International Journal of Advancements in Research & Technology, Volume 1, Issue6, November-2012
ISSN 2278-7763

A New Approach to Design of an optimized Grid Tied Smart Solar Photovoltaic (PV) System

M. Mehedi Farhad[1*], M. Mohammad Ali[2], M. Asif Iqbal[3], N. Nahar Islam[4], N. Ashraf[5]

[1, 2, 3, 4, 5] Department of Electrical and Electronic Engineering, Ahsanullah University of Science and Technology, Dhaka, Bangladesh.
Email: [1*]mehedi.farhad99@gmail.com; [2]marfiraj@yahoo.com; [3]asif_iqbal_eee@yahoo.com; [4]m0m0237@yahoo.com; [5]aust061@yahoo.com

ABSTRACT

Energy is the key element for the economical development of a country. With the increasing concern about the global demand for Renewable Energy (RE) energy, it is very much important to reduce the cost of the whole solar photovoltaic (PV) system. Still now most of the solar photovoltaic (PV) system is highly expensive. In this paper we have shown that grid tied solar system can be developed by omitting the energy storage device like large capacity battery bank. It will not only reduce the internal losses for charging and discharging of battery bank but also at the same time a large amount of cost of the battery will be reduced. So, the system maintenance cost will be reduced also. We have proposed a new approach to design a photovoltaic (PV) solar power system which can be operated by feeding the solar power to the national grid along with the residential load. Again if there is an extra power demand for residential load along with the solar power then this system can also provide an opportunity to consume the power from the national grid. The total system is controlled with the help of some the sensors and a microcontroller. As a whole a significant reduction in the system costs and efficient system performance can be realized.

Keywords: Smart control, Grid connected PV system, PV system without storage, Net metering, Grid-tie inverter.

1 INTRODUCTION

BANGLADESH is one of the world's poorest and most densely populated country. Energy crisis is the biggest obstacle for economical development of any country as well as in Bangladesh. Due to the rising cost and depleting storage of fossil fuels along with the increasing concern for global climate change, utilization of RE in national scale has become essential for this country. At present, Bangladesh relies heavily on fossil fuels especially Natural Gas (NG) resources for its power generation and its present proven NG reserve would be ceased by 2015. The only way to save the fossil fuels like Natural Gas, Furnace Oil, Coal etc are in small scale use of them. According to the National Energy Policy the projected demand in 2005 was 5720MW with deficiency of around 700MW and will increase gradually to 11,794MW by 2020 for low economic growth of 6% and for a higher growth rate of around 8% it should be 17,580 MW. That is why Bangladesh government recognizes the indispensability of Renewable Energy policy on 18 December 2008 where target has been set to generate 5% of the total electricity from Renewable Energy sources by 2015 and 10% by 2020[1].

This target is incredible but not impossible: mainly due to the geographical location of Bangladesh. To achieve this target we need to install more solar PV system with the most effective manner. According to the data up to September 2011, more than 1 million off-grid solar PV systems have been installed in the rural area throughout this country having capacity 50MW. But still the growth rate of PV system and its contribution to the national energy is not sufficient due to the technical inconvenience and installation cost of the PV system. This paper presents an improved and cost efficient way to synchronize the PV array output with the utility grid using a special control scheme. So that, an individual solar PV system owner can acts as an electricity provider to the national power grid.

2 CONVENTIONAL OFF-GRID AND GRID-TIED SYSTEM

PV systems can be installed without being connected with the conventional grid line are off grid system and most of this systems make use of the large capacitive battery as energy storage device. They store the energy in day time and use it at night time. One the other hand there is a very little use of on grid or grid tied system.

