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Comparison of lyapunov function and delta modulated controller techniques for compensation of active and reactive power in micro grid systems



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Abstract:

Distributed generation units in micro-grid can be connected to utility grid as alternative energy sources besides providing power to their local loads. The distributed generation units are interfaced with utility grid using inverter. With inverter control, both active and reactive power pumped into the utility grid from the distributed generation units can be controlled. Reactive power ow control allows the distributed generation units to be used as static var compensation units besides energy sources. This paper has presented a power ow control approach for a DG.

unit in micro-grid. The proposed approach achieves decoupled P and Q control under grid-connected mode, an integral approach to conduct the power ow control has been developed to control P by adjusting the power angle and control Q by adjusting the filter capacitor voltage. This paper has described control system algorithm for the proposed power controller. Simulation and experiment results have demonstrated strong P and Q regulation capability, fast enough response, and purely sinusoidal line current.

The stability of the control system is ensured by either Transformations or by direct methods like Lyapunov methods. A Spatial repetitive controller can also be used to improve the performance of the current controller by estimating the periodic disturbances of the system. The proposed control hysteresis and other methods provides superior performance over the conventional multiple proportional-integral and proportional-resonant control.

But because of its High complexity in SRC and Lyupunov Methods this paper proposes a new model of Inverter controlling Technique which is developed to take care of unbalances both in grid voltages and line side inductors. When compared to Lyupunov alone or repetitive controller the operation of Delta modulator is simple and does not require large computational complexity .even though it is a transformation based controller it has its advantages in terms of inverter controlling strategiesThe proposed model is compared with existing models like spatial repetitive controller and Lyapunov based methods and the whole simulation is performed with the help of Matlab software.

Keywords: Delta modulator, Lyapunov, Micro Grid, Hysteresis. SRC.

I INTRODUCTION:

The centralized and regulated electric utilities have always been the major source of electric power production and supply. However, the increase in demand for electric power has led to the development of distributed generation (DG) which can complement the central power by providing additional capacity to the users. These are small generating units which can be located at the consumer endorany where with in the distribution system. DG can be beneficial to the consumers as well as the utility. Consumers are interested in DG due to the various benefits associated with it: cost saving during peak demand charges, higher power quality and increased energy efficiency. The utilities can also benefit as it generally eliminates the cost needed for laying new transmission/distributionlines.

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Distributedgenerationemploysalternateresourcessuchasmicro-turbines, solar photovoltaic systems, fuel cells and wind energy systems. This thesis lays emphasis on the fuel cell technologyand its integration with the utility grid.

The World Energy Forum has predicted that fossil based oil, coal and gas reserves will be exhausted in less than another 10 decades. Fossil fuels account for over 79% of the primary energy consumed in the world, and 57.7% of that amount is used in the transport sector and are diminishing rapidly. The exhaustion of natural resources and the accelerated demand of conventional energy have forced planners and policy makers to look for alternate sources. Renewable energy is energy derived from resources that are regenerative, and do not deplete over time. Concern about the development of applications of, and the teaching about, renewable energies have increased markedly in recent years.The sun is regarded as a good source of energy for its consistency and cleanliness, unlike other kinds of Energy such as coal, oil, and derivations of oil that pollute the atmosphere and the environment. Most scientists, because of the abundance of sunshine capable of satisfying our energy needs in the years ahead, emphasize the importance of solar energy.

Solar energy is obviously environmentally advantageous relative to any other renewable energy source, and the linchpin of any serious sustainable development program. It does not deplete natural resources, does not cause CO2 or other gaseous emission into air or generates liquid or solid waste products. Concerning sustainable development, the main direct or indirectly derived advantages of solar energy are the following; no emissions of greenhouse (mainly CO2, NOx) or toxic gasses (SO2, particulates), reclamation of degraded land, reduction of transmission lines from electricity grids, increase of regional/national energy independence, diversification and security of energy supply, acceleration of rural electrification in developing countries. Moreover, solar energy is a vital that can make environment friendly energy more flexible, cost effective and commercially widespread. Photovoltaic source are widely used today in many applications such as battery charging, water heating system, satellite power system, and others. Recently, researchers have strongly promoted the use of solar energy as a viable source of energy.

