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Design and Analysis of a Grid Connected Renewable Home Energy System

Rani T R
Electrical & Electronics Department
Government Engineering college Idukki
Thrissur , India

Raji Krishna
Electrical & Electronics Department
Government Engineering college Idukki
Trivandrum, India

***Abstract*—The objective of this paper is to design and analyse a grid connected renewable home energy system to reduce the cost energy saving. The proposed system consists of hybrid PV and Wind, uncontrolled rectifier, multi-input dc-dc converter, a full bridge inverter, bidirectional energy meter. The design of PV and Wind are introduced. The perturbation and observation method is used for maximum power point tracking algorithm for the given input sources. The operational principle and design of multi input dc-dc converter and full bridge inverter are explained. The digital signal processor is used to realize the control circuit. Experimental results have shown the performance of the system.**

***Index Terms*—PV , Wind energy, multi input inverter**

I.INTRODUCTION

Due to the fast depletion of fossil fuels the researches on the renewable energy source has become popular. The rapid growth of Power electronics technology[1]-[3] increases the applications of renewable energy sources. Whenever the sun is shining, wind is blowing, water is running a grid connected system allows to power home with renewable energy. Hybrid PV/wind power system has higher reliability to deliver power continuously than the either individual sources[4],[5]. Any excess electricity produce is fed back into the grid. When renewable resources are unavailable, electricity from the grid supplies the needs, eliminating the expense of electricity storage devices like batteries.

In addition, power providers in most states allow net metering, an arrangement where the excess electricity generated by grid-connected renewable energy systems "turns back" the electricity meter as it is fed back into the grid. If use of electricity is more then the system feeds into the grid during a given month, payment to the power provider is only for the difference between what used and what produced.

Currently, requirements for connecting distributed generation systems like home renewable energy or wind systems to the electricity grid vary widely. But all power providers face a common set of issues in connecting small renewable energy systems to the grid, so regulations usually have to do with safety and power quality, contracts (which may require liability insurance), and metering and rates.

Power providers want to be sure that the system includes safety and power quality components. These components include switches to disconnect the system from the grid in the event of a power surge or power failure (so repairmen are not electrocuted) and power conditioning equipment to ensure that the power exactly matches the voltage and frequency of the electricity flowing through the grid.

Usually, for the hybrid PV/wind power system two separate converters are used[7]. Another approach is to use the multi-input converter which helps to combine these renewable energy sources at the dc bus end. The schematic diagram of the proposed system is shown in fig.1, which consists of PV array, Wind turbine, multi input dc-dc converter, single phase full bridge inverter.

II. PV ARRAY

Solar panels generate free power from the sun by converting sunlight to electricity with no moving parts, zero emissions, and no maintenance. The solar panel, the first component of a electric solar energy system, is a collection of individual silicon cells[8] that generate electricity from sunlight. The photons (light particles) produce an electrical current as they strike the surface of the thin silicon wafers. A single solar cell produces only about 1/2 (.5) of a volt. However, a typical 12 volt panel about 25 inches by 54 inches will contain 36 cells wired in series to produce about 17 volts peak output. If the solar panel can be configured for 24 volt output, there will be 72 cells so the two 12 volt groups of 36 each can be wired in series, usually with a jumper, allowing the solar panel to output 24 volts. When under load (charging batteries for example), this voltage drops to 12 to 14 volts (for a 12 volt configuration) resulting in 75 to 100 watts for a panel of this size.

A. SOLAR PANEL DESIGN

In order to design a solar panel we have to consider certain factors such as solar access for the given location, chance of shading and its effect on the system, available area, if it is roof mounted find out the orientation and tilt angle. Also for the selected tilt angle and orientation the average solar radiation. Temperature effects on the modules and effect dirt on the modules. Consider the system losses that is power loss in the cable.

