RESEARCH ARTICLE OPEN ACCESS

Application of Photovoltaic (PV) Solar Farm In STATCOM to Regulate the Grid Voltage

Arul. A[1], Suresh.S[2], Ramesh. R[3], Ananthi. M[4]
[1,3,4]*M.E (Applied Electronics)-IFET COLLEGE OF ENGINEERING Villupuram*
[2] *Asst. Professor-MRK INSTITUTE OF TECHNOLOGY Kattumannarkoil.*

Abstract
In this paper presents a method of integrating the connections between photovoltaic (SF) and wind farm in the nearest surrounding place. The energy distribution of both depends upon the storage batteries, which are one of the main advantageous of distribution system. This method using point to common coupling to regulate voltage on the late night, when the solar farm is not generating any useful Power. The proposed method of Photovoltaic (SF) as elastic AC Transmission system controller-static synchronous compensator and wind farm as Flexible DC transmission must be enable improved connections of wind energy conversion system (WECS) to the grid. The proposed method results show on SIMULINK in MATLAB. The entire system achieved to the reversible direction of grid voltage regulation using the Photovoltaic (SF) and storage energy to the batteries.
Keywords— Photovoltaic solar farm (PV-SF), Battery storage, Wind energy conversion system (WECS), stat-com, point to common coupling (PCC), converter/inverter, voltage regulation.

I. INTRODUCTION

Renewable energy is a kind of energy generated from natural resources. Sunlight, wind, water, geothermal heat, and biomass can generate energy for human use. Renewable energy supplied 18 percent of the energy consumption of the world in 2006 [1], and the investment in renewable energy is increasing rapidly worldwide [2].

In a renewable energy conversion system, in wind, solar PV, and fuel cells, power converters are necessary for grid integration [3]. For the wind energy conversion system, two types of generators are normally used to produce electricity. One is the PMSG; the other is the DFIG [4]. For both, their output has an AC voltage often at a frequency other than 60 Hz, the electric utility grid frequency in the United States. As a result, power converters are needed at the interface to the AC grid, which permits energy to flow from the wind turbine into the grid.

For solar energy and fuel cell energy conversion systems, there are some differences. The output voltage of the solar panel and the fuel cell is DC. Again, since the grid is an AC power system, a DC/AC power converter is necessary to integrate solar or fuel cell systems to the grid.

Wind is air in motion caused by natural factors like the uneven heating of the earth's surface by the sun, the rotation of the earth and the irregularities of the earth's surface. Wind energy has been used for centuries to move ships, pump water and grind grain. In the twentieth century, windmills were commonly used across the Great Plains to pump water and to generate electricity.

Most renewable energy comes either directly or indirectly from the sun. Solar energy can be used for generating electricity, and for hot water heating and solar cooling. Solar energy is produced when the sun is shining during the day and is complementary to wind energy, which tends to reach its highest production at night.

In an extreme situation new lines may need to be constructed at a very high expense. Cost effective techniques therefore need to be explored to raise transmission capacity. A novel research has been reported on the night time usage of a PV solar farm (when it is normally dormant) where a PV solar farm is utilized [5] as a Static Compensator (STATCOM) – a FACTS device for performing voltage control, thereby improving system performance and growing grid connectivity of neighbouring wind farms.

It is known that voltage control can support in increased transient permanence and power transmission limits, several shunt connected FACTS devices, such as, Static Var Compensator (SVC) and STATCOM are utilized worldwide for improving transmission capacity.

This project presents a novel night-time application of a PV solar farm by which the solar farm inverter is employed as a STATCOM for voltage control in order to improve power transmission capacity during nights. During day time also, the solar farm while supplying real power output is still made to operate as a STATCOM [6] and provide voltage control using its remaining inverter MVA capacity (left after what is needed for real power generation). This day time voltage regulation is also shown to substantially enhance stability and power transfer limits.