Solar energy possesses characteristics that make it highly attractive as a primary energy source that can be integrated into local and regional power supplies since it represents a sustainable environmentally friendly source of energy that can reduce the occupants' energy bills.

Solar radiation is available at any location on the surface of the earth. The energy intensity of the sun to the world, the atmosphere on the kW per square meter is about 1.35.

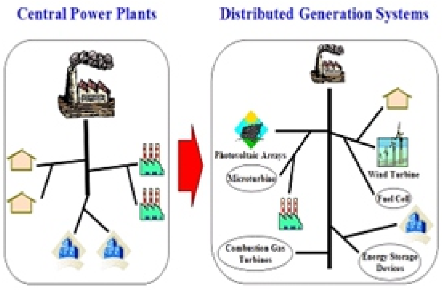

Figure 1.1: A large central power plant and distributed generation systems

Recently, the use of distributed generation systems under the 500 kW level is rapidly increasing due to technology improvements in small generators, power electronics, and energy storage devices. Efficient clean fossil-fuels technologies such as micro-turbines, fuel cells, and environmental-friendly renewable energy technologies such as biomass, solar/ photovoltaic arrays, small wind turbines and hydro turbines, are growingly used for new distributed generation systems. These DGS are applied to a standalone , a grid-interconnected, a standby, peak shavings , a cogeneration etc. and have a lot of benefits such as environmental friendly and modular electric generation, increased reliability/stability, high power quality, load management, fuel flexibility, uninterruptible service, cost savings, on-site generation, expandability, etc.

Fuel cells are also well used for distributed generation applications, and can essentially be described as batteries which never become discharged as long as hydrogen and oxygen are continuously provided. The hydrogen can be supplied directly, or indirectly produced by reformer from fuels such as natural gas, alcohols, or gasoline. Each unit ranges in size from 1-250 kW or larger MW size.

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Even if they offer high efficiency and low emissions, today's costs are high. Phosphoric acid fuel cell is commercially available in the range of the 200 kW, while solid oxide and molten carbonate fuel cells are in a pre-commercial stage of development. The possibility of using gasoline as a fuel for cells has resulted in a major development effort by theautomotive companies. The recent research work about the fuel cells is focused towards the polymer electrolyte membrane (PEM) fuel cells. Fuel cells in sizes greater than 200 kW, hold promise beyond 2005, but residential size fuel

II. CONTROLLER FOR INVERTER CURRENT:

In this paper, the three-phase local bus voltage is referred to as grid voltage vga, vgb, and vgc with respect to the utility grid neutral N as shown in Fig. 2. It can be understood from Fig. 1 that the PEC converter extracts maximum power Pmpp from the renewable energy source. The load draws average active power PL and average reactive power QL from the grid (i.e., complex load power, SL = PL + jQL). The total load active power is shared by the grid average active power Pg and the average active power provided by the inverter Pinv. The inverter active power flow is controlled in such a way that when the dc link battery is not fully charged, certain amount of active.

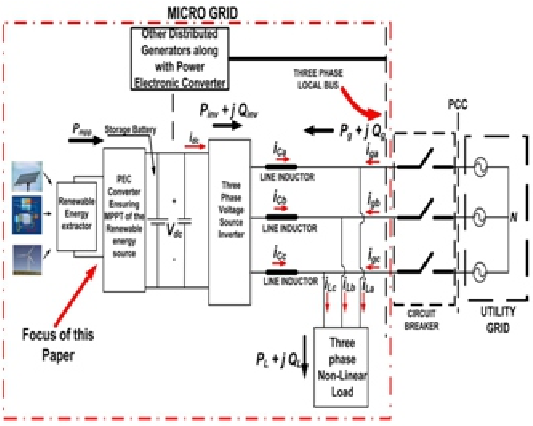

Fig 2.1 Renewable energy source based inverter interface between micro grid and main grid

The details of different current reference estimation methods are analyzed. The present paper focuses on the current control methodology of the CCVSI.

