Automatic Control of Hybrid Renewable Energy System Using Artificial Neural Network

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Abstract- **Hybrid renewable energy systems are the most preferred generation systems than the conventional one. The attributes which makes it more preferable are like low fuel cost, pollution free and eco-friendly as well. Besides its series of advantages it has some disadvantages like presence of harmonics and grid connected issues where it fails to have a control over reactive power. These disadvantages can be overcome by using artificial neural network. The artificial neutral network (ANN) is the computational model based on the structure and functions of biological neural networks. It is the one of the best methods which enables automatic control over the hybrid renewable systems. This paper mainly focus on the control of the real and reactive power, power factor and total harmonic distortion. A successful control of this will eventually increase the efficiency of the system and hence quality power can be supplied to the consumers. Our proposed system deals with the use of artificial neural network between the point of common coupling and the grid. Current from the point of common coupling is compared with the reference signal by ANN. In accordance to the output, power injected into the grid is varied to maintain the real power.**

Index Terms- ANN- Artificial Neural networks, Real power, Harmonics, Point of common coupling, Reactive power.

I. INTRODUCTION

Hybrid renewable energy systems are well developed power generating centres which is being used for electrifying the rural areas as it is not feasible to extend the grid on rural areas. The cost of fuel for the conventional energy sources increases day by day. So the scenario is in such a way that we have to move towards the renewable energy sources. Our aim of this paper is to provide automatic control for the hybrid renewable energy systems by using the artificial neural networks (ANN).

Variable speed wind turbines have many advantages which are well documented in the literatures [1], [2]. The wind turbine has an ability to operate with maximum aerodynamic efficiency, and the power fluctuations can be absorbed as inertial energy in the blades. In some applications, the wind turbine may be augmented by an additional power source, usually a diesel generator .These systems are called wind–diesel systems[3],[4] and may be used to supply electricity energy to stand-alone loads, e.g., small villages that are not connected to the main utility. Most diesel generation systems operate at a constant speed due to the restriction of constant frequency at the generator terminals. However, diesel engines have high fuel consumption when operating with less load and constant speed. In order to improve the efficiency and avoid wet stacking, a minimum load of about 30% to 40% is usually recommended by the manufacturers [5]. Variable-speed operation can increase the efficiency, where the fuel consumption can be reduced to 40% [5], especially when operating at low load. Moreover, the life expectancy can be increased with a lower thermal signature. In order to avoid frequent start/stop of the diesel generator, an energy storage system is often used. The maximum power point tracking (MPPT) [6], voltage conversions and the topologies of power electronic converter are studied in this paper. The maximum power point of photovoltaic (PV) array is variational, so a search for algorithm is needed according to the current–voltage (I–V) and power–voltage (P–V) characteristics of the solar cell. The perturbation and observation (P&O) MPPT algorithm is commonly used, due to its ease of implementation. It is based on the observation that if the operating voltage of the PV array is perturbed in a given direction and the power drawn from the PV array increases, which means that the operating point is moving toward the MPP, so the operating voltage must be further perturbed in the same direction. Other- wise, with the operating point moving away from the MPP, the direction of the operating voltage perturbation must be reversed. By using the P&O method, impedance matching is conducted between a boost converter and PV array in order to realize the MPPT function [7], [8]. Diesel generators are generally used to supply power to re-mote areas where grid connection is not available. However, power generation from diesel generators is not eco-friendly as they produce pollutant gases and the cost of the diesel is also not economical and perennial as well. The dynamic performance of a stand-alone wind-solar system with battery storage was analysed. Methodologies for optimal design or unit sizing of stand- alone or grid-connected hybrid systems are proposed using steady-state analysis [10]–[12], where the steady-state performance of a grid-connected wind-PV system with battery storage was also analysed [13]. The general requirements of MPPT are: simple, low cost, quick tracking when condition keeps changing, and small output power fluctuation. The traditional methods are simple and low cost without good tracking performance, such as hill climbing, P&O, and incremental conductance, etc. [7], [8]. In this paper, a stand-alone hybrid energy system consisting of wind, PV and diesel is proposed with the battery for energy storage. Wind and PV are the primary power sources of the system to take full advantages of renewable energy, and the diesel is used as a backup system. The dynamic model and control of the system is studied. The concept and principle of the hybrid system with its supervisory control were delineated. Classical techniques of maximum power tracking were applied to PV array and the wind-turbin e control.

