International Journal of Science Engineering and Advance Technology

BESS based Multi input inverter for Grid connected hybrid pv and wind power system

Seshadri Pithani[1], Mr.B,D.S.Prasad[2]
[1]PG Scholar, Pydah College of Engineering, Kakinada, AP, India.
[2]Assistant Professor, Pydah College of Engineering, Kakinada, AP, India.

***Abstract*—This paper proposes BESS based multi input inverter for grid connected hybrid PV and wind power system. This system will simplify the power system and reduce the cost. The proposed system consists of a battery system, multi-input dc–dc converter and a full-bridge dc–ac inverter. Now a days the power demand is more, to get the demand renewable energy sources take important role. Here perturbation and observation method is used to for the MPPT algorithm to get maximum output. Design and operation of the proposed system has explained. BESS (battery energy storage system) has got much importance in renewable energy sources world. The proposed system was designed and implemented in MATLAB/SIMULINK software. The simulation results have shown the performance of the proposed BESS based multi input inverter for grid connected hybrid PV and wind power system.**

***Index Terms*—Inverter, photovoltaic (PV), wind energy, BESS**

I. INTRODUCTION

Generally, PV power and wind power are complementary since sunny days are usually calm and strong winds are often occurred at cloudy days or at nighttime. Hence, the hybrid PV/wind power system therefore has higher reliability to deliver continuous power than either individual source. Traditionally, a substantial energy storage battery bank is used to deliver the reliable power and to draw the maximum power from the PV arrays or the wind turbine for either one of them has an intermittent nature. However, the battery is not an environmental friendly product because of its heavy weights, bulky size, high costs, limited life cycles, and chemical pollution. Therefore, it is very common to utilize the solar or wind energy by connecting them to the ac mains directly. Usually, two separated inverters for the PV array and the wind turbine are used for the hybrid PV/wind power system. An alternative approach is to use the multi-input inverter for combining these renewable energy sources in the dc end instead of the ac end. It can simplify the hybrid PV/wind power system and reduce the costs. The objective of this paper is to propose a BESS based multi input inverter for grid connected hybrid PV and wind power system. The proposed multi-input inverter has the following advantages:

1) Power from the PV array or the wind turbine can be delivered to the utility grid individually or simultaneously,
2) Maximum power point tracking (MPPT) feature can be realized for both solar and wind energy,
3) A large range of input voltage variation caused by different insolation and wind speed is acceptable.

II. DESIGN & OPERATION

The schematic diagram of the proposed multi-input inverter is shown in Fig. 1. It consists of a buck/buck-boost fused multi-input dc–dc converter and a full-bridge dc/ac inverter. The input dc voltage sources, are obtained from the PV array and the rectified wind turbine output voltage. By applying the pulse-with-modulation (PWM) control scheme with appropriate MPPT algorithm to the power switches, the multi-input dc–dc converter can draw maximum power from both the PV array and the wind turbine individually or simultaneously. The dc bus voltage will be regulated by the dc/ac inverter with sinusoidal PWM (SPWM) control to achieve the input output power-flow balance. Details of the operation principle for the proposed multi-input inverter are introduced as follows.

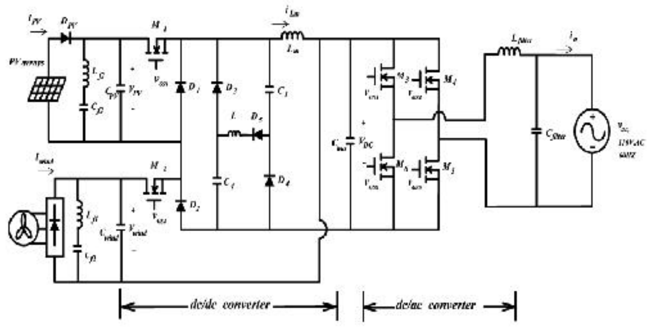

Fig. 1 Schematic diagram of the proposed multi-input inverter

A. PV Array

The PV array is constructed by many series or parallel connected solar cells. Each solar cell is form by a –junction semiconductor, which can produce currents by the photovoltaic effect. Typical output power characteristic curves for the PV array under different insolation are shown in Fig. 2. It can be seen that a maximum power point exists on each output power characteristic curve. Therefore, to utilize the maximum output power from the PV array, an appropriate control algorithm must be adopted.