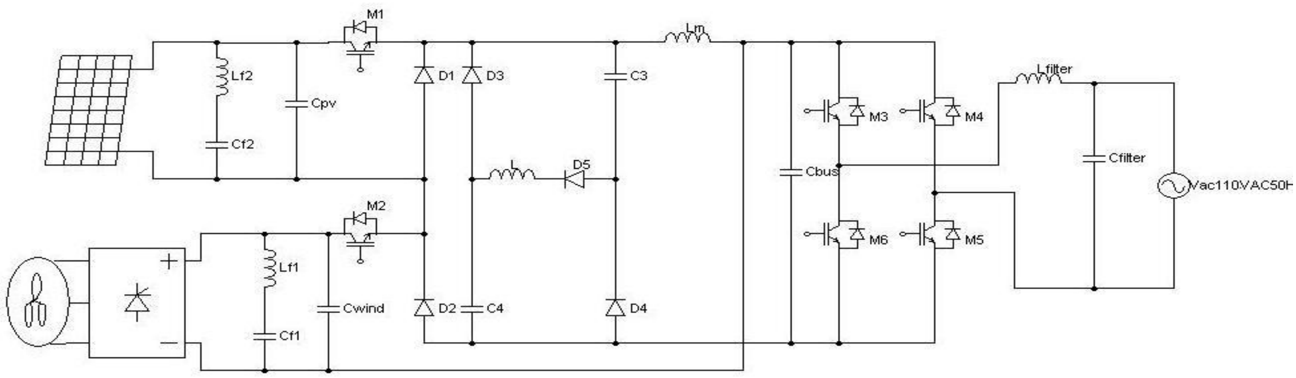

Fig.1 Schematic diagram of the proposed system

Step1: Find out the total power and energy consumption of all the loads that should be supplied by the PV system. That can be find out by multiplying watt hours per day by 1.3(energy lost in the system)

Step2: in order to find the sizing of the PV module calculate the total peak watt(Wp) of PV panel capacity, which depends on the climate of site location. So consider panel generation factor to find the peak watt of solar panel.

Cosider a home having the following electrical appliance:

18W Fluorescent lamp, 4 hours per day – 3 No
60W Fan , 2 hours per day -- 3 No
100 W Tv , 5 hours per day - 1 No
Total use = (3*18*4) + (3*60*2) + (500) = 1076 Wh/day
Total PV panels energy needed = 1076*1.3 = 1398.8 Wh/day
Wp of the PV panel capacity needed = 1398.8/3.22
= 434.4Wp
Number of Pv panel needed = 434.4/110
= 3.95 modules

The above implies the home energy system should be power by at least 4 modules of 110Wp PV modules.

III. MPPT ALGORITHM

MPPT has been developed[10]-[12] by different techniques. Among that P&O (Perturbation and Observation) method is used here. The Fig.2 Shows the MPPT algorithm by P&O method which is used for producing the gate signals of switches in the multi input inverter.

IV. WIND TURBINE

Home wind turbines are different form huge and small wind turbines. Home wind turbines are not large but they should produce more energy than consume. In order to design a wind turbine the following factors are need to consider: the place for installation is the prime factor i.e

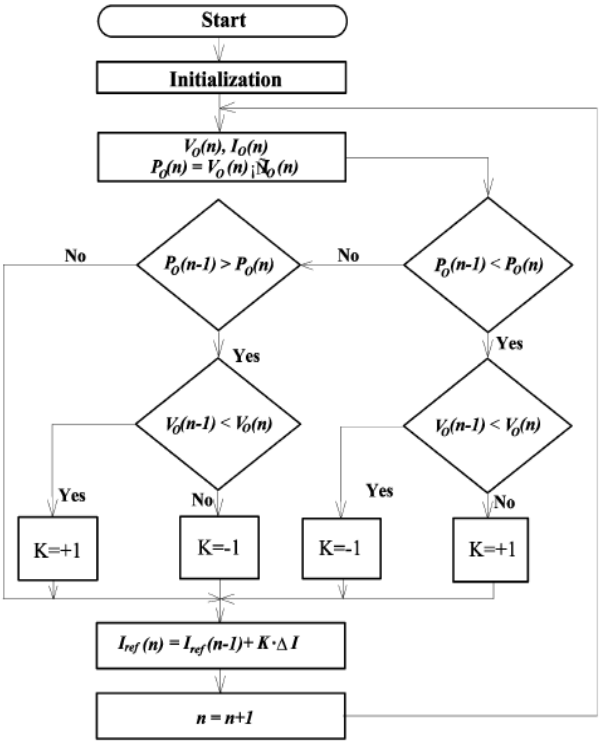

Fig.2 MPPT algorithm with P&O Method

the availability of wind in the given area, readymade kits are available check it out and also find the installation costs.

