IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)
e-ISSN: 2278-1676,p-ISSN: 2320-3331, Volume 10, Issue 1 Ver. III (Jan – Feb. 2015), PP 20-26
www.iosrjournals.org

Autonomous control of interlinking converter in hybrid PV-wind microgrid

M.Shamily[1], M.Saravanan[2]
[1](Student, Department of EEE, Thiagarajayar College of Engineering, Madurai, Tamilnadu, India)
[2](Professor, Department of EEE, Thiagarajayar College of Engineering, Madurai, Tamilnadu, India)

Abstract: *This project aims to develop a simple model of autonomous control of the interlinking converter in hybrid ac-dc microgrid (MG). In the last several years, efforts toward the standardization of these MGs have been made. Various renewable and non-conventional microsources made by DG, an alternative option for modern electrical grids. The microgrid concept reduce multiple reverse conversions in an AC or DC grid and also make a possibilities of connections to variable AC and DC renewable sources and loads to power system. The interconnection of DGs to the grid through power electronic converters has provided safe operation and protection of equipment. The objective is to make the hybrid microgrid in autonomous operation by ensure proper active power sharing proportionally among its DG's. Power sharing considered depend only on the source ratings within the hybrid microgrid, where the existing schemes are mostly for an ac or a dc microgrid, but not both in co-existence. A suitable control scheme developed for controlling the interlinking converter to share active power proportionally among its distributed sources (DG's) and will be verified by MATLAB simulation.*

Keywords: *Droop control, Frequency variation, Hybrid microgrid, Interlinking converter, Renewable energy source, Voltage deviation.*

I. Introduction

Any small-scale localized station with its own resources, generations and loads and definable limitations qualifies as a microgrid. Microgrids can be intended as standby power or to booster the main power grid during periods of heavy demand and for reducing costs and enhancing reliability. The modular nature of microgrids could make the main grid less susceptible to limited adversity. Modularity also means that microgrids can be used to gradually modernize the prevailing grid [1]. The practice of using microgrids is known as distributed, detached, decentralized, region or embedded energy generation.

Microgrid operates in grid-connected and islanded mode where in grid connected mode, MG connected parallel to main grid to either draw or supply to grid. For the former, each microsource can be operated like a current source with maximum power transferred to the utility/grid. That is possible only when the grid has larger capacity, and can hence be treated as an infinite bus [2]. In contrast, if the mains grid is not comparatively larger or is simply disconnected due to the occurrence of a fault, the islanded mode of operation with more stringent supply–demand balancing requirements will be triggered. Without a large capacity of grid and a system voltage, each microsource must now regulate its own terminal voltage within an allowed range determined by its internally generated reference. The microsource thus appears like a controlled voltage source, whose output should rightfully share the load demand with the other sources. The sharing should properly be in proportion to their power ratings so as not to overstress any individual entity. It should also be achieved with no or minimal communication link that is not detrimental to the overall system operation if it fails. This is important since most microsource is widely dispersed, and hence impractical to link by wires. Avoiding the wiring would then constrain measurements to be taken only within the local vicinity of each microsource. So far, this can only be met by the droop control method [3], where virtual inertia is intentionally added to each microsource. The voltage and frequency variations of the microgrid are fixed by the mains grid, which usually is treated as an infinite bus with much larger generation capacity and in islanded mode-disconnected from main grid due to abnormal condition in grid. The system voltage and frequency control are established by the own DGs.

In conventional AC power systems, DC power obtained from AC voltage source by converting it, using an AC/DC converter to supply DC loads [4]. AC/DC/AC converters are also used in industrial drives to control motor speed. Because of the environmental issues associated with conventional power plant renewable resources are connected as distributed generators or ac microgrids. AC sources in a DC grid have to be converted into DC and AC loads connected using DC/AC inverters into DC grid. DC systems use power electronic based converters to convert AC sources to DC and distribute the power using DC lines [5]. Changes in the produced power and the load consumed power can be compensated as a lump of power in the DC gird. The system cost and loss reduce because of the requirement of only one AC grid connected inverter. Therefore the efficiency is reduced due to multistage conversions in an AC or a DC grid. So to reduce the process of multiple DC/AC/DC or AC/DC/AC conversions in an individual AC or DC grid, hybrid AC/DC microgrid is proposed, which also helps in reducing the energy loss due to reverse conversion [6],[7].

