International Journal of Scientific Engineering and Technology ISSN : 2277-1581
Volume No. 6, Special Issue 3. PP : 174-177 22-23 Dec. 2017

Hybrid Energy Management System design with Renewable Energy Sources (Fuel Cells, PV Cells and Wind Energy): A Review

Seema Agrawal, Seemant Chourasiya, D.K. Palwalia
Corresponding Author: Seema10dec@gmail.com

Abstract : This paper presents a novel adaptive scheme for energy management in stand-alone hybrid power systems. The proposed management system is designed to manage the power flow between the hybrid power system and energy storage elements in order to satisfy the load requirements based on artificial neural network (ANN) and fuzzy logic controllers. The neural network controller is employed to achieve the maximum power point (MPP) for different types of photovoltaic (PV) panels, based on Levenberg Marquardt learning algorithm. The statistical analysis of the results indicates that the R2 value for the testing set was 0.99.The advance fuzzy logic controller is developed to distribute the power among the hybrid system and to manage the charge and discharge current flow for performance optimization. The developed management system performance was assessed using a hybrid system comprises PV panels, wind turbine, battery storage, and proton exchange membrane fuel cell (PEMFC). To improve the generating performance of the PEMFC and prolong its life, stack temperature is controlled by a fuzzy logic controller. Moreover, perturb and observe (P&O) algorithm with two different controller techniques the linear PI and the nonlinear passivity based controller (PBC) are provided for a comparison with the proposed MPPT controller system. The comparison revealed the robustness of the proposed PV control system for solar irradiance and load resistance changes. Real time measured parameters and practical load profiles are used as inputs for the developed management system. The proposed model and its control strategy offer a proper tool for optimizing the hybrid power system performance, such as the one used in smart house applications. The research work also led to a new approach in monitoring PV power stations. The monitoring system enables system degradation early detection by calculating the residual difference between the model predicted and the actual measured power parameters. Measurements were taken over 21 month's periods; using hourly average irradiance and cell temperature. Good agreement was achieved between the theoretical simulation and the real time measurement taken the online grid connected solar power plant.

INTRODUCTION

Therefore, a solar-wind hybrid power system model will be presented [1-3]. The system will consist of

a) PV panels, to convert the sunlight into direct current,
b) wind turbine, to convert the kinetic energy from the wind into mechanical energy,
c) DC generator, to convert the mechanical energy from the turbine into electrical energy,
d) MPPT, to operate the PV at the maximum power point (MPP),
e) fuel cells, which performs as a backup power source,
f) battery bank, to supply energy to the system when is needed and store it when is not needed,
g) DC/DC converters, to steps-up the voltage to a higher DC voltage,
h) DC/AC inverters, to generate AC waveform from the DC signal, (i) main controller, to ensure the continuous power supply for the load demand. A schematic diagram of a basic hybrid system is shown in Figure 1.

I. Hybrid Power System: Modeling & Simulation

In power applications and system design, modeling and simulation are essential to optimize control and enhance system operations. The dynamic simulation model is described for a hybrid power system comprises PV panels, wind turbine, fuel cells, battery bank, converters and controllers.

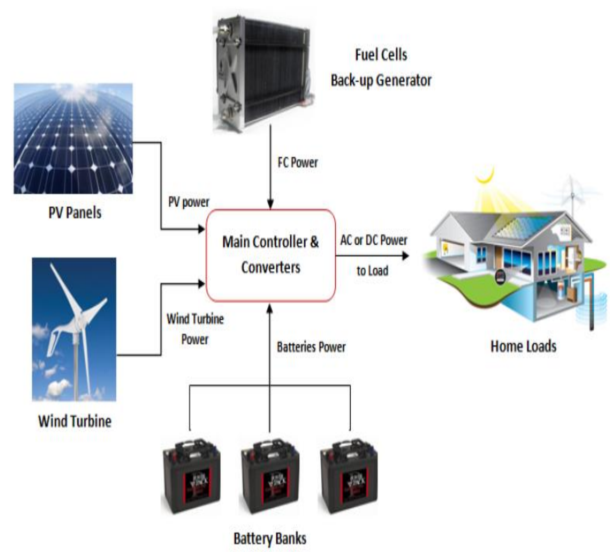

Fig.1- Block diagram of a hybrid power generation system

The main controllerwill have developed to ensure the continuous power supply for the load demand [4-5].The following subsections present the implementation of the PV/wind turbine/ PEMFC/Li-Ion battery system model [6]. Modeling and simulation are implemented using MATLAB/ Simulink and SimPowerSystem software packages. The block diagram of the developed hybrid power system is shown in Figure 2.