II. PV SOLAR FARM AS BATTERY CHARGER

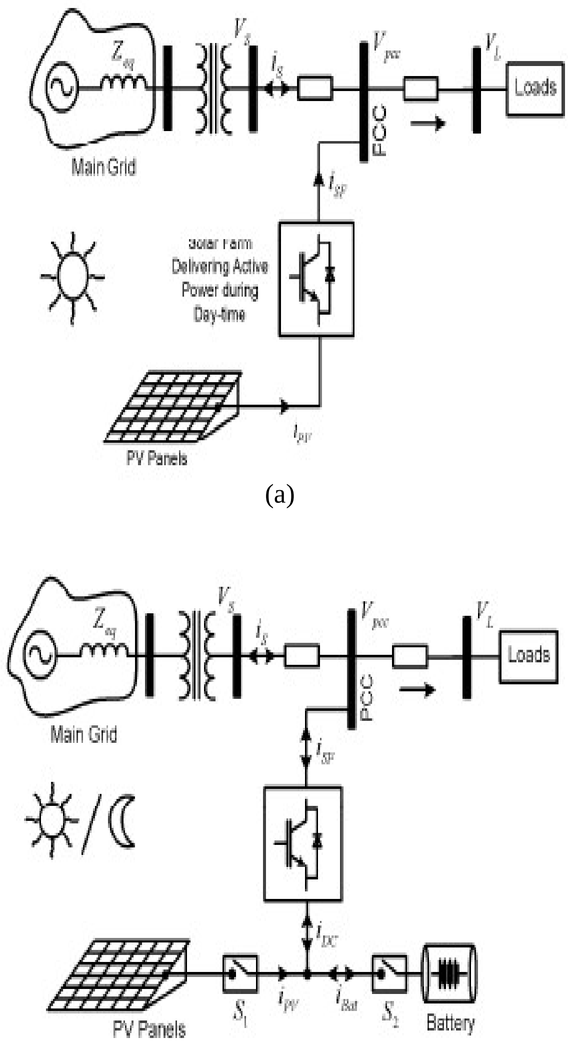
A typical PV solar farm is basically inactive during night time and the bidirectional inverter used to deliver the PV DC power as three-phase AC power to the grid, remains unutilized as well. Fig.1 (a) & (b) shows the possible operational modes of the solar farm. The point at which the solar farm is connected to the grid is called the point of common coupling (PCC).

In Fig.1, V_S and i_S represents the voltage and current at the secondary of the distribution transformer; V_{PCC} and V_L denote voltages at PCC and load terminal respectively; and i_{PV} is the current delivered by the PV solar panels. AC current drawn/delivered by the solar farm inverter and the DC current flowing through the storage battery are represented by i_{SF} and i_{Batt}, respectively.

Fig.1 (a) shows the block diagram representation of traditional utilization of a PV solar farm. The PV solar farm in this case supplies power to the main grid during the day time (remaining unutilized during the night). Fig. 1(b) shows a system configuration to utilize the solar farm inverter as a battery charger. In this case, a storage battery is connected on DC side of the solar farm inverter. Switch (S_1) in Fig.1 (b) is utilized to disconnect the PV solar panels especially during night-time and to charge [7] the storage batteries from the main grid. In some cases, the battery charging process can be incorporated in the maximum power point tracking (MPPT) algorithm. An additional DC to DC converter, such as a buck/boost converter may be required to enhance the battery charging/discharging operation. An automatic mechanism or control loop may also be essential to avoid excessive overcharging of the batteries and low battery voltage condition during discharging process.

Advantages using batteries on DC side of PV solar farm are given below:

- Produce active power in entire 365 days.
- Used energy storage and voltage regulator
- Stored battery energy can be utilized for emergency backup.
- Better PV solar power dispatch ability.
- Distribution system reliability.
- Uninterruptible power source (UPS) when used capacitive.



(a)

(b)

Fig.1.Utilization of PV solar farm bidirectional inverter: (a) Normal operation during day-time to inject real power (b) Solar farm inverter as battery charger system configuration.

III. STATCOM

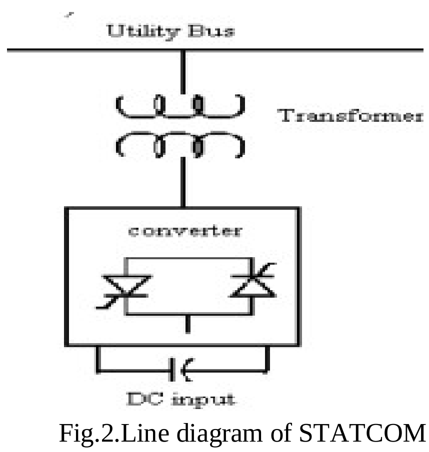


Fig.2.Line diagram of STATCOM

Recently the Voltage Source Inverter (VSI) based Static VAR compensators have been used for reactive power control. These compensators are known as Advanced static VAR compensator (ASVC) or static VARcompensator (STATCOM) in Fig.2 is a shunt connected reactive compensation equipment which is capable of generating and/ absorbing reactive power whose output can be varied so as to maintain control of specific parameters of power system [8].

