

Optimum AC-DC Interconnected Grid Control

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ABSTRACT:

It is necessary to electrify remote locations with a micro-grid by means of existing renewable energy sources available locally. The microgrid configuration represents the energy distribution architecture from the generating sites to the consumers and finally the interconnection between these sites and consumers. The hybrid grid consists of both ac and dc networks connected together by bidirectional converters .

The hybrid ac/dc micro grid is used to reduce the processes of dc–ac–dc or ac–dc–ac conversions in an individual ac or dc grid.AC sources and loads are connected to the ac network whereas dc sources and loads are tied to the dc network. Energy storage systems can be connected to dc or ac links. The coordination control techniques are proposed for smooth power transfer between ac and dc links and for stable system operation under various generation and load conditions. The proposed hybrid grid can operate in a grid-tied or autonomous mode.

Here photovoltaic system, wind turbine generator and battery are used for the development of Hybrid Microgrid. Also control mechanisms are implemented for the converters to properly coordinate between the AC sub-grid and DC sub-grid. The system is simulated in the MATLAB/ SIMULINK environment.

Keywords :

Microgrid, Converters, Wind turbine, P. V. system.

1. INTRODUCTION:

The major challenges in electricity sector are: a) expanding access to electricity for sections of population not reached by the grid, and b) meeting increased demands from sections of populations within the reach

of the grid. Renewable energy (RE) sources such as solar, wind, bio and hydro are considered attractive in this venture both for grid fed and off grid systems.20% penetration of RE in electricity generation globally is considered necessary in the coming decade (by 2020). Power systems are undergoing considerable change in operating requirements mainly as a result of deregulation and due to large number of distributed energy resources (DER) in the network. In many cases DERs include different technologies that allow generation in small scale (micro sources) and some of them take advantage of renewable energy resources (RES) such as solar, wind or hydro energy . Having micro sources close to the load has the advantage of reducing transmission losses as well as preventing network congestions. When power can be fully supplied by local renewable power sources, long distance high voltage transmission can be avoided. Recently more renewable power conversion systems are connected in low voltage ac distribution systems as distributed generators or ac micro grids due to environmental issues caused by conventional fossil fueled power plants.

On other hand, more and more dc loads such as mlight-emitting diode (LED) lights and electric vehicles (EVs) are connected to ac power systems to save energy and reduce carbon emission. AC micro grids have been proposed to facilitate the connection of renewable power sources to conventional ac systems. However, dc power from photovoltaic (PV) panels or fuel cells has to be converted into ac using dc/dc boosters and dc/ac inverters in order to connect to an ac grid. In an ac grid, embedded ac/dc and dc/dc converters are required for various home and office facilities to supply different dc voltages. Recently, dc grids are emerging due to the development and deployment of renewable dc power sources and their inherent advantage for dc loads in commercial, industrial and residential applications. However, ac sources have to be converted into dc before connected to a dc grid and dc/ac inverters are required for conventional ac loads.

Multiple conversions required in individual ac or dc grids may add additional loss to the system operation and will make the current home and office appliances more complicated. The hybrid microgrid grid is used to provide reliable, high quality electric power in an environmentally friendly and sustainable way.

One of most important feature is the advanced structure which can facilitate the connections of various ac and dc generation systems, energy storage options, and various ac and dc loads with the optimal asset utilization and operation efficiency. To achieve those goals, power electronics technology plays an important role to interface different sources and leads to a smart grid.

This paper is an attempt to explain technology for power generation to energize local loads using locally available renewable sources such as wind, solar, bio and hydro (individually or in any possible hybrid combination) in combination with appropriate storage systems as necessary dependent on source and load variations and a coordination between these sources to get constant supply. Since energy management, control, and operation of a hybrid grid are more complicated than those of an individual ac or dc grid, different operating modes of a hybrid ac/dc grid have been studied.

The coordination control schemes among various converters have been proposed to harness maximum power from renewable power sources and to minimize power transfer between ac and dc networks, as well as to maintain the stable operation of both ac and dc grids under variable supply and demand conditions when the hybrid grid operates in both grid tied and islanding modes.

