Line Integration of Bidirectional Inverter with Buck Boost for Microgrid

M.SHYAMALA[1], M.PALANISELVI[2] AND A.CHITRA[3]

[1]Department of Electrical & Electronics Engineering, PET Engineering College, Tirunelveli, Tamil Nadu, India
[2]Department of Electrical & Electronics Engineering, PET Engineering College, Tirunelveli, Tamil Nadu, India
[3]Department of Electrical & Electronics Engineering, PET Engineering College, Tirunelveli, Tamil Nadu, India

Article Info

Article history:

Received on 3rd February 2015
Accepted on 12th February 2015
Published on 19th February 2015

Keyword:

Distributed generation (DG).
Line-interactive Uninterruptible Power supply(UPS),
Micro-grid.

ABSTRACT

Line-interactive uninterruptible power supply (UPS) systems are good candidates for providing energy storage within a micro-grid. Power can be imported from the grid by the UPS to charge its battery in grid-connected mode. The UPS supplies local distributed loads in parallel with other sources in stand-alone mode. In this paper, Power flow is controlled using the frequency and voltage drooping technique. It improves the reliability, economy and efficiency.

Corresponding Author:

Shyamala.M
Electrical and Electronics Engineering,
PET Engineering College,
Tirunelveli, India
Email Id: shyamshiju24@gmail.com

I. INTRODUCTION

To increase reliability, energy storage systems within a micro-grid are essential. Energy is stored while in grid connected mode, when the distributed generation (DG) systems produce excess power. To meet the load demands. The energy storage system needs to be able to work in grid-connected and stand alone modes. Battery and AC power inverter which are perpetually connected to the UPS output in line interactive design, and the battery can be charged by operating the inverter in reverse. The transfer switch can shift electrical flow from the battery to the system output in case of power failure. The line interactive design's high level of efficiency and reliability, as well as its relatively small size and low cost make it well-suited for a range of uninterruptible-power applications. A line interactive UPS differs from an auxiliary or emergency power system or stand by generator in that it will provide near-instantaneous protection from input power interruptions, by supplying energy stored in batteries. The main application of UPS is to protect electrical equipment where an unexpected power disruption could cause injuries.

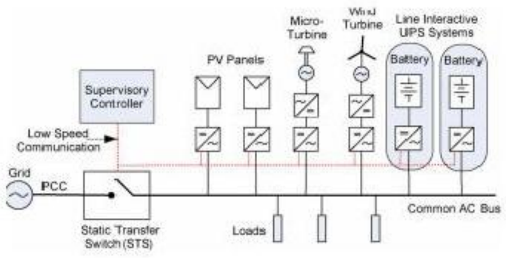

Fig: 1 Structure of micro-grid

II SYSTEM OVERVIEW

The overall structure of a micro-grid consists of DG units, supervisory controller, local loads, and a static transfer switch. STS is used at the PCC to isolate the micro-grid from the grid in the case of grid faults. The UPS system consists of a battery, a bidirectional dc/dc converter and a bidirectional three-phase dc/ac converter with an output LCL filter. When the power flows from the grid to the battery, the dc/dc converters operates in buck mode and boost insulated gate bipolar transistor (IGBT) is held open. When the power flows in opposite direction, the buck IGBT is held open and the dc/dc converter operates in boost mode regulating the dc link voltage to a suitable level in order to inject power into the grid. During battery charging mode, the buck IGBT is pulse width modulated and, the controller operates either in current mode or voltage mode depending upon the battery voltage, when battery discharges, the boost IGBT is modulated to regulate the dc link voltage. During battery charging, the dc link voltage is controlled by the three-phase dc/ac converter. When discharging, however, the dc link voltage is controlled by the dc/dc converters operating in boost mode.