B. MPPT Algorithm

Different MPPT techniques have been developed. Among these techniques, the perturbation and observation (P&O) method with the merit of simplicity is used in this paper. The perturbation of the output power is achieved by periodically changing (either increasing or decreasing) the controlled output current. The objective of the P&O method is to determine the changing direction of the load current. Fig. 3 shows the flow chart of the MPPT algorithm with P&O method for the proposed multi-input inverter. Since there are two individual input sources, each one of them needs an independent controller. However, both of the controllers can be implemented by using one integrated controller. At the beginning of the control scheme, the output voltage and output current of the source (either the PV array or the wind turbine) are measured, then the output power can be calculated. By comparing the recent values of power and voltage with previous ones, the P&O method shown in the flow chart can determine the value of reference current to adjust the output power toward the maximum point.

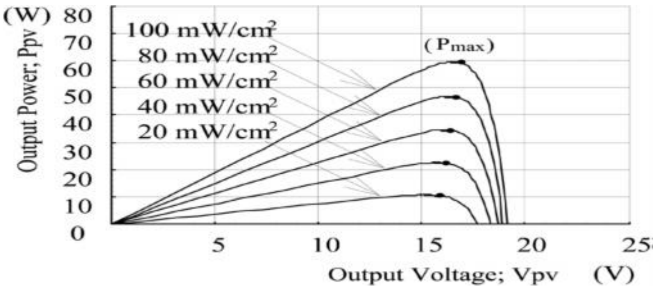

Fig. 2 Typical output power characteristic curves of the PV array under different insolation

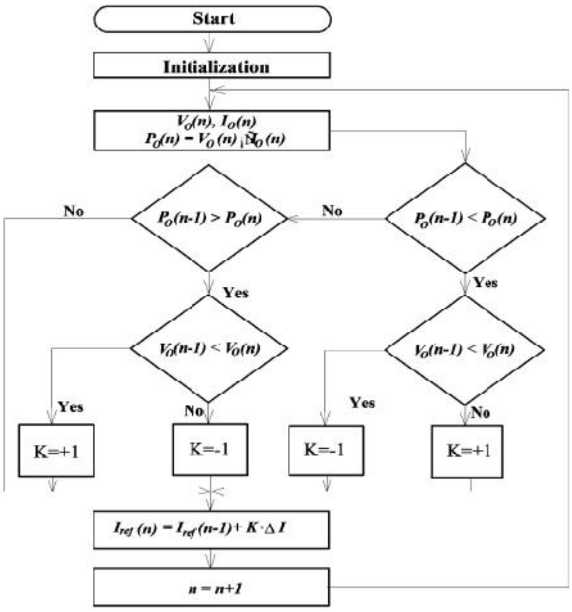

Fig. 3 Flow chart of the MPPT algorithm with P&O method

C. Wind Turbine

Among various types of wind turbines, the permanent magnet synchronous wind turbine, which has higher reliability and efficiency, is preferred. The power of the wind can be derived as

$$P_{\text{wind}} = \frac{1}{2}\rho A V_{\text{wind}}^3 \qquad (1)$$

Where the wind turbine is a function of the tip speed ratio which is defined as

$$\lambda_{\text{tip}} = \frac{wr}{V_{\text{wind}}} \qquad (2)$$

A typical curve is shown in Fig. 4, where the maximum value of is only achieved at a particular tip speed ratio. Since the speed of the wind is not constant, the rotational speed of the wind turbine must be adjustable to ensure a constant tip speed ratio to gain the maximum. The output current change of the wind turbine will cause of the rotational speed as well as to change. Since is a function of, the output power of the wind turbine will change, too. Therefore, by controlling the output current of the wind turbine, the rotational speed of the wind turbine blades can be adjusted to achieve the appropriate tip speed ratio. Eventually, the maximum value of Cp can be obtained and the maximum power can be transferred from the airstream to the wind turbine to produce the maximum electrical power.