BLOCK DIAGRAM:

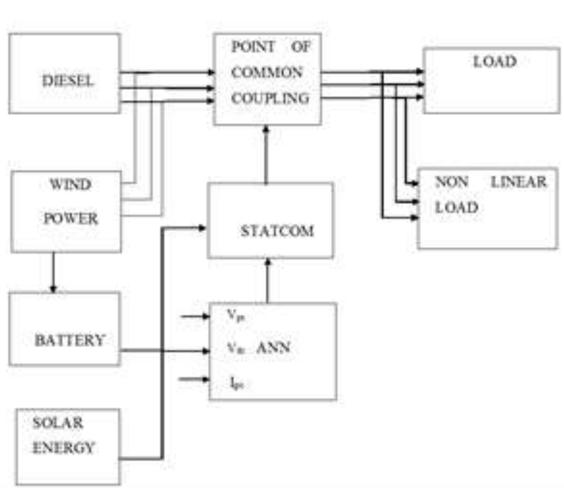

Fig 1: Block diagram of Proposed System

II. SYSTEM OVERVIEW AND MODEL DESCRIPTION

The proposed solar and diesel–wind hybrid system is shown in Fig. 1. Dynamic models of the main components were developed using MATLAB/Simulink, consisting of

1) Wind energy conversion system (WECS);
2) Diesel generator system;
3) PV generation system;
4) Battery energy storage system (BESS)

A. WIND ENERGY CONVERSION SYSTEM

The amount of power produced by a turbine can be expressed as,

Where

$P = 0.5pAC_pV^3$ 1

$C_p = f(\lambda,\beta)$ 2

$\lambda = R\Omega/V$ 3

The turbine is coupled to the permanent magnet synchronous generator shaft is connected to the gearbox whose gear ratio G in order to set the generator shaft speed within a desired speed range. Neglecting the transmission losses, the power p of the wind turbine referred to the induction generator side of the gearbox, is given by:

$P_i = P/G$ 4

The torque balance equation of mechanical motion of the induction generator side is given as

$T_s = J(2/p)dw/dt + T_e$ 5

With J is the inertia, p number poles of the induction generator, OJ r the rotor speed of induction generator and Te the electromagnetic torque.