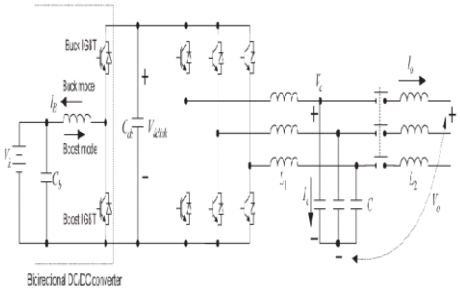

Fig: 2 Circuit diagram of line interactive UPS

III PROPOSED SYSTEM

This proposed line interactive uninterruptible power supply system supplies the power continuously without any interruption when the distribution unit is shutdown. Power can be imported from the grid by the UPS to charge its battery in grid-connected mode. Power can also be exported when required. This proposed line interactive UPS has two controllers such as voltage controller and current controller. Both the controllers' controls the power flow during grid connected mode to make sure that the power output follows the demand precisely. These UPS continually condition and regulate AC utility power to equipment via a power converter. The UPS battery will support the loads through the inverter when the utility power falls. The power converter suppresses voltage spikes and regulates the voltage to provide the required power to equipment loads.

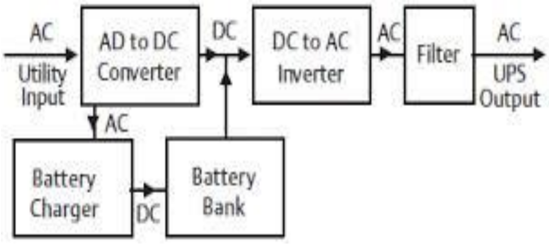

Fig: 3 Block diagram of UPS

IV DROOP-METHOD CONCEPT

With the aim of connecting several parallel inverter with-out control the droop method is often proposed. The applications of such a kind of control are typically industrial UPS systems or islanding micro-grids. The conventional droop method is based on the principle that the phase and the amplitude of the inverter can be used to control active and reactive-power flow. Hence, the conventional droop method can be expressed as follows:

$$\omega = \omega^* - mP \qquad (1)$$

$$E = E^* - nQ \qquad (2)$$

Where E is the amplitude of the inverter output voltage; ω is the frequency of the inverter; ω∗ and E∗ are the frequency and amplitude at no-load, respectively; and m and n are the proportional droop coefficients. The active and reactive powers flowing from an inverter to a grid through an inductor can be expressed as follows

$$P = \left(\frac{EV}{z}Cos\phi - \frac{V*V}{z}\right)Cos\theta + \frac{EV}{z}Sin\phi Cos\theta \qquad (3)$$

$$Q = \left(\frac{EV}{z}Cos\phi - \frac{V*V}{z}\right)Sin\theta - \frac{EV}{z}Sin\phi Cos\theta \qquad (4)$$

Where Z and θ are the magnitude and the phase of the output impedance, respectively; V is the common bus voltage; and φ is the phase angle between the inverter output and the micro-grid voltages. Notice that there is no decoupling between P −ω and Q−E. However, it is very important to keep in mind that the droop method is based on two main assumptions.

Assumption 1: The output impedance is purely inductive, and Z = X and φ = 90 with (3) and (4) become

$$P = \frac{EV}{x}Sin\phi \qquad (5)$$

$$Q = \frac{EV}{x}Cos\phi - \frac{V*V}{x} \qquad (6)$$

This is often justified due to the large inductor of the filter inverter and to the impedance of the power lines. However, the inverter output impedance depends on the control loops, and the impedance of the power lines is mainly resistive in low- voltage applications. This problem can be overcome by adding an output inductor, resulting in an LCL output filter, or by programming virtual output impedance through a control loop.

Assumption 2: The angle φ is small; we can derive that sinφ ≈ φ and cosφ ≈ 1, and consequently,

$$P \approx \frac{EV}{x}\phi \qquad (7)$$

$$Q \approx \frac{V}{x}(E - V) \qquad (8)$$

Note that, taking into account these considerations, P and Q are linearly dependent on φ and E. This approximation is true if the output impedance is not too large, as in most practical cases. In the droop method, each unit uses frequency instead of phase to control the active-power flows, considering that they do not know the initial phase value of the other units. However, the initial frequency at no load can be easily fixed as ω∗. As a consequence, the droop method has an inherent tradeoff between the active-power sharing and the frequency accuracy, thus resulting in frequency deviations. In frequency restoration loops were proposed to eliminate these frequency deviations. However, in general, it is not practical, since the sys- tem becomes unstable due to inaccuracies in inverters' output frequency, which leads to increasing circulating currents.