2.1 Conventional Off Grid System

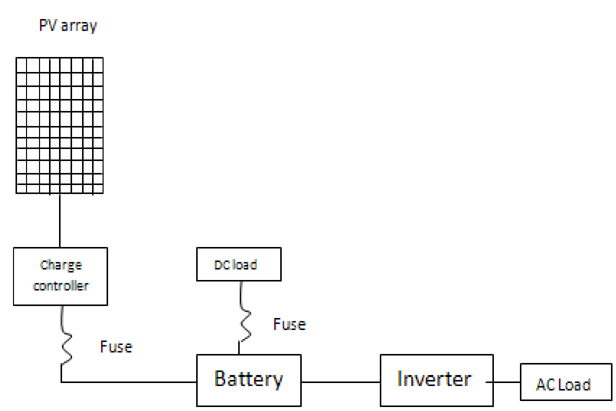

Fig. 1 Schematic diagram of a off-grid PV system with AC and DC loads.

Typical configuration of a off-grid PV system is depicted above in Fig 1. This system is consists of a PV array with a charge controller, battery and DC load. This can be operated to drive an AC load by using an Inverter.

2.2 Conventional Grid Tied PV System

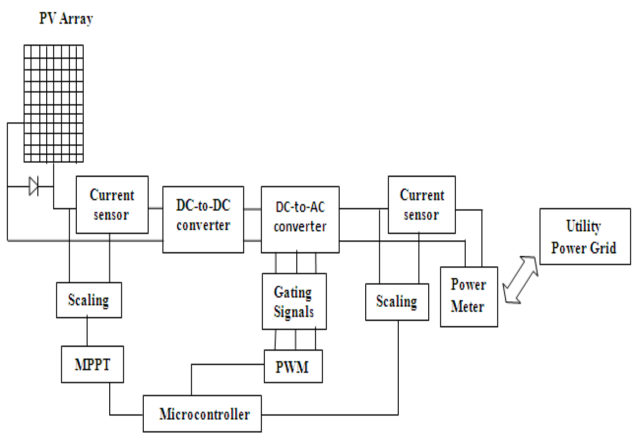

Fig. 2 Block diagram of a grid-tied PV system

Still grid tied PV system is not a popular PV installation system in the world. Some of the grid tied system has been designed earlier which was not so efficient at all. But to reach the goal of having more energy from renewable sources, we need to grab every opportunity of scaling up. Configuration of a typical grid-tied PV system is given above in Fig2.

3 Proposed Grid-Tied PV System

Energy is vital for the progress of a nation and it has to be conserved in a most efficient manner. In this paper we proposed an innovative design of a grid-tied PV system without storage device. This system is capable to feed solar energy to the utility power grid when grid power is available and backup the on-site load as well when the grid power is unavailable.

.

3.1 System Layout

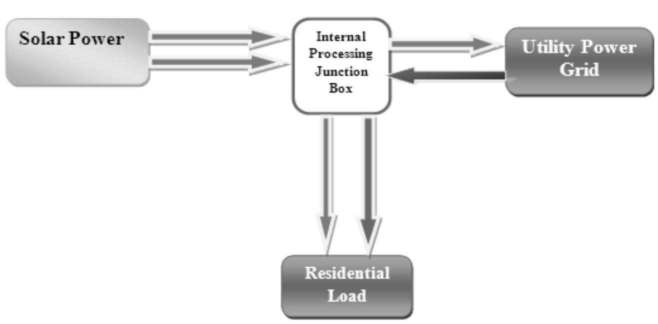

Fig.3 Layout diagram of the planned grid-tied PV system.

A newly designed grid-tied PV system is shown in Fig.3. Here the grid-tied PV system is consists of an internal processing junction box with its three end point. These are solar power, utility power grid and Residential load. Here this system always tries to feed the solar power to the utility power grid. At the same time the residential load will consume the power from the utility power grid. But if the grid power is unavailable then the residential load demand will be supplied by the solar power.