The control method for micro-grid is divided into two groups. One is a real-time direct control according to the operation mode, in which the generated, stored, and consumed output power are measured and transmitted to the main controller through high-speed communication link. This method can offer highly safe operation for the micro-grid if a fast data transmission between the main controller and the local controllers is possible but it is less reliable and lead to malfunction if any problem in transmission and wiring [8]. Another method is an autonomous control without using a communication link, droop control method used to regulate the converter output voltage. The communication based method is not most suitable for microgrid control, since distributed generators, loads in microgrids connected to it. To overcome this problem, droop control is used to control the power sharing in microgrid without using communication system, thereby improving the microgrid performance [9],[10],[11]. The droop regulation technique is implemented to regulate the exchange the active and reactive powers between grids, in order to keep the grid voltage frequency and amplitude under control. This method improves the performance characteristics due to the circulating current among the connected converters [12]. The main idea to support droop control which has self-regulation capability of synchronous generator while in grid connected mode, decrease the delivered active power when the grid frequency increases and decrease the injected reactive power when the grid voltage and amplitude increases[13],[14].

II. Droop Control For Ac And Dc Microgrid

Droop control is the control strategy commonly applied to generators for primary frequency control (and occasionally voltage control) to allow parallel generator (e.g., load sharing) Active power and reactive power transmitted across a lossless line are

$$P = V_1 V_2 \sin\delta / X \qquad (1)$$

$$Q = V_2 (V_2 - V_1 \sin\delta)/X \qquad (2)$$

This forms the basis of frequency and voltage droop control where active and reactive power are adjusted according to linear characteristics, based on the following control equations:

$$f - f_o = -K_p (P - P_o) \qquad (3)$$

$$V - V_o = -K_q (Q - Q_o) \qquad (4)$$

Where

f - system frequency,

f_o - base frequency,

K_p - frequency droop control setting ,

P - active power of the unit ,

P_o - base active power of the unit,

V - voltage at the measurement location,

V_o - base voltage,

Q - reactive power of the unit,

Q_o - base reactive power of the unit,

K_q - voltage droop control setting.

These two equations are plotted in the characteristics below:

The frequency droop characteristic above can be interpreted as follows: when frequency falls from f_0 to f, the generated power output is permitted to increase from P_0 to P. A drop in frequency indicates a load increases and a need of much more active power. Many parallel units with the same droop characteristic increase their active power output which cause drop in frequency [15]. The increase in active power output will stabilize the reduction in frequency and the units will settle at active power outputs and frequency at a steady-state point on the droop characteristic. The droop control characteristic therefore allows many units to share load without the units aggressive each other to control the load.

1. DROOP CONTROL OF DC SUB-MICROGRID

The droop control of dc sub-microgrid can be performed similarly as ac sub-microgrid, but it is simpler than the ac sub-microgrid. The reactive power control of sharing not need for dc side of operation [16]. Here the resistance used as droop for the dc sub-microgrid. The droop characteristics shown in Fig.1.

2. DROOP CONTROL OF AC SUB-MICROGRID

The droop control principle can be applied to both active power and reactive power sharing in ac sub-microgrid. The objective is to develop an autonomous control for coordinate the power sharing [18]. The droop characteristics shown in Fig.2.