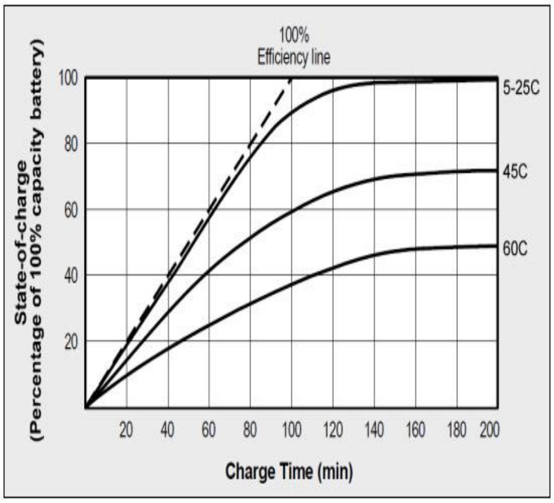

Fig: 4 Droop characteristics as a function of the batteries' charge level

V EXPERIMENTAL RESULT

A complete micro-grid system was built and tested experimentally. The experimental setup is illustrated in Fig. 1. It includes two 60-kW line-interactive UPS systems and an STS with a supervisory controller. In addition, a 60-kW resistive load is used as a local load. The controller parameters of the converter are shown in Table I. The low communication link between the STS and the UPS units was realized using the Controller Area Network (CAN) protocol. The power demand references were set by the supervisory controller of the STS and sent via the CAN bus. In addition, for the purpose of testing different scenarios, the power demand could be set by the user via the CAN-bus- connected computer. An update signal of the status of the STS is also sent to the UPS units via the CAN bus. The UPS unit was operating in grid- connected mode charging the battery at 1-kW rate (note that the current is 180◦ out of phase with respect to the voltage, which means that the UPS is importing power from the grid). When the grid fails, the UPS moves seamlessly to stand-alone mode and starts supplying the local load. However, when the dc link drops below the boost reference (Vdclink_1 = 750 V), the boost starts to regulate the dc link voltage and it raises it to 750 V. The critical load does not see any power interruption. The two UPS units behave exactly the same, as can be seen from their current signals. In Fig. 6, the two UPS units were operating in grid-connected mode charging their batteries at a 10-kW rate. When the grid fails, the two inverters move almost seamlessly from grid-connected mode to stand-alone paralleling mode and start sharing the critical load equally. The UPS charging current looks quite distorted, and this is because each unit generates only 17% of its rated power. Fig. 7 shows the transient response when the active power demand Pref changes from−10 to 60 kW by the user interface. The controller ramps up the power demand gradually (to avoid any unnecessary transient as discussed earlier), and thus, the current changes amplitude and phase gradually. The dc link voltage drops from 800 V (controlled by the ac/dc active rectifier) to 750 V (controlled by the dc/dc converter). Fig. 8 shows the dc link voltage controller transient response during transition from battery discharging mode (the dc link voltage is controlled by the dc/dc converter) to battery charging mode (the dc link voltage is controlled by the ac/dc converter). The dc link shows good transient response. Fig. 10 shows the starting sequence of one UPS unit in grid- connected mode. Initially, the inverter voltage is controlled to have the same magnitude and frequency as the grid voltage, and it is also synchronized so that the power angle is minimized to be virtually zero. The two voltage signals across its terminals are healthy and in phase when the STS controller is satisfied, it closes the STS so the micro-grid is connected to the main grid.

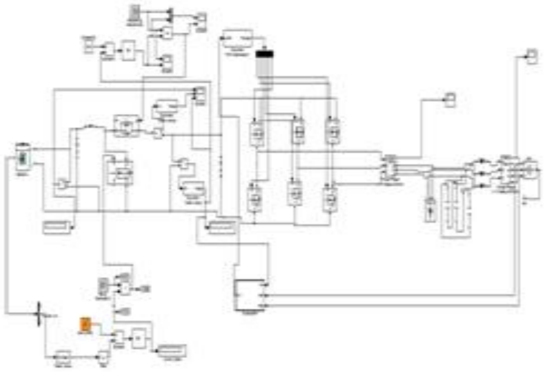

Fig: 5 Simulation of line interactive UPS

TABLE I
DC/AC CONVERTER PARAMETER VALUES

Symbol	Value	Description
L_1	350µH	Inverter-side filter inductor
C	160µF	Filter capacitor
L_2	250µH	Grid-side filter inductor
C_{dc}	2000µF	DC link capacitor
P_{max}	60kW	Maximum active power rating
Q_{max}	45kVAR	Maximum reactive power rating
V_{dclink_max}	1000 V	Maximum allowed transient value of the DC-link voltage (trip limit)