3.2 Schematic Diagram and the Relay Position

As the illustration in Fig.4, the power flow from the PV array and the utility power grid is controlled by three relay. The positions of the relays are also shown in Fig.4. During normal operation relay 3 always at Normally Close (NC) position. At day time when sunlight and grid power is available relay 1 and relay 2 both will be at NC position. So that the solar power will feed to the grid through relay 1 and at the same time residential load will consume power from utility power grid through relay 2. But if grid power is unavailable relay 2 will be off and relay 3 will be at Normally Open (NO) position. So that, the solar power can flows to the residential load. Again if there is any overloading situation due to the residential load the relay 3 will be operate to disconnect the connection and ensure the safety of the system. At the same time it will generate a signal to the consumer for reducing the load. This is how the system will operate with a most efficient manner.

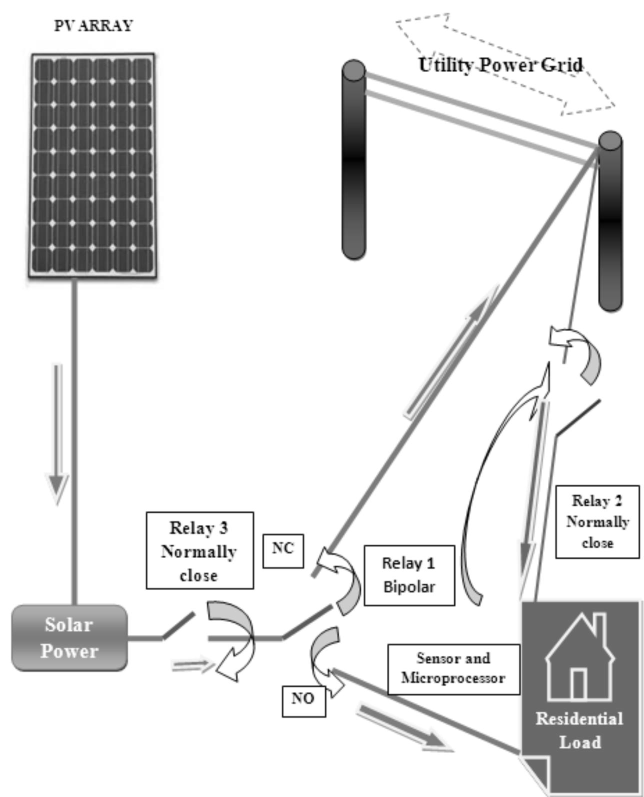

Fig. 4 Schematic diagram of the planed grid-tied PV system

3.3 Grid-Tied PV System Block Diagram

Fig.5 demonstrates the block diagram of the control scheme. The system block diagram consists of solar PV array, MPPT charge controller, DC to DC converter, High efficient Grid Tie inverter, AC three phase synchronizer, Microcontroller, DC power measuring device, CT, PT, ADC (Analogue to Digital converter), Relays and Metering device. We can describe all those elements in three parts:

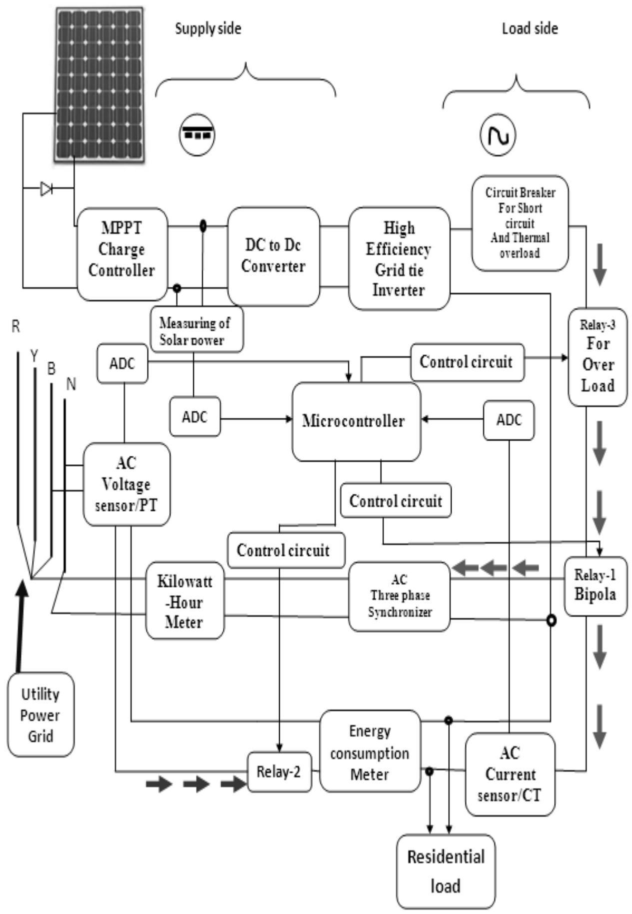

Fig. 5 Grid-Tied PV system block diagram.

3.3.1 Voltage Control of Solar PV Array

The power output of a PV array depends on the voltage level where it operates under a given condition of irradiance and cell-surface temperature. For efficient operation, a PV array should operate near at the peak point of the V-I curve [2]. Various Maximum Power Tracking (MPPT) techniques have been proposed in [3] and [4]. The MPPT device of the block diagram in Fig.6 always tries to stable the PV output voltage and also ensure the maximum power output of the PV system.

3.3.2 Grid Tie Inverter

The inverter is the heart of the PV system and is the focus of all utility-interconnection. An inverter is a device that converts direct current to alternating current. The PV inverters are classified into two categories, Stand Alone Type and Synchronous Grid Tie Type. Synchronous inverter is a special type of inverter which is specially designed for solar panel [5]. This type of inverter always collect the data of voltage and frequency of utility power grid by a AC synchronizer and synchronize the inverter output with the utility power grid. So that, it is possible to install a medium to large-size PV array and remain hooked up to the utility power grid [5].

3.3.3 Control Section

The power measuring block measures the solar power with respect to time. The AC current sensor senses the residential load current which can be converted in power by multiply with the system voltage. The output of the measured solar power and the load demand goes to the microcontroller through two ADC (Analogue to Digital converter). The availability of the grid power can be detected by a PT. The output of the PT goes to the microcontroller through another ADC. With the help of these data microcontroller will send signal to the relay control circuit. Then the relays will operate according to the decision of the microcontroller. The relay control circuit consists of a 1kΩ resistance and a NPN Transistor (BD135). Fig.6 shows the relay control circuit. Here pic16F88, 28 pin microcontroller with 16MHZ clock pulse generator and IC7805 voltage regulator can be used to obtain best performance of the system.

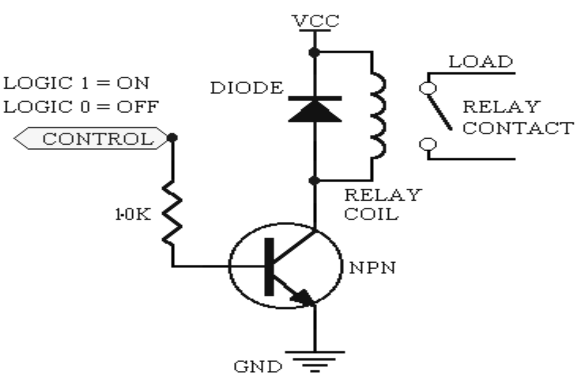

Fig. 6 Relay control circuit.

4. Flow Chart of the Control Scheme

Fig. 7 shows the flow chart of the control scheme. According to the flow chart we develop a programme in Micro-c and also in assembly code to check the system performance. Here, after initialization of the system parameter the microcontroller always check the availability of grid power and solar power and take decision to control the relay 1 and relay 2. The microcontroller also compares the solar power with the residential load to control the relay1 and relay 3. According to the technical requirement in IEEE 1547, to prevent islanding situation the microcontroller always monitor the voltage and frequency of the grid and disconnect the grid tie inverter from the grid for any worse situation by controlling relay 1.

