International Journal of Emerging Engineering Research and Technology
Volume 4, Issue 1, January 2016, PP 22-28
ISSN 2349-4395 (Print) & ISSN 2349-4409 (Online)

Coordinated Control Strategy of Solar Photovoltaic Generators with MPPT and Battery Storage in Micro Grids

[1]S.Raphael Kanthi Kamal, [2]M.Jyothi

[1]*PG Scholar, Dept of Power Electronics, QCET, JNTUA, Nellore, AP, India.*
[2]*Assoc professor, Dept of EEE, QCET, JNTUA, Nellore, AP, India.*

ABSTRACT

The micro grid conception permits small distributed energy resources (DERs) to act during a coordinated manner to produce a necessary quantity of active power and supportive service once needed. This paper proposes an approach of coordinated and integrated management of solar PV generators with the most power point following (MPPT) management and battery storage management to produce voltage and frequency (V-f) support to an islanded small grid. Also, active and nonnative/reactive power (P-Q) management with star PV, MPPT and battery storage is projected for the grid connected mode. The management ways show effective coordination between electrical converter V-f (or P-Q) management, MPPT management, and energy storage charging and discharging management. The paper additionally shows a good coordination among taking part small resources whereas considering the case of fixing irradiance and battery state of charge (SOC) constraint. The simulation studies area unit dispensed with the IEEE 13-bus feeder check system in grid connected and islanded small grid modes. The results clearly verify the effectiveness of projected management strategies. The simulations area unit dispensed in Mat science lab and Simpower systems.

Keywords: Active and Reactive Power management, Distributed Energy Resource (DER), Distributed Generation (DG), most electrical outlet following (MPPT), Voltage and Frequency management, star electrical phenomenon (PV).

INTRODUCTION

The micro grid is a collection of distributed generators or micro resources, energy storage devices, and loads which operate as a single and independent controllable system capable of providing both power and heat to the area of service . The micro resources that are incorporated in a micro grid are comprised of small units, less than 100 kW, provided with power electronics (PE) interface. Most common resources are Solar Photovoltaic (PV), Fuel Cell (FC), or micro turbines connected at the distribution voltage level. In a micro grid, the micro sources and storage devices are connected to the feeders through the Micro source controllers (MCs) and the coordination among the micro sources is carried out by the central controller (CC) . The micro grid is connected to the medium voltage level utility grid at the point of common coupling (PCC) through the circuit breakers. When a micro grid is connected to the grid, the operational control of voltage and frequency is done entirely by the grid; however, a micro grid still supplies the critical loads at PCC, thus, acting as a PQ bus. In islanded condition, a micro grid has to operate on its own, independent of the grid, to control the voltage and frequency of the micro grid and hence, acts like a PV (power-voltage) bus. The operation and management in both the modes is controlled and coordinated with the help of micro source controllers (MCs) at the local level and central controller (CCs) at the global level. Similar to the traditional synchronous generator frequency control, the micro grid voltage and frequency control can also be performed using droop control methods. The present work provides fast response characteristics for voltage and frequency control as compared to the secondary control considered in . The analogy between inverter control and the synchronous generator control in an islanded micro grid is studied in detail in. In the islanded mode, there is the necessity of having a reference voltage and frequency signals in the micro grid inverter control. This paper proposes several control algorithms through

Address for correspondence:

which the capability of PV generators for voltage and frequency (V-f) control and active and nonnative/reactive power (P-Q) control in islanded and grid connected micro grids could be harnessed. Detailed models of PV, battery, inverter and converter are considered for the study.