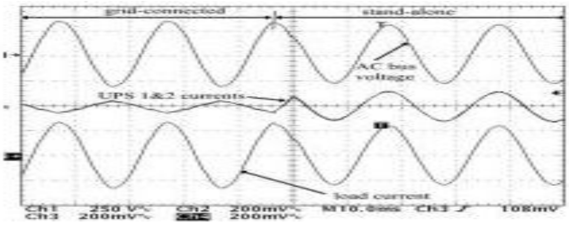

Fig: 6 Grid-connected to stand-alone transition of two UPS unit

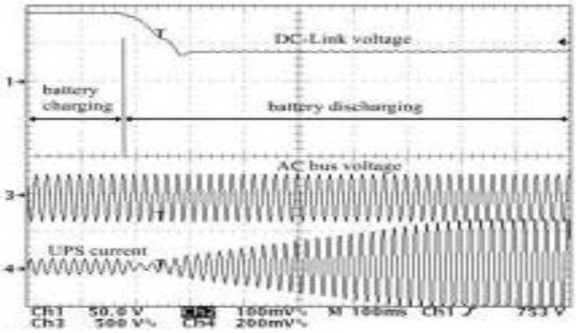

Fig: 7 Battery charging to discharging mode transition

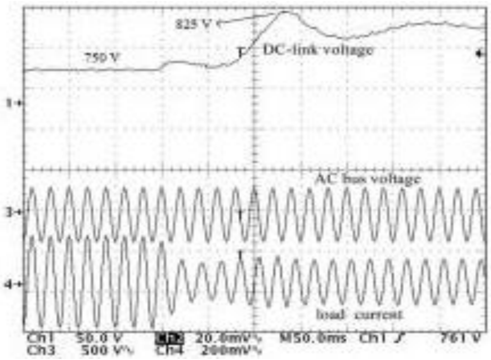

Fig: 8 DC link voltage controller transient response

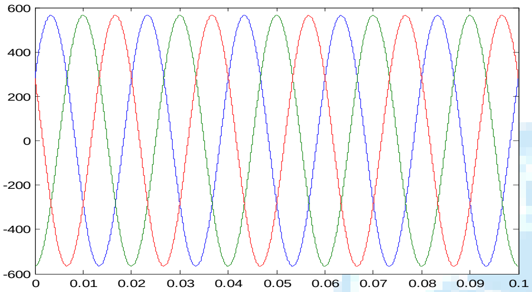

Fig: 9 Grid side output voltage

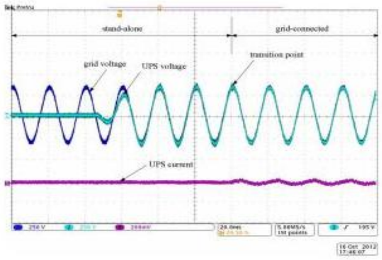

Fig: 10 UPS starting in grid-connected mode

VI CONCLUSION

In the proposed method the line integration bidirectional inverter with buck boost for micro-grid supplies the continuous power demand of the various loads by grid connected mode when the generation unit is shutdown. In grid connected mode, power can be imported from the grid by the UPS to charge its battery. Power can also export when required. The main advantage of this line integration UPS is line synchronized and the energy stored in a battery can be utilized more efficiently. And also this would improve the reliability, economy and efficiency of the micro-grid.

REFERENCES

[1] J. C. Wu and H. L. Jou, “A new UPS scheme provides harmonic suppression and input power factor correction,” IEEE Trans. Ind. Electron., vol. 42, no. 6, pp. 629–635, Dec. 1995.

[2] Y. Lin, G. Joos, and J. F. Lindsay, “Performance analysis of parallel processing UPS systems,” in Proc. IEEE Appl. Power Electron. Conf. Expo., Mar. 1993, pp. 533–539.