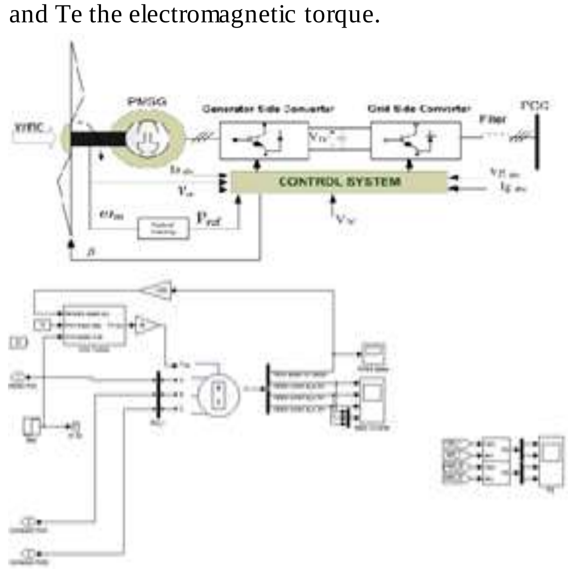

Fig 2: Wind energy conversion system (WECS) Simulink Diagram

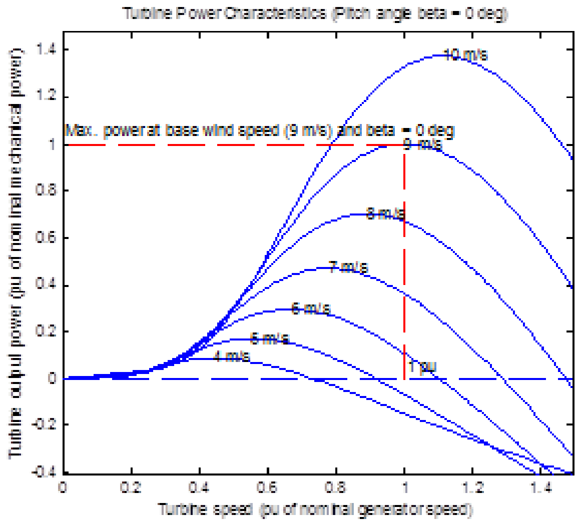

Fig 3: Waveform of Wind energy conversion system (WECS)

B.DIESEL GENERATOR

The diesel-generator set (DGS) model is composed of combustion, drive train, and synchronous generator models. A common governor model is used in this paper; the essential features can be described by the transfer function described in [3]. The fuel consumption of a diesel engine depends on the speed and torque of the machine. Fig. 3 shows the fuel consumption curves of a diesel engine for various rotational speeds. It can be seen that at 20% rated power, there isa50% fuel saving than that at 0.6 rated speed. According to Fig. 3, a continuous function for the optimal operation versus speeds can be formed tangent to all the curves. In order to minimize the fuel consumption, the speed demand (optimum speed) for the diesel engine is calculated by building up a look-up table where the optimal power-speed curve is implemented

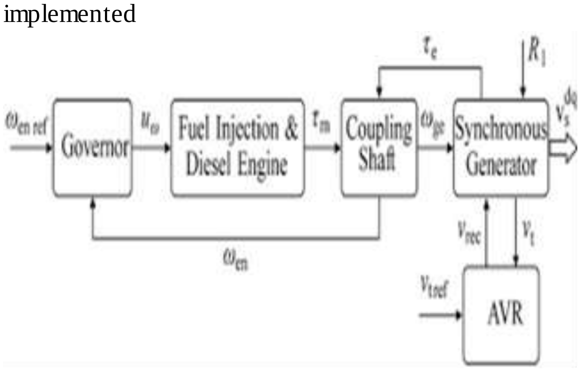

Fig 4: Diesel generator system

C.SOLAR PV PANEL

The Photovoltaic Array Model Solar cell is a p-n junction, with characteristics similar to that of diodes. Parameters of the solar cell are shown in Fig. 4. The relation between the array terminal current and voltage is

$Vpv = nKT \ln((Isc/Ipv) + 1)$ 6

$Ipv = Isc - Ipvo[\exp(q(Vpv + IpvRs)/nkT) - 1]$

$(Vpv + RsIsc)/Rsh$

Where Rs and Rsh are the series and shunt resistances, respectively.

ISC is the light induced current, n is the ideal factor of p-n junction, IPVO is the diode saturation current, K is Boltzmann constant (8.63×10−5J/◦K), and q is the electronic charge. ISC depends on the irradiance level S and the array temperature T with

$ISC = Iref\,[1 + ht\,(Tc - Tref)]$ 7

Sref

where Iref is the short-circuit current under the reference ir-radiance strength Sref and temperature Tref, ht is cell module temperature coefficient, while IPVO depend on T only .

