

Bi-Directional Multilevel Converter For An EnergyStorage Applications

1.Arunprasath.A
PG Scholar
Dept. of EEE
SNS college of technology
Coimbatore
ap.arunprasath10@gmail.com

2.Ramakrishnan.C
Assistant Professor(SG)
Dept. of EEE
SNS college of technology
Coimbatore
ramramki.krishna@gmail.com

3.Vijayakumar.R
Assistant Professor
Dept.of EEE
SNS college of technology
Coimbatore
r.vijayakumarpse@gmail.com

Abstract:This project proposes a single phase bi-directional multi-level converter for an energy storage applications. This bi-directional multi-level converter can be operated in both sides (AC-DC) & (DC-AC).The proposed topology is based on the H-bridge structure with four switches connected to the DC-link. A simple phase opposition disposition PWM method that requires only one carrier signal is also suggested. The switching sequence to balance the capacitor voltage is considered. The operating principle of the proposed converter is verified through a simulation and an experiment.

Keywords :Bidirectional Multilevel converter, Renewable energy sources (solar, wind), battery.

I.INTRODUCTION

As the penetration level of the renewable energy resources such as wind, solar, fuel cells, etc is increasing, dependence on these resources to support load demand in modern power distribution system is also growing. In the current global climate, demand for a renewable energy system has increased due to the environmental issues and limited fossil resources. Along with this demand, Photovoltaic(PV) and Wind Turbine (WT) systems have become the most common type of the grid connected renewable energy systems. However, to connect these systems to the grid, output voltage and frequency adjustment are the challenging issues. Various types of converters have been utilized to provide grid connected renewable energy systems.

In PV or Fuel Cell (FC) applications, DC-DC converters are required to adjust the variable and low quality output voltage of the PV panels or fuel cells. A DC-AC converter is employed to generate desired voltage and frequency for the grid connection. As well, an AC-DC-AC converter is necessary for the WT systems as wind energy is variable during the system operation. In response to the growing demand for medium and high power applications, multilevel inverters have been attracting growing consideration in variable speed WT and PV systems recently. Multilevel converters enable the output voltage to be increased without increasing the voltage rating of switching components, so that they offer the direct connection of renewable energy systems to the grid voltage without using expensive, bulky, and heavy transformers. In addition, multilevel inverters synthesis stair case output voltage which is

closer to sinusoidal voltage using DC link voltages compared with two-level inverter.

Synthesizing a stepped output voltage allows reduction in harmonic content of voltage and current waveforms and eventually size of the output filter. Among different types of the multilevel converters, cascade converters is usually used in PV applications due to its modularity and structure. However, the number of switches is more than the other types of multilevel converters and needs several separated DC sources. The diode- clamped converter is another type of multilevel converters which is widely used in transformerless grid connected systems due to its minimum number of active power components and shared DC link voltage. Due to the structure of the diode-clamped converter, it suffer from neutral point voltage balancing .So the converter can boost the low input DC voltage of the renewable energy sources and at the same time adjust the voltage across each capacitor to the desired voltage levels, thereby solving the main problem associated with capacitor voltage imbalance in this multilevel converter including solar panels to absorb and directly convert sunlight into electricity, a solar inverter to change the electrical current from DC to AC, as well as mounting, cabling and other electrical accessories to set-up a working system.

It may also use a solar tracking system to improve the system's overall performance or include an integrated battery solution, as prices for storage devices are expected to decline. Strictly speaking, a solar array only encompasses the ensemble of solar panels, the visible part of the PV system, and does not include all the other hardware, often summarized as balance of system. Moreover, PV systems convert light directly into electricity and shouldn't be confused with other solar technologies, such as concentrated solar power and solar thermal, used for both, heating and cooling. Bidirectional multilevel converter.

II.BI-DIRECTIONAL MULTILEVEL CONVERTER

A Bidirectional Multilevel Converter can convert either from AC to DC (rectification) or from DC to AC (inversion). A complete bidirectional multilevel converter system always includes at least one converter operating as a rectifier (converting AC to DC) and at least one operating as an inverter (converting DC to AC).