For home installation the average size of wind turbines would be in 100 – 1000 watt range. For an efficient wind turbine to generate electricity the wind speed ranges from 5.33 to 9m/s. So before design find out the average wind speed in that area. One of the main component is the wind turbine blades. For the proper working of turbine they have to sized and pitched correctly. The wind blades should be anywhere from 20 -60 % of the height of the wind mill. Three blades are common Highly reliable and efficient permanent magnet synchronous wind turbine is preferred[13]-[16] more.

Power of the wind P_{wind} can be derived as

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

Where is the air density (kg/m^3), A is the area swept by wind blades in m^2 , V_{wind} is the wind speed in m/s.

The mechanical power generated by the wind is given by

$$P_m = C_p * P_{wind} \quad (2)$$

Where C_p is the power coefficient function, which is a nonlinear function depending on the tip speed ratio and pitch angle.

Tip speed ratio is given by

$$TSR = \frac{wr}{V_w} \quad (3)$$

To get the maximum power from the wind turbine the same MPPT technique is used here also.

V. MULTI INPUT DC-DC CONVERTER

Instead of using separate converter for each energy sources here using a single multi-input dc-dc converter topology[17]. It is a combination of buck and buck-boost converter.

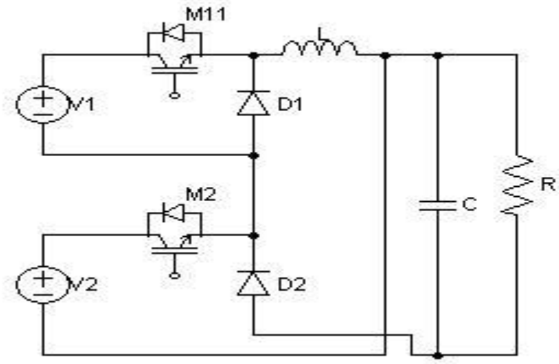

Fig.3 Multi input dc-dc converte

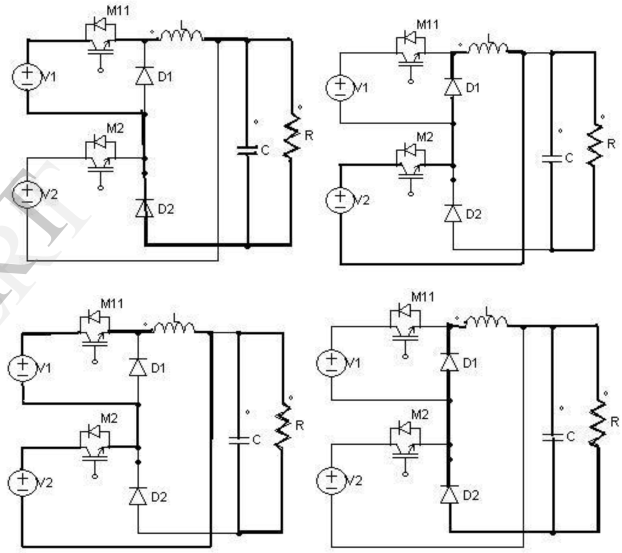

Fig. 4 Different modes of operation multi input dc-dc converter(a) Mode 1 (b) Mode 2 (c) Mode 3 (c) Mode 4

From conduction status of the switches M1 and M2 the above converter has four different modes of operation. The equivalent circuits are shown in figure. In this configuration even if one of the sources is failed the other source still provide the energy which is very useful in the case renewable energy application.

The relationship between the input and output voltage can be obtained from the volt second balance theorem on the inductor

The following equation can be obtained by applying volt-second balance theorem on inductor:

$$(d_2 - d_1) * T_s * (V_2 - V_1) + d_1 * T_s * (V_1 + V_2) = (1 - d_1) T_s V_o \quad (4)$$

Where d_1 & d_2 are the duty ratios of M_1 & $_{M2}$ and T_s is the switching period.

From (2), expression for the output voltage can be obtained:

$$V_o = \frac{d_2}{1-d_1} V_2 + \frac{d_1}{1-d_1} V_1 \qquad (5)$$

If the conducting time M_2 is longer than that of M_1 then the mode sequence of operation in one switching cycle will differ that is ModeII, Mode IV, Mode III. So the volt second balance equation becomes:

$$(d_2 - d_1) * T_s * (V_1) + d_2 * T_s * (V_1 + V_2) = (1 - d_1) T_s V_o \qquad (6)$$

From (4) voltage expression obtained will be same as in(3),which implies the switches can be controlled independly.