III.DELTA MODULATED CONTROLLER:

The basic circuit for sampled form of delta modulated current controller is shown in fig..In delta modulation scheme for inverters, the input signal to controller is sine wave and output is the modulated waveform. The feedback path consists of an integrator filter and the forward path consists of a Hysteresis quantizer. The input signal and the signal derived from the modulator output by low pass filtering of the integrator are compared to produce error signal. The quantizer determines this error signal to produce the modulated wave in such manner that error is minimized and kept between certain levels. The integrator shown in fig.3(c), when used in the feedback path of the modulator output low pass filtering having fixed cut off frequency determined by the following transfer function.

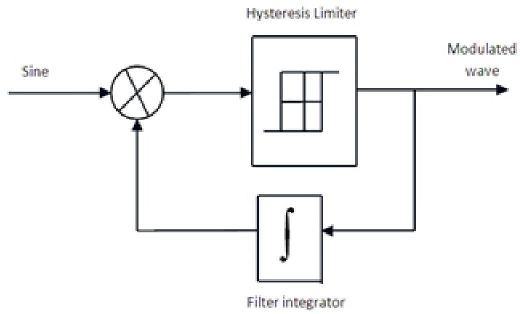

Fig 3.1 block diagram Delta modulator controller

Rather than quantizing the absolute value of the input analog waveform, delta modulation quantizes the difference between the current and the previous step, as shown in the block diagram in Fig. 1.The modulator is made by a quantizer which converts the difference between the input signal and the average of the previous steps. In its simplest form, the quantizer can be realized with a comparator referenced to 0 (two levels quantizer).The matlab designs for the delta modulated controllers are given below.

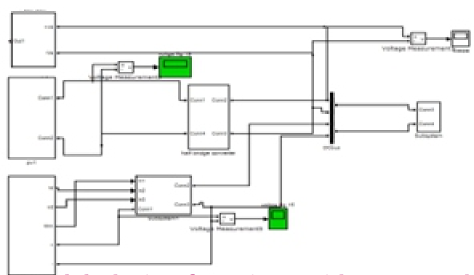

Fig 3.2 Matlab design for Micro grid connected Inverter

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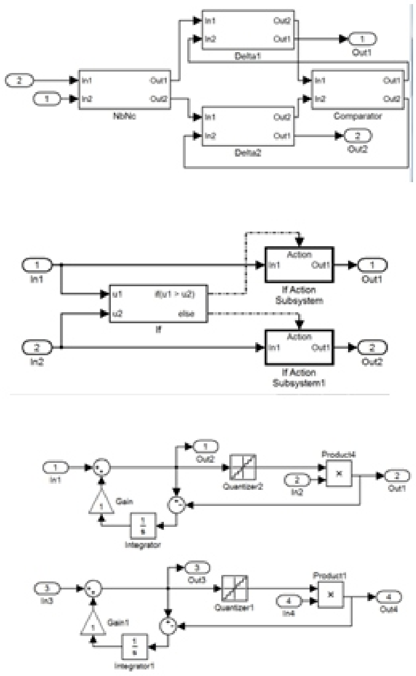

Fig.3.3 The delta modulator controller, (ii) & (iii) the inner subsystems of the controller in simulation.

IV.LYAPUNOV FUNCTION CONTROLLER:

In the theory of ordinary differential equations (ODEs), Lyapunov functions are scalar functions that may be used to prove the stability of an equilibrium of an ODE. For many classes of ODEs, the existence of Lyapunov functions is a necessary and sufficient condition for stability. Whereas there is no general technique for constructing Lyapunov functions for ODEs, in many specific cases, the construction of Lyapunov functions is known.

For instance, quadratic functions suffice for systems with one state; the solution of a particular linear matrix inequality provides Lyapunov functions for linear systems; and conservation lawscan often be used to construct Lyapunov functions for physical systems.