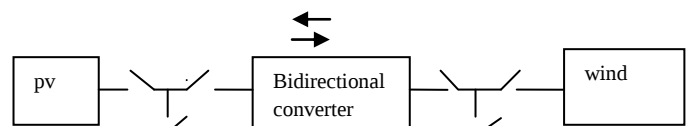




Figure1: **Bidirectional Multilevel converter For Energy Storage Applications**

Its consists of two types of operation modes they are inverter mode , rectification mode.

(a) Inverter mode:

In this mode we are using solar pv, dc/ac converter, ac load. A photovoltaic (pv) system directly converts solar energy into electrical energy. the basic device of a pv system is the pv cell, cells may be grouped into form arrays. The voltage and current are available at the terminals of pv device may directly feed small loads such as lighting systems and dc motors or connect to a grid using proper energy conversion devices.

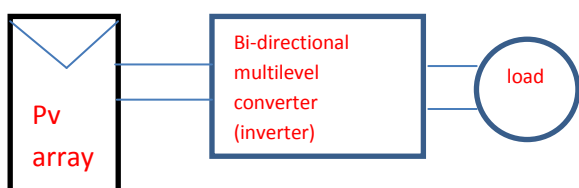


Figure 2. Inverter Mode

This photovoltaic system consists of three main parts which are pv module, balance of system and load. The major components in this systems are charger, battery, & inverter. A photovoltaic cell is basically a semiconductor diode whose P-N junction is exposed to the light. Photovoltaic cells are made of several types semiconductors using different manufacturing process. The eqt circuit of pv cells is shown in the figure. Here pv cell is represented by a current source in parallel with diode. R_s & r_p represent series and parallel resistance respectively. The output current & voltage from pv cell are represented by I & v . the net cell current I is composed of the light generated current i_{pv} & the diode current i_d .

(b) Rectification mode:

Here AC-DC conversion take placed, AC-DC converter serve as a rectifier. They convert the AC-DC in number of industrial, domestic and other several applications. Rectifier used as standalone units of ac system because of their virtually unlimited output power & fine controllability.

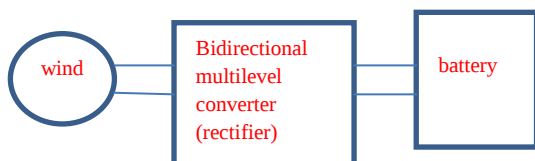


Figure 3. Rectification Mode

III. PHOTOVOLTAIC SYSTEM

OPERATING PRINCIPLE OF PV CELL

Solar cells are the basic components of photovoltaic panels. The semiconductor material currently used for solar cell production is silicon. Solar cells take the advantage of the photoelectric effect: the ability of some semiconductors to convert electromagnetic radiation directly into electrical current. The charged particles generated by the incident radiation are separated conveniently to create an electrical current by an appropriate design of the structure of the solar cell, will be explained in brief below. The commonly used solar cell is configured as a large-area p-n junction which is made from two different layers of silicon doped with a small quantity of impurity atoms.

the light-generated current which depends directly on the irradiation: if it is higher, then it contains more photons with enough energy to create more electron-hole pairs and consequently more current is generated by the solar cell.

BOOST CONVERTER:

The boost converter converts an input voltage to a higher output voltage. The boost converter is also called a step-up converter. A boost converter is a DC-to-DC power converter .with an output voltage greater than its input voltage. It is a class of switched mode power supply (SMPS) containing at least two semiconductors (a diode and a transistor and at least one energy storage element, a capacitor C , inductor L or the two in combination. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple

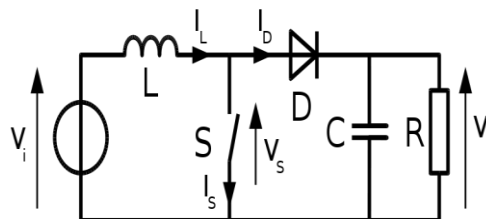


Figure 4. Circuit Diagram of Boost Converter

Power for the boost converter can come from any suitable DC sources,. A process that changes low DC voltage to a high DC voltage is called DC to DC conversion .It "steps up" the source voltage. Since power must be conserved the output current is lower than the source current.