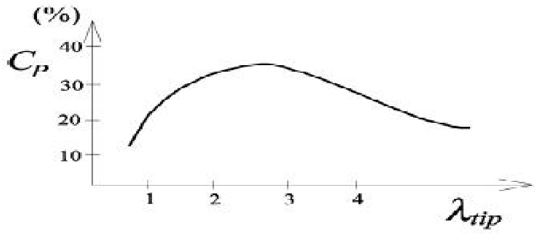

Fig. 4 Typical curve

For the convenience of experiment, instead of natural wind, a controllable dc motor is used to drive the wind turbine to simulate the actual operation situation under the natural air-stream. Fig. 5 shows the conceptual block diagram of the experimental setup for wind power generation system. For different dc voltage provided by the dc motor controller, the dc motor will receive a limited maximum power to drive the directly coupled wind turbine. When the output power of the wind turbine is small, the dc motor will request small power from the dc source to drive the wind turbine. When the output current of the wind turbine is increased, the output voltage and the rotational speed will be decreased. Also, the dc motor needs to provide a larger torque to the wind turbine. Since the dc motor has limited maximum input power predetermined by the control box, it can only provide limited maximum torque to the wind turbine which can only generate a limited maximum power to the load. Fig. 6 shows typical output power characteristic curves of the wind turbine under different driving power from the controllable dc motor. These curves have same characteristics with those driven by the natural air-stream. Each one of the curves represents a constant driving power from the dc motor. The output power of the wind turbine is drawn by an electronic load. The load current is gradually increased, and then the output power can be measured.

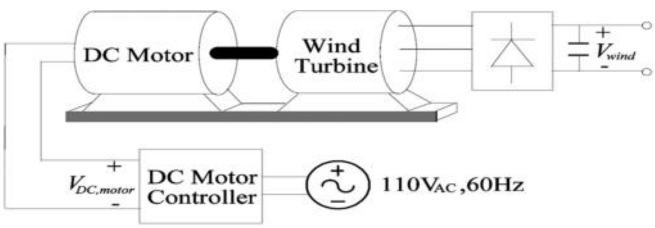

Fig. 5 Conceptual block diagram of the experimental setup for wind power generation system

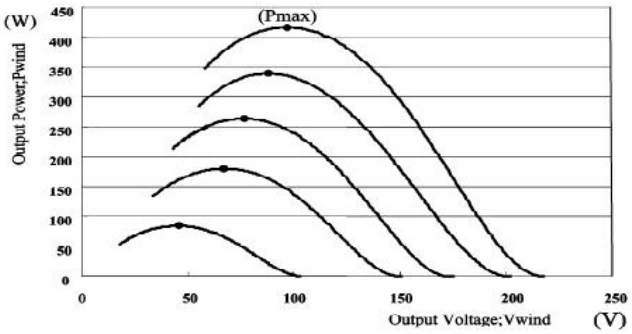

Fig. 6 Typical output power characteristic curves of the wind turbine for different wind speed

Output power characteristic curves shown in Fig. 6 imply that the wind turbine will generate different maximum output power for different wind speed. Because the output power characteristic curves of the wind turbine are similar to those of the PV array shown in Fig. 2, the P&O method is adopted as the MPPT algorithm for the wind turbine. Therefore, a power electronic converter with appropriate controller is needed to process the wind energy which varies considerably according to the meteorological conditions such as wind speed.

D. Multi-Input DC–DC Converter

The proposed multi-input dc–dc converter is the fusion of the buck-boost and the buck converter. Syntheses of the multi-input dc–dc converter are done by inserting the pulsating voltage source of the buck converter into the buck-boost converter. In order not to hamper the normal operation of the buck-boost converter and to utilize the inductor for the buck converter, the pulsating voltage source of the buck converter must be series-connected with the output inductor.

Base on the conduction status of the switches M1 and M2, the multi-input dc–dc converter has four operation modes. Fig. 7(a)–(d) show the equivalent circuits for Mode I through Mode IV, respectively. When switches M1 or M2 are turned off, diodes D1 and D2 will provide a free-wheeling path for the inductor current. If one of the voltage sources is failed, the other voltage can still provide the electric energy, normally. Therefore, it is very suitable for renewable energy applications. Details of the circuit operation principle can be found in [17].