International Journal of Scientific Engineering and Technology ISSN : 2277-1581
Volume No. 6, Special Issue 3. PP : 174-177 22-23 Dec. 2017

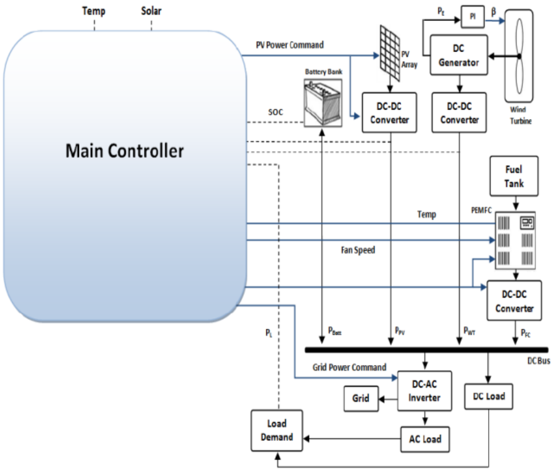

Fig. 2 - Block diagram of the developed hybrid power system

A. The photovoltaic model

A model of PV panel with moderate complexity which includes the series resistance, the saturation current of the diode, and the temperature independence of the photocurrent source is considered based on the Shockley diode equation. The PV model is built and implemented using Simulink to verify the nonlinear I–V and P–V output characteristics [7]. Each function uses a notation with a meaningful lettering to make it readable and maintainable; e.g. reverse saturation current function stands for the implementation of Equation (1).

$$I_{o\alpha} = \frac{I_{sc}}{\exp\left(\frac{qv_{OC}}{K_B F T_C}\right)-1} \qquad (1)$$

Where $I_{o\alpha}$is the cell's reverse saturation current at a solar radiation and reference temperature; $v_{oc}$is the cells open circuit voltage. The cell ideal factor (*F*) is dependent on the cell technology.The inputs for the proposed PV model are solar irradiation, cell temperature and PV manufacturing data sheet information. In this chapter, ADT 12AS PV module is taken as an example. The proposed PV model was simulated using MATLAB/Simulink, [8] as shown in Figure 3.

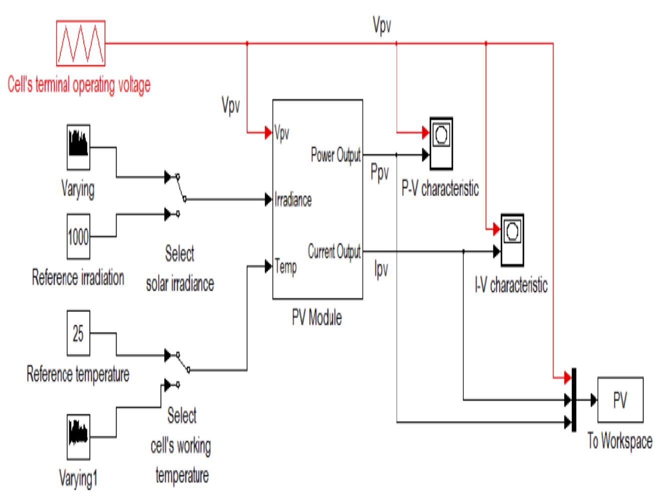

Fig.3 - Implementation of the PV model

B. The wind turbine model

The amount of power that a wind turbine can extract from the wind depends on the turbine design. Factors such as the wind speed and the rotor diameter affect the amount of power that a turbine can extract from the wind. The wind turbine was modelled using the mathematical equations [2].

$$P_W = \frac{1}{2}\rho A_S V^3 \qquad (2)$$

Where ρ is the air density in (kg/m3), A_S is the swept area of blades (m²), v is the wind speed (m/s). As illustrated, there are three inputs and one output. The three inputs are the generator speed, the pitch angle, and the wind speed. The output is the torque applied to the generator shaft.The built-in SimPowerSystem block model of a DC machine is used as a power generator driven by the wind turbine (MathWorks 2012). As shown in Figure 6, the rotor shaft is driven by the wind turbine which produces the mechanical torque according to the generator and wind speed values [10].