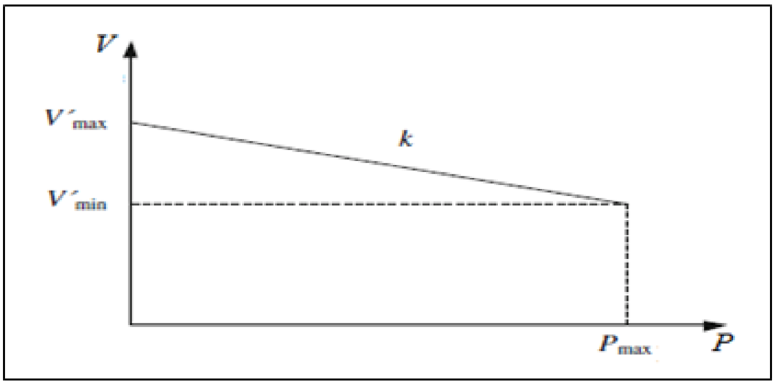

Fig. 1. Droop characteristics for dc sub-microgrid

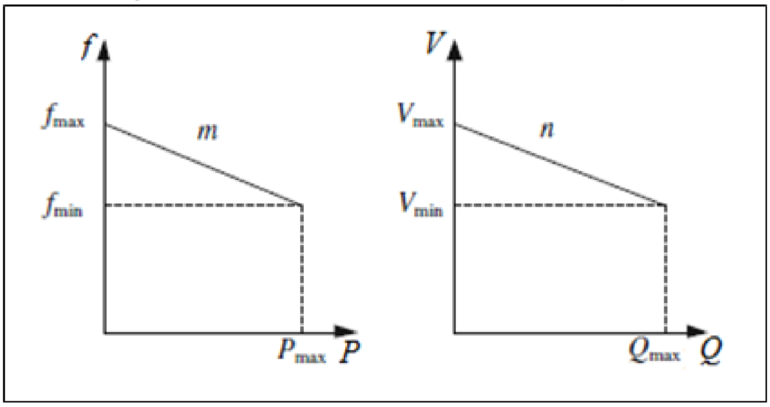

Fig. 2. Droop characteristics for ac sub-microgrid

III. System Structure

Fig. 3 shows an example of hybrid microgrid formed by an ac sub-microgrid and a dc sub-microgrid. Each sub-microgrid has its own sources and loads of the same kind of grouped together so as to ensure the power sharing needed. Among the sub-microgrids there is an interlinking converter between it, depending on the ratings and those of the sub-microgrids. Regardless of the placement, the role of interlinking converter is to provide the bidirectional energy transfer between the sub-microgrids, depending on their prevailing internal supply-demand conditions. The formed hybrid microgrid can then be tied to the ac utility mains through the switch as with other ac microgrid. This switch will stay on under normal grid connected mode of operation and if its main is strong with large capacity, maximum energy from the hybrid microgrid. Supply and demand balancing within the microgrid is, therefore, less effective with the mains which behaving like an infinite bus. Its control is therefore, less involved with independently operating sources and storages in both sub-microgrids.

If fault is takes place in utility/main grid which is sensed by the relevant devices, the switch will break to form an islanded mode of operation i.e., isolated from the main. Islanding mode of operation should be done carefully than the grid-tied mode due to supply and demand condition will be differ because it's not depend on main supply i.e., from the infinite bus. That also means sources can no longer produce optimal or maximum power continuously if the combined capacity of loads are not capable of absorbing the full amount of power generated. The right amount of energy should be produce that would meet the demand, while not to overstress the sources. The sharing can certainly be realized by adding an explicit communication link, together with its accomplished cost, which may cause single point of failure, for that droop control is considered, where sources are responsible for the load demand and it share with the other loads by maintaining the values of terminal voltage, magnitude, frequency, and phase. During steady-state condition, each of them producing a fraction of the demand in proportion to power rating.

Presently, droop control method is considered and it is well established in this field, but mainly focused on the ac microgrid. Here the droop control considered for the both ac and dc microgrid separately using the concept of interlinking converter between the two shown in Fig. 1 and Fig. 2.

The PV panel used as dc sources has rating of 20kW, where the temperature and irradiation are controlled to obtain the appropriate voltage needed for the model i.e., 400V, and the MPPT controller used to find the peak power which is to be deliver to the load needed. The MPPT algorithm of MP&O used to obtain the peak power. The wind-diesel generator used as ac source has a rating of 20kW and 12kVar , at low wind speeds both the induction generator and the diesel-driven synchronous generator are required to feed the load. When the wind power exceeds the load demand, it is possible to shut down the diesel generator. In this all-wind mode, the synchronous machine is used as a synchronous condenser and its excitation system controls the grid voltage at its nominal value. A secondary load bank is used to regulate the system frequency by absorbing the wind power exceeding consumer demand.