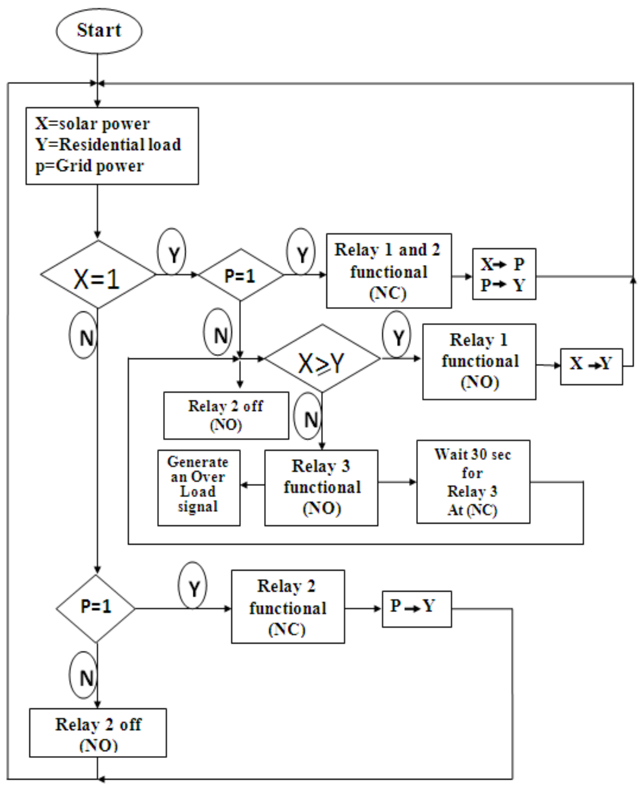

Fig. 7, Flow chart of the control scheme

5 Net Metering System

In our system a solar photovoltaic (PV) plant owners can also enjoy the opportunity of net metering by selling energy to the National grid when the consumed energy is less than the Delivered energy. Here we use two meter for metering the consumed and delivered power. The energy consumption/billing meter will record how much energy is consumed by the costumer from the utility power grid. When the kilowatt-hour meter will record the amount of energy is delivered from the solar system to utility power grid. Fig.8 shows the net metering system.

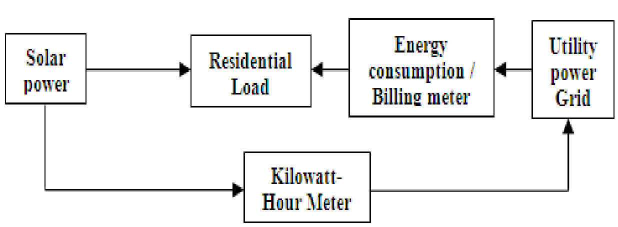

Fig. 8, Net metering system

6 ADVANTAGES OF THE DESIGNED SYSTEM

A typical solar system would require a large battery bank to storage the solar energy. By removing this expensive storage device the system installation cost can be maintained within an acceptable limit. Grid tied system is more power efficient than a conventional solar system. It ensures full utilization of solar energy whereas battery discharge rate is 60% to 65% in conventional off-grid solar system in Bangladesh. As energy storage capacity of these batteries degrade with time and need replacement which required extra cost for the system owner. This grid-tied system also represents the consumer as an energy provider to the utility power grid. Net metering allows system owners to get credit for any electricity from the system sends to the national grid. If the grid power is unavailable, still the system will continue to supply critical on-site loads.

7 Cost Analysis of the PV system

Fig.9 shows the graph of installation cost vs. PV array Wp of a PV system with and without storage device. Here for a typical system we assume the relative cost components as: PV array $ 1.207 per Wp, Battery $1.207 per AH, Inverter $ 0.6030 per Watt, Charge controller $1.207 per Amp. This graph shows that the system cost will be cheap for a same Wp PV array installation without storage device (Battery).