VI. SINGLE PHASE FULL BRIDGE INVERTER

Design of inverter components includes: Modelling of Switch, Design of Inductor, design of DC capacitor, Design of AC capacitor.

A. Modelling of Switch

The duty ratio gives the full idea about the modelling of the switch. Here w have chosen unipolar PWM for the switching of the power switches. Let the modulating signal for switches M_3 and M5 is Vm = m(t). Then the duty ratio

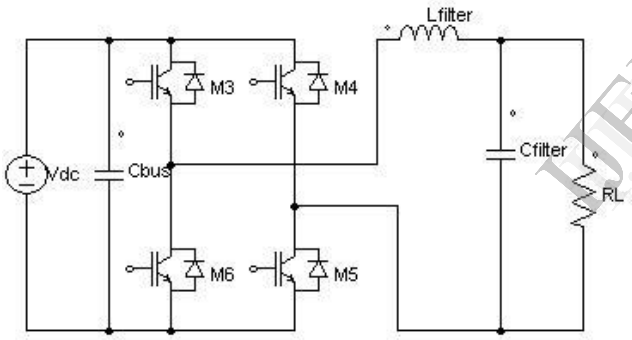

Fig.5 single phase full bridge inverter

of the switch M_3 is given by

$$d_3(t) = \frac{1+m(t)}{2} \qquad (7)$$

and the duty ratio of M_5 $d_5(t)$ is $1 - d_3(t)$
the modulating signal of M_4 and M_6 is –m(t) implies the duty raio of the switch M_4 is given by

$$d_4(t) = \frac{1-m(t)}{2} \qquad (8)$$

and the duty ratio of M_6 is $d_6(t)$ is $1 - d_4(t)$

B. Design of Inductor

For an inductor the maximum ripple occurs at p.f. angle, θ = 90°. There are two condition for the occurrence of maximum ripple. That is $V_{dc} < 2V$ and $V_{dc} > 2V$
If $V_{dc} > 2V$ the maximum ripple condition is $wt_m = 90°$
If $V_{dc} < 2V$the maximum ripple condition is $wt_m = \sin^{-1}\frac{V_{dc}}{2V}$
In practice normally $V_{dc} < 2V$. Therefore peak to peak ripple in current is given by

$$\Delta i_{pk\text{-}pk} = \frac{V_{dc}/2}{2Lf_s}\left\{\frac{V}{2V} + \frac{wL1}{2V}\right\} \qquad (9)$$

Inductance $$L = \frac{V_{dc}}{8f_s} \frac{1}{\Delta i_{pk-pk} - \frac{V_{dc}}{8f_s}\frac{wI}{V}} \qquad (10)$$

C. Design of DC capacitor

For designing a dc capacitor in practice the peak to peak ripple is chosen as 5% of rated voltage.
Dc capacitor ripple current is given by :

$$I_{c(rns)max} = \frac{I\,(V+wLI)}{2\sqrt{2}Vdc} \qquad (11)$$

Dc capacitance is given by :

$$C = \frac{\sqrt{2}\, I_{c(rms)max}}{w\Delta v_{c(pk-pk)}} \qquad (12)$$

D. Design of AC capacitance

Let the inverter current contains 10% peak to peak ripple. If the converter operate with resistive load, this 10% ripple appear across the voltage which is not desirable.so to reduce this leads to large inductor. So by providing a capacitor we can bypass the high frequency component .

And the value of AC capacitance is given by

$$C = \frac{1}{L}\frac{10}{2\pi f_s}^{2} \qquad (13)$$

VII. NET METERING

Net metering is available and it allows the renewable fuel energy generator to work in parallel with the electric company’s electrical system.

The net metering helps to measure the flow of electricity in two direction. It measures the amount of energy used from electric company also the excess energy supplied to the grid. So when the monthly electric bill is calculated, the customer has to pay only for that difference in electric energy. If the customer generates more electrical energy than is used from the utility electrical system, then the customer receives a kWh credit, which is applied to future bills.

VIII. CONTROL SCHEME

The control block diagram of the proposed multi input dc-dc converter and full bridge inverter is shown in the fig. By using a control unit, digital signal processor DSP TMS320F2808 and auxiliary analog circuits the hardware implementation of control circuit is realized.