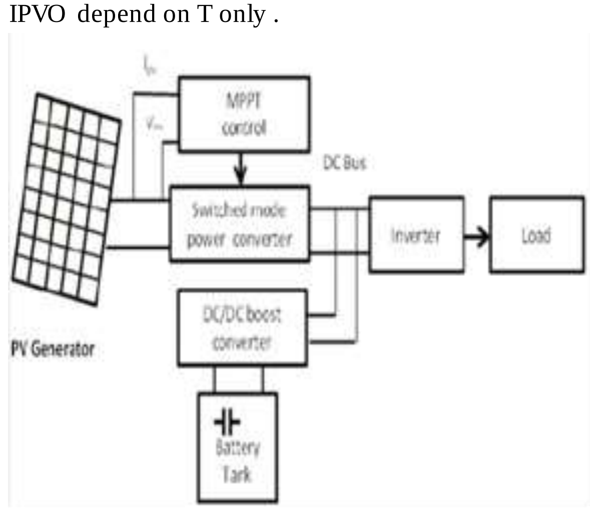

Fig 5: PV generation system

D. OUTPUT CHARACTERISTICS OF SOLAR CELL

The output characteristics are drastically affected due to the irradiation and temperature. Equations show that the solar cell has nonlinear output characteristics. The P–V and I–V characteristics are shown in fig. When the output voltage changing from solar array is small, the change of output current is extremely small and the solar array is considered as a constant current source. However, the current decreases as quickly as the voltage exceeds the critical value.

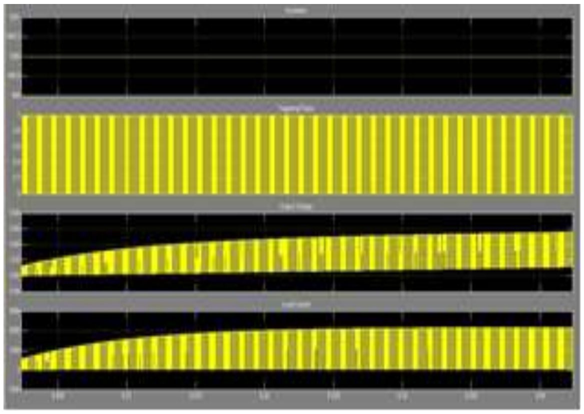

Fig 6:-Solar output Characteristics

E. BATTERY ENERGY STORAGE SYSTEM

The battery load current changes rapidly according to changes in weather conditions and power command for the bus inverter in which the dc bus voltage Vdc becomes larger than the upper limit Vdc and the charging mode begins with that voltage command V operation. The dc-bus voltage must be regulated to stay within a stable region regardless of the battery-current variation. When the dc bus voltage Vdc becomes larger than the upper limit Vdc up, charging mode begins with the voltage command Vdc equal to the upper limit and continues until the dc voltage reaches the limit. If Vdc goes below the lower limit Vdc lw, then the voltage target is bounded at the lower limit and the converter starts operating in boost mode

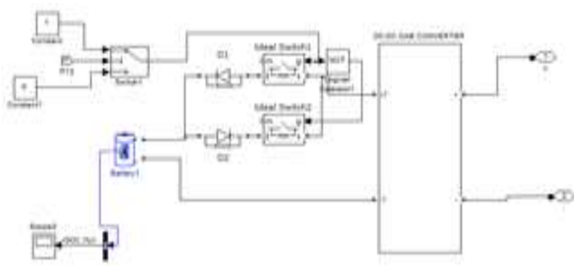

Fig 7: Battery energy storage system (BESS)

F.ARTIFICIAL NEURAL NETWORK

Artificial neural network is a connectionist systems are a computational approach used in computer science and other research disciplines, which is based on a large collection of neural networks (artificial neurons), loosely mimicking the way of biological brain solves problems with large branch of biological neurons connected by axons. Each neural unit is connected with many others, and links can be inhibitory in their effect on the activation state of connected neural units. Each individual neural unit may have a summation function which combines the values of all its inputs together. There may be a threshold function or limiting function on each connection and on the unit itself, such that the signal must surpass the limit before propagating to other neurons. These systems are self-learning and trained, rather than explicitly programmed, and excel in areas where the solution or feature detection is difficult to express in a traditional computer program.

