National Conference on Recent Research in Engineering and Technology (NCRRET-2015)
International Journal of Advance Engineering and Research Development (IJAERD)
e-ISSN: 2348 - 4470 , print-ISSN:2348-6406

MicroGrid during Grid-connected mode and Islanded mode - A Review

[1]Kalpesh C. Soni, [2] Firdaus F. Belim
[1]Assistant Professor, [2]Assistant Professor
[1, 2] Electrical Engineering Department,
[1]Dr. Jivraj Mehta Institute of Technology, Mogar, Anand, Gujarat,
[2]Goverment Engineering College, Palanpur, Gujarat
[1]skalpesh54@gmail.com, [2]firdaus.ele@gmail.com

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. Micro grids (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, V/f 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:

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

Technology developments in the last few years are bringing up new forms of electricity production – the Microsources (MS). The interconnection of small modular generation sources to low voltage distribution systems can form a new type of power system, the MicroGrid (MG). MG can be connected to the main power network or be operated autonomously, if they are isolated from the power grid in face of a planned or unplanned event. In addition, fast system recovery (Black Start capabilities) after major fault conditions can be provided. A MG comprises also an hierarchical control and management system: in an upper level, the MiocroGrid Central Controller (MGCC) provides the technical and economical management of the MG; in a lower level, Load Controllers (LC) can be used for load control, making use of an interruptibility concept; also MicroSource Controllers (MS) are used to locally control the active and reactive power production levels [3].

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) [4] 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 [5]. In a typical microgrid, the microsources may be rotating generators or Distributed Energy Resources (DER) interfaced by power electronic inverters [6]. 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. [7].

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 [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) [33].

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].

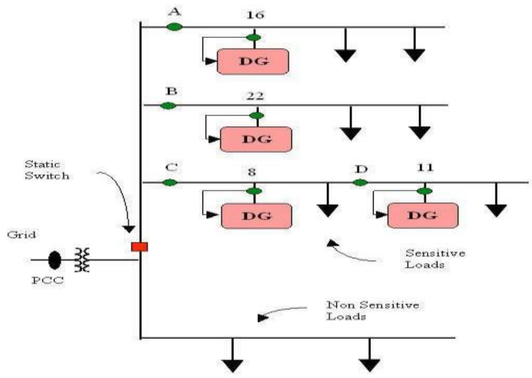

Fig-2.1 MicroGrid concept [11]

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].

a) MICROGRID CONTROL DURING GRID-CONNECTED MODE

PQ CONTROL: - Fig.-3.1 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.-3.1.1 can be equivalent to the part above the dashed line of Fig. 2.3.2 [15].

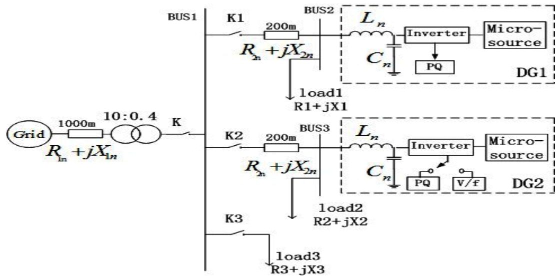

Fig.3.1. Microgrid modeling [15]

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. 3.1.1, 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].

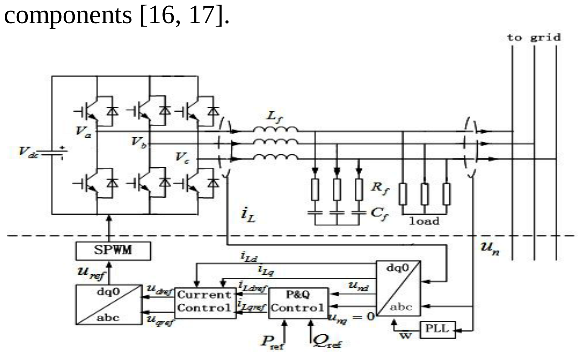

Fig.3.1.1 PQ control schematic [15]

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. 3.1.1 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 *Lqi*. Thus, control of P and Q is decoupled.

b) MICROGRID CONTROL DURING ISLANDED MODE

V/f CONTROL:-In islanded mode the distributed sources operating with PQ control strategy lose their voltage and frequency references, which were previously dictated by the main grid. The storage device which was previously being operated with a PQ control changes to V/f control. The storage device provides the power imbalance that was being supplied from the main grid to the microgrid before the islanding instant. Rest of microsources could either be operated at the same set points or may change their set points based on the supply and demand. It is assumed that the storage device has an adequate reserve to be able to provide the same power imbalance as the main grid. There is also the droop control method where multi-power sources participate in the power balance during the island mode [6].

