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# CO-ORDINATED CONTROL WITH SYNCHRONIZED V-F AND P-Q TECHNIQUES USING MPPT AND BATTERY STORAGE IN MICROGRIDS

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**ABSTRACT:** The Proposed Coordinated V-f and P-Q Control of Solar Photovoltaic Generators With MPPT and Battery Storage in Micro grids to act in a coordinated manner to provide a necessary amount of active power and ancillary service when required .Micro grid is essentially an active distribution network because it is the conglomerate of DG systems and different loads at distribution voltage level. The generators or micro sources employed in a Micro grid are usually renewable/non-conventional DERs integrated together to generate power at distribution voltage. Several control methods have the capability for controlling V-f and P-Q in both grid and micro grid is harnessed. The major novelty of the system lies in the co ordination among different controls like MPPT, Battery and V-f /P-Q at the Pv and inverter side. The Simulations are carried out with the IEEE 13-bus feeder system in grid and islanded micro grids. The Simulation Results are carried out in Mat lab and Sim Power Systems.

***Index terms:*—**Active and reactive power control, distributed energy resource (DER), distributed generation (DG), maximum power point tracking (MPPT), voltage and frequency control, solar photovoltaic (PV).

## I. INTRODUCTION

Renewable energy is currently widely used. One of these resources is solar energy. The photovoltaic (PV) array normally uses a maximum power point tracking (MPPT) technique to continuously deliver the highest power to the load when there are variations in irradiation and temperature. Renewable or non-conventional electricity generators employed in DG systems or Micro grids are known as distributed energy resources (DERs) or micro sources. One major aim of Micro grids is to combine all benefits of non-conventional/ renewable low-carbon generation technologies and high-efficiency combined heat and power (CHP) systems. Solar PV generation involves the generation of electricity from free and inexhaustible solar energy. Solar energy reaches the PV cell in two components, direct and diffuse. The direct component is about 85% and comes through direct radiation. The diffuse component is about 15% and comes through scattered diffusion in the atmosphere. Most PV modules are equipped with maximum power point tracking (MPPT) systems that maximize the power output from the modules by shifting the operating point depending on the solar irradiance.

Most PV modules are equipped with maximum power point tracking (MPPT) systems that maximize the power output from the modules by shifting the operating point depending on the solar irradiance. Micro grids have the flexibility to undergo rapid changes in configuration by islanding, re-aligning, starting and stopping of generations. In some cases, there may not be any economic alternative to the existing mode of operation of distribution lines because of high reconfiguration costs. Micro grids require wide-range control to ensure system security, optimal operation, emission reduction and seamless transfer from one operating mode to the other without violating system constraints and regulatory requirements. This control is achieved through a central controller (CC) and the dedicated micro source controllers (MCs) connected to the micro sources and the storage devices.

The co ordination among individual proposed control methods like MPPT at PV Side ,battery control and V- f and P-Q are jointly linked through a power balance at the DC and AC side of the inverter which has the capability of handling battery state of charge through co-ordination between micro resources in the micro grid. The PV system configuration describes the modeling of the battery storage with the proposed V-f and P-Q control.

## II. PROPOSED SYSTEM

Fig.1 shows the PV system configuration for V-f and P-Q control with PV operating at MPP including the battery storage backup. It is a two-stage configuration where a DC-DC boost converter is used for MPPT control. The system also considers a battery back-up in case of emergencies while maintaining the voltage and frequency of the micro grid or while trying to supply the critical loads. A battery is connected in parallel to the PV to inject or absorb active power through a bidirectional DC-DC converter. When the battery is absorbing power, the converter operates in the buck mode and when battery is injecting power to the grid, it operates in the boost mode. The operation mode is maintained through the control signal provided to the converter switches.

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The anticipated control strategy also provides a smooth transition of PV side PQ control in grid connected mode to V-f control in islanded mode. The anticipated control algorithms are also capable of handling the battery SOC constraint. The anticipated 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. The wished-for control strategy used in micro grids, Synchronous generators, Diesel generators also in distributed generators. The PV system is connected to the grid through a coupling inductor $L_c$. The coupling inductor filters out the ripples in the PV output current. The connection point is called the point of common coupling (PCC) and the PCC voltage is denoted as Vt (t).