Informally, a Lyapunov function is a function that takes positive values everywhere except at the equilibrium in question, and decreases (or is non-increasing) along every trajectory of the ODE. The principal merit of Lyapunov function-based stability analysis of ODEs is that the actual solution (whether analytical or numerical) of the ODE is not required.In this paper Lyapunov based functions [1] are used for stability improvement.

IV.a) Design of Non linear control law based on Lyapunov function:

It can be seen from (1) that the three-phase grid-connected inverter consists of two states, x1 and x2. Thus, for arbitrary waveform tracking in these two states, a nonlinear control law is derived based on the Lyapunov function method [41], i.e., the first principle of absolute stability. Considering the positive definite Lyapunov function as

$$V = \frac{1}{2} e^T e \qquad (1)$$

$$e = \begin{bmatrix} e_1 \\ e_2 \end{bmatrix} = \begin{bmatrix} x_1^* - x_1 \\ x_2^* - x_2 \end{bmatrix} \qquad (2)$$

where x1 and x are the tracking references of x1 and x2, respectively.

For a typical microgrid application, the grid voltage as well as inverter unpredictable nonlinearities do not change frequently, so the slow dynamics of SRC control laws are dominated by the fast dynamics of Lyapunov function control laws in the case of sudden change in current references.

V. SPATIAL REPETITIVE CONTROLLER:

In repetitive controllers are synthesized and operate in time domain, which is in accordance with the fact that models or differential equations of physical systems are mostly derived using time as the independent variable. One of the key steps for designing a repetitive controller is to determine the period, or equivalently, the number of delay taps (q−1 , q is the one step advance operator). This can usually be done by analyzing the periodic tracking or disturbance signal using techniques such as fast Fourier transform (FFT). To ensure effectiveness of the design, an underlying assumption is that the frequency constitutions of the periodic tracking or disturbance signal do not vary with respect to time, which corresponds to a stationary or time-invariant frequency spectrum of the signal. This assumption can be satisfied when the design objective is to track a pre specified periodic trajectory. However, it might be violated for disturbance rejection problems where the frequency constitutions of the disturbance are time-varying.

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For a motion system with rotary components such as gear-train, the disturbances due to gear eccentricity or tooth profile error are inherently angular displacement dependent or spatially periodic. They are periodic with respect to angular displacement, but not necessarily periodic with respect to time.

IV. b) Repetitive Controller in Parallel With the Lyapunov Function-Based Controller:

In the above diagram the repetitive controller I connected in parallel with the Lyapunov Based Controller the Equations for Lyapunov & SRC controller are derived from [1]

$$\begin{bmatrix} u_{lf1}(k) \\ u_{lf2}(k) \end{bmatrix} = \begin{bmatrix} \frac{x_1^*(k)-x_1^*(k-1)}{T_s} - a_{11}x_1(k) - a_{12}x_2(k) \\ \frac{x_2^*(k)-x_2^*(k-1)}{T_s} - a_{21}x_1(k) - a_{22}x_2(k) \end{bmatrix} + \begin{bmatrix} \lambda_1 [x_1^*(k) - x_1(k)] \\ \lambda_2 [x_2^*(k) - x_2(k)] \end{bmatrix} \quad (22)$$

Where λ1 & λ2 are are to be strictly positive quantities. the remaining equations are solved using [1] where usrc1,usrc2 are solved using the following equation.

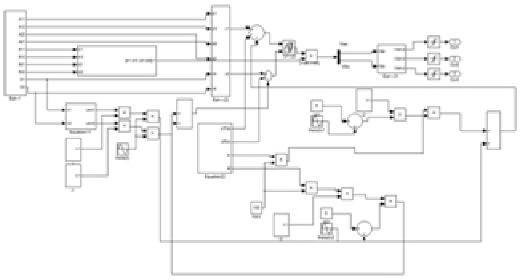
$$\begin{bmatrix} u_{\text{src}1}(t) \\ u_{\text{src}2}(t) \end{bmatrix} = \begin{bmatrix} -d_1 \\ -d_2 \end{bmatrix}$$