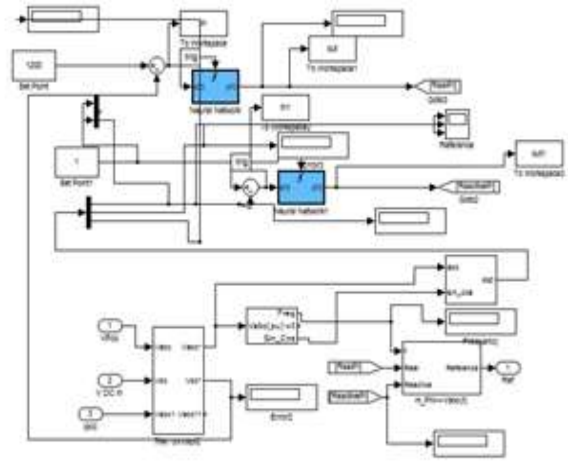

Fig 8: Simulink diagram of ANN

III. MATLAB SIMULATION AND ITS RESULT

The dynamic model of the each system and its simulations are given below, The THD value, PF at source and load are displayed after simulation and the simulated outputs are shown in the figure given below.

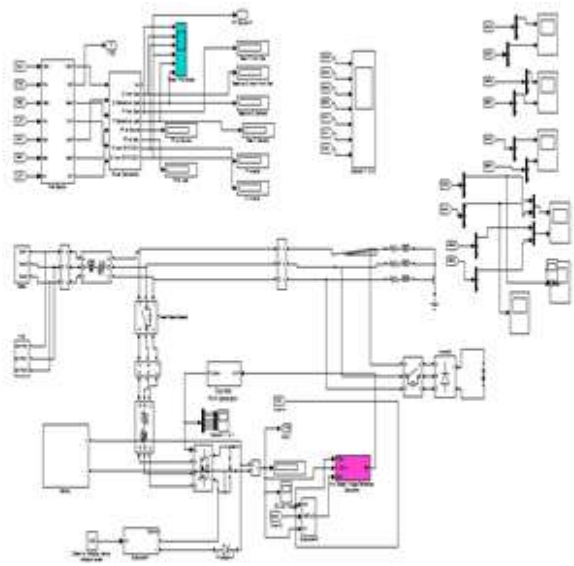

Fig 9: Simulink diagram of our proposed system

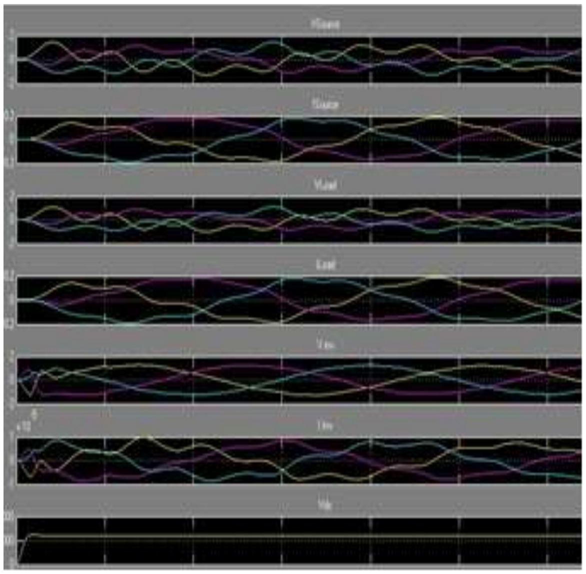

Fig 10: Waveform of source voltage and current curve and also the load voltage and current, DC link

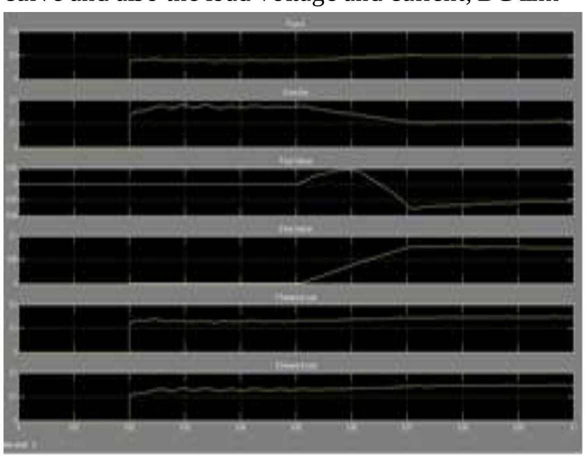

Fig 11: Waveform of generated power, Power demand and Inverter Power.