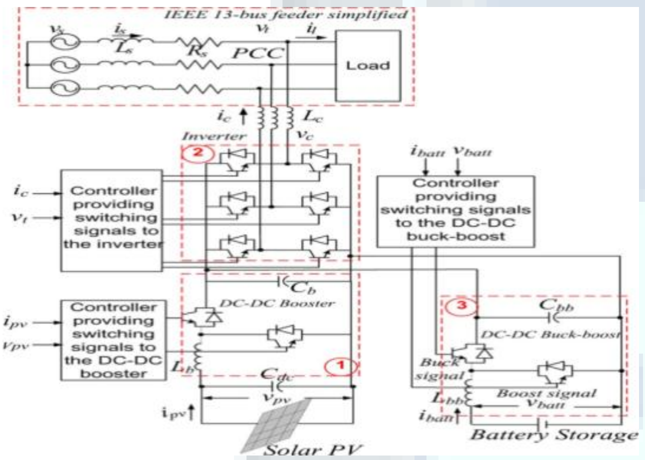


Fig.1 V-f control with solar PV generator operating at MPPT with a battery storage system.

According to the instantaneous power definitions, for a balanced three-phase system, if $v_t(t)$ and $v_c(t)$ denote the instantaneous PCC voltage and the inverter output, then the average power of the PV denoted as P(t), the apparent power S(t)and the average reactive power Q(t)of the PV are as given below:

$$P(t) = \frac{2}{T}\int_{t-\frac{T}{2}}^{t} v_t(\tau) i_c(\tau) d\tau = \frac{V_t(t)V_c(t)}{\omega L_c}\sin\alpha$$

$$S(t) = V_t(t)I_c(t) = \frac{v_t(t)}{\omega L_c}\sqrt{V_t(t)^2 + V_c(t)^2 - 2V_t(t)V_c(t)\cos\alpha}$$

$$Q(t) = \sqrt{S^2(t) - P^2(t)} = \frac{V_t(t)}{\omega L_c}(V_c(t)\cos\alpha - V_t(t))$$

***Battery Modelling:***

In this paper, the battery model is taken from the MATLAB SimPowerSystems library with appropriate parameters which will be used for the proposed V-f and P-Q controls. Due to the intermittent and uncertain nature of solar power output and also the highly fluctuating load demands, deep cycle lead acid batteries are the most common type of battery storage in micro grid applications because the maximum capacity of the battery can be utilized. Hence, in this paper, a battery is modeled as a lead acid battery with appropriate choice of parameters for deep cycle application. It is assumed that the lead acid battery can be discharged up to SOC of 20% and can be charged up to SOC of 80%.

The battery discharge and charge model for a lead acid battery is given by

$$V_{\mathrm{Batt}} = V_0 - R\cdot i - K\frac{Q}{Q-\mathrm{it}}(\mathrm{it} + t^*) + \mathrm{Exp}(t)$$

$$V_{\mathrm{Batt}} = V_0 - R\cdot i - \left[K\frac{Q}{\mathrm{it} - 0.1Q}\right] i^* - \left[K\frac{Q}{Q-\mathrm{it}}\right]\cdot \mathrm{it} + \mathrm{Exp}(t)$$

***Mppt and Battery Integrated V-f Control Method***

The MPPT and battery integrated diagram is shown in fig.2. The loop 1 is a MPPT control at the PV array side which uses the reference MPP .Another feedback PI Controller is used for voltage control a AC side

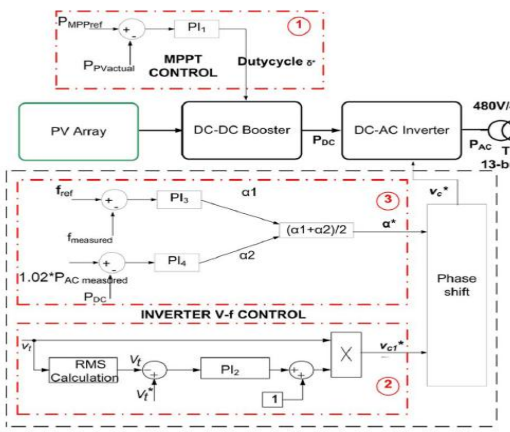


Fig.2 Integrated solar pv MPPT and V-f control diagram

The control scheme can be specified as the controller gains for this loop.

$$v_{c1}^*(t) = v_t(t)\left[1 + K_{P2}(V_t^*(t) - V_t(t)) + K_{I2}\int_0^t ((V_t^*(t) - V_t(t))dt)\right]$$

In eq 1 has been added to the right-hand side such that when there is no injection from the PV generator, the PV output voltage is exactly the same as the terminal voltage.