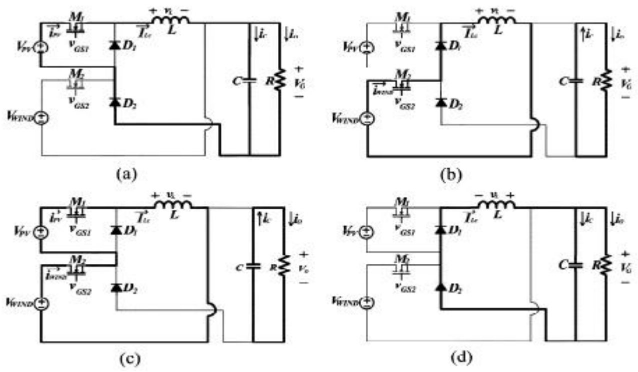

Fig. 7 Equivalent circuits for the multi-input dc–dc converter (a) Mode I (b) Mode II (c) Mode III (d) Mode IV

The input-output voltage relationship can be derived from the steady-state volt-second balance analysis of the inductor. If M1 has longer conduction time than M2 has, then the equivalent operation circuit for one switching cycle will follow the sequence of Mode I, Mode III, and Mode IV. On the other hand, if M2 has longer conduction time than M1 has, the sequence becomes Mode II, Mode III, and Mode IV. In either case, the output voltage can be expressed as

$$V_{\mathrm{DC}} = \frac{d_1}{1-d_2} V_{\mathrm{PV}} + \frac{d_2}{1-d_2} V_{\mathrm{Wind}} \qquad (3)$$

Similarly, the average input and output current can be obtained

$$I_{PV} = \frac{d_1}{1-d_2} I_o \qquad (4)$$

$$I_{Wind} = \frac{d_2}{1-d_2} I_o. \qquad (5)$$

From the above derived steady-state voltage and current equations, different power distribution demands of the multi-input dc–dc converter can be achieved.

E. Control Scheme

The conceptual control block diagram of the proposed multi-input inverter is shown in Fig. 8. The hardware implementation of the control circuit is realized by using a central control unit, digital signal processor (DSP) TMS320F240, and auxiliary analog circuits. The sensed voltage and current values for the PV array and the wind turbine are sent to the DSP where the MPPT algorithm will determine the reference current for the PV array and the wind turbine.

The PWM Comparator1 and Comparator2 will generate desired gate signals for power switches M1 and M2 according to the current error signals e1 and e2, respectively. The dc/ac inverter will inject a sinusoidal current into the ac mains. The SPWM gate signals of switches M3 through M6 for producing sinusoidal ac current is generated by the DSP where the amplitude of the ac current is determined by the error signal of the measured dc bus voltage and the reference one. If the measured dc bus voltage is less than the reference value, then the amplitude of the ac output current will be decreased in order to increase the dc bus voltage. On the contrary, if the dc bus voltage is higher than the reference one, then the amplitude of the ac output current will be decreased. On the other point of view, the dc bus voltage is regulated by the dc–ac inverter and the input-output power balance can be achieved.

For practical operation considerations, functions of soft-start, over-voltage protection, over-current protection, and under-voltage protection are all realized by the controller, too. Since both of the input currents for the PV array and the wind turbine is controlled by the MPPT algorithm with P&O method, the starting current is gradually increased and the soft-start function of the input current is naturally obtained. Also, during the starting transition, the ac output current for the utility line is limited by the reference current command and the small amount of input power. Therefore, the soft-start demand for the output current is achieved naturally. In order to control the proposed multi-input inverter properly, the central control unit, DSP, need to sense the input voltages, input currents, dc bus voltage, output voltage, and output current, continuously. Therefore, no extra sensor is needed to realize these protection functions.