OPERATING PRINCIPLE

The principle that drives the boost converter is the tendency of an inductor to resist changes in current by creating and destroying a magnetic field. A schematic of a boost power stage is shown in figure 2.4. (a) When the switch is closed, current flows through the inductor in clockwise direction and the inductor stores some energy by generating a magnetic field. Polarity of the left side of the inductor is positive in figure 2.5.

(b) When the switch is opened, current will be reduced as the impedance is higher. The magnetic field previously created will be destroyed to maintain the current flow towards the load. Thus the polarity will be reversed. As a result two sources will be in series causing a higher voltage to charge the capacitor through the diode D . in figure 2.5.

If the switch is cycled fast enough, the inductor will not discharge fully in between charging stages, and the load will always see a voltage greater than that of the input source alone when the switch is opened. Also while the switch is opened, the capacitor in parallel with the load is charged to this combined voltage. When the switch is then closed and the right hand side is shorted out from the left hand side, the capacitor is therefore able to provide the voltage and energy. The basic principle of a Boost converter consists of 2 distinct states

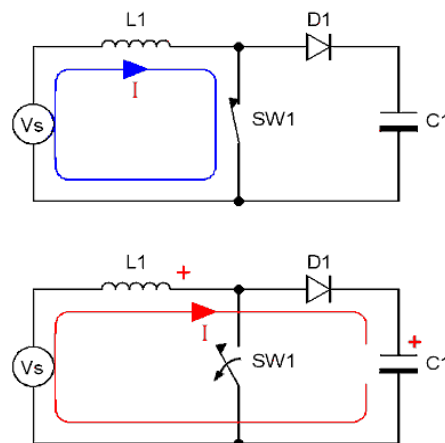


Figure 5 Operation Mode of the Boost Converter

- 1) In the On-state, the switch S is closed, resulting in an increase in the inductor current;
- 2) In the Off-state, the switch is open and the only path offered to inductor current is through fly back diode D, the capacitor C and the load R. This results in transferring the energy accumulated during the On-state into the capacitor.
- 3) The input current is the same as the inductor current as can be seen in figure 2.5. So it is not discontinuous as in the buck converter and the requirements on the input filter are relaxed compared to a buck converter.

IV. WIND ENERGY CONVERSION SYSTEM

Based on turbine wind energy conversion system are of 2 types
a) fixed speed b) variable speed wind turbine. The speed of the turbine is adjusted in order to capture maximum power in VSWT whereas the turbine speed is fixed in FSWT in spite of varying wind speed. The power in the wind is given by kinetic energy of air,

$$P_{air} = \frac{1}{2} \rho A V_w^3$$

The power transferred to the wind turbine rotor is reduced by the power coefficient, C_p

$$C_p = \frac{P_{wind\ turbine}}{P_{air}}$$

$$P_{wind\ turbine} = C_p * P_{air} = \frac{1}{2} \rho A V_w^3$$

The aerodynamic power of the wind turbine is

$$P_{out} = \frac{1}{2} \rho \pi R^2 w V^2 C_p$$

The power coefficient C_p is related to the tip speed ratio (TSR) and pitch angle β

$$\lambda = \frac{\omega R}{V}$$

The tip speed ratio λ and the power coefficient C_p are the dimensionless and so can be used to describe the performance of any size of wind turbine rotor. The wind turbine can produce maximum power when turbine operates at a maximum C_p . Therefore it is necessary to keep the rotor speed at an optimum value of the tip speed ratio λ_{opt} . The turbine is coupled to PMSG for the conversion of mechanical energy into electrical energy.