The signals for the switches M_1 and M_2 are generated by the PWM comparator 1 and 2. The switches M_3, M_4,M_5

and M_6 are triggered by SPWM signals. The amplitude of the ac current is determined by the error signal of the measured dc bus voltage and $V_{dc\ ref.}$

Functions of softstart, overvoltage protection, overcurrent protection and under voltage protection are realized by the controller for practical operation consideration. MPPT algorithm with P & O method is used to control the input currents of the both renewable

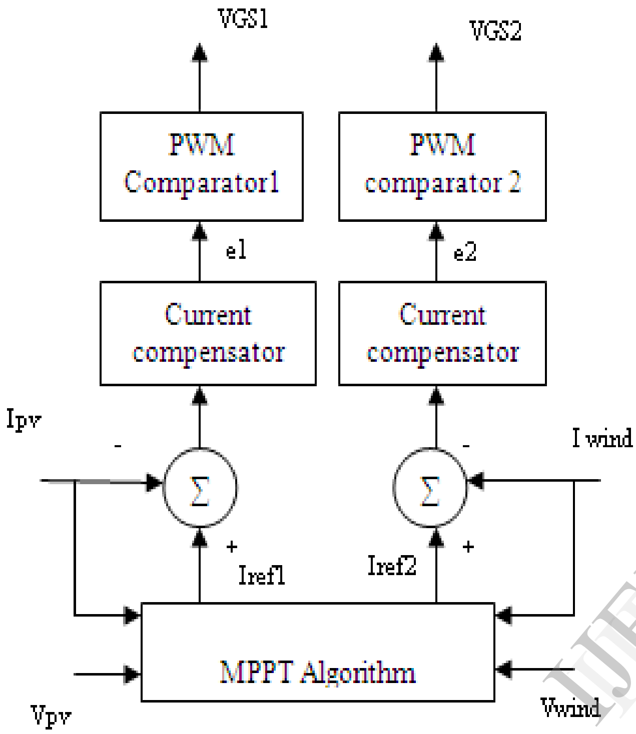

Fig.6 Control block of the multi input converter

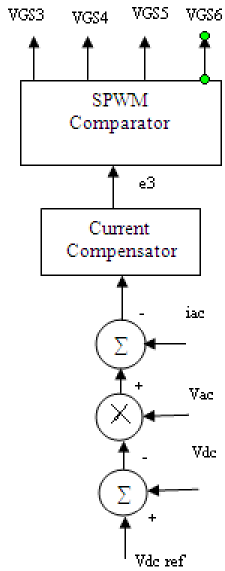

Fig.7 Control block of the full bridge inverter

For the proper working of the given system the DSP, central control unit need to sense the input voltages dc bus voltage, output voltage, input currents, and output current continuously

IX. SIMULATION RESULTS

The simulation of the above proposed system has done in PSIM. Powersim (PSIM) is a fast simulation software used at circuit level or system level with a friendly user interface [5]. It is especially used in simulation of power converters and control circuits. The PSIM simulation package consists of three programs: circuit schematic editor SIMCAD, PSIM simulator, and waveform processing program SIMVIEW. Simview display helps in evaluating the different waveform results. Psim version 9 introduced new wind and solar modules for renewable energy simulation needs. Parameter data from datasheets can be stored in Psim for comparing with the results. Similarly wind module works along with the motor drive module.

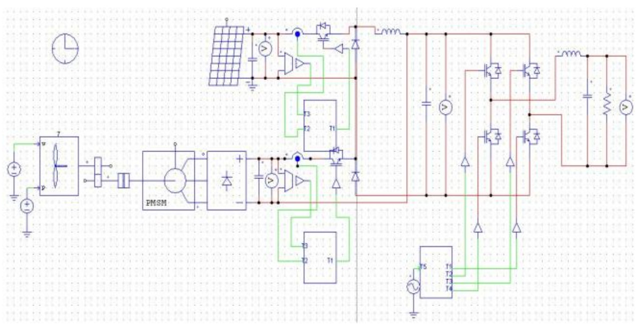

Fig.8 Simulation diagram

The measured waveforms of gate driving signals of $M_1(V_{GS1})$ and $M_2(V_{GS2})$ are shown in fig.10.