The STATCOM provides operating characteristics similar to rotating synchronous compensator without mechanical inertia, due to the STATCOM employ solid state power switching devices it provides rapid controllability of the three phase voltages, both in magnitude and phase angle. The STATCOM basically consist of step down transformer with a leakage reactance, a three phase GTO or IGBT voltage source inverter (VSI), and a DC capacitor.

IV. PROPOSED UTILIZATION OF COMBINED SOLAR FARM AND WIND FARM TO REGULATE ENERGY IN PCC VOLTAGE

If the power generated by a DG is more than load demand connected downstream of the PCC, the excess power flows back towards the main grid. A substantial amount of this reverse power flow may cause voltage [9] to rise on the distribution feeder. The voltage rise due to reverse power flow is one of the major concerns in any DG system (wind/solar/other) as it may cause the distribution feeder voltage to raise more than the allowable limit (typical ± 5%) specified by the utility standards.

Since wind velocity is generally higher during the night- times, a wind plant may produce more power causing significant amount of reverse power to flow towards main grid. Furthermore, during the night-time the condition worsens as the load on the system is generally lower as compared to the day time levels. On the other hand, it may be noted that solar farms do not produce any real power and remain unutilized during the night-time.

It is quite likely in the near future that wind and solar farms may be located on the same distribution feeder. This complementary operational condition of wind farm producing excessive power while solar farm remaining in idle condition, especially during the night-time, can be utilized to enhance the overall system performance by using the solar farm inverter to perform additional tasks.

In this paper, this approach is utilized to regulate the feeder voltage. The concept is to exchange (store/deliver) the real power from the feeder by incorporating storage batteries on the DC side of the solar farm inverter. In the future as more AC-DC-AC converter- inverter based wind plants are employed, such battery systems can be incorporated in wind plants (to store excess solar/other power) Fig.4 shows the block diagram representation of the proposed system operational configuration. The distribution system consists of PV solar and wind farms connected on the same feeder. Several rechargeable batteries are connected to DC side of the solar farm inverter. Switches S1 and S2 are utilized to select one or multiple operational modes [10].

The bidirectional inverter of the solar farm is operated as fully controlled active rectifier to charge the batteries at unity power factor operation. Further, with adequate control, the batteries can be charged by drawing constant charging current to extract power at fixed rate or variable charging current for rapid charging to extract power at different rates if the power generation from wind farm increases suddenly.

The operational modes of proposed utilization of solar farm are explained below:

(i) The voltage and flow of power at PCC is monitored. During night-time, if the PCC voltage is observed to increase beyond a certain level, for example 1.025 pu, or a significant amount of reverse power flow is detected, the battery charging loop is activated. Part of the wind generated real power (ΔPWF) is extracted and utilized to charge the batteries such that the voltage at PCC will be regulated. Several batteries can be charged simultaneously if very high amount of reverse power flow causing significant voltage rise at PCC is noticed.

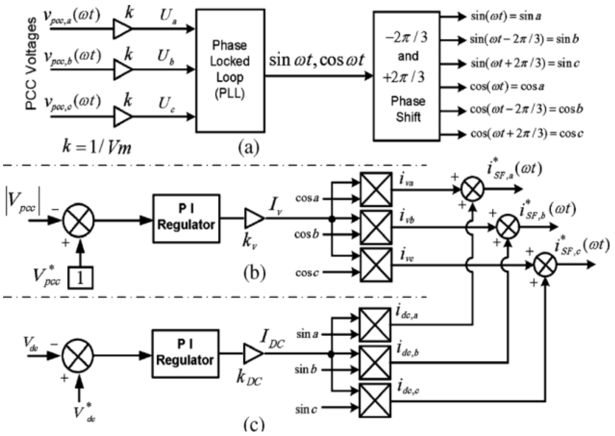
(ii) During the day-time, this stored energy in the batteries is delivered back to the PCC. For example, during early morning hours or late afternoon hours when the power generated from PV solar farm is not at its peak, the battery will be connected in parallel with solar farm generated output. Thus the PV solar farm and storage battery will simultaneously support the load power demand.

V. SOLAR FARM INVERTER CONTROLLER

The control schemes used to achieve the proposed concept are shown in Fig 3. The controller is composed 2-PI based regulate the voltage loops. One loop regulate the PCC voltage, and the another loop regulate dc-bus voltage across SF inverter capacitor at maintain a constant level. The lead-lag reactive power during voltage drop and rise are regulated by point in common coupling voltage.