The voltage equation of the PMSG in the dq-axes reference frame can be expressed as follows:

$$V_{sd} = R_s i_{sd} + L_s \frac{d}{dt} (i_{sd}) - \omega_p L_s i_{sq}$$

$$V_{sq} = R_s i_{sq} + L_s \frac{d}{dt} (i_{sq}) + P \omega L_s i_{sd} + P \omega \phi_m$$

$$T_{em} = P \phi_m i_{sq}$$

V. BATTERY ENERGY STORAGE SYSTEM

Developing technology to store electrical energy so it can be available to meet demand whenever needed would represent a major breakthrough in electricity distribution. The storage battery or secondary battery is such battery where electrical energy can be stored as chemical energy and again converted to electrical energy are required. The battery utilizes the excess energy and store in it known as charging of battery. When the load demand is higher than the source the deficient energy is supplied by the battery known as discharging of battery. Lead acid battery is modeled.

VI. ENERGY STORAGE APPLICATIONS

Energy storage can supply more flexibility and balancing to the grid, providing a back up to intermittent renewable energy. locally, it can improve the management of distribution networks, reducing costs and improving efficiency. In the way, it can ease the market introduction of renewable, accelerate the decarbonisation of the electricity grid, improve the security and efficiency of electricity transmission and distribution, stabilise transmission and distribution, stabilise market prices for electricity while also ensuring a higher security of energy supply. Batteries

provide highly flexible storage capacity and can be placed at several different places of the grid to ensure efficiency including connection to a feeder of res such as (photovoltaic, wind, etc)

VII. SIMULATION RESULTS:

OVERALL SIMULATION DIAGRAM

The proposed system consists of bi-directional multilevel converter, photovoltaic and wind energy sources along with battery model. The main aim of the proposed system is to provide continuous supply to the load. Conditions are evaluated based on which, the sources should supply the load. The bi-directional converter act as the rectifier and inverter based on the energy sources which supply the load and battery.

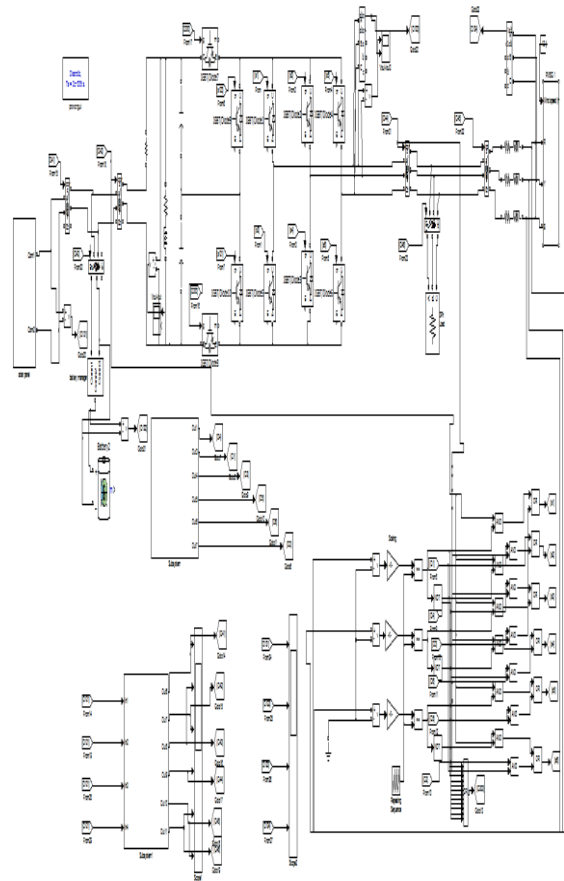


Figure 6. Overall Simulation Diagram of the Proposed System

OUTPUT WAVEFORM OF PV

The waveform in the figure 2 describes the output voltage from PV which is 80V and is boosted to 500V. MPPT algorithm is built to track the maximum power. The switching pulses from the MPPT algorithm is also given in the figure 7