The major contribution and novelty of the proposed control methods lie in the coordination among individual proposed control methods: MPPT control at the PV side, battery control, and V-f/P-Q control algorithm at the inverter side. These three control algorithms at three stages are jointly linked through a power balance objective at the DC and AC side of the inverter so that the DC side voltage is indirectly controlled at the desired value in order to maintain the AC side voltage at the utility desired voltage. Also, the proposed control methods have the capability of Handling battery state of charge (SOC) constraints through the coordination of controls between participating micro resources in the micro grid. This is a very important contribution from this work as compared to other literatures in this area. At the same time, the controls can seamlessly transform from one mode e.g., inverter P-Q control in grid connected mode to V-f control in islanded mode. The proposed control methods are validated with satisfactory results. The controls are developed in abc reference frames using the RMS/average values of voltages and active and reactive power. Hence, it is easy and efficient to implement, and avoids the transformation to and from other reference frames which greatly simplifies the control strategies. The chosen control parameters in the proposed methodologies are, however, dependent on the PV, battery, and external power grid conditions. These parameters can be adaptively achieved with the changing system conditions which could be a very promising future direction of this work.

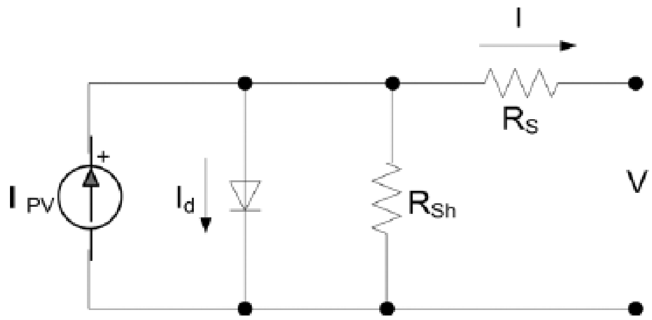


Fig1. *One diode equivalent circuit of Solar PV.*

SOLAR PV MODELING AND VALIDATION

The commonly accepted solar cell model is a one diode model. This work uses the single diode model of the solar cell to model the Kyocera KC200GT solar array, which is shown in Fig. 1. The I-V characteristics of a solar array, as shown in Fig. 2, are represented by (1).

The I-V characteristics of a solar module are shown in fig. are represented by equation(1).

$$I = I_{\mathrm{PV}} - I_0 \left[\exp\left(\frac{V + R_s I}{V_{\mathrm{therm}} a} \right) - 1 \right] - \frac{V + R_s I}{R_{\mathrm{sh}}} \qquad (1)$$

where I_{PV} and I_o are the photo current and the diode saturation currents, respectively V_{therm} $(=N_s kT/q)$ is the thermal voltage of the array, N_s being the cells connected in series for greater output voltage, k is the Boltzmann constant $(1.3806503 \times 10^{-23}\ \mathrm{J/K})$, T (Kelvin) is the temperature of the p-n junction of the diode, and q $(1.60217646 \times 10^{-19}\mathrm{C})$ is the electron charge; Rs and Rsh are the equivalent series and shunt resistances of the array, respectively; and a is the ideality factor usually chosen in the range $1 \leq a \leq 1.5$. Here a is taken as 1.

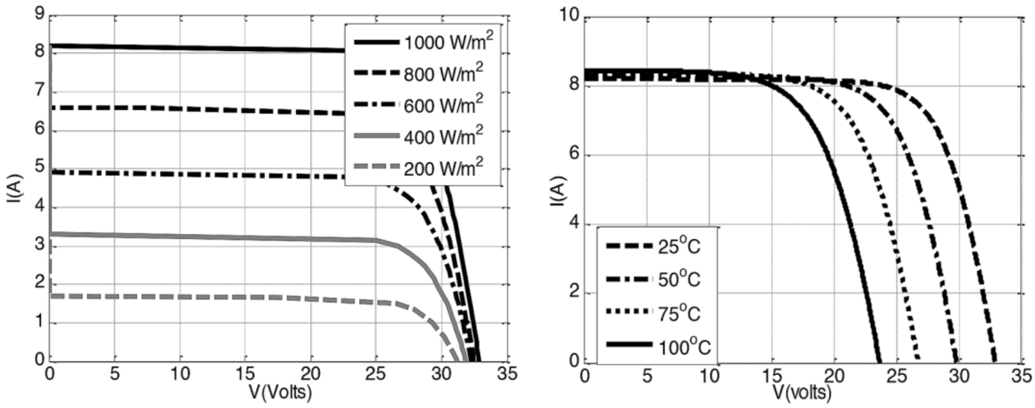
With change in cell temperature and solar irradiance the output of PV cell is changed, since they are linearly dependent, proven by equation (2).