These DG's follow frequency droop (f-P) and voltage droop (V-Q) characteristics to change the operating points in order to follow the power imbalance caused by the disconnection of the main grid. However there are disadvantage involved with droop control that include poor voltage regulation, high voltage distortion and loss of synchronism with the main grid which poses a problem while resynchronization with the main grid [14].

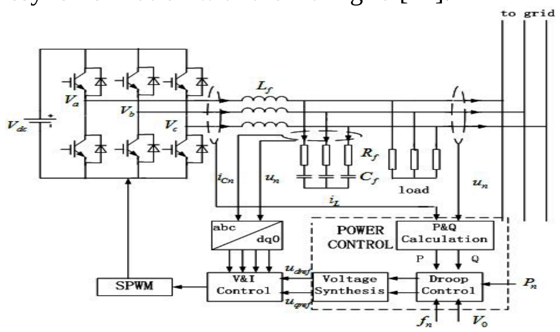

Fig.-3.1.2 V/f control schematic [17]

IV. CONCLUSIONS

In this paper, a three-bus microgrid is presented, which includes microsources, inverters and loads. The control of inverters is critical because the control flexibility allows the microgrid to present itself to the bulk power system as a single controlled unit, have plug-and-play simplicity for each microsource, and meet the customers' local needs.

This paper presents two control strategies for the microgrid, PQ control and V/f control respectively. The PQ control is suitable for the DGs whose output power is adjustable and the V/f control is suitable for the DGs whose output power is stable. The PQ control makes the DGs output the reference power according to the actual situation and the V/f control makes the DGs share of power between the DG systems when the microgrid islands from the utility and provide frequency support when the microgrid is in islanded mode.

REFERENCES

1] Shyam Naren Bhaskara, Badrul H. Chowdhury,"Microgrids – A Review of Modeling, Control, Protection, Simulation and Future Potential", IEEE, 2012.

[2] R.H.Lasseter, "MicroGrids", in Power Engineering Society Winter Meeting, 2002. IEEE,2002, pp. 305-308, vol.1.

[3] J. A. Peças Lopes, C. L. Moreira, A. G. Madureira, F. O. Resende, X. Wu, N. Jayawarna, Y. Zhang, N. Jenkins, F. Kanellos, N. Hatziargyriou: "Control Strategies for MicroGrids Emergency Operation"

[4] R.H.Lasseter, "CERTS MICROGRID", IEEE, 2007.

[5] Shuiming Chen, Hongqiao Yu,"A review on overvoltages in microgrid", IEEE, 2010.

[6] Michael Angelo Pedrasa, Ted Spooner, "A Survey of Techniques Used to Control Microgrid Generation and Storage during Island Operation." AUPEC2006.

[7] Prasenjit Basak, A. K. Saha, S. Chowdhury, S. P. Chowdhury, "Microgrid Control Techniques and Modeling", IEEE, 2009.

[8] M. D. Govardhan and Ranjit Roy, "A Review on key issues of microgrid" in IEEE PES Innovative Smart Grid Technologies – India, 2011.

[9] E. Perea, J. M. Oyarzabal, R. Rodrı´guez, "Definition, evolution, applications and barriers for deployment of microgrids in the energy sector", Elektrotechnik & Informationstechnik (2008) 125/12: 432–437, JUNE 2008.