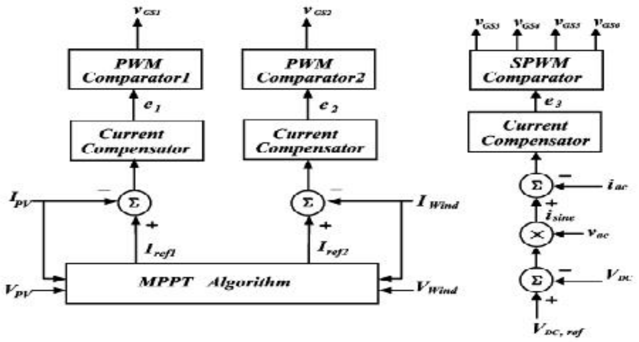

Fig. 8 Conceptual control block diagram of the proposed multi-input inverter

III. SIMULATION RESULTS

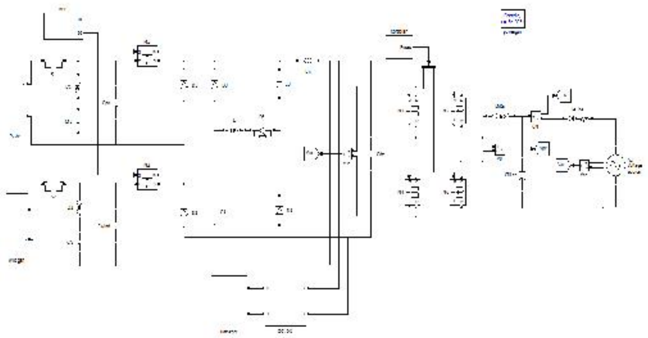

Fig 9 simulation diagram of proposed system with BESS

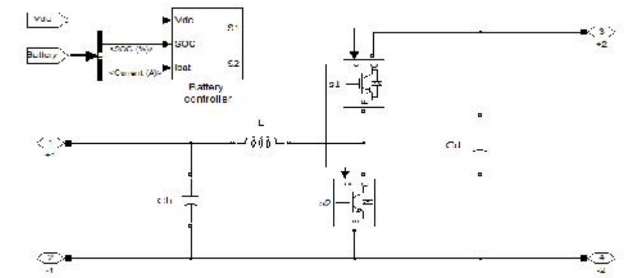

Fig 10 simulation diagram of Charging discharging DC-DC converter

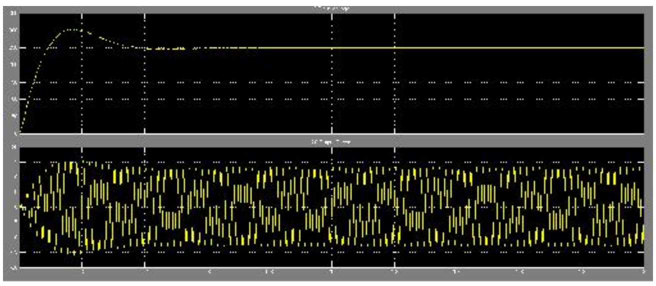

Fig 11 multi-input inverter when both of the PV array and wind is supplying Vdc, Io

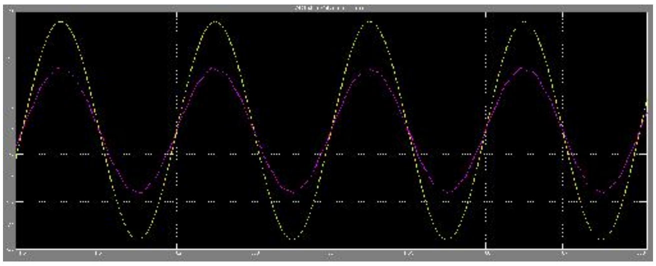

Fig 12 multi-input inverter when both of the PV array and wind is supplying vo, io

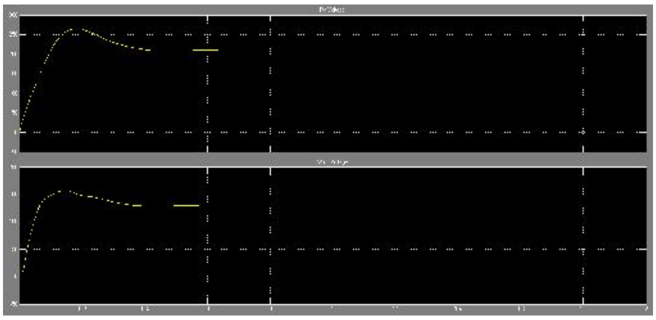

Fig 13 multi-input inverter when both of the PV array and wind is supplying Vpv, Vwind