A. MICROGRID:

Microgrid can be framed as an electrical system which includes electricity generation, energy storage, loads that normally operate along with the main utility grid and can disconnect and operate autonomously as well. The Microgrid consists of micro sources with power electronic interfaces. These micro sources usually are micro turbines, PV panels, and fuel cells, bio mass, bio gas are placed at customer sites. They are low cost, low voltage with reduced carbon emissions level. Power electronics interface provide the control and flexibility required by the Microgrid.

B. HYBRID MICROGRID:

Depending on locally available energy sources, Hybrid Microgrid systems can be developed often in combination with a storage element to match the available energy with the load. Many combinations are possible depending on local conditions, such as Wind-Diesel, Wind- Bio, Wind- Battery, Hydro-Bio, Wind-Solar, Hydro-Solar etc. Storage Systems includes Fuel Cells, Battery, Super Capacitor, Pump Storage, Fly Wheel.

2. PROPOSED HYBRID SYSTEM:

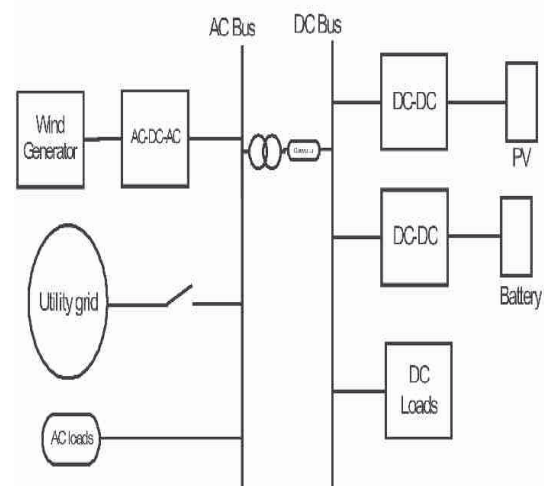


Fig. 1 Wind - Solar hybrid system.

Fig. 1 shows a hybrid microgrid system configuration where various ac and dc sources and loads are connected to the corresponding dc and ac networks. A renewable hybrid system, composed of PV panels and wind turbines as renewable energy sources, batteries as an electrical energy storage device, is considered.

The AC and DC buses are coupled through a three phase transformer and a main bidirectional power flow converter to exchange power between DC and AC sides. The transformer helps to step up the AC voltage of the main converter to utility voltage level and to isolate AC and DC grids.

3. MATHEMATICAL MODELING AND SIMULATION OF WIND PV HYBRID MICROGRID:

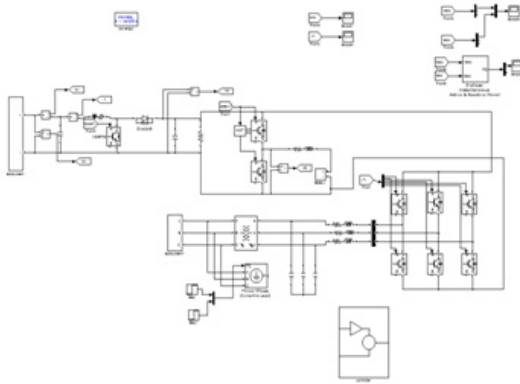


Fig 2. Schematic Representation of Hybrid Microgrid.

A schematic representation of hybrid grid is shown in Fig 2. It is modeled in the MATLAB/ Simulink to verify the operation of the system under various load and source conditions. Doubly fed induction generator of 50kW rating is connected to ac bus as ac source.

Forty kW PV arrays are connected to dc bus through a dc/dc boost converter as dc sources. A 65 Ah battery as energy storage is connected to dc bus through a bidirectional dc/dc converter. Variable dc load (20 kW–40 kW) and ac load (20 kW–40 kW) are connected to dc and ac buses respectively.

The rated voltages for dc and ac buses are 400 V and 400 Vrms respectively. A three phase bidirectional dc/ac main converter with R-L-C filter connects the dc bus to the ac bus through an isolation transformer. A wind generation system consists of doubly fed induction generator (DFIG) with back to back AC/DC/AC PWM converter connected between the rotor through slip rings and AC bus.

A DFIG wind generation system is connected to AC bus to simulate AC sources. A variable DC and AC load are connected to their DC and AC buses to simulate various loads. The AC and DC buses are coupled through a three phase transformer and a main bidirectional power flow converter to exchange power between DC and AC sides.

The transformer helps to step up the AC voltage of the main converter to utility voltage level and to isolate AC and DC grids. Boost converter, main converter, and bi-directional converter share a common DC bus.