$$\begin{bmatrix} u_{\text{src}1}(i,\theta_k) \\ u_{\text{src}2}(i,\theta_k) \end{bmatrix} = \begin{bmatrix} u_{\text{src}1}(i-1,\theta_k) + K_{\text{src}}e_1(i-1,\theta_{k+N_1}) \\ u_{\text{src}2}(i-1,\theta_k) + K_{\text{src}}e_2(i-1,\theta_{k+N_1}) \end{bmatrix}. \quad (23)$$

$$\begin{bmatrix} u_1 \\ u_2 \end{bmatrix} = \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} \begin{bmatrix} v_{iac} \\ v_{ibc} \end{bmatrix}$$

$$\Rightarrow \begin{bmatrix} v_{iac} \\ v_{ibc} \end{bmatrix} = \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}^{-1} \begin{bmatrix} u_1 \\ u_2 \end{bmatrix} \quad (2)$$

Matlab design for Repetitive controller in parallel with the Lyapunov Function based controller is given and the results include the current controlled Voltage source inverter currents and voltages as well as grid voltages and currents are shown



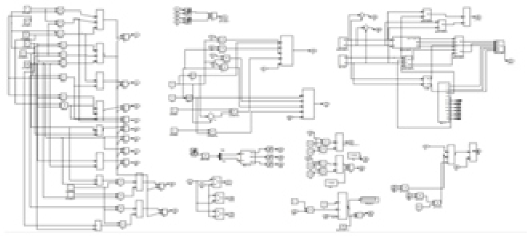


Fig 5.1 SRC and Lyapunov controller

VI. SIMULATION RESULTS:

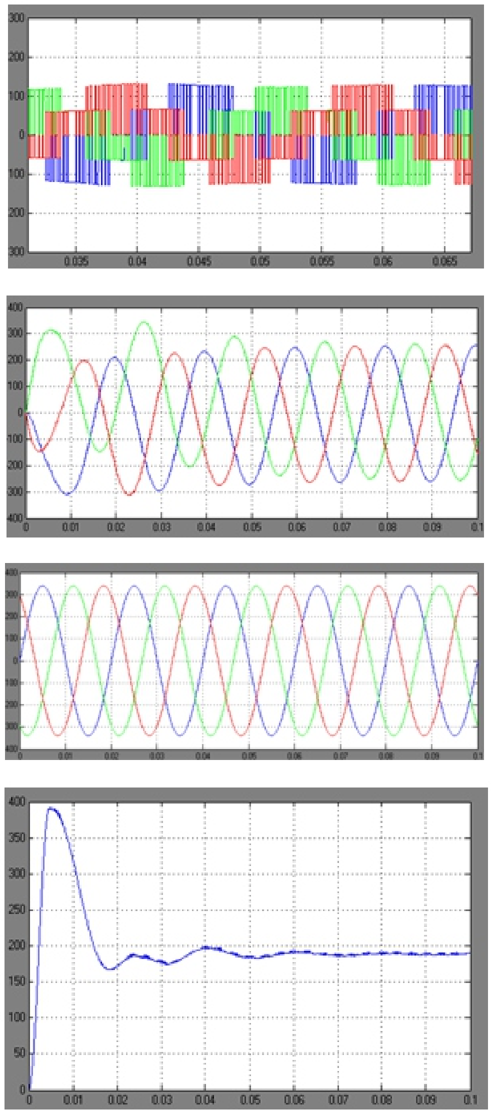


Fig 6.1Voltage source inverter currents and voltages as well as grid voltages and currents are shown for 1000P and 2000P with zero Q and 1000 Q respectively for Delta Modulator