$$I_{\mathrm{PV}} = (I_{\mathrm{PV},n} + K_1 \Delta T) \frac{G}{G_n} \qquad (2)$$

where $I_{\mathrm{PV},n}$ is the photocurrent at the standard test condition (STC, 25 C and 1000 W/m2); K_I is the short circuit current/ temperature coefficient; ΔT is the difference between the actual and nominal temperature in$I_{\mathrm{PV},n}$n; G is the irradiation on the device surface; and G_n is the nominal radiation, both in W/m. based on equation(3), can be calculated as

$$I_{\mathrm{PV},n} = \frac{R_{\mathrm{sh}} + R_s}{R_{\mathrm{sh}}} I_{\mathrm{sc}} \qquad (3)$$

We can develop a PV model by all the above essential equations and parameters, finally confirmed with the board data sheet. Fig 5.2(a) shows the I-V characteristics of PV module KC200GT at various irradiance levels. And fig 5. 2(b) shows the I-V characteristics of PV module KC200GT at various cell temperatures .The solar PV panel parameters under study are shown in table 1.



a) b)

Fig.I-V. *Characteristics of Kyocera KC200GT of PV module (a) varying irradiance; (b) varying cell temperature.*

Table1. *Solar Pv Panel Parameters Under Stc i.e., 1000 W/m² and 25°c*

Model	Kyocera KC200GT
P_{MPP}	200W
V_{MPP}	26.30V
I_{MPP}	7.61A
V_{OC}	32.90V
I_{SC}	8.21A