The frequency control is carried out by controlling the active power output at the inverter side as shown in the outermost loop3. The referenced microgrid frequency of 60 Hz is compared with the measured value and this error is fed to the PI controller that provides the phase shift contribution which shifts the voltage waveform in timescale such that the active power injected will be enough. The DC side active power is compared with the value of AC side power.

$$\alpha_1^* = K_{P3}(f_{\mathrm{ref}} - f_{\mathrm{measured}}) + K_{I3}\int_0^t (f_{\mathrm{ref}} - f_{\mathrm{measured}})dt$$

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$$\alpha_2^* = K_{P4}(1.02 * P_{\mathrm{AC}} - P_{\mathrm{DC}}) + K_{I4}\int_0^t (1.02 * P_{\mathrm{AC}} - P_{\mathrm{DC}})dt.$$

The phase shift contributions from DC and AC sides, and are then averaged as given by

$$\alpha^* = (\alpha_1^* + \alpha_2^*)/2.$$

The contributions explained are same in the case of Modification of V-f control with battery SOC i.e.,in the P-Q control method.

## III. SIMULATION RESULTS

The results obtained from the co-ordinate V-f control are presented from the P-Q control.

***A. Test of V-f Control in Micro grid Mode***

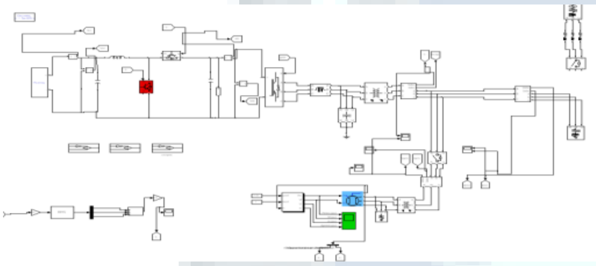

Fig.3 V-f control block diagram

***Results:***

The diesel generator produces a fixed amount of 1.25 MW for both cases throughout the Simulation period as shown in Figure (A). Figure (B) shows the microgrid frequency which initially dips to 57.8 Hz due to the load generation imbalance.

Fig. (A) P DIESEL, Q DIESEL

Fig. (B) FREQUENCY

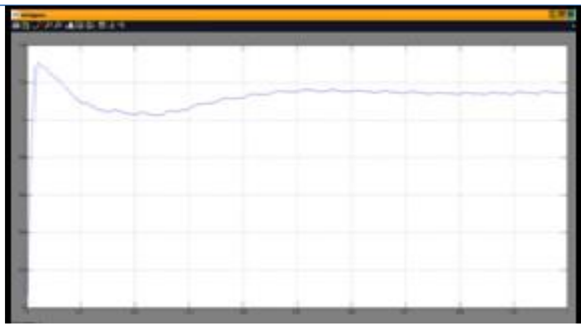

Fig. (C) VOLTAGE(P.U)

Figure (C ) shows the plot of the PCC voltage in p.u. It can be observed that the voltage is also quickly regulated at 1 p.u. after the control is started. Figure(D) shows the active and reactive power injection from the PhV inverter to regulate the frequency and voltage of the microgrid.

Fig. (D(a)) P INVERTER

Fig.(D(b)) Q INVERTER

Figure (E)which shows the active power from the PhV, the battery, and the inverter, respectively, for both cases.

Fig. (E(a) PPV

Fig. (E(b)) P INVERTER

In Case 1, solar irradiance is abundant at 1000W/m2 and hence, the PhV generates 100 kW which is more than required to maintain the microgrid frequency. The surplus 20 kW goes to charge the battery.

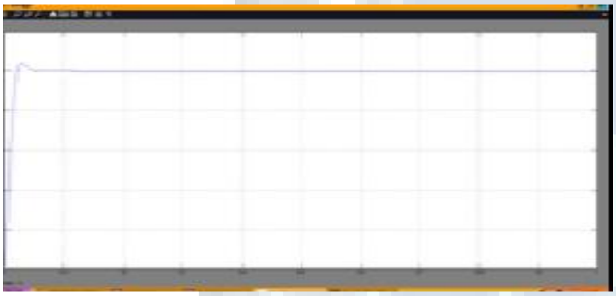

Fig.(F) BATTERY SOC

Figure (F)shows the state of charge (SOC) of the lead acid battery considered for this study.