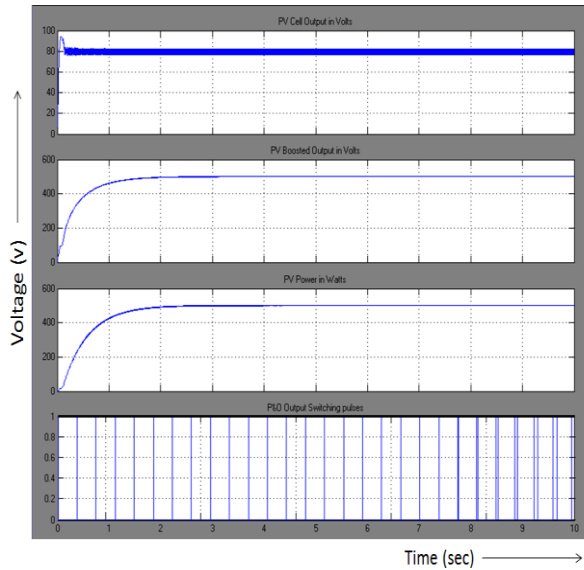


Figure 7 Output Waveform of PV

MULTI-LEVEL CONVERTER

A 5 level multi-level inverter output is shown in the figure 3. The condition when wind power is unable to supply the load, PV supplies the load. The output voltage 90V from PV is boosted to 500V dc which is given to the multi-level inverter.

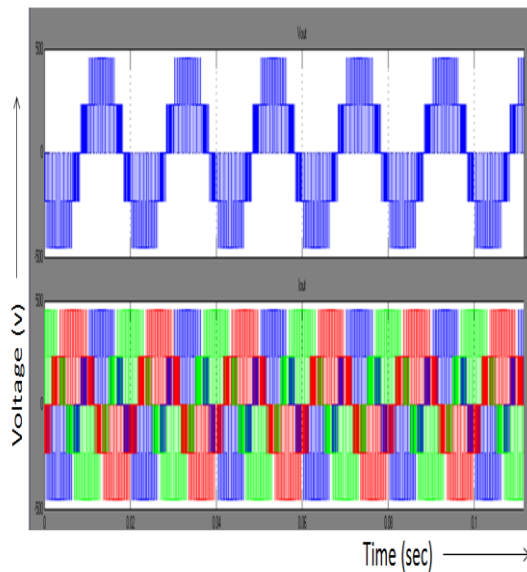


Figure 8 Output Waveform of Multi-Level Inverter.

SWITCHING PULSES FOR INVERTER

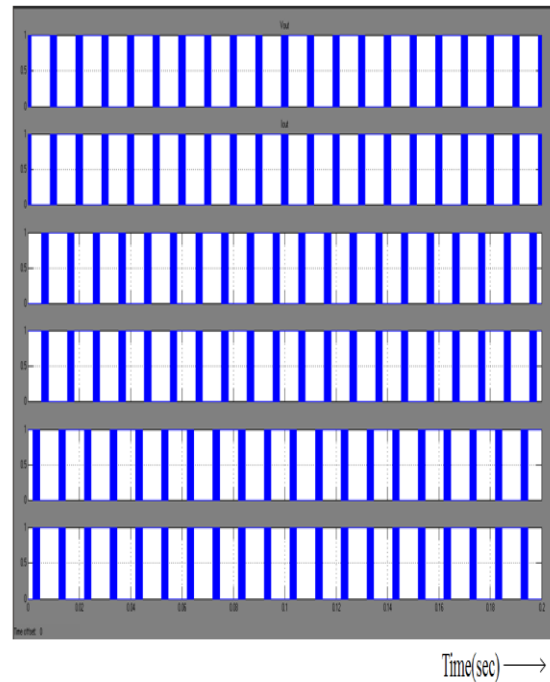


Figure 9 Switching Pulses for Multi-Level Inverter.