Table solar PV panel parameters

SIMULINK BLOCK DIAGRAM

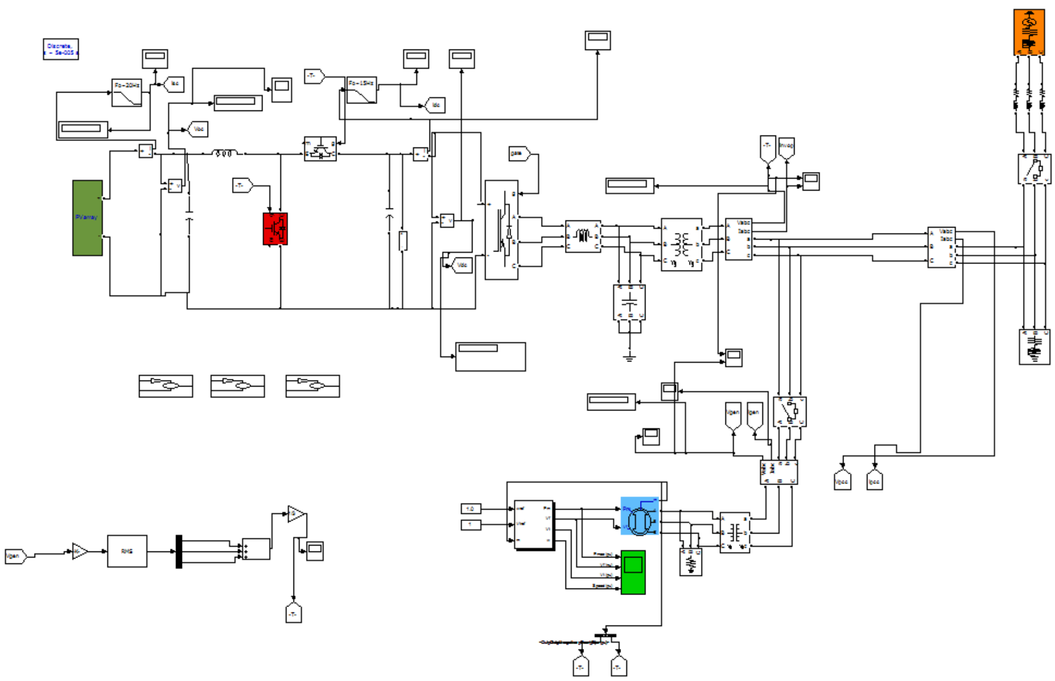


Fig. *Simulink block diagram (V-F case)*

For obtaining maximum power output there are many MPPT techniques, of that perturb and observe (P&O) method is simple to implement.

SIMULINK DIAGRAM OF P & O METHOD

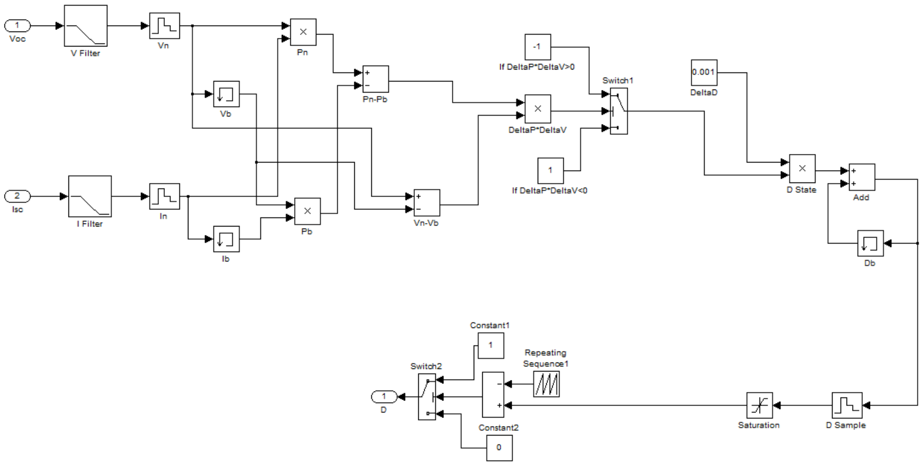


Fig. *Simulink Diagram of P & O Method*

While moving from the grid connected to micro grid mode, the diesel generator is controlled to generate a fixed amount of active power according to the command from the central controller. The diesel generator produces a fixed amount of 1.25 MW throughout the simulation period as shown in Fig. It also shows the reactive power generated from the diesel generator in fig.