Fig. (G) VDC

Figure (G) shows the DC voltage for both cases. It can be seen that the voltages are stably maintained at around 850 V and 600 V for two cases, respectively.

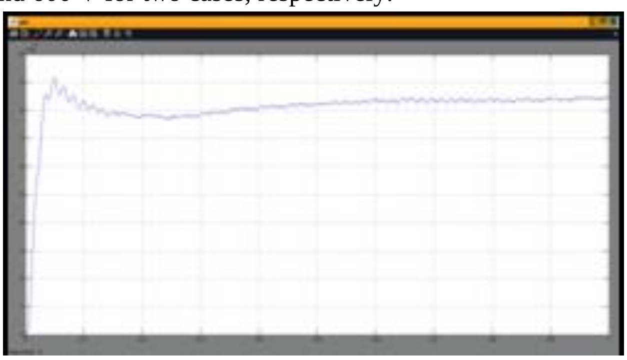

Fig. (H) PDC

Figure (H) shows the active power at the DC and AC sides of the inverter for both cases.

***V-f Control of microgrid wih diesel generator:***

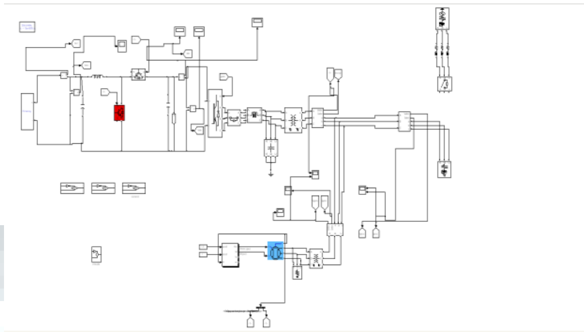

Fig.4 Block diagram

***Results:***

Fig:(A) FREQUENCY

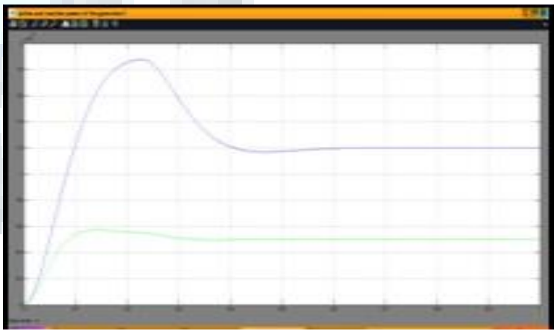

Fig: (B)ACTIVE & REACTIVE POWER(P DIESEL,Q DIESEL)

Fig : (C) ACTIVE AND REACTIVE POWER(P INVERTER,Q INVERTER)

Fig: (D)VOLTAGE(P.U)

Fig. (a) shows the frequency of the microgrid which shoots up in the beginning and then, gradually decreases and stays at 60 Hz in around 8 sec. Fig. (b) shows the voltage plot of the microgrid. It is also clear that it takes around 10 sec for the voltage to settle down to 1 pu. Fig. (c) shows the power generated from the diesel generator and Fig.(d) shows the active and reactive power injection from the PV inverter which is operated at constant PQ mode.

***V-f Control showing grid to microgrid transition:***

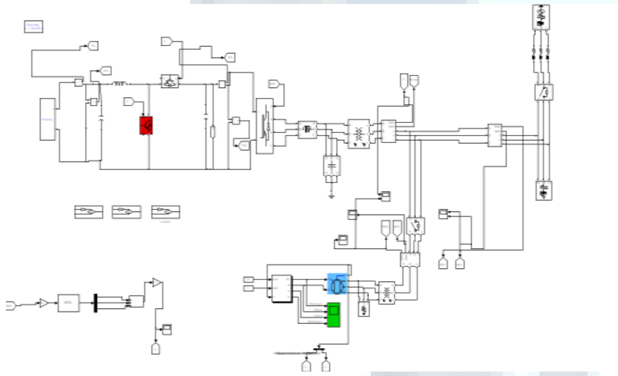

Fig.5 Block diagram

***Results:***

Fig. (a) shows the frequency of the system and voltage at PCC both in grid connected and islanded cases.