[10] Ming Ding, Yingyuan Zhang, and Meiqin Mao, "Key Technologies for Microgrids-A Review", 2008
[11] Sylvain Baudoin, Ionel Vechiu, and Haritza Camblong, "A review of voltage and frequency control strategies for islanded", 2012.
[12] Prasenjit Basak, Dr. S. Chowdhury, Dr. S.P. Chowdhury, and Dr. S. Halder nee Dey, "Simulation of Microgrid in the Perspective of Integration of Distributed Energy Resources", IEEE, 2011.
[13] Duan Yubing, Gong Yulei, Li Qingmin, Wang Hui , "Modelling and Simulation of the Microsources Within a Microgrid", pp. 2667-2671, 2007.
[14] Manohar Chamana, Stephen B.Bayne, "Modeling and Control of Directly Connected and Inverter Interfaced Sources in a Microgrid", 2010.
[15] LIU Jianye, LIU Jia, GU Xiao, LI Yunshan, "Model and control of a DC microgrid made up by solar and wind", 2012 International Conference on Computer Science and Electronics Engineering, IEEE, 2012.
[16] Huan Qin, XinAi, Jiajia Xu, "Control Strategy of MicroGrid with Different Types of DG and Its Dynamical Simulation", 2012 China International Conference on Electricity Distribution (CICED 2012), 2012.
[17] Liping Su, Guojie Li, Zhijian Jin, "Modeling, Control and Testing of a Voltage-Source-Inverter-Based Microgrid", IEEE, 2011.
[18] Prasenjit Basak, A. K. Saha, S. Chowdhury, S. P. Chowdhury, "Microgrid Control Techniques and Modeling", IEEE, 2009.
[19] Emanuel Serban, Helmine Serban, "A Control Strategy for a Distributed Power Generation Microgrid Application with Voltage and Current Controlled Source Converter", Power Electronics, IEEE Transactions, IEEE, 2010.
[20] C.M. Colson, M.H. Nehrir, "A Review of Challenges to Real-Time Power Management of Microgrids", 2009 IEEE Power & Energy Society General Meeting, IEEE, 2009.
[21] Meysam Shamshiri, Chin Kim Gan,Chee Wei Tan, "A Review of Recent Development in Smart Grid and Micro-Grid Laboratories", 2012 IEEE International Power Engineering and Optimization Conference (PEOCO2012), Melaka, Malaysia: 6-7 June 2012, IEEE, 2012.
[22] A.L. Kulasekera, R.A.R.C. Gopura, K.T.M.U. Hemapala, N. Perera , "A Review on Multi-Agent Systems in Microgrid Applications", 2011 IEEE PES Innovative Smart Grid Technologies – India, IEEE, 2011.
[23] Sushil Thale and Vivek Agarwal, "A smart control strategy for the black start of a microgrid based on pv and other auxiliary sources under islanded condition", IEEE, 2011.
[24] Michael Angelo Pedrasa, Ted Spooner, "A Survey of Techniques Used to Control Microgrid Generation and Storage during Island Operation".
[25] Guerrero, J.M.; Chandorkar, M.; Lee, T.; Loh, P.C.; , "Advanced Control Architectures for Intelligent Microgrids—Part I: Decentralized and Hierarchical Control," Industrial Electronics, IEEE Transactions on , vol.60, no.4, pp.1254-1262, April 2013.
[26] Sreelekshmi R S & Sunitha R, "Analysis of Inverter Fed Microgrids for Different Modes Of Operation In Matlab/Simulink", International Journal Of Power System Operation And Energy Management Issn: 2231 – 4407, Volume-2, Issue-1, 2.
[27] Rodrigo A F. Ferreira, Henrique AC. Braga, Andre A Ferreira and Pedro G. Barbosa, "Analysis of Voltage Droop Control Method for dc Microgrids with Simulink: Modelling and Simulation".
[28] Prasenjit BASAK, S. CHOWDHURY, S.P. CHOWDHURY, "SIMSCAPE BASED MODELING AND SIMULATION OF A PV GENERATOR IN MICROGRID SCENARIO", 22nd International Conference on Electricity Distribution, Paper 0997, C I R E D, Stockholm, 10-13 June 2013.
[29] Yanbo CHE, Zhangang YANG, K.W. Eric Cheng, "Construction, Operation and Control of a Laboratory-Scale Microgrid", 2009 3rd International Conference on Power Electronics Systems and Applications, 2003.
[30] J. A. Peças Lopes, C. L. Moreira, F. O. Resend, "CONTROL STRATEGIES FOR MICROGRIDS BLACK START AND ISLANDED OPERATION".
[31] Josep M. Guerrero, Juan C. Vásquez, José Matas, Miguel Castilla, and Luis García de Vicuña, "Control Strategy for Flexible Microgrid Based on Parallel Line-Interactive UPS Systems", IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 56, NO. 3, pp. 726-736, MARCH 2009.
[32] J. A. Peças Lopes, C. L. Moreira, A. G. Madureira, "Defining Control Strategies for MicroGrids Islanded Operation", IEEE TRANSACTIONS ON POWER SYSTEMS, VOL. 21, and NO. 2, pp. 916-924, MAY 2006.
[33] Mike Barnes, Giri Ventakaramanan, Junji Kondoh, Robert Lasseter, Hiroshi Asano, Nikos Hatziargyriou, Jose Oyarzabal, Tim Green, "Real-World MicroGrids- An Overview", 2007.
[34] P. Piagi, & R.H. Lasseter, "Autonomous control of microgrids", Proceedings of IEEE Power & Energy Society 2006 General Meeting, 2006.