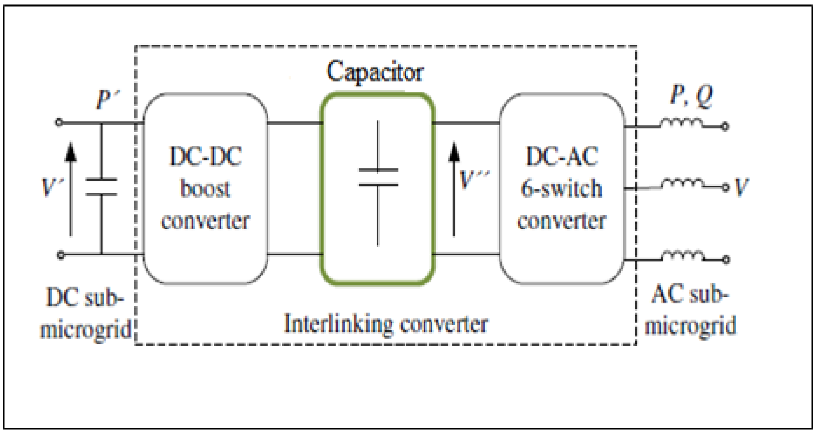

Fig. 3. Overall block diagram oh hybrid microgrid

IV. Control Of Interlinking Converter

Droop control scheme is employed to explain the concept of interlinking converter where the controllable loads with different capacities are taken into account. A control method of interlinking converter composed of ac and dc sub-microgrid taken as a sources and renewable energy sources used instead of sources. A configuration which consist of DC-link capacitor could integrate the converter by injecting voltage to full-bridge converter (perform both inversion and rectification operation). The balanced and linear load is taken into account and the control strategies were developed for the interlinking converter. The above summarized methods can be effectively enhancing the performance of a hybrid microgrid. But they mainly focus on the AC side and DC side performance and the corresponding control schemes. The challenge is to design an autonomous control for interlinking converter connecting both ac and dc sub-microgrids and share the power proportionally among the sub-microgrids.

The complexity while using interlinking converter is thus the different droop control variable used by two sources are frequency of AC and voltage of DC. Note that these combined characteristics need not be fully linear. This integration is initially not possible because of the different axes labelled as frequency of ac sub-microgrid and voltage of dc sub-microgrid.

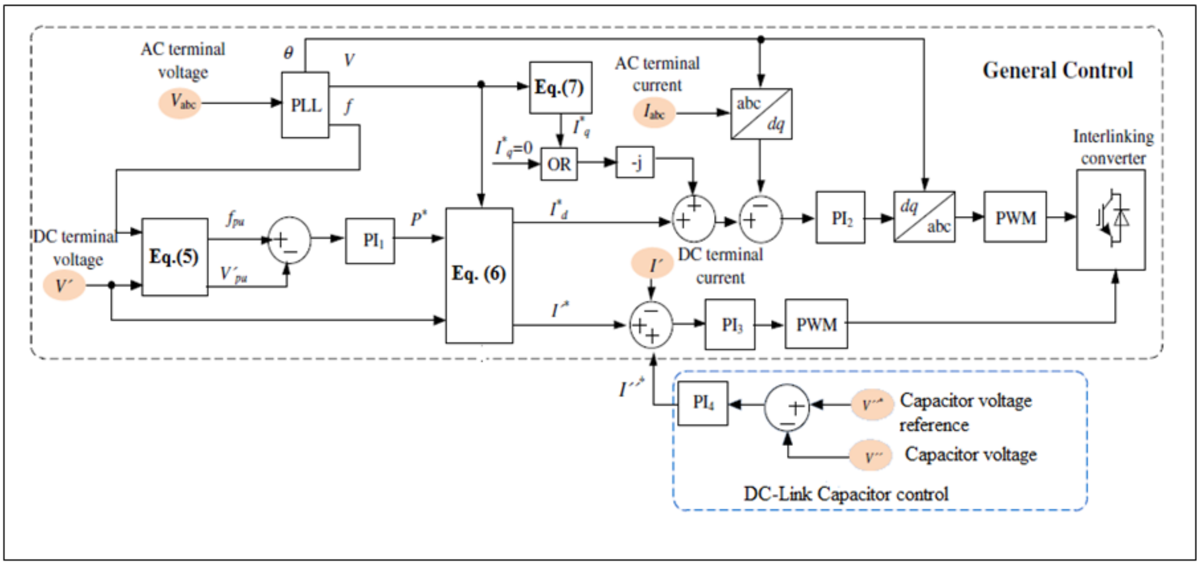

Fig. 4. Control scheme of interlinking converter

The error of the variable brought to the common per unit range as -1 to 1 or other preferred values by using the two equations:

$$f_{pu} = \frac{f - 0.5\left(f_{max} + f_{min}\right)}{0.5\left(f_{max} - f_{min}\right)}$$

$$V'_{I,pu} = \frac{V'_{I} - 0.5(V'_{I,max} + V'_{I,min})}{0.5(V'_{I,max} - V'_{I,min})} \quad (5)$$

where V'_I represents the dc terminal voltage of the interlinking converter pu represents per unit range value and $\max$ *and* $\min$ represents the maximum and minimum values of the each variable, respectively. Upon regulated variables, droop characteristics for both sub-microgrid plots as horizontal and vertical axes. The error of the regulated variables (f_{pu}-$V'_{I,pu}$) can then be fed to the PI (proportional-integral) controller, taken as PI_1. While during steady-state condition, the error is fed as input to the PI_1 controller would be zero. That is two regulated variables have been equalized ($f_{pu}=V'_{I,pu}$) like that ac microgrid network would have naturally done as it delivering the supply and demand condition .

The PI controller work well with the ac and dc grids, and it can be used in interlinking converter where multiple PI controllers are used. Here PI controllers used for power sharing in both ac and dc sub-microgrids. Slight deviance might however in practice, caused due to different terminal voltages because of different finite impedance and parameter mismatches within the dc sub-microgrid. The dc sub-microgrid does not deal with reactive power control only active power control is needed by using terminal voltage and for ac microgrid, both active and reactive power control needed by using frequency and terminal voltage. The setting of Q^*_I taken as zero during ac to dc power transfer will not be restraining when the ac sub-microgrid is under-loaded. The ac sub-microgrid has ability to manage its own reactive power production without the aid of the interlinking converter. Here, tracking is prescribed by four PI controller placed in synchronous frame followed by the result of pulse-width modulation. The final control scheme diagram assembled for each interlinking converter is shown in Fig.4.

The active and reactive power measured at the source terminal of the interlinking converter for using as reference value for its frequency and voltage magnitude. The interlinking converter realized by measuring the dc voltage and using phase-locked loop (PLL) to detect the voltage amplitude and ac frequency. The abc-to-dq transform and dq-to-abc transform used for ac sub-microgrid to produce pulse-width modulation i.e., to make in synchronous frame and dc sub-microgrid always in rotating frame. These quantities are converted to current reference command instead of voltage which is exhibited by the interlinking converter.

$$I^*_{I,d} = 2P^*_I/3V_I\,;\left(I'_I\right)^* = -P^*_I/V'_I \quad (6)$$

$$Q^*_I = \left(V_I - V_{I,max}\right)/v_I\,;I^*_{I,q} = -2Q^*_I/3V_I \quad (7)$$

where v_I is the droop co-efficient for sharing of reactive power. The PI controller values used are as follows:

Table:1 Gain values of Kp and Kq

Proportional gain Kp	**Integral gain Ki**	**Based on**
$Kp_1 = 0.01$	$Ki_1=1000$	Acceptable error band e_B=0.05, initial transient error band $(f_{pu} - V'_{I,pu})$
$Kp_2 = 0.3$	$Ki_2 = 2000$	Time-lap filter for representing computational delay
$Kp_3 = 0.3$	$Ki_3 = 2000$	Low-pass filter for representing capacitor charging dynamics
$Kp_4 = 0.1$	$Ki_4 = 10$	PI_2 and PI_3

V. Simulation Result

The simulation was executed in MATLAB/Simulation with the droop control scheme applied to the hybrid microgrid as shown in Fig.5. The solar PV system used for dc supply and wind-diesel generator for AC source. The total rating are taken as 20kW, frequency range is chosen as 49Hz $\leq f \leq$ 51Hz and 5kVAr of reactive power, ac supply voltage chosen as 255V $\leq V_{ac} \leq$ 270V for an ac sub-microgrid. The corresponding values chosen for dc sub-microgrid are 20kW with the dc voltage range as 393V $\leq V_{dc} \leq$ 410V. The active power are chosen as equal, and droop co-efficient are intentionally tuned to the generated power as always balanced. A modulation range of 0.85≤ m ≤ 0.92 used as typical value for practice. The PI controllers provide a suitable performance in terms of setting time and minimize the frequency deviation.