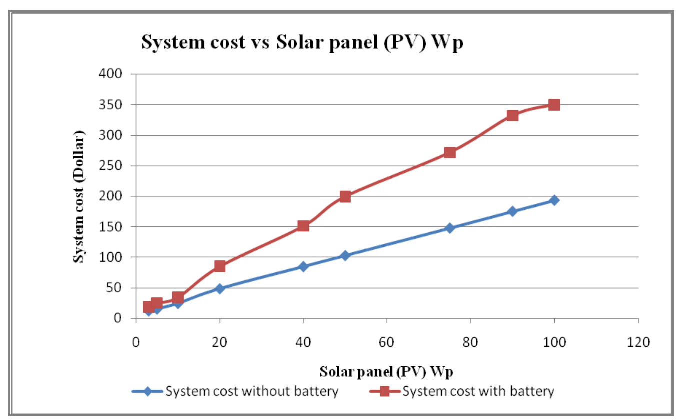

Fig. 9. System cost vs. solar panel (PV) Wp

8 Performance of a Typical System with Storage

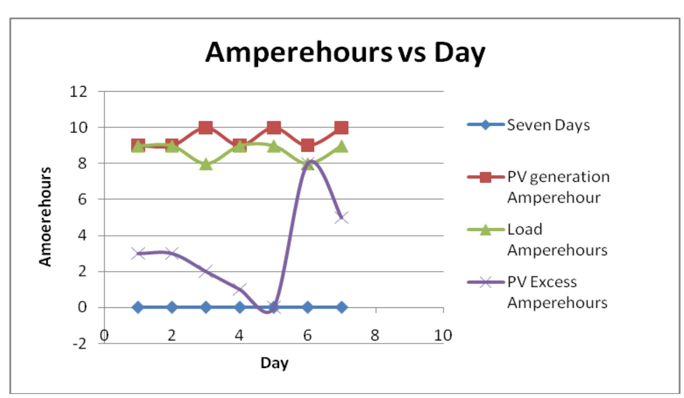

Fig. 10, Ampere-hour vs days of a typical PV system

As Bangladesh is a compact, flat country with little geographic variation, the solar radiation data collected at one point may be treated as reasonably representative of the whole country [6]. Fig.10 shows the graph of Ampere-hour vs days. Here for this system we use a solar panel of Pmax 87W, Vpmax 17.4V, Ipmax 5.02A, Voc 21.7V and Isc 5.34 A at temperature 25oC. We have measured this data from our experimental set up. The data was collected on April 2012.

9 CARBON EMISSION CALCULATION

The power sector of Bangladesh is responsible of emitting 40% of carbon dioxide (CO2) Gas (15.24 million tons), whereas 30% of CO2 emits from the power sector throughout the world [7], [8]. This emission of CO2 and other green house gases is responsible for temperature rising and global warming. Over the past 100 years, temperature has increased by 050 degree Celsius due to the global warming. However in the next 40 years, the temperature in Bangladesh is projected to rise by 1.5 to 2.0 degree Celsius [9], [10]. It is estimated that climate change could affect more than 70 million people in Bangladesh [11]. Agriculture is the largest sector of this country's economy that accounts for about 23.87% of the total GDP [12]. However rise in temperature of 4 degree Celsius would decrease the food grain production some 28% and 68% for rice and wheat respectively [12]. According to the information of International Energy Agency (IEA) Bangladesh emits CO2 585.2873g/KWh production of energy. For Bangladesh with an economic growth rate of 6%, prediction indicated the demand on 2020 is 11794 MW. That means if we want to generate 10% of total energy by renewable energy sources, we can protect almost 105005.416 kg of CO2 from release to the environment.

10 LIMITATION OF THE DESIGNED SYSTEM

In this paper we have come within the reach of a new PV system design. But in our design we have also some limitations. This grid-tied system without storage can't supply power during night or rainy day when sunlight is not sufficient. Again power output from certain renewable energy sources, like wind and solar, can be intermittent. Fluctuation in output can negatively affect power grid frequency, voltage, component performance, causing instability in the power generation system and interrupted service to the customers.