OUTPUT WAVEFORM OF PMSG

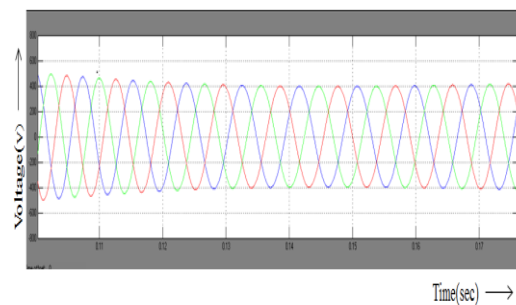


Figure 10 Output Waveform of PMSG

OUTPUT WAVEFORM OF RECTIFIER

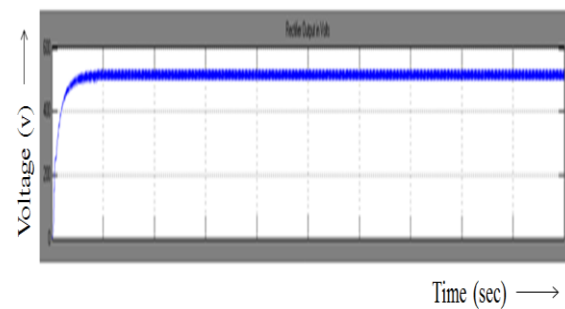


Figure 11. Rectifier Output Waveform.

Multi-level converter acts as rectifier when the charge in the battery is very low. When the wind power is very high than the load demand excess power is given to the converter and rectified into 500V dc as shown in the figure 6.4 and battery is charged.

SELECTION OF MODES

1. $W_p = L_p$ and $PV = B_p$, only wind will supply the load.
2. $W_p = L_p$ and $PV > B_p$, wind will supply the load and pv supply the load.
3. $W_p > L_p$ and $PV > B_p$, wind will supply the load.
4. $W_p > L_p$ and $PV < B_p$, wind and battery together supply the load.
5. $W_p < L_p$ and $PV > B_p$, pv will supply the load.
6. $W_p < L_p$ and $PV < B_p$, battery supply the load.

CONTROL LOGIC

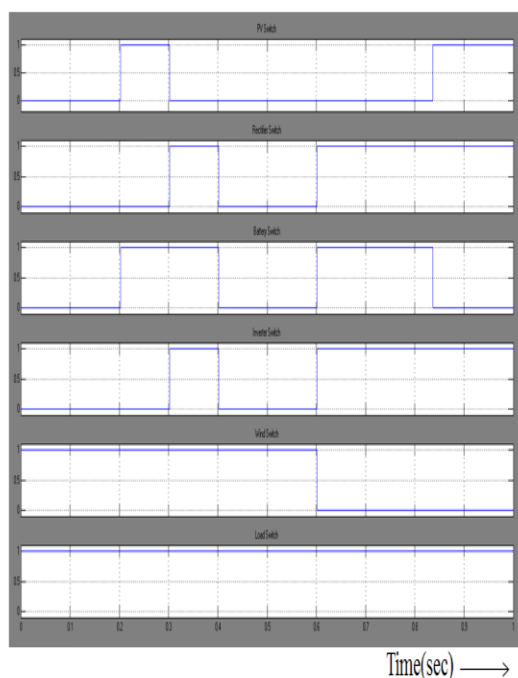


Figure 12. Switching Conditions Output

The figure 7 describes that when the wind power is equal to the load power then pv, battery are in off condition. At 0.2s when the wind power drops, pv is switched on to support the load, battery level is checked so excess power from pv is used to charge the battery and inverter is on. When pv drops then the battery support the load and rectifier is still on. Again at 0.6s wind and solar generation is completely stops battery supports the load continuously. After 0.83s pv is on and the process is carried out routinely. Therefore load is supplied continuously without any interruption.