A phase-locked loop (PLL) based organize approach is used to keep synchronization with PCC voltage. A hysteresis current controller is utilized to perform switching of inverter switches. To facilitate the reactive power exchange, the dc- side capacitor of SF is controlled in self-supporting mode, and thus, eliminates the need of an external dc source (such as battery).

Fig.3.SF as STATCOM—controller diagrams.



(a) Synchronization. (b) PCC voltage regulation loop. (c) DC bus voltage regulation loop.

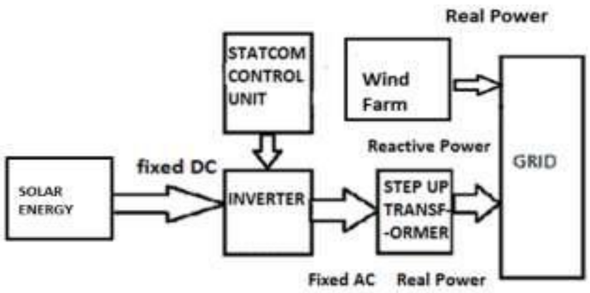


Fig.3 (d) Generalized system block diagram of Distributed Generators as STATCOM

VI. SIMULATION STUDY AN RESULTS

To authenticate the entire concept presented in the paper, Simulation is readout in SIMULINK/MATLAB. A model in Fig.5 is developed for the system in Fig.4. The length of line L1, L2 and L3 are: 5 km, 1 km and 0.5 km, respectively. All parameters are in per unit (pu) with base value of 150 MVA and 25.7 kV. The simulation results are given in Fig 6 to 11.

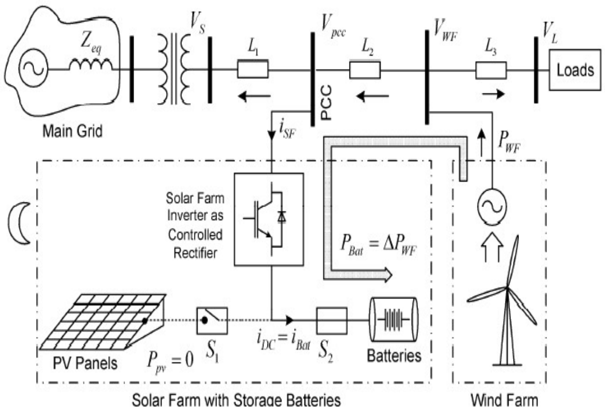


Fig 4.Block Diagram representation of proposed utilization of solar farm inverter during night time.

.

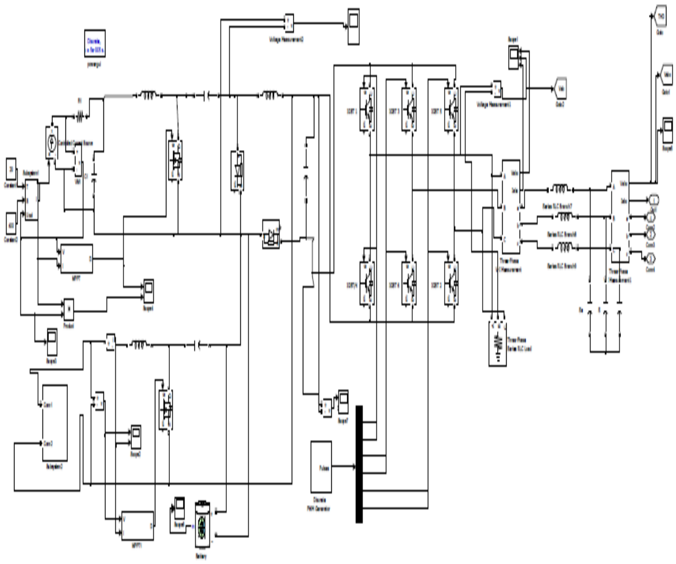


Fig.5.Simulation model of the proposed system

The Fig.6 shows under the normal condition of the grid voltage in 150KVA and PCC voltages with lot of power quality disturbances when the SF inverter [11] is not acted as STATCOM. Fig.6 and Fig.7 shows the regulated grid voltage and PCC voltage without any disturbances when the SF inverter is acted as STATCOM.