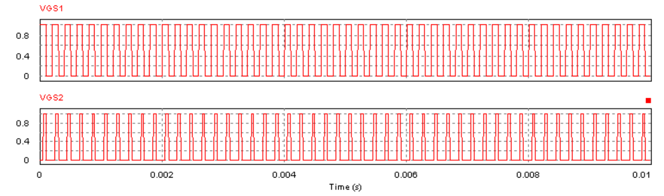

Fig. 8 Waveforms of gate driving signals, V_{GS1} and V_{GS2}

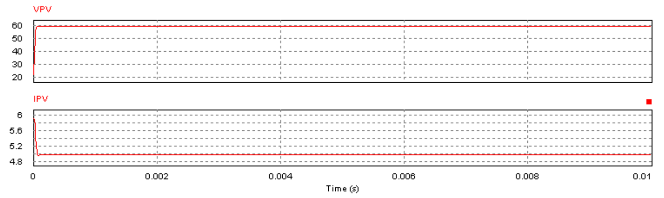

Fig.9 voltage and current waveforms of PV

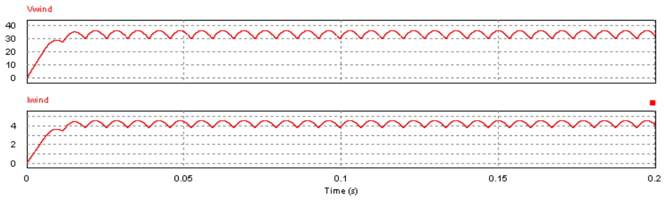

Fig.10 voltage and current waveforms of Wind

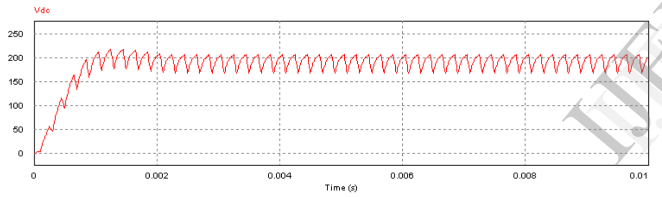

Fig.11 dc bus voltage

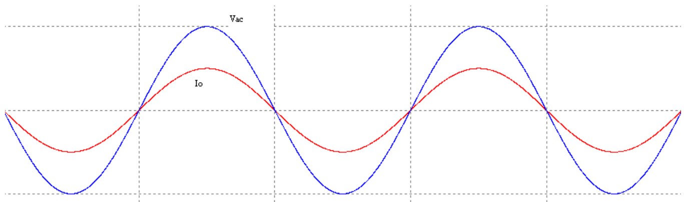

Fig.12 The output voltage and ac output current waveform when only PV array is supplying power(300V/div; 5A/div; 5ms/div)

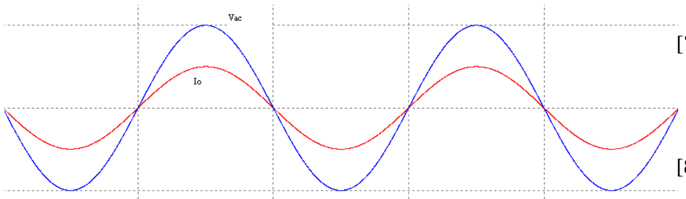

Fig.13 The ac output voltage and current waveforms when only the wind turbine is supplying power (300V/div; 5A/div ; 5ms/div)

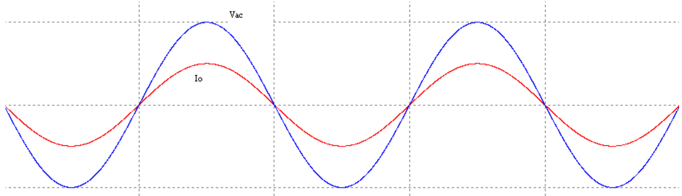

Fig.14 The ac output voltage and current waveforms when both PV and Wind are supplying power (300V/div; 10A/div; 5ms/div)

X. CONCLUSION

A grid connected home energy system has designed and it is analysed by using PSIM software. Power from both the renewable energy sources can be delivered to the home energy system individually or simultaneously. The control circuit is realized using a central control circuit and DSP. To verify the performance of the system experimental results are shown under different condition.

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. IEEEInt. Telecommun. Energy Conf.*, 2003, pp. 27–32.