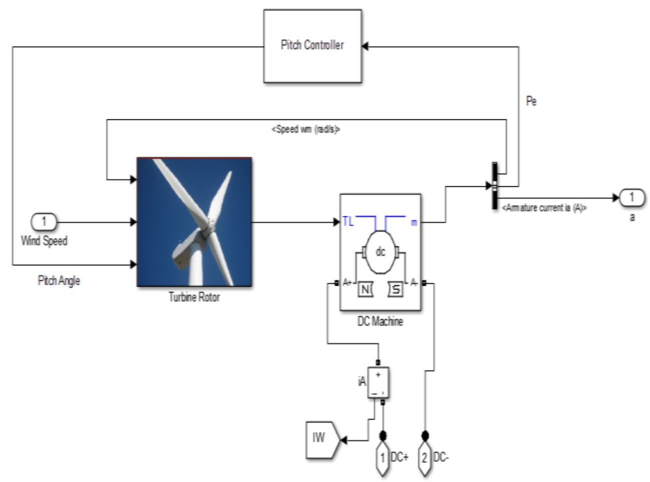

Fig. 6 – Implementation of the wind turbine DC generator model

A Proportional Integral (PI) controller is used to control the blade pitch angle in order to limit the electric output power to the nominal mechanical power [11].

C. The Li-Ion battery model

The model of the Li-Ion battery is implemented in MATLAB/Simulink based on the mathematical

$$V_{batt} = E_O - K\frac{Q}{Q-it}it - R_i - K\frac{Q}{it+0.1Q}i^* + Aexp(-Bit)$$

Where E_O is the battery constant voltage (V), K is the polarization constant (Ah-1), Q is the maximum battery capacity (Ah), it (∫ idt) is the actual battery charge (Ah), R is the internal resistance (Ω), i is the battery current (A), i* is the low frequency current dynamics (A), A is the exponential zone amplitude (voltage drop during the exponential zone) (V), and B is the exponential zone time constant inverse (Ah) −1. It is implemented using several standard Simulink blocks as well as some of the SimPowerSystem blocks as shown in Figure 7. The output of this model is a vector containing three signals: state-of-charge (SOC), battery current and battery voltage [12].

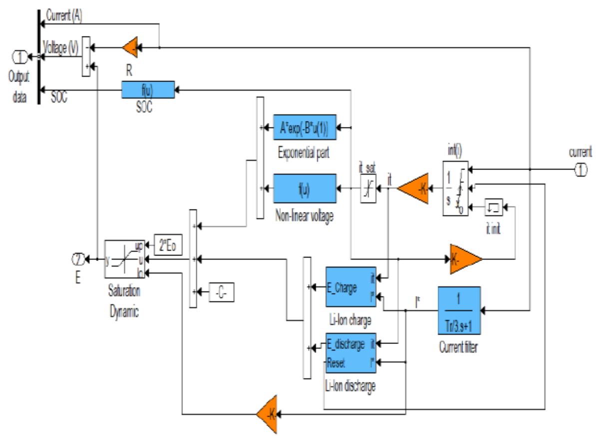

Fig. 7 - Subsystem implementation of the Li-Ion battery model

The main feature of this battery model is that the parameters can easily be deduced from a manufacturer's discharge curve.

D. *The PEMFC stack model*

The fuel cell stack voltage (V_{fc}) is described as

$$V_{fc} = \left(E_{OC} - NA\ln\left(\frac{I_{fc}}{I_O}\right) \times \frac{1}{\frac{sT_d}{3} + 1} \right) - R_{ohm} I_{fc}$$

Where E_{oc} is the open circuit voltage (V), N is the number of cells, A is the Tafel slope (V), I_o is the exchange current (A), I_{fc} is the fuel cell current (A), T_d is the response time (sec), and R_{ohm} is the internal resistance (Ω). The dynamic model of PEMFC is built and implemented using MATLAB/Simulink. The modified fuel cell modelcombines the features of chemical [13] and electrical models [14]. Hence, it's suitable for electrical simulation programs and can represent the effect of operating parameters on the stack. The model is implemented as shown in Figure 8.Fuel cell manufacturers provide specifications of their stacks which include the peak power, polarization curve, number of cell, etc.The PEMFC stack model is modified to include a fuzzy logic temperature controller areused to obtain the models parameters.