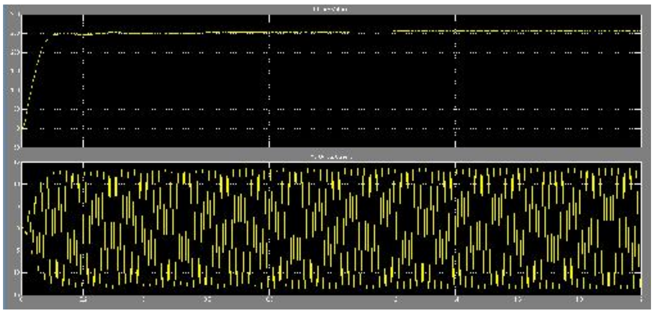

Fig 14 multi-input inverter when only the PV array is supplying Vdc, Io

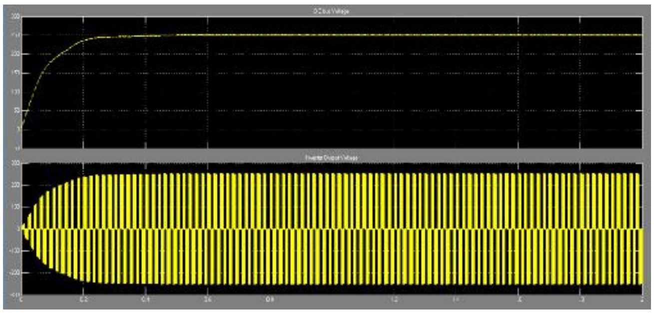

Fig 15 multi-input inverter when only the PV array is supplying Vdc, Vinv

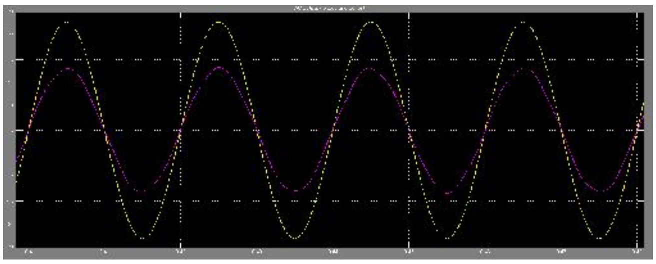

Fig 16 multi-input inverter when only the PV array is supplying vo, io

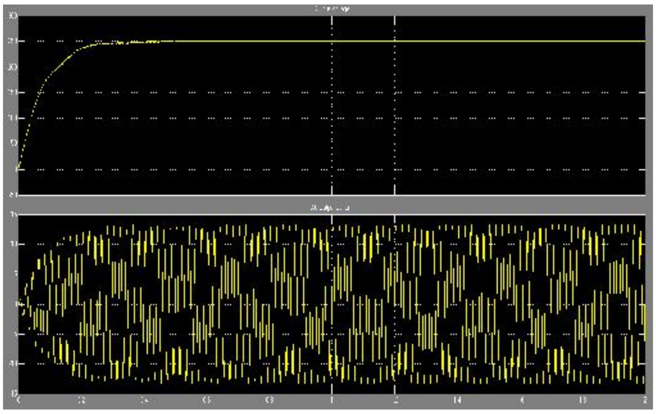

Fig 17 multi-input inverter when only the Wind is supplying Vdc, Io

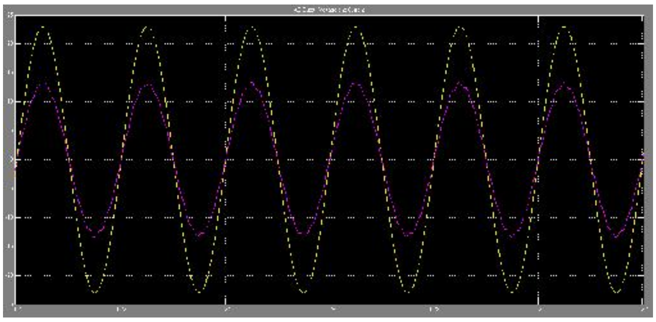

Fig 18 multi-input inverter when only the Wind is supplying vo, io

CONCLUSION

A BESS based multi input inverter for grid connected hybrid PV and wind power system. It has the following advantages:

1) Power from the PV array or the wind turbine can be delivered to the utility grid individually or simultaneously,

2) MPPT feature can be realized for both PV and wind energy,

3) A large range of input voltage variation caused by different insolation and wind speed is acceptable.

In this paper, The perturbation and observation method is adopted to realize the MPPT algorithm for the PV array and the wind turbine. The control circuit is implemented by using a DSP and auxiliary analog circuits to accomplish the desired control functions and circuit protection. Simulation results under different operation conditions were shown to verify the performance of the proposed multi-input inverter with desired features.