For grid tie PV system the output of the PV array is connected to DC-DC boost converter that is used to perform MPPT functions and increase the array terminal voltage. A DC link capacitor is used after the DC converter. An LC low pass filter is connected at the output of the inverter to attenuate high frequency harmonics and prevent them from propagating into the power system grid. The AC bus is connected to the utility grid through a transformer and circuit breaker.

In the proposed system, PV arrays are connected to the DC bus through boost converter to simulate DC sources. Output of solar panel mainly varies due to solar radiation level and ambient temperature. A battery with bidirectional DC/DC converter is connected to DC bus as energy storage. A capacitor C_{pv} is connected to the PV terminal in order to suppress high frequency ripples of the PV output voltage. In isolated mode the bidirectional DC/DC converter maintain the stable DC bus voltage through charging or discharging the battery. Modeling of the various components in the hybrid microgrid is described in the following section.

A. MODELING OF WIND TURBINE:

The aerodynamic model of the wind turbine gives a coupling between the wind speed and the mechanical torque produced by the wind turbine. P_m is the mechanical power produced by the wind turbine rotor can be defined as:

$$P_m = 0.5 \rho A C_p(\gamma, \beta) V \omega^3 \quad (1)$$

Where

A : swept wind turbine rotor area

C_p : performance coefficient of the wind turbine

V : wind speed

ρ : air density

γ : tip speed ratio of the rotor blade tip speed to wind speed

β : blade pitch angle

A generic equation is used to model C_p(γ, β).

$$C_p(\lambda, \beta) = c_1 \left(\frac{c_2}{\lambda} - c_3 \beta - c_4 \right) e^{\frac{-c_5}{\lambda} + c_6 \lambda} \quad (2)$$

With

$$\frac{1}{\lambda} = \frac{1}{\lambda + 0.08\beta} - \frac{0.035}{\beta^3 + 1} \quad (3)$$

The coefficients c to c_6 are: $c = 0.5176$, $c = 116$, $c = 0.4$, $c = 5$, $c = 21$ and $c = 0.0068$. The C_p, γ characteristics, for different 5 6 pnb values of the pitch angle β , are illustrated below. The maximum value of c_p ($c_{pmax} = 0.48$) is achieved for $\beta = 0$ degree and for $\gamma = 8.1$. This particular value of β is defined as the nominal value (β_{min}).

B.MODELING OF PV PANEL:

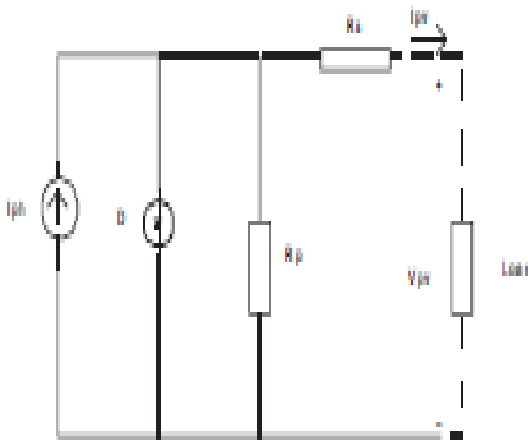


Fig. 3 Equivalent Circuit of a Solar Cell.

$$I_{pv} = n_p I_{ph} - n_p I_{sat} [\exp((V + I R_{sh}) / V_T) - 1] \quad (4)$$

$$I_{ph} = (I_{ss0} + k_i (T - T_r)) \cdot s / 1000 \quad (5)$$

$$I_{sat} = I_{rr} \exp((V - V_r) / V_T) \quad (6)$$

MODELING OF DFIG:

d, q, s , and r denote d -axis, q -axis, stator and rotor respectively. ω is the angular synchronous speed and slip speed respectively. L represents inductance and Flux linkage is λ . V and I represent voltage and current respectively. T_m is mechanical torque T_{em} is the electromagnetic torque. The voltage equations of an induction machine in a rotating $d-q$ coordinate are as:

$$v_{ds} = R_s i_{ds} + \frac{d}{dt} \lambda_{ds} - (\omega_e \lambda_{qs})$$

$$v_{qs} = R_s i_{qs} + \frac{d}{dt} \lambda_{qs} + (\omega_e \lambda_{ds})$$

$$v_{dr} = R_r i_{dr} + \frac{d}{dt} \lambda_{dr} - (\omega_e \lambda_{qr})$$

$$v_{qr} = R_r i_{qr} + \frac{d}{dt} \lambda_{qr} + (\omega_e \lambda_{dr})$$

$$T_m - T_{em} = \frac{J}{n_p} \frac{d\omega_r}{dt}$$

C.Modeling and Control of Main Converter:

To smoothly exchange power between dc and ac grids and supply a given reactive power to the ac link, control is implemented using current controlled voltage source for the main converter. Fig. 4 shows the control diagram for the main converter. Two PI controllers are used to get real and reactive power control respectively. DC bus voltage is adjusted to constant through PI regulation whenever there is change in source conditions or load. When a sudden dc load drop causes power excess at dc side, the main converter is controlled to transmit power from the dc to the ac side.

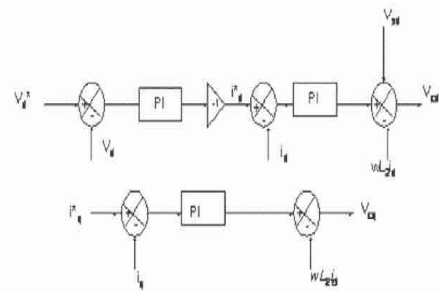


Fig 4 Control diagram of Main Converter.

The active power absorbed by capacitor C_d leads to the rise of dc-link voltage. The negative error ($V_d^* - V_d$) caused by the increase of V_d produces a higher active current reference i_d^* through the PI control. The active current i_d and its reference i_d^* are both positive.

A higher positive reference will force active current i_d to increase through the inner current control loop. Therefore, the power excess of the dc grid can be transferred to the ac side. In the same way, a sudden increase of dc load causes the power lack and V_d fall at the dc grid. The main converter is controlled to supply power from the ac to the dc side.

The positive voltage error caused by ($V_d^* - V_d$) drop makes the magnitude of i_d^* increase through the PI control. Because i_d and i_d^* are both negative, the magnitude of i_d is increased through the inner current control loop. Therefore, power is transferred from the ac grid to the dc side.

D.MODELING AND CONTROL OF BOOST CONVERTER:

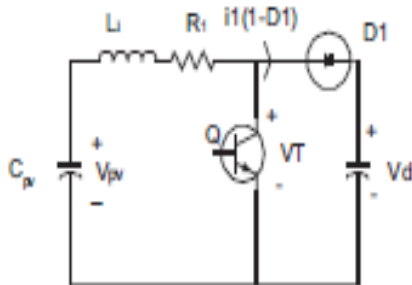


Fig. 5 Boost converter.

The boost DC-DC converter is used to step up the input voltage by storing energy in an inductor L_1 for certain time period, and then uses this energy to boost the input voltage to a higher value.

The circuit diagram for a boost converter is shown in Fig 5. When switch Q is closed, the input source charges up the inductor while diode D_1 is reverse biased to provide isolation between the input and the output of the converter. When the switch is opened, energy stored in the inductor and the power supply is transferred to the load. The current and voltage equations at dc bus are as below:

$$V_{pv} - V_t = L_1 \frac{di_1}{dt} \quad (12)$$

$$I_{pv} - i_1 = C_{pv} \frac{dV_t}{dt} \quad (13)$$

$$V_t = V_d(1-d_1)$$

The reference value of the solar panel terminal voltage is determined by the basic P&O algorithm to catch the maximum power. Dual loop control for the dc/dc boost converter has the objective to provide a high quality dc voltage. The outer voltage loop helps in tracking of reference voltage with zero steady state error and inner current loop help to improve dynamic response.

E.MODELING AND CONTROL OF BATTERY CONVERTER:

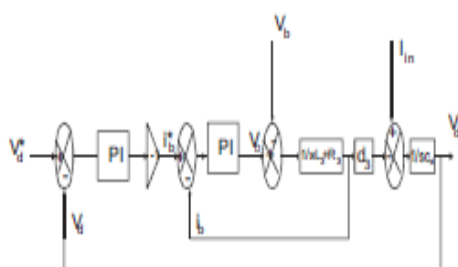


Fig 6 Control of battery converter

The battery converter is a bidirectional DC/DC converter and can be modeled as to provide a stable dc-link voltage. The dual loop control scheme is applied for the battery converter as shown in fig 6. The injection current is $I = i_1(1-d_1) - i_1$. It should be noted that the output of the outer voltage loop is multiplied by -1 before it is set as the inner loop current reference.