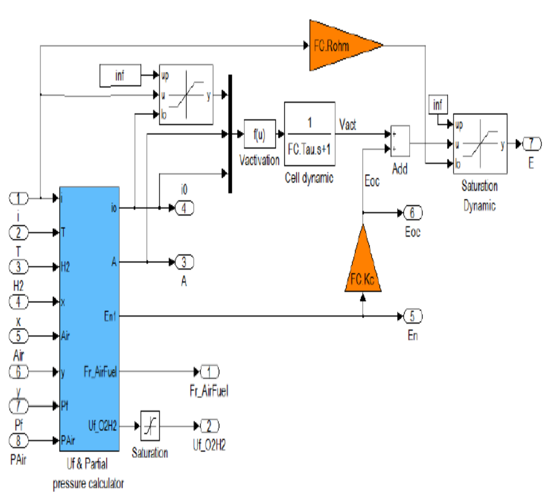

Fig. 8 - Subsystem implementation of the PEMFC stack model

II. Hybrid Systems Energy Controller Based on Artificial Intelligence

Anovel adaptive scheme for energy management in stand-alone hybrid power systems,the proposed management system is designed to manage the power flow between the hybrid power system and energy storage elements in order to satisfy the load requirements based on artificial neural network (ANN) and fuzzy logic controllers [15]. The method offers an on-line energy management by a hierarchical controller between four energy sources comprises photovoltaic panels, wind turbine, battery storage, and proton exchange membrane fuel cell [16]. The proposed method includes a MPPT controller in the first layer, to achieve the maximum power point (MPP) for different types of PV panels; two different techniques will be presented (P&O and neural network). In the second layer, an advance fuzzy logic controller will be developed to distribute the power among the hybrid system [17] and to manage the charge and discharge current flow for performance optimization. Finally in the third layer, smart controllers are developed to maintain the stability of the PEMFC temperature and to regulate the fuel cell/battery set points to reach best performance [18]. Figure 9 shows the proposed control structure for the hybrid generation system.

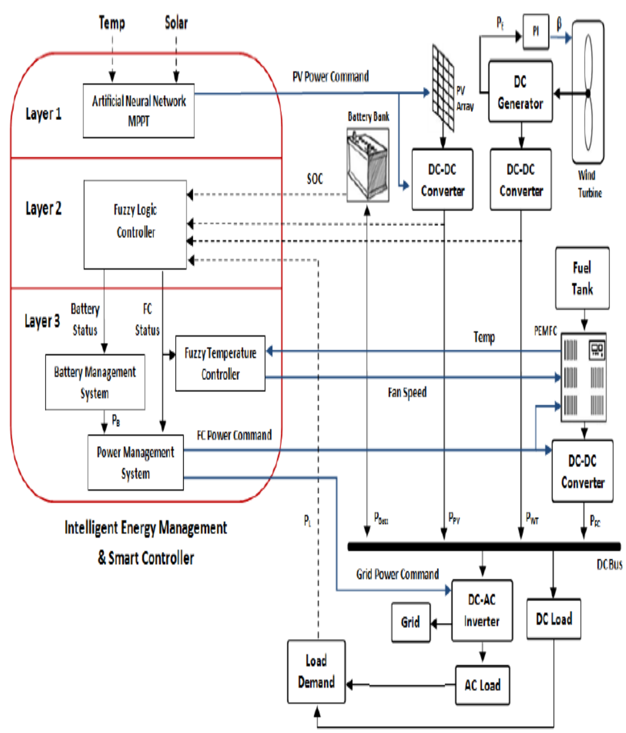

Fig. 9 - Block diagram of the proposed system

III. Simulation Discussion

The dynamics simulation models for each of the: PV array, wind turbine, PEM fuel cell, and Li-Ion battery were explained and shown. Afterward, an optimized energy management [19-22]based on a hierarchical controller has been implemented to satisfy important objectives such as: optimal operation of PV panel, battery charge balance, optimal operation of FC, and load. Here, P&O algorithm with linear and non-linear controllers are provided for a comparison with the proposed MPPT controller system [23-29].

IV. Conclusion

The analysis of simulation results has shown that the adaptive algorithm developed is suitable for stand-alone hybrid power systems. This control algorithm is capable of:

- Extracting maximum power from the PV panels with tracking efficiency exceed 94.5%.
- Splitting the power between the power sources to sustain the efficiency of the system.
- Regulating the PEMFC on/off status according to external environmental changes and to load demand expectation
- Optimizing the generating performance of the PEMFC by maintaining the temperature stable and equal to the stack operating temperature (e.g. 65%).