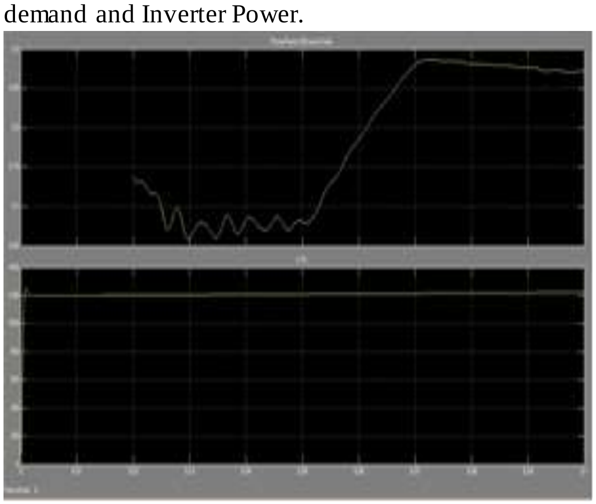

Fig12: Wave form of Power Factor and DC link Voltage

IV. FFT ANALYSIS OF SOURCE CURRENT, LOAD CURRENT, INVERTER CURRENT

The total Harmonic Distortion is an indicator of the distortion of a signal. It is widely used in Electrical Engineering and Harmonic Management in particular For a signal y, The THD is defined as

$$THD = \sqrt{\sum_{h=2}^{h=H}\left(\frac{Y_h}{Y_1}\right)^2} = \frac{\sqrt{Y_2^2 + Y_3^2 + \ldots + Y_H^2}}{Y_1}$$