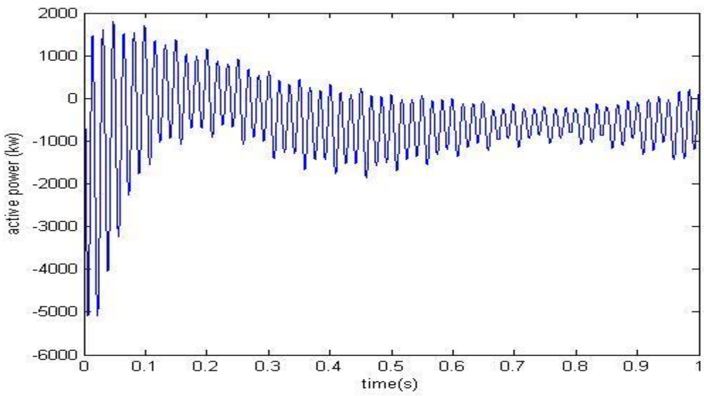


Fig. *Active Power Of Diesel Generator*

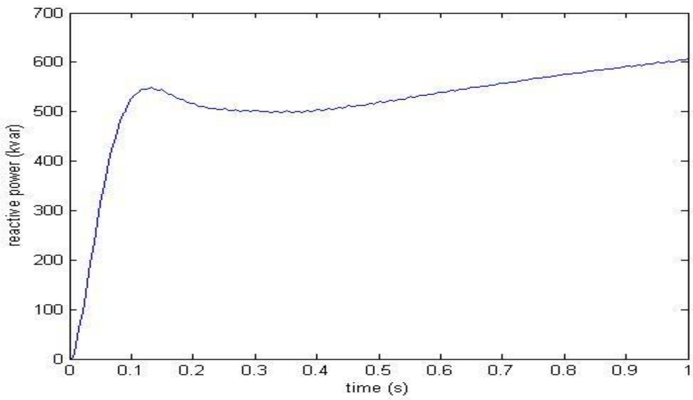


Fig. *Active Power Of Diesel Generator*

In the islanded mode, the active power generated by the diesel generator is not enough to fulfill the power demand of the micro grid. Fig. shows the micro grid frequency which initially dips to a value of 57.8 Hz due to the load-generation imbalance. The frequency control from the PV generator starts at 2.2 sec. Which quickly regulates the frequency back to 60 Hz in 2 sec . Fig. shows the plot of the PCC voltage in P.U. It can be observed that voltage is also quickly regulated at 1 P.U. after the control is started.

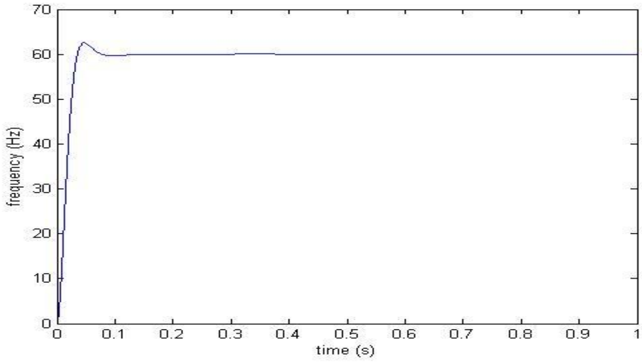


Fig. *Frequency*

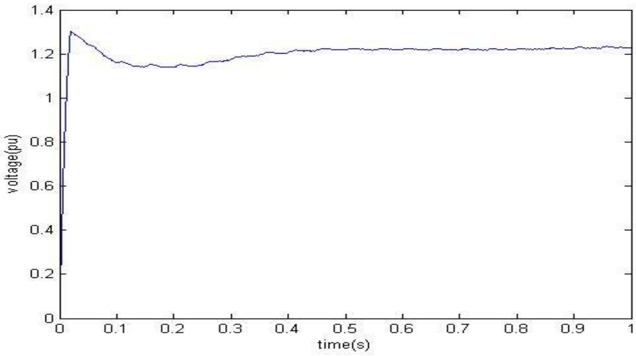


Fig. *Voltage P.U.*

Fig. shows the active and reactive power injection from the PV inverter which regulates the frequency and voltage of the micro grid. The active power injection from the inverter, which is required to maintain the frequency at 60 Hz in both cases, is around 80 kW.