A transient steps was performed for the modeled system and the results are shown in Fig. 4. The first transient event are plot as initially a load demand of 3kW decreased on dc sub-microgrid and the same increased in ac sub-microgrid before t=0.5s. If the sub-microgrids are equally loaded, then there is no active and reactive power transfer takes place through interlinking converter, these are shown from t=0s to 0.5s. Both current values of ac and dc side are noted as zero, therefore, no active power transfer takes place. After t=0.5s, the ac load demand increased as 20kW and dc as in 1.7kW. Reactive power generation not takes place in interlinking converter during ac to dc power transfer.

The second transient event shown in same Fig.5 are plot as initially a load demand of 3kW increased on dc sub-microgrid and the same decreased in ac sub-microgrid before t=0.5s. If the sub-microgrids are equally loaded, then there is no active and reactive power transfer takes place through interlinking converter, these are shown from t=0s to 0.5s. After t=0.5s, the ac load demand increased as 20kW and dc as in 2.2kW. The transfer of power from the dc to ac sub-microgrid to activate reactive power control of the interlinking converter. The reactive power of 12kVAr produced which is shown in Fig.5. The total load demand in interlinking converter is well shared in hybrid microgrid. This paper presents a power sharing scheme for interlinked microgrid based on droop control principle.

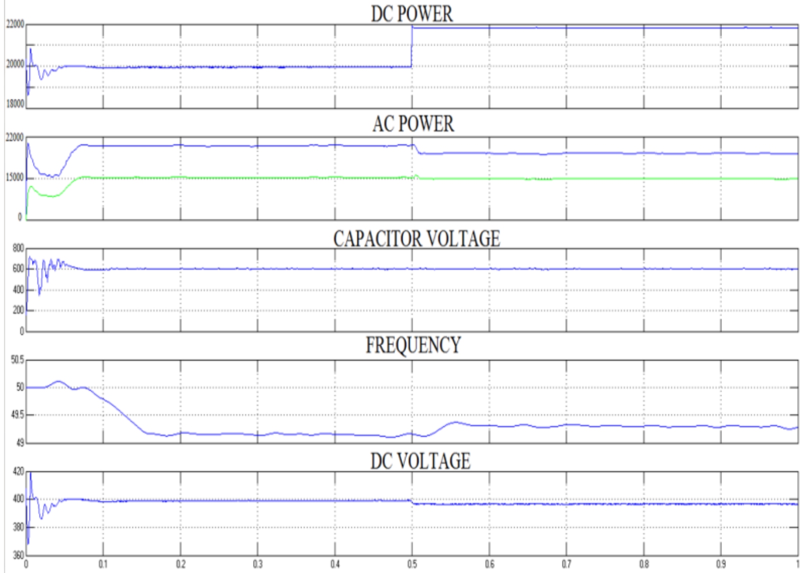

Fig. 5. Simulation for over loaded and under loaded condition of hybrid microgrid

References

[1]. F. Mura, C. Meyer, and R. W. De Doncker, Stability analysis of highpower dc grids, IEEE Trans. Ind. Appl., vol. 46, no. 2, pp. 584–592, Mar./Apr. 2010.

[2]. P. C. Loh and F. Blaabjerg, Autonomous control of distributed storages in microgrids, in Proc. IEEE ICPE, 2011, pp. 536–542.

[3]. H. Farhangi, The path of the smart grid, IEEE Power Energy Mag., vol. 8, no. 1, pp. 18–28, Jan./Feb. 2010.

[4]. Y. Ito, Y. Zhongqing, and H. Akagi, DC micro-grid based distribution power generation system, in Proc. IEEE IPEMC, 2004, vol. 3, pp. 1740–1745.