Fig.(A) FREQUENCY

A similar response can be observed in the voltage profile at PCC as shown in Fig.(b).

Fig.(B) VOLTAGE (P.U)

This is due to the faster control characteristics of PV and battery integrated system involved in V-f control in islanded case. Fig. (c) shows the active and reactive power injection from the PV inverter.

FIg. (C(a)) P INV

Fig.(C (b)) Q INV

Fig.(d) shows the power injection at Bus 650 of the IEEE 13-bus system. The injection is from the substation in the grid connected mode. In contrast, in islanded mode, the injection comes from the diesel generator which is maintained at a constant value of 1.25 MW.

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Fig . (D(a)) P INJ

Fig. (D(b)) Q INJ

The results presented here clearly show the effectiveness of the V-f and P-Q control algorithms even when the microgrid transitions from the grid connected to the islanded mode.

***Test of P-Q Control:***

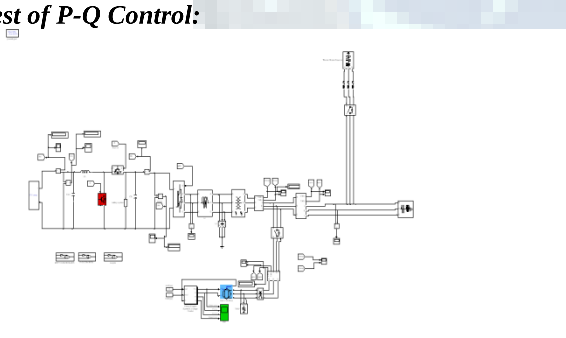

Fig.6 Block diagram

***Results:***

Fig.(a) shows the active and reactive power from the diesel generator. The diesel generator produces a constant active power of 1250 kW throughout the simulation .

Fig.(A) P DIESEL, Q DIESEL

Fig.(b) shows the reference and actual active and reactive power of the solar PhV inverter

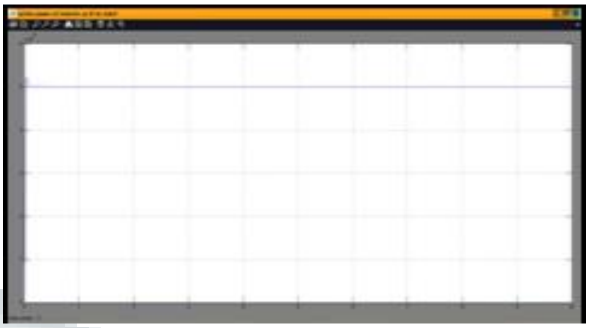

Fig. B(a) P REF

Fig. B(b) QREF

Figure (c) shows the plot of active power from the PhV generator, the inverter injection, and the active power to and from the battery.

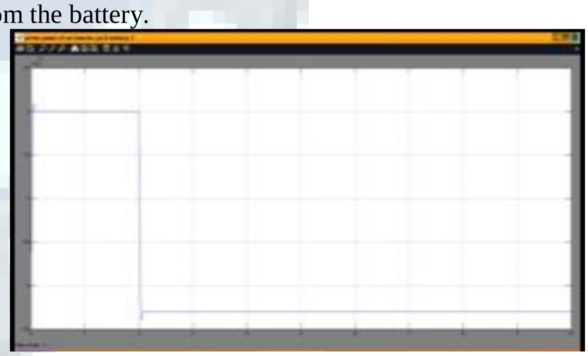

Fig. C (a) PPV

Fig. C (b) P INV

Figure (d) shows the SOC of the battery. It is clear that the SOC increases because of the respective charging and discharging scenarios. It validates the effectiveness of the battery control algorithm adopted in controlling the bidirectional power flow to and from the battery.

Fig. (D) BATT SOC

Figure (e) shows the DC side voltage at the inverter input. It is stably maintained at around 1012 V and 740 V for Cases 3 and 4, respectively. This also validates the indirect control of the DC side voltage through the power balance between AC and DC sides of the inverter

Fig. (E) VOLTAGE (VDC)

Similarly, Figure (f) shows the active power measured at the DC and AC sides of the inverter. Clearly, the DC side active power is slightly greater than the AC side power which means that the control algorithm also takes care of the efficiency of the inverter in the model.