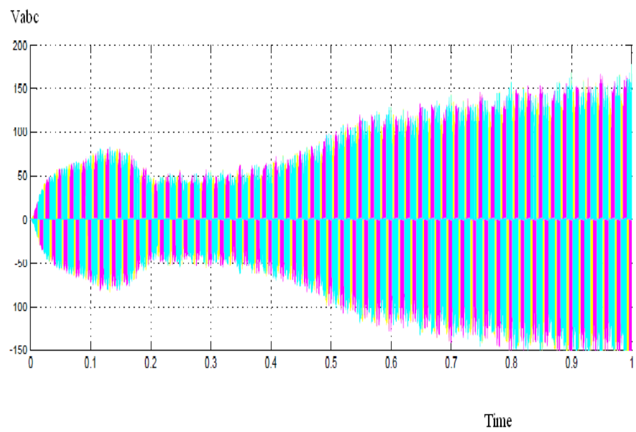


Fig 6. Grid voltage of distribution generator

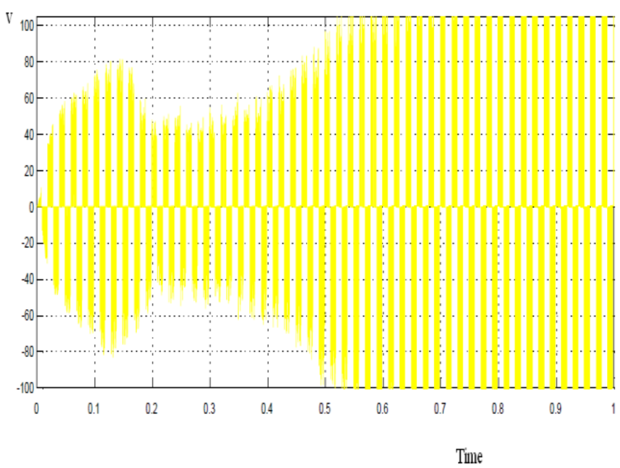


Fig 7. PCC voltages with SF are inactive.

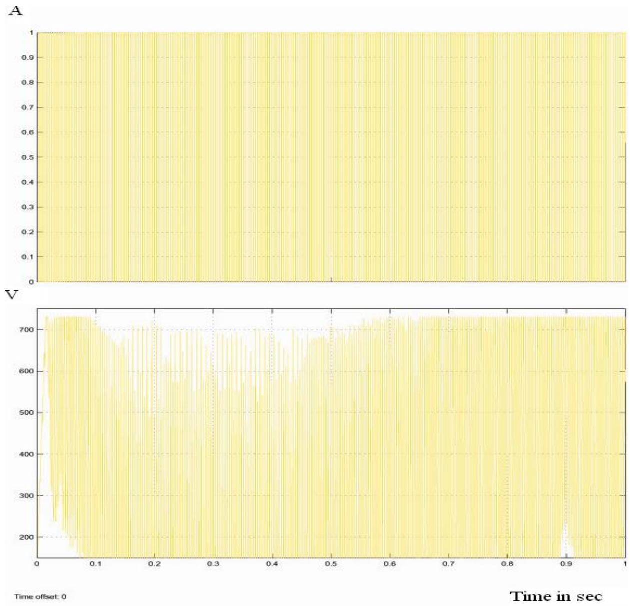


Fig 8. MPPT output for voltage and current (SF is active)