Current is defined positive when flowing into the battery, where the preset dc-link voltage is set to constant value. A decrease of V_{dc} caused by sudden load increase or decrease of solar irradiation, the positive voltage error $(V_{dc}^* - V_{dc})$ multiplied by -1 through the PI produces a negative i_b for the inner current loop, which makes the battery to transfer from charging into discharging mode and to rise V_{dc} back to its preset value. The battery converter is transferred from discharging into charging mode in the similar control method. The equations used for modeling of battery converter are:

$$V_D - V_b = L_3 \frac{di_b}{dt} + R_3 i_b \quad (14)$$

$$V_D = V_d \cdot d_3 \quad (15)$$

$$i_1(1-d_1) - i_{ac} - i_{dc} - i_{bd3} = i_c = C_d \frac{dV_D}{dt} \quad (16)$$

5. SIMULATION RESULTS:

The following wave forms shows the grid line voltage and current.

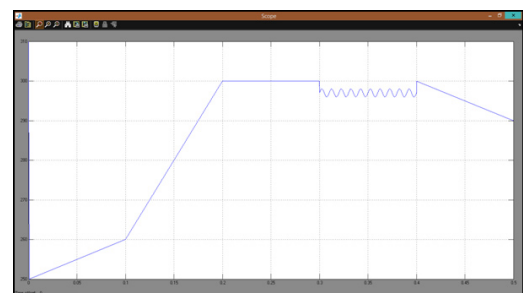


Fig 7 Voltage of Solar Panel.

Fig.7 shows the voltages of solar panel for various solar irradiances ranging from 400 w/m² to 1000 w/m² to 400w/m² in grid connected mode. MPPT algorithm is tracking the optimal voltage from 0 to 0.2 sec.

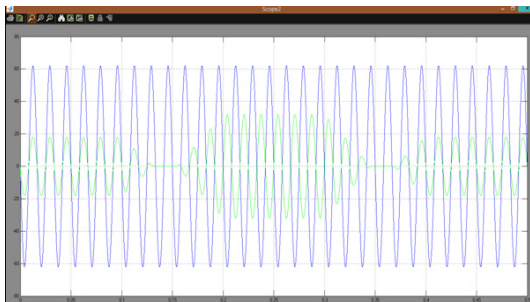


Fig 9 Voltage and Current at AC side of main Converter.

Fig 9 shows the voltage and current variation in MATLAB at the ac side of main converter when solar irradiation changes from 400 w/m² to 1000 w/m² to 400 w/m² with a fixed DC load. Power is supplied from DC side between time interval of 0.15sec to 0.35sec when solar irradiation value is high and for other time period power is supplied by AC side when solar irradiation value is 400 w/m².

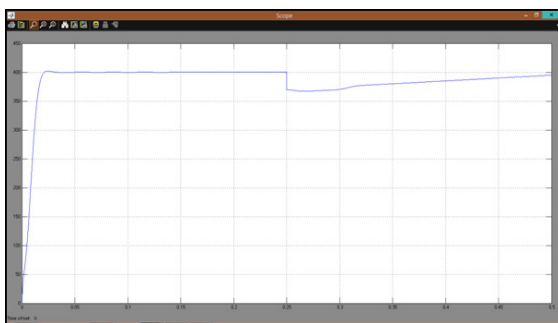
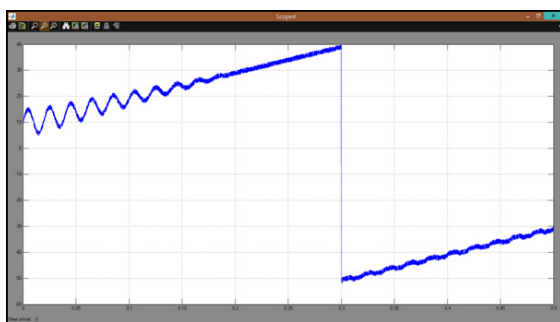


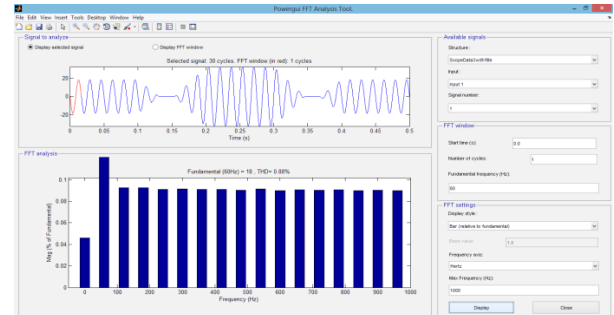
Fig 10 DC bus voltage in isolated mode.