Fig. (F (a)) PAC

FIG.21 (F (b)) PDC

## IV. CONCLUSION

Several control methods of solar PhV generators in grid connected and islanded microgrid scenarios are proposed, investigated and validated. The P-Q control algorithm without storage can be helpful in supplying the active and reactive power loads in grid connected microgrid case. The response time of the control is very short which means that the controls can quickly track the load variation. A new simplified, yet effective MPPT and voltage (P-V) control algorithm can be implemented for the maximal utilization of the solar resource in providing the total active power generation to the grid and at the same time providing local voltage support. The unique feature of this control algorithm lies in controlling the DC side voltage stably at the desired value without using the voltage and current control loops as in traditional control algorithms. It, therefore, provides greater insight of the controller parameters to be used in the system since the parameters for both active power control loops at the AC and the DC sides are close enough to be identified easily. The proposed V-f control method shows satisfactory results with reducing voltage and frequency back to the nominal value and P-q control can be effectively used in supplying some critical loads of a micro grid with solar PV and battery.

## REFERENCES:

[1] R. H. Lasseter, “MicroGrids,” in Proc. IEEE Power Engineering Society Winter Meeting, 2002, vol. 1, pp. 305–308.

[2] S. Chowdhury, S. P. Chowdhury, and P. Crossley, “Microgrids and ActiveDistribution Networks,” 2009, IET Renewable Energy Series 6.

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

[4] 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.

[5] B. Awad, J.Wu, and N. Jenkins, “Control of distributed generation,” Electrotechn. Info. (2008), vol. 125/12, pp. 409–414.

[6] J. C. Vasquez, J. M. Guerrero, E. Gregorio, P. Rodriguez, R. Teodorescu,and F. Blaabjerg, “Adaptive droop control applied to distributedgeneration inverters connected to the grid,” in Proc. 2008 IEEE ISIE,pp. 2420–2425.

[7] H. Bevrani and S. Shokoohi, “An intelligent droop control for simultaneous voltage and frequency regulation in islanded microgrids,” IEEE Trans. Smart Grid, vol. 4, no. 3, pp. 1505–1513, Sep. 2013.

[8] J. C. Vasquez, J. M. Guerrero, M. Savaghebi, and R. Teodorescu,“Modelling, analysis and design of stationary reference frame droop controlled parallel three-phase voltage source inverters,” in Proc. 2011 IEEE 8th ICPE & ECCE, pp. 272–279.

IPHV8I1057X
**International Journal Of Advanced Research and Innovation -Vol.8, Issue .I**
*ISSN Online: 2319 – 9253*
*Print: 2319 – 9245*

[9] T. L. Vandoorn, B. Meersman, J. D. M. De Kooning, and L. Vandevelde, "Analogy between conventional grid contro and islanded microgrid control based on a global DC-link voltage droop," IEEE Trans. Power Delivery, vol. 27, no. 3, pp. 1405–1414, Jul. 2012.
[10] H. Laaksonen, P. Saari, and R. Komulainen, "Voltage and frequency control of inverter based weak LV network microgrid," presented at the Int. Conf. Future Power Syst., Amsterdam, The Netherlands, Nov.17, 2005.
11] 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.
[12] H. Li, F. Li, Y. Xu, D. T. Rizy, and J. D. Kueck, "Adaptive voltage control with distributed energy resources: Algorithm, theoretical analysis, simulation and field test verification," IEEE Trans. Power Syst.,vol. 25, pp. 1638–1647, Aug. 2010.
[13] H. Li, F. Li, Y. Xu, D. T. Rizy, and S. Adhikari, "Autonomous and adaptive voltage control using multiple distributed energy resources," IEEE Trans. Power Syst., vol. 28, no. 2, pp. 717–730, May 2013.
[14] L. D.Watson and J.W. Kimball, "Frequency regulation of a microgrid using solar power," in Proc. 2011 IEEE APEC, pp. 321–326.
[15] M. G. Molina and P. E. Mercado, "Modeling and control of grid-connected photovoltaic energy conversion system used as a dispersed generator," in Proc. 2008 IEEE/PES Transm. Distrib. Conf. Expo.: Latin America, pp. 1–8

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