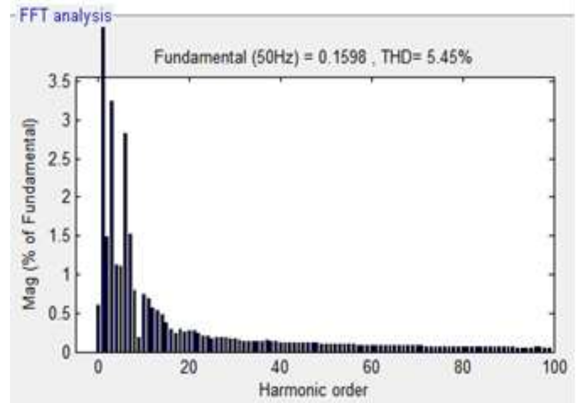

Fig13: Source Current Harmonics

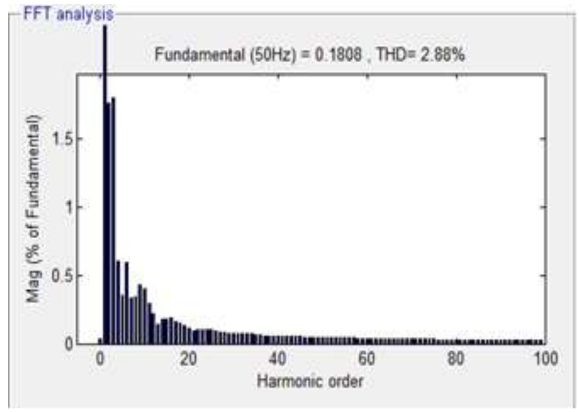

Fig 14: Load Current Harmonics

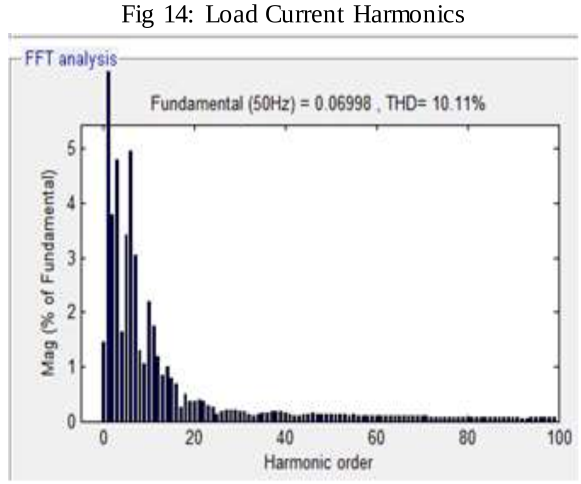

Fig 15: Inverter Current Harmonics

Without ANN	With ANN
THD at Source Current= 6.25% THD at Load Current = 8.8%	THD at Source current =5.25% THD at Load Current = 2.88%
Power Factor = 0.74	Power Factor = 0.87

V. CONCLUSIONS

The existing hybrid energy systems are controlled by using the VI controllers which does not provide automatic control over them whereas our proposed system makes use of artificial neural network (ANN) that provides intelligent control varying the power produced according to the demand automatically. The entire system is modeled using MATLAB and the output is simulated.

REFERENCES

[1] G. Abad, M. A. Rodriguez, G. Iwanski, and J. Poza, "Direct power control of doubly-fed-induction-generator-based wind turbine under unbalanced grid voltage," IEEE Trans. Power Electron., vol. 25, no. 2, pp. 442–452, Feb. 2010.

[2] S. M. B. Wilmshurst, "Control strategies for wind turbines," Wind Eng., vol. 12, pp. 236–249, Jul. 1988.

[3] A. J. Rudell, J. A. M. Bleijs, L. Freris, D. G. Infield, and G. A. Smith, "A wind diesel system with variable speed flywheel storage," Wind Eng., vol. 17, pp. 129–145, May 1993.

[4] R. Dettmer, "Revolutionary energy—A wind/diesel generator with fly- wheel storage," Inst. Electr. Eng. Rev., vol. 36, pp. 149–151, Apr. 1990.

[5] Z. Chen and Y. Hu, "A hybrid generation system using variable speed wind turbines and diesel units," in Proc. IEEE Ind. Electron. Soc. Annu. Meeting Conf., Nov. 2003, pp. 2729–2734.

[6] B. S. Borowy and Z. M. Salameh, "Dynamic response to a stand-alone wind energy conversion system with battery energy storage to a wind gust," IEEE Trans. Energy Convers., vol. 12, no. 1, pp. 73–78, Mar. 1997.

[7] N. Femia, G. Petrone, G. Spagnuolo, and M. Vitelli, "Optimization of perturb and observe maximum power point tracking method," IEEE Trans. Power Electron., vol. 20, no. 4, pp. 963–739, Jul. 2005.

[8] B. Yang, Y. Zhao, and X. He, "Design and analysis of a grid-connected photovoltaic power system," IEEE Trans. Power Electron., vol. 25, no. 4, pp. 992–1000, Apr. 2010.

[9] R. Chedid and S. Rahman, "Unit sizing and control of hybrid wind-solar power systems," IEEE Trans. Energy Convers., vol. 12, no. 1, pp. 79–85, Mar. 1997.

[10] W. D. Kellogg, M. H. Nehrir, G. Venkataramanan, and V. Greez, "Generation unit sizing and cost analysis for stand-alone wind, photovoltaic, and hybrid wind/PV systems," IEEE Trans. Energy Convers., vol. 13, no. 1, pp. 70–75, Mar. 1998.

[11] R. Chedid and S. Rahman, "A decision support technique for the design of hybrid solar–wind power systems," IEEE Trans. Energy Convers., vol.13, no. 1, pp. 76–83, Mar. 1998.

[12] D. Das, R. Esmaili, L. Xu, and D. Nichols, "An optimal design of a grid connected hybrid wind/photovoltaic/fuel cell system for distributed energy production," in Proc. 32nd Annual. Conf. IECON, Nov. 6–10, 2005, pp. 2499–2504.