[4] S. A. O. da Silva, P. F. Donoso-Garcia, P. C. Cortizo, and P. F. Seixas, “A three-phase line-interactive UPS system implementation with series– parallel active power-line conditioning capabilities,” IEEE Trans. Ind. Appl., vol. 38, no. 6, pp. 1581–1590, Nov./Dec. 2002.

[5] B. H. Kwon, J. H. Choi, and T. W. Kim, “Improved single-phase line-interactive UPS,” IEEE Trans. Ind. Electron., vol. 48, no. 4, pp. 804–811, Aug. 2001.

[6] F. Barrero, S. Martinez, F. Yeves, F. Mur, and P. M. Martinez, “Universal and reconfigurable to UPS active power filter for line conditioning,” IEEE Trans. Power Del., vol. 18, no. 1, pp. 283–290, Jan. 2003.

[7] C. -C. Yeh and M. D. Manjrekar, “A reconfigurable uninterruptible power supply system for multiple power quality applications,” IEEE Trans. Power Electron., vol. 22, no. 4, pp. 1361–1372, Jul. 2007.

[8] R. Tirumala, N. Mohan, and C. Henze, “Seamless transfer of grid connected PWM inverters between utility-interactive and stand-alone modes,” in Proc. IEEE APEC, Dallas, TX, USA, Mar. 2002, pp. 1081–1086.

[10] H. Tao, J. L. Duarte, and M. A. M. Hendrix, “Line-interactive UPS using fuel cell as the primary source,” IEEE Trans. Ind. Electron., vol. 55, no. 8, pp. 3005–3011, Aug. 2008.

[11] M. Arias, A. Fernandez, D. G. Lamar, M. Rodriguez, and M. M. Hernando, “Simplified voltage-sag filler for line-interactive uninterruptible power supplies,” IEEE Trans. Ind. Electron., vol. 55, no. 8, pp. 3005–3011, Aug. 2008.

[12] H. Kim, T. Yu, and S. Choi, “Indirect current control algorithm for util- ity interactive inverters in distributed generation systems,” IEEE Trans. Power Electron., vol. 23, no. 3, pp. 1342–1347, May 2008.

[13] W. J. Ho, J. B. Lio, and W. S. Feng, “A line-interactive UPS structure with built-in vector-controlled charger and PFC,” in Proc. Int. Conf. Power Electron. Drive Syst., 1997, pp. 127–132.

[14] Y. Okui, S. Ohta, N. Nakamura, H. Hirata, and M. Yanagisawa, “Develop- ment of line interactive type UPS using a novel control system,” in Proc. IEEE Int. Telecommun. Energy Conf., 2003, pp. 796–801.

[16] 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.

[17] R. M. Kamel, A. Chaouachi, and K. Nagasaka, “Three control strate- gies to improve the microgrid transient dynamic response during isolated mode: A comparative study,” IEEE Trans. Ind. Electron., vol. 60, no. 4, pp. 1314–1322, Apr. 2013.

[18] J. M. Guerrero, L. G. de Vicuña, 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.

[19] M. Savaghebi, A. Jalilian, J. C. Vasquez, and J. M. Guerrero, “Autonomous voltage unbalance compensation in an islanded droop- controlled microgrid,” IEEE Trans. Ind. Electron., vol. 60, no. 4, pp. 1390–1402, Apr. 2013.

[20] J. C. Vasquez, J. M. Guerrero, M. Savaghebi, and R. Eloy-Garcia, “Modeling, analysis, and design of stationary-reference-frame droop- controlled parallel three-phase voltage source inverters,” IEEE Trans. Ind. Electron., vol. 60, no. 4, pp. 1271–1280, Apr. 2013.

Author Profiles:

Shyamala.M received the B.E ng degree from KNSK College of Engineering in 2013. Doing M.E on Power Electronics and Drives from PET Engineering College, in2015.

Palaniselvi.M received B.E degree in Electrical and Electronics Engineering and M.E degree in Power System Engineering. She is working as an assistant professor in PET Engineering College.

Chitra.A received the B.E degree, from CSI Institute ofTtechnology, Thovalai and M.E from Annamalai University. She has published a journal in Review of step down converter with efficient ZVS operation.