REFERENCES

[1] T.-F. Wu, C.-H. Chang, Z.-R. Liu, and T.-H. Yu, “Single-Stage converters for photovoltaic powered lighting systems with MPPT and charging features,” in *Proc. IEEE APEC*, 1998, pp. 1149–1155.

[2] M. Kolhe, J. C. Joshi, and D. P. Kothari, “Performance analysis of a directly coupled photovoltaic water-pumping system,” *IEEE Trans. Energy Conv.*, vol. 19, no. 3, pp. 613–618, Sep. 2004.

[3] A. M. De Broe, S. Drouilhet, and V. Gevorgian, “A peak power tracker for small wind turbines in battery charging applications,” *IEEE Trans. Energy Conv.*, vol. 14, no. 4, pp. 1630–1635, Dec. 1999.

[4] L. Solero, F. Caricchi, F. Crescimbini, O. Honorati, and F. Mezzetti, “Performance of a 10 kW power electronic interface for combined wind/PV isolated generating systems,” in *Proc. IEEE PESC*, 1996, pp. 1027–1032.

[5] S. Wakao, R. Ando, H. Minami, F. Shinomiya, A. Suzuki, M. Yahagi, S. Hirota, Y. Ohhashi, and A. Ishii, “Performance analysis of the PV/wind/wave hybrid power generation system,” in *Proc. IEEE World Conf. Photovolt. Energy Conv.*, 2003, pp. 2337–2340.

[6] B. S. Borowy and Z. M. Salameh, “Methodology for optimally sizing the combination of a battery bank and PV array in a wind/PV hybrid system,” *IEEE Trans. Energy Conv.*, vol. 11, no. 2, pp. 367–375, Jun. 1996.

[7] S. B. Kjaer, J. K. Pedersen, and F. Blaabjerg, “A review of single-phase grid-connected inverters for photovoltaic modules,” *IEEE Trans. Ind. Appl.*, vol. 41, no. 5, pp. 1292–1306, Sep./Oct. 2005.

[8] S. J. Chiang, K. T. Chang, and C. Y. Yen, “Residential photovoltaic energy storage system,” *IEEE Trans. Ind. Electron.*, vol. 45, no. 3, pp. 385–394, Jun. 1998.

[9] G. B. Shrestha and L. Goel, “A study on optimal sizing of stand-alone photovoltaic stations,” *IEEE Trans. Energy Conv.*, vol. 13, no. 4, pp. 373–378, Dec. 1998.

[10] J. H. R. Enslin and D. B. Snyman, “Combined low-cost, high-efficient inverter, peak power tracker and regulator for PV applications,” *IEEE Tran. Power Electron.*, vol. 6, no. 1, pp. 73–82, Jan. 1991.

[11] K. H. Hussein, I. Muta, T. Hoshino, and M. Osakada, “Maximum photovoltaic power tracking: An algorithon for rapidly changing atmospheric conditions,” *Proc. Inst. Elect. Eng.*, vol. 142, no. 1, pp. 59–64, 1995.

[12] C. Hua, J. Lin, and C. shen, “Implementation of a DSP-controlled photovoltaic system with peak power tracking,” *IEEE Trans. Ind. Electron.*, vol. 45, no. 1, pp. 99–107, Feb. 1998.

[13] O. F. Walker, *Wind Energy Technology*. New York: Wiley, 1997.

[14] P. Gipe, *Wind Energy Comes of Age*. New York: Wiley, 1995.

[15] K. Amei, Y. Takayasu, T. Ohji, and M. Sakui, “Amaximum power control of wind generator system using a permanent magnet synchronous generator and a boost chopper circuit,” in *Proc. Power Conv.*, 2002, vol. 3, pp. 1447–1452.

[16] R. Cardenas, R. Pena, G. Asher, and J. Cilia, “Sensorless control of induction machines for wind energy applications,” in *Proc. IEEE PESC*, 2002, pp. 265–270.

[17] Y.-M. Chen, Y.-C. Liu, and S.-H. Lin, “Double-Input PWM DC/DC converter for high/low voltage sources,” in *Proc. IEEE Int. Telecommun. Energy Conf.*, 2003, pp. 27–32.