Fig 10 shows the DC bus transient response in isolated mode in MATLAB. It is observed that at 0.3sec voltage drops with the change in dc load from 20kW to 40kW.

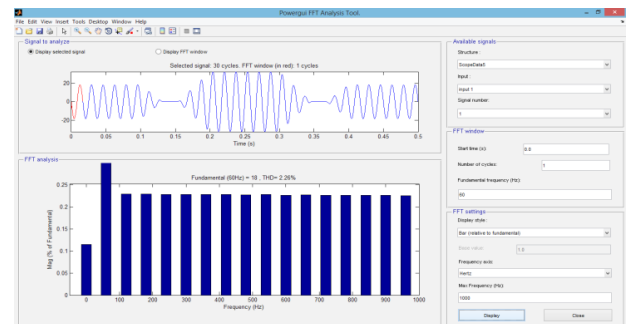


The above figure shows the battery current and voltage wave forms

HARMONIC ANALYSIS:



Above figure contains circuit with filter due to connection of filter harmonics distortion is reduced and the total %THD is 0.88.



Above figure shows circuit without filters in this harmonics are high compared to the previous one, and the total %THD is 2.29.

6. CONCLUSION:

The aim of this paper is to accelerate realization of the main benefit offered by smaller-scale Distributed Generation to use renewable energy. A hybrid micro grid is modeled using MATLAB/Simulink. The coordinated control is proposed to maintain stable system operation under various load and resource conditions. The microgrid concept enables high penetration of DG without requiring re-design or re-engineering of the distribution system itself.

Although the hybrid grid can reduce the processes of DC/AC and AC/DC conversions in an individual AC or DC grid, there are lots of practical problems for the implementation of the hybrid grid based on the current AC dominated infrastructure. The hybrid grid may be feasible for small isolated industrial plants with both PV systems and wind turbine generator as the major power supply.

REFERENCES:

- [1] R. H. Lasseter, "MicroGrids," in Proc. IEEE Power Eng. Soc. Winter Meet., Jan. 2002, vol. 1, pp. 305–308.
- [2] C.Wang, "Power Management of a Stand-Alone Hybrid Wind- Microturbine Distributed Generation System," IEEE Trans. Energy Conv., Sep. 2009.
- [3] D. J. Hammerstrom, "AC versus DC distribution systems-did we get it right?," in Proc. IEEE Power Eng. Soc. Gen. Meet., Jun. 2007, pp. 1–5.
- [4] D. P. Hohm and M. E. Ropp, "Comparative Study of Maximum Power Point Tracking Algorithms" June 2002 in Progress In Photovoltaic: Research and applications.
- [5] R. H. Lasseter and P. Paigi, "Microgrid: A conceptual solution," in Proc. IEEE 35th PESC, Jun. 2004, vol. 6, pp. 4285–4290.
- [6] S. A. Daniel and N. Ammasai Gounden, "A novel hybrid isolated generating system based on PV fed inverter-assisted wind-driven induction generators," IEEE Trans. Energy Conv., vol. 19, no. 2, pp. 416–422, Jun. 2004.
- [7] C.Wang and M. H. Nehrir, "Stand-alone hybrid wind-microturbine distribution system" IEEE Trans. Energy Conv., 39th North American Power Symposium 2007.
- [8] M. E. Ropp and S. Gonzalez, "Development of a MATLAB/Simulink model of a single-phase grid-connected photovoltaic system," IEEE Trans. Energy Conv., vol. 24, no. 1, pp. 195–202, Mar. 2009.
- [9] Saeid Esmaeili, Mehdi Shafiee, "Simulation of Dynamic Response of Small Wind- Photovoltaic-Fuel Cell Hybrid Energy System" Scientific Research, Smart Grid and Renewable Energy, Aug 2012, 3, 194-203.