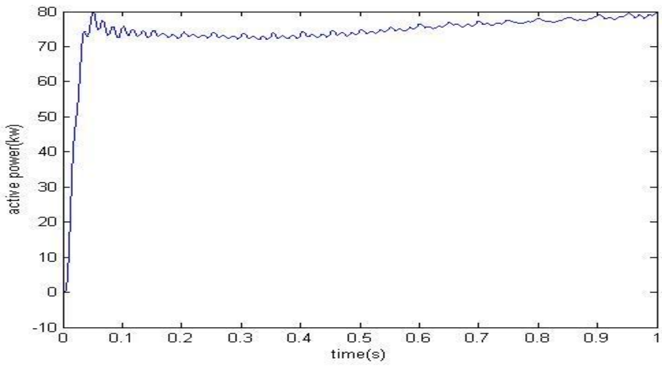


Fig. *Inverter active power*

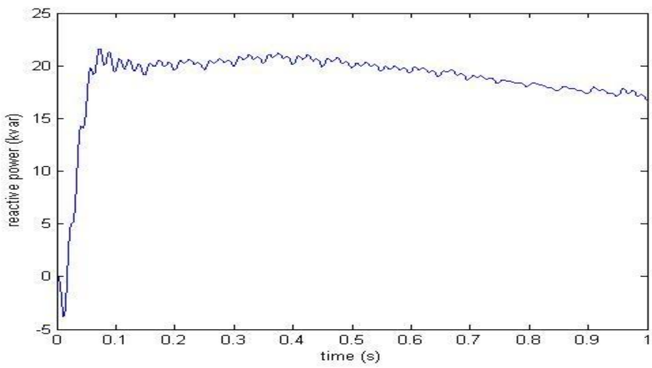


Fig. *Inverter reactive power*

Fig. shows the DC voltage. It can be seen that the voltages are stably maintained at around 850 V. Fig. shows the active power at the DC side.

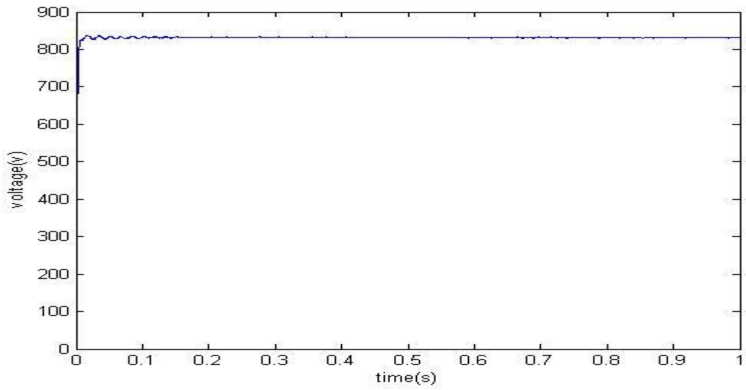


Fig. *DC Voltage*

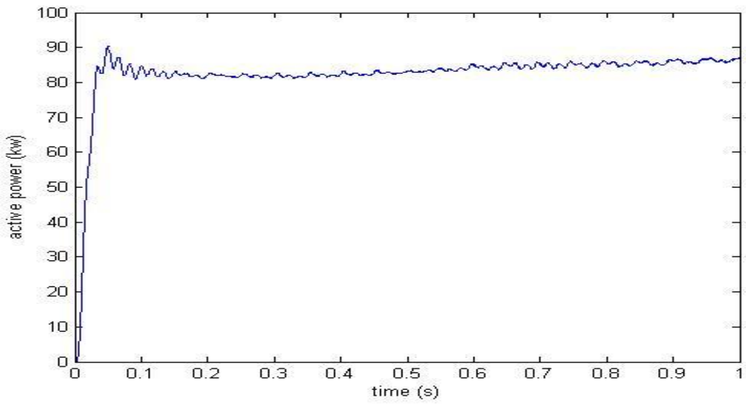


Fig. *Active power at DC*

CONCLUSION

This paper proposes and presents coordinated strategies of V-f control and P-Q control, respectively, for micro grids with PV generator and battery storage. In the control strategies, the PV generator is operated at MPP, and the battery storage acts as a buffer in order to inject and absorb deficit or surplus power by using the charge/discharge cycle of the battery. The thesis contributes in demonstrating the control strategies with effective coordination between inverter V-f (or P-Q) control, MPPT control, and energy storage control.

The proposed control strategy also provides a smooth transition of PV side PQ control in grid connected mode to V-f control in islanded mode. This is the most essential feature required in the modern micro grid controllers. The proposed control algorithms are also capable of handling the battery SOC constraint. An effective seamless transformation of controls from V-f to constant active power and voltage control at the PV side and from constant active power control to frequency control at the diesel generator is validated with satisfactory results. This feature helps the controller to adapt to the changing irradiance levels while considering the battery availability.