VIII. CONCLUSION AND FUTURE SCOPE:

This paper proposed a new multilevel converter topology based on an H-bridge converter with four switches connected to the dc link. The power semiconductor switching devices that configure the H-bridge circuit in the proposed multilevel converter are only responsible for polarity reversal of the ac output voltage and the five level output voltages are generated by

the appropriate switching of the dc link switches. The switching devices in the H-bridge converter are synchronised according to the output voltage signal. Therefore, switching loss is smaller than that of the other converter. The configuration of the control circuit is simple because the PWM signal is generated by using only one carrier signal. The number of the switching devices in the proposed MLC is fewer than that in the conventional multilevel converter thus the reliability of the proposed system is high, and cost of the system can be low. A unit cell can be produced as a module, and extending output voltage level is achieved simply by connecting the module in a series. The construction of the 3-phase multilevel converter is also possible. The additional features as rectification from ac to dc to store the energy in battery is also added with the dc to ac conversion. Both input energy is taken from renewable sources to supply the load.

This Converter can be used as bi-directional converter for energy storage applications. To improve power rating, 3-phase converter has been developed and used. The battery bank also included to store energy in the batteries. When ever the solar energy & wind energy is more than the demand of the load.

REFERENCES

1. Sang-Hyup Han, Heung-Geun Kim, Honnyong Cha, Tae-Won Chun, and Eui-Cheol Nho, "Bi-Directional Multi-Level Converter for an Energy Storage System", Journal of Power Electronics, Vol. 14, No. 3, pp. 499-506, May 2014.
2. Ebrahim Babaei, "Charge Balance Control Methods for a Class of Fundamental Frequency Modulated Asymmetric Cascaded Multilevel Inverters", Journal of Power Electronics, Vol. 11, No. 6, November 2011.
3. Sixing Du, Jinjun Liu, and Jiliang Lin, "Leg-Balancing Control of the DC-link Voltage for Modular Multilevel Converters", Journal of Power Electronics, Vol. 12, No. 5, September 2012.
4. Mohammad-Ali Rezaei, Hossein Iman-Eini, and Shahrokh Farhangi, "Grid-Connected Photovoltaic System Based on a Cascaded H-Bridge Inverter", Journal of Power Electronics, Vol. 12, No. 4, July 2012.
5. Woo-Young Choi and Jae-Yeon Choi, "High-Efficiency Power Conditioning System for Grid-Connected Photovoltaic Modules", Journal of Power Electronics, Vol. 11, No. 4, July 2011.
6. P. Dash and M. Kazerani, "Dynamic modeling and performance analysis of a grid-connected current-source inverter-based photovoltaic system," IEEE Trans. Sustain. Energy, vol. 2, no. 4, pp. 443-450, Oct. 2011.
7. Junfeng Liu, K. W. E. Cheng, Senior Member, IEEE, and Yuanmao Ye, "A Cascaded Multilevel Inverter Based on Switched-Capacitor for High-Frequency AC Power Distribution System" IEEE Transactions on Power electronics, vol. 29, no. 8, aug. 2014.
8. M. H. Nehrir, C. Wang, K. Strunz, H. Aki, R. Ramakumar, J. Bing, Z. Miao, and Z. Salameh, "A Review of Hybrid Renewable/Alternative Energy Systems for Electric Power Generation: Configurations, Control, and Applications", IEEE Transactions on sustainable energy, vol. 2, no. 4, october 2011.
9. Tao Zhou and Bruno Francois, "Energy Management and Power Control of a Hybrid Active Wind Generator for Distributed Power Generation and Grid Integration", IEEE transactions on industrial electronics, vol. 58, no. 1, january 2011.
10. O.C. Onar, M. Uzunoglu, M.S. Alamint, "Modeling, control and simulation of an autonomous wind turbine/photovoltaic/fuel cell/ultra-capacitor hybrid power system", journal of power sources 185 (2008) 1273-1283.
11. S.M. Mousavi G, "An autonomous hybrid energy system of wind/tidal/microturbine/battery storage", int j electrical power and energy systems 43 (2012) 1144-1154.

12. Chedid, R.Tajeddine, F. Chaaban, R. Ghajar, "Modeling and Simulation of PV Arrays under Varying Conditions," 17th IEEE mediterraneanelectrotechnical conference, 13-16 April 2014.