11 CONCLUSION

This system has been designed with a concept of micro photovoltaic power station. Still the solar PV system installation cost is not within an acceptable limit. Proper step should be taken to reduce the solar PV system cost. So that, the general electricity consumer can concentrates their attention in grid-tied PV system. We hope there will be occur a lot of activity regarding grid-tied PV system and then our work may help to decide an optimized way.

So, in this paper we have shown an advanced grid-tied PV system which is suitable for Bangladesh as well as for other countries to produce more energy from renewable energy sources. Thus every photovoltaic system which is installed in any where can be treated as a micro PV power station, no matter what ever the generation capacity of the plant.

ACKNOWLEDGMENT

This study was made possible with the help of the installed PV system at Ahsanullah University of Science and Technology. Special thanks to Assistant Professor Md. Maruf Hossain, Assistant Professor Md. Jakaria Rahimi and Embedded System Engineer Fahad Mirza for their useful discussion.

REFERENCES

[1] Islam Sharif "Renewable energy development in Bangladesh", Executive Exchange on the use and integration of Renewable Energy in the Power Sector, Madrid, Spain, October 19-23, 2003

[2] M. Rejwanur Rasid Mojumder, Arif M. Waliullah Bhuiyan, H. Kadir, M. Nizamul Haque Shakil, Ahmed-Ur-Rahman, "Design & analisis of an optimized Grid-Tied PV system: Perspective Bangladesh" IACSIT international journal of engineering and technology, Vol.3, No. 4, August 2011.

[3] T. Noguchi et al., "Short-current pulse-based maximum-power-point tracking method for multiple photovoltaic-and-converter module system," IEEE Trans. Ind. Electron., vol. 49, no. 1, pp. 217–223, Feb. 2002.

[4] K. H. Hussein, "Maximum photovoltaic power tracking: An algorithm for rapidly changing atmospheric conditions," Proc. Inst. Electr. Eng.—Generation, Transmission, Distribution, vol. 142, no. 1, pp. 59–64, Jan. 1995.K. Elissa, "An Overview of Decision Theory," unpublished. (Unplublished manuscript)

[5] M. Gohul, T. Jayach, A. M. Ali, T. G. Raju, N.Santhosh Kumar, M.R. Saravanan, "Anew design of grid tie inverter for a grid interactive solar photovoltaic power generation-An alternative option for energy conservation & security" IJECT Vol. ,2, Issue 3, Sept.2011.

[6] Md. Amzad Hossain, "Renewable energy :The panacea for village Bangladesh "

[7] M. A.H. Mondan, "Implication of renewable energy technologies in the Bangladesh power sector: long term planning strategies," Ph.D. thesis Center for Development Research (ZEF), University of Bonn, Germany, Oct. 2010.

[8] T. Jilani, K. Gomi, and Y. Matsuoka, "Integration of sustainable and low carbon society towards 2025 in Bangladesh," in international Conference on Climate Change Effects and Energy Development in Bangladesh, Germany, Jul. 2011.

[9] A. U. Ahmed, Bangladesh Climate Change Impact and Vulnerability: A Synthesis. Department of Environment and Foresty, Government of Bangladesh, 2006.

[10] T. Islam and A. Neelim, "Assessing Fluctions of Temperature," in Climate Change in Bangladesh: A Closer Look into Temperature and Rainfall Data. Bangladesh: The University Press Limited, 2010, pp. 80.

[11] A. Rahaman, M. Alam, K. Mainuddin, L. Ali, S. M. Alauddin, M. G. Rabbani, M. M. U. Miah, M. Rabi-Uzzaman, and S. M. A. Amin, "The probale impacts of climate change on proverty and economic growth and the options of coping with adverse effect of climate change in Bangladesh," Support to Monitoring PRS and MDGs in Bangladesh, Planning Commission, Government of the Peoples's Republic of Bangladesh & UNDP Bangladesh, May 2009.

[12] L. Hassan, "Climate change and food security: Sustainable agricultural production system for reducing food insecurity in Bangladesh," in International Conference on Climate Change Effects and Energy Development in Bangladesh, Germany, July 2011.