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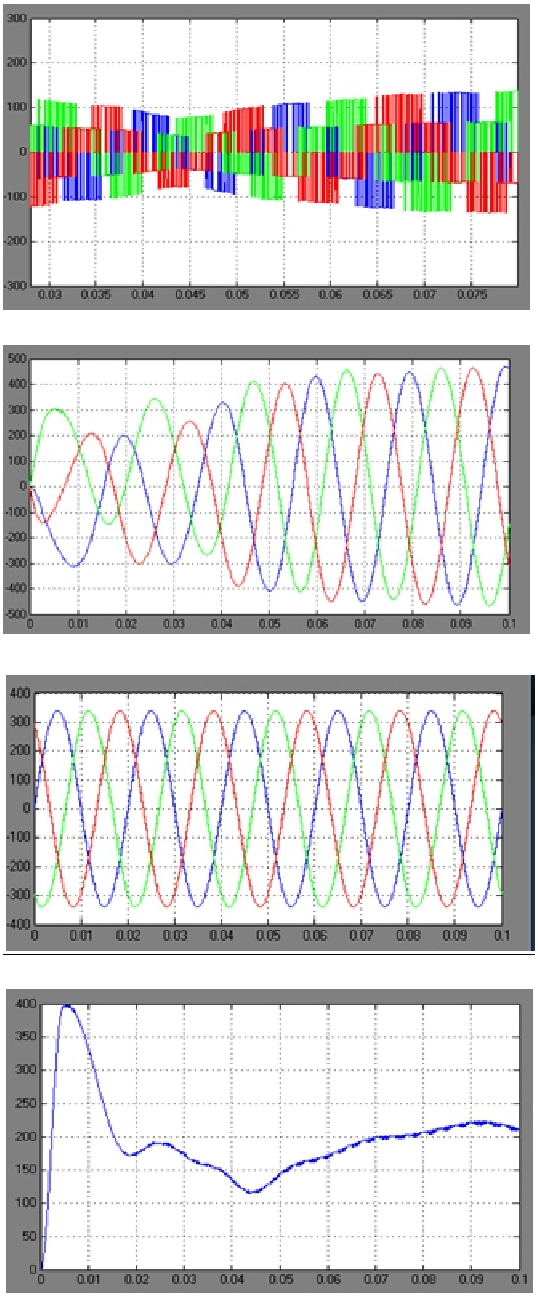

Fig 6.2.Voltage source inverter currents and voltages as well as grid voltages and currents are shown for 1000P and 2000P with zero Q and 1000 Q respectively for Lyupunov and SRC controller in parallel

CONCLUSION:

A new current control strategy for a parallel connected threephase renewable energy source-based inverter to connect to the generalized microgrid system is proposed.

The control strategy is implemented using transformations and is able to take care of unbalance conditions in both the grid voltage as well as line side inductances and load. The proposed method also reduces the THD of the grid current along with the proper grid active as well as reactive power control. The proposed control method is implemented in the digital controller and requires Park's transformation block unlike the method where multiple controllers are implemented conventional in synchronously rotating dual reference frame and gives superior performance.The proposed controller is also capable of rejecting the effect of grid voltage harmonics in the grid currents. When compared to Lyupunov alone or repetitive controller the operation of Delta modulator is simple and does not require large computational complexity .even though it is a transformation based controller it has its advantages in terms of inverter controlling strategies. The Comparision of delta modulated controller with the lyapunov function, and gives best results in delta modulated controller. The effectiveness of the controller.

References:

[1]Lyapunov function-based current controller to control active and reactive power flow from a renewable energy source to a generalized three-phase microgrid system-ieee 2013

[2] Y. Xue, J. Deng, and S. Ma, "Power flow control of a distributed generation unit in microgrid," in Proc. IEEE Int. Power Electron. Motion Control Conf., 2009, pp. 2122–2125.

[3] J. M. Carrasco, L. G. Franquelo, J. T. Bialasiewicz, E. G. Galvan,R. C. P. Guisado, M. A. M. Prats, J. I. Leon, and N. M. Alfonso, "Powerelectronicsystems for the grid integration of renewable energy sourcesA survey," IEEE Trans. Ind. Electron., vol. 53, no. 4, pp. 1002–1016,Aug. 2006.

[4] F. Blaabjerg, R. Teodorescu, M. Liserre, and A. V. Timbus, "Overviewof control and grid synchronization for distributed power generationsystems," IEEE Trans. Ind. Electron., vol. 53, no. 5, pp. 1398–1409,Oct. 2006.