[5]. B. Kroposki, T. Basso, and R. DeBlasio, Microgrid standards and technologies, in Proc. IEEE PES Gen. Meet., 2009, pp. 1–4.

[6]. Poh Chiang Loh, Ding Li, Yi Kang Chai, and Frede Blaabjerg, Autonomous Control of Interlinking ConverterWith Energy Storage in Hybrid AC–DC Microgrid, IEEE transactions on industry applications, vol. 49, no. 3, May/June 2013.

[7]. H. Nikkhajoei and R. H. Lasseter, Distributed generation interface to the CERTS microgrid, IEEE Trans. Power Del., vol. 24, no. 3, pp. 1598–1608, Jul. 2009.

[8]. De Brabandere. K, Bolsens. B, Van Den Keybus. J, Woyte. A, Driesen. J, and Belmans. R, ―A voltage and frequency droop control method for parallel inverters‖,. IEEE Trans. Power Electron., vol. 22, no. 4, pp. 1107. 1115, Jul. 2007.

[9]. Dong Chen, Lie Xu and Liangzhong Yao, DC Voltage Variation Based Autonomous Control of DC Microgrids, IEEE transactions on power delivery, vol. 28, no. 2, april 2013.

[10]. Hassan Nikkhajoei, and Robert H. Lasseter, Distributed Generation Interface to the CERTS Microgrid, IEEE transactions on power delivery, vol. 24, no. 3, July 2009.

[11]. Inam Ullah Nutkani, Poh Chiang Loh, and Frede Blaabjerg, Droop Scheme With Consideration of Operating Costs, IEEE transactions on power electronics, vol. 29, no. 3, March 2014.

[12]. Josep M. Guerrero, Mukul Chandorkar, Tzung-Lin Lee, and Poh Chiang Loh, Advanced Control Architectures for Intelligent Microgrids—Part I: Decentralized and Hierarchical Control, IEEE transactions on industrial electronics, vol. 60, no. 4, April 2013.

[13]. Kuo. H. H, Yeh. S. N., and Hwang. J. C, ―Novel analytical model for design and implementation of three-phase active power filter controller, ‖ Proc. Inst. Elect. Eng.—Elect. Power Appl., vol. 148, no. 4, pp. 369–383, Jul. 2001.

[14]. Poh Chiang Loh,Ding Li, Yi Kang Chai, and Frede Blaabjerg, Autonomous Operation of Hybrid Microgrid With AC and DC Subgrids , IEEE transactions on power electronics, vol. 28, no. 5, May 2013.

[15]. Sandeep Anand, Baylon G. Fernandes, and Josep M. Guerrero, Distributed Control to Ensure Proportional Load Sharing and Improve Voltage Regulation in Low-Voltage DC Microgrids, IEEE transactions on power electronics, vol. 28, no. 4, april 2013.
[16]. Tine L. Vandoorn, Bart Meersman, Jeroen D. M. De Kooning, and Lieven Vandevelde, ―Analogy Between Conventional Grid Control and Islanded Microgrid Control Based on a Global DC-Link Voltage Droop‖, IEEE transactions on power delivery, vol. 27, no. 3, july 2012.
[17]. Inam Ullah Nutkani, Poh Chiang Loh, and Frede Blaabjerg, Distributed Operation of Interlinked AC Microgrids with Dynamic Active and Reactive Power Tuning, IEEE transactions on industry applications, vol. 49, no. 5, September/October 2013.
[18]. Tine L. Vandoorn, Bart Meersman, Jeroen D. M. De Kooning, and Lieven Vandevelde, Analogy Between Conventional Grid Control and Islanded Microgrid Control Based on a Global DC-Link Voltage Droop, IEEE transactions on power delivery, vol. 27, no. 3, July 2012.
[19]. Baochao Wang,Manuela Sechilariu, and Fabrice Locment, Intelligent DC Microgrid With Smart Grid Communications: Control Strategy Consideration and Design, IEEE transactions on smart grid, vol. 3, no. 4, December 2012.
[20]. Chi Jin, Peng Wang, Jianfang Xiao, Yi Tang, and Fook Hoong Choo, Implementation of Hierarchical Control in DC Microgrids, IEEE transactions on industrial electronics, vol. 61, no. 8, August 2.