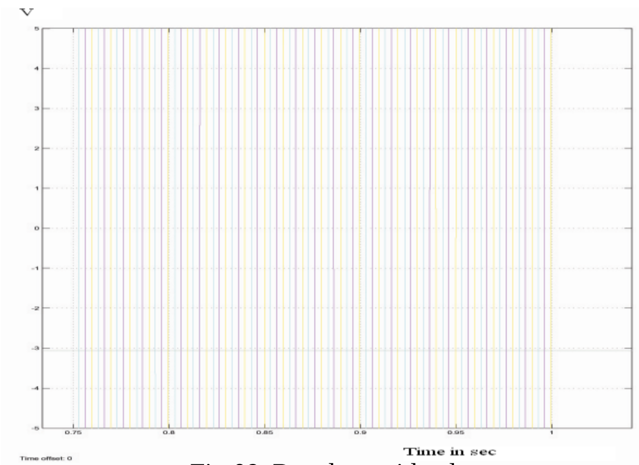


Fig 09. Regulate grid voltage

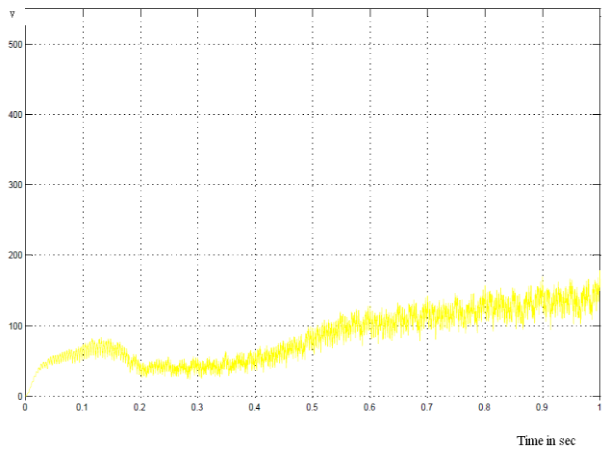


Fig 10. Output voltage at 150KVA (Battery storage of active power).

VII. CONCLUSIONS

In this Paper combination of Photovoltaic solar farm and wind energy conversion system (WECS) based to distributed the production of energy in above varies system are storage in to battery. The two directions inverter acts as a switch of PV solar farm is using a battery charger especially during the late-night to charge the batteries and energy would be storage. The proposed method introduced concept of indirect feeder link paths to regulate the voltage control is presented in which the voltage level increase, automatically the extensive amount of reverse power flow from WF is controlled by utilizing the solar farm inverter to charge the batteries and storage the power. The proposed system was simulated using Simulink blocks in MATLAB. Simulation results verify the achievement and efficiency of the proposed approach to regulate the feeder voltage by exchanging real active power through the storage batteries. In future work, the proposed approach will be expanded for a medium voltage large scale PV Solar- wind farm power based distribution system. This paper strategy implies operating PV solar plant and wind farm as a distributed generator [providing megawatts (MW)] and ancillary services provider at day time.

REFERENCES

[1] Renewables 2007 Global Status Report. Available: http://www.ren21.net/pdf/RE2007_Global_Status_Report.pdf

[2] Global Trends in Sustainable Energy Investment 2007: Analysis of Trends and Issues in the Financing of Renewable Energy and Energy Efficiency in OECD and Developing countries. Available: http://sefi.unep.org/fileadmin/media/sefi/docs/publications/SEFI_Investment_Report_2007.pdf

[3] Arai, J., Iba, K., Funabashi, T., Nakanishi, Y., Koyanagi, K. and Yokoyama, R., “Power electronics and its applications to renewable energy in Japan,” Circuits and Systems Magazine, IEEE, vol. 8, issue 3, pp. 52-66, third quarter, 2008.

[4] Tan, K. and Islam, S., “Optimum control strategies in energy conversion of PMSG wind turbine system without mechanical sensors,” IEEE Trans. on Energy Conversion, vol. 19, issue 2, pp. 392-399, Jun. 2004.

[5] Wei Li and Joos, G., “Comparison of Energy Storage System Technologies and Configurations in a Wind Farm,” Power Electronics Specialists Conference, 2007. PESC 2007. IEEE, pp.1280-1285, 17-21, June 2007.

[6] Rajiv k. Varma,Vinod Khadkikar, and Ravi seethapathy, Night *Time application of PV solar Farm as STATCOM to Regulate Grid voltage*, IEEE Transactions on energy conversion, vol. 24, pp. 983-985, December 2009.

[7] Rajiv k. Varma, Vinod Khadkikar, and Ravi Seethapathy, Grid voltage regulation utilizing storage batteries in PV solar – wind plant based Distributed Generation System,IEEE Electrical Power & Energy Conference, October 2009.

[8] Amirnaser Yazdani Prajna Paramita Dash, A Control Methodology and Characterization of Dynamics for a Photovoltaic (PV) System Interfaced with a Distribution Network, IEEE Transactions on power delivery, vol, 24, No. 3, pp.1538-1551 July 2009.

[9] B. Roberts, Capturing *grid power*, IEEE Power and Energy *Mag*., vol.7, no.4, pp. 32-41, July-Aug. 2009.

[10] R. Fioravanti, V. Khoi, W. Stadlin, "Large-scale solutions," IEEE Power and Energy Mag., vol.7, no.4, pp.48-57, July-Aug. 2009.

[11] L. Wei and G. Joos, Comparison of Energy Storage System Technologies and Configurations in a Wind Farm, in Proc. IEEE Power Electr. Spec. Conf., 17-21Jun., 2007, pp. 1280-1285.