References

i. *N. Shaheen, N. Javaid, Z. Iqbal, K. Muhammad, K. Azad and F. A. Chaudhry, "A Hybrid Algorithm for Energy Management in Smart Grid," Network-Based Information Systems (NBiS),2015IEEE 18th International Conference on, Taipei, 2015, pp. 58-63.*

ii. *Ahmed, N.A., Al-Othman, A.K., & Al-Rashidi, M.R. (2011) Development of an Efficient Utility Interactive Combined Wind/Photovoltaic/Fuel Cell Power System with MPPT and DC Bus Voltage Regulation, Electric Power Systems Research, 81, (5), pp. 1096–1106*

iii. *Ahmed, N.A., Miyatake, M., & Al-Othman, A.K. (2008) Power Fluctuations Suppression of Standalone Hybrid Generation Combining Solar PV/Wind Turbine and Fuel Cell Systems, Energy Conversion and Management, 49, (10), pp. 2711-2719.*

iv. *Hau, E. (2006). Wind Turbines: Fundamentals, Technologies, Application, Economics, 2nd edn. Springer, Berlin, Germany.*

v. *Hwas, A., &Katebi, R. (2012) Wind Turbine Control using PI Pitch Angle Controller, IFAC Conference on Advances in PID Control, Brescia, Italy.*

vi. *Muljadi. E., & Butterfield, C.P. (2001) Pitch-Controlled Variable Speed Wind Turbine Generation, IEEE Trans. Industry Applications, 37, (1), pp. 240– 246.*

vii. *Borowy, B.S., & Salameh, Z.M. (1996) Methodology for Optimally Sizing the Combination of a Battery Bank and PV Array in a Wind/PV Hybrid System, IEEE Trans. Energy Conversion, 11, (2), pp. 367–373.*

viii. *Qiuli, Y., Srivastava, A.K., Choe, S.-Y., Gao, W. (2006) Improved Modeling and Control of a PEM Fuel Cell Power System for Vehicles, SoutheastCon, 2006. Proceedings of the IEEE, pp. 331 – 336*

ix. *Souleman, N.M., Tremblay, O., &Dessaint, L.-A. (2009) A Generic Fuel Cell Model for the Simulation of Fuel Cell Power Systems, IEEE Power & Energy Society General Meeting, pp. 1-8.*

x. *Natsheh, E.M., &Albarbar, A. (2013) Hybrid Power Systems Energy Controller Based on Neural Network and Fuzzy Logic, Smart Grid and Renewable Energy, 4, (2), pp. 187-197.*

xi. *Wang, C., &Nehrir, M.H. (2008) Power Management of a Stand-alone Wind/PV/Fuel Cell Energy System. IEEE Trans. Energy Conversion, 23, (3), pp. 957-967.*

xii. *Esram, T., Urbana, I.L., Chapman, P.L. (2007) Comparison of Photovoltaic Array Maximum Power Point Tracking Techniques, IEEE Trans. Energy Conversion, 22, (2), pp. 439 – 449.Celik, A.N. (2003) Techno-Economic Analysis of Autonomous PV–Wind Hybrid Energy Systems using Different Sizing Methods, Energy Conversion and Management, 44, (12), pp. 1951-1968.*

xiii. *Das, D., Esmaili, R., Longya, X., & Nichols, D. (2005) An Optimal Design of a Grid Connected Hybrid Wind/Photovoltaic/Fuel Cell System for Distributed Energy Production, 31st Annual Conference of IEEE, Industrial Electronics Society, Raleigh, NC.*

xiv. *Dursun, E., &Kilic, O. (2012) Comparative Evaluation of Different Power Management Strategies of a Standalone PV/Wind/PEMFC Hybrid Power System, Electrical Power and Energy Systems, 34, (1), pp. 81-89.*

xv. *Kim, S.K., Jeon, J.H., Cho, C.H., Kim, E.S., &Ahn, J.B. (2009) Modeling and Simulation of a Grid-Connected PV Generation System for Electromagnetic Transient Analysis, Solar Energy, 83, (5), pp. 664- 678.*

xvi. *Villalva, M.G., Gazoli, J.R., & Filho, E.R. (2009) Comprehensive Approach to Modeling and Simulation of Photovoltaic Arrays, IEEE Trans. Power Electronics, 24, (5). pp 1198–1208.*

xvii. *Hajizadeh, A., &Golkar, M.A. (2007) Intelligent Power Management Strategy of Hybrid Distributed Generation System. International Journal of Electrical Power & Energy Systems, 29, (10), pp. 783–795.*

xviii. *Kim, M., Sohn, Y.-J., Lee, W.-Y., & Kim, C.-S. (2008) Fuzzy Control Based Engine Sizing Optimization for a Fuel Cell/Battery Hybrid Mini-Bus. Journal of Power Sources, 178, (2), pp. 706-710.*

xix. *C. H. Cai, D. Du and Z. Y. Liu, "Battery state-of-charge (SOC) estimation using adaptive neuro-fuzzy inference system (ANFIS)," Fuzzy Systems, 2003. FUZZ '03. The 12th IEEE International Conference on, 2003, pp. 1068-1073 vol.2.*