The proposed V-f control method shows a very satisfactory performance in reviving highly reduced voltage and frequency back to the nominal values in a matter of only 2 seconds. It is much faster than the diesel generator control which takes around 10 seconds to settle down. Hence, PV and battery installations might be applied effectively in restoring the micro grid frequency and the voltage at PCC after disturbances. Similarly, the proposed integrated and coordinated P-Q control algorithm can be effectively used in supplying some critical loads of a micro grid with solar PV and battery.

For obtaining maximum power output there are many MPPT techniques, of that perturb and observe (P&O) method is simple to implement. Perturb and observe method is used in this thesis. Even incremental conductance method is also used for tracking the maximum power output from the PV. It can track maximum power point at varying temperature and irradiance.

Thus by this maximum utilization of the solar resource we can provide voltage - frequency support during islanded mode of operation and real - reactive power support during grid connected mode by using battery storage equipment.

REFERENCES

[1] L. D.Watson and J.W. Kimball, "Frequency regulation of a microgrid using solar power," in *Proc. 2011 IEEE APEC*, pp. 321–326.

[2] T. Ota, K. Mizuno, K. Yukita, H. Nakano, Y. Goto, and K. Ichiyanagi, "Study of load frequency control for a microgrid," in Proc. 2007AUPEC Power Eng. Conf., pp. 1–6.

[3] L. Xu, Z. Miao, and L. Fan, "Coordinated control of a solar battery system in a microgrid," in *Proc. 2012 IEEE/PES Transm. Distrib. Conf. Expo. (T&D)*, pp. 1–7.

[4] R. H. Lasseter, "MicroGrids," in *Proc,IEEE Power Engineering Society Winter Meeting*, 2002, vol. I , pp. 305-308.

[5] S. Chowdhury, S. P. Chowdhury, and P. Crossley, "Microgrids and ActiveDistribution Networks," 2009, IET Renewable Energy Series 6.

[6] H. Saadat, *Power System Analysis*, 2nd ed. New York, NY, USA:Mc- Graw Hill, 2002.

[7] J. A. P. Lopes , C. L. Moreira, and A. G. Madureira, "Defining control strategies for MicroGrids islanded operation," *IEEE Trans. Power Syst.*, vol. 21, pp. 916-924,2006.

[8] 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,pp.4510-4519,2009.

[9] H. Li, F. Li, Y. Xu, D. T. Rizy, and J. D. Kueck, " Adaptive voltage control with distributed energy resources: Algorithm, therectical analysis, simulation and field test verification*," IEEE Trans. Power syst*,vol. 25,pp. 1638-1647, Aug. 2010.

[10] H. Li, F. Li, Y . Xu, D. T. Rizy, and S. Adhikari, "Automonus and adaptive voltage control using multiple distributed energy resources, "*IEEE Trans. Power Syst*., vol. 28. no. 2,pp.718-730, May 2013

[11] J N. Kakimoto, S. Takayama, H. Satoh, and K. Nakamura," Power modulation of photovoltaic generator for frequency control of powersystem," *IEEE Trans.Energy Conv*., vol. 24,pp.943-949,2009.

[12] J. M. G. Villalva, J. R. Gazoli, and E. R. Filho, "Comprehensive approach to modeling and simulation of photovoltaic arrays," *IEEE Trans. Power Electron*, vol. 24,n0. 5, pp. 1198-1208,2009.

[13] M. Lokanandham, K. Vijaya bhaskar, "Incremental Conductance based MPPT for photo voltaic system," *IJERA*, vol. 2, Issue 2, Mar-Apr 2012, pp. 1420-1424.

[14] Y. Xu, H. Li, D. T. Rizy, F. Li, and J. D. Kueck, "Instantaneous active and nonactive power control of distributed energy resources with a current limiter," in *Proc. IEEE Energy conversion Congr*. Expo., 2010, pp. 3855-3861.

[15] O. Tremblay and L. A. Dessaint, "Experimental validation of a battery dynamic model for EV applications*," World Electric Vehicle J.,*vol. 3, 2009.