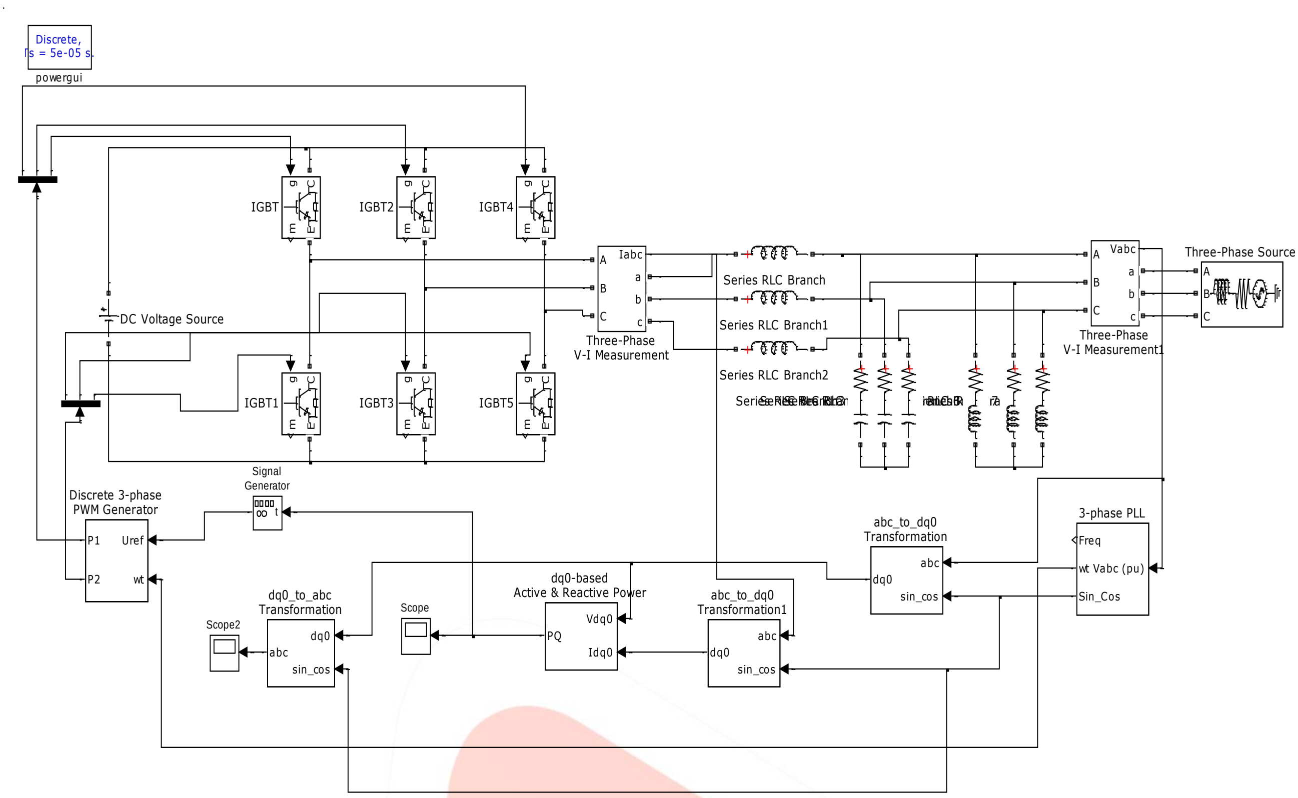

Fig.3 PQ control Scheme in MATLAB/SIMULINK

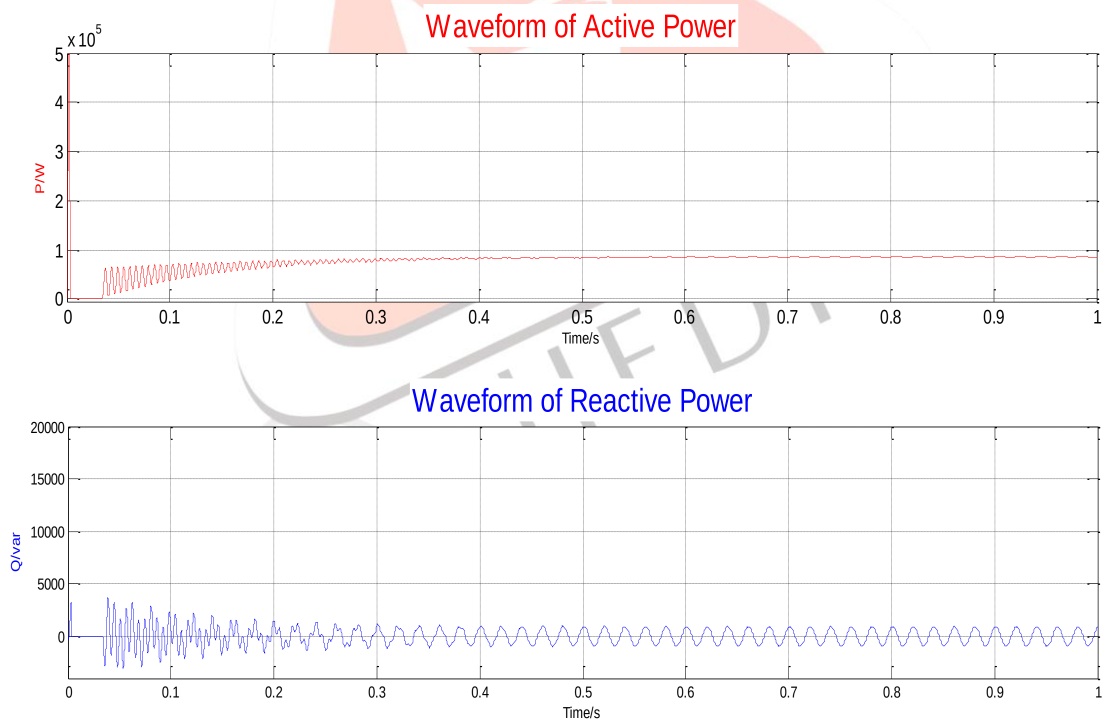

Fig.4 Waveforms of active and reactive power during Grid-connected mode

V. CONCLUSION

Microgrid system is very bulky system it contains source, inverter and the load. PQ (Active and Reactive power) control is suitable for the DGs whose output power is adjustable. The PQ control mode is used in this paper. Their dynamic and steady state behaviors were examined in a Matlab/Simulink simulation environment. We can get the desired output waveforms of Microgrid operation when it is interfaced with main grid.

VI. FUTURE WORK

After PQ control during main grid connection, I will present V/f i.e., voltage and frequency control of Microgrid operation during islanded mode. When Microgrid is operated in autonomous mode, voltage and frequency does not match with load. So that there is need of V/f control strategy for Microgrid operation in islanded mode.

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