[4b] T. Zhou and B. Francois, "Energy management and power control of a hybrid active wind generator for distributed power generation and grid integration," IEEE Trans. Ind. Electron., vol. 58, no. 1, pp. 95–104, Jan. 2011.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

[5] P. Rodriguez, A. Luna, I. Candela, R. Mujal, R. Teodorescu, and F. Blaabjerg, "Multiresonant frequency-locked loop for grid synchronization of power converters under distorted grid conditions," IEEE Trans. Ind. Electron., vol. 58, no. 1, pp. 127–138, Jan. 2011.

[6] M. P. Kazmierkowski, M. Jasinski, and G. Wrona, "DSP-based control of grid-connected power converters operating under grid distortions," IEEE Trans. Ind. Informat., vol. 7, no. 2, pp. 204–211, May 2011.

[7] J. He, Y. W. Li, and M. S. Munir, "A flexible harmonic control approach through voltage-controlled DG-grid interfacing converters," IEEE Trans. Ind. Electron., vol. 59, no. 1, pp. 444–455, Jan. 2012.

[8] F. Gonzalez-Espin, E. Figueres, and G. Garcera, "An adaptive synchronous-reference-frame phase-locked loop for power quality improvement in a polluted utility grid," IEEE Trans. Ind. Electron., vol. 59, no. 6, pp. 2718–2731, Jun. 2012.

[9] G. Buticchi, D. Barater, E. Lorenzani, and G. ranceschini, "Digital control of actual grid-connected converters for ground leakage current reduction in PV transformerless systems," IEEE Trans. Ind. Informat., vol. 8, no. 3, pp. 563–572, Aug. 2012.

[10] J. M. Guerrero, J. C. Vasquez, J. Matas, L. G. de Vicuna, and M. Castilla, "Hierarchical control of droop-controlled ac and dc microgrids—A general approach towards standardization," IEEE Trans. Ind. Electron., vol. 58, no. 1, pp. 158–172, Jan. 2011.

[11] J. M. Guerrero, J. Matas, L. G. de Vicuna, M. Castilla, and J. Miret, "Decentralized control for parallel operation of distributed generation inverters using resistive output impedance," IEEE Trans. Ind. Electron., vol. 54, no. 2, pp. 994–1004, Apr. 2007.

[12] J. M. Guerrero, J. C. Vasquez, J. Matas, M. Castilla, and L. G. de Vicuna, "Control strategy for flexible microgrid based on parallel line-interactive UPS systems," IEEE Trans. Ind. Electron., vol. 56, no. 3, pp. 726–736, Mar. 2009.

[13] J. M. Guerrero, J. Matas, L. G. de Vicuna, M. Castilla, and J. Miret, "Wireless-control strategy for parallel operation of distributed-generation inverters," IEEE Trans. Ind. Electron., vol. 53, no. 5, pp. 1461–1470, Oct. 2006.

[14] J. C. Vasquez, J. M. Guerrero, A. Luna, P. Rodriquez, and R. Teodorescu, "Adaptive droop control applied to voltage-source inverters operating in grid-connected and islanded modes," IEEE Trans. Ind. Electron., vol. 56, no. 10, pp. 4088–4096, Oct. 2009.

[15] J. C. Vasquez, R. A. Mastromauro, J. M. Guerrero, and M. Liserre, "Voltage support provided by a droop-controlled multifunctional inverter," IEEE Trans. Ind. Electron., vol. 56, no. 11, pp. 4510–4519, Nov. 2009.

[16] J. M. Guerrero, L. G. de Vicuna, J. Matas, M. Castilla, and J. Miret, "Output impedance design of parallel-connected UPS inverters with wireless load-sharing control," IEEE Trans. Ind. Electron., vol. 52, no. 4,pp. 1126–1135, Aug. 2005.

[17] S. Dasgupta, S. K. Sahoo, and S. K. Panda, "Single-phase inverter control techniques for interfacing renewable energy sources with microgrid—Part I: Parallel connected inverter topology with active and reactive power flow control along with grid current shaping," IEEE Trans. Power Electron., vol. 26, no. 3, pp. 717–731, Mar. 2011.

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