THOMSON REUTERS ENDNOTE
[Benhamdane* *et al.*, 6(2): February, 2017]
IC™ Value: 3.00
ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

MANAGEMENT STRATEGY OF HYBRID WIND/ SOLAR SYSTEM

Tahar Benhamdane*, A. Boudghène Stambouli, Tayeb Alloui
* Department of Electrical Engineering of USTO-MB, BP 1505, EL M'Naouer Oran(31000), Algeria

DOI: 10.5281/zenodo.291869

ABSTRACT

In this paper, the design and model of the hybrid wind /photovoltaic system using Matlab/Simulink environment is studied. The objective of this work is the study of a hybrid central power, which combines two renewable energy sources (wind, solar) with storage and an emergency generator. The management of different energy sources is ensured by a manager who controls the opening and closing switches, depending on weather conditions (illumination, wind speed).To be assured the good performance of this system, we have proposed an energetics flow management algorithm that takes into consideration the meteorological conditions (wind and the solar irradiation).When the wind/PV hybrid system generated power from is not sufficient to supply the load demand, the diesel generator turns on to supply the power shortage and the ultra-capacitor (UC) bank serves as a short duration power source to meet the excess power that cannot be satisfied by the diesel generator because of their response time. We examined the dynamic performance of the hybrid system and its potentiality in autonomous operation by simulation results.

KEYWORDS: Hybrid, Wind, Solar, Ultra-capacitor, Diesel, Management Strategy.

INTRODUCTION

Alternative or renewable energy sources have attracted great attention around the world to solve the problem of the continued increase in emissions of greenhouse. The cost of fuel and transport, which are often expensive fossil fuels and growing concern about climate change and global warming problem, can be treated by using renewable energy sources for electricity production [1]. Independent photovoltaic (PV) or wind generator (WTG) alone cannot provide a reliable power supply due to the intermittent nature of solar radiation and wind speed [2]. So the problem can be solved by using hybrid systems. But the major problem is to store the energy generated by wind or photovoltaic for later use when the power is greater than the power required variable, conventional batteries or a diesel generator was used as a second source energy. In the literature there are many studies in real time related to production hybrid energy systems (Solar - wind). In this paper, the hybrid system is designed and modeled using the Matlab / Simulink environment. Combining photovoltaic array system (PV), wind turbine system, ultra-capacitor and diesel generator system are used for the production of electricity. The UC bank serves as a short duration power source to meet the excess power that cannot be satisfied by the photovoltaic or the wind system. Simulation results are presented to examine the dynamic performance of the system and its potentiality in autonomous operation.

HYBRID WIND/PHOTOVOLTAIC/DIEZEL GENERATOR/ ULTRA-CAPACITOR SYSTEM DESCRIPTION AND MODELING.

In this section, the dynamic simulation model is described for the wind /PV/ Diesel generator /UC hybrid generation system. The block diagram of the integrated overall system is shown in Figure 1. The developed system consists of a horizontal axis wind turbine compiled to a permanent magnet synchronous generator (PMSG), an AC/DC rectifier, UC system and diesel generator. The DC bus collects the total energy from the wind and PV subsystems and uses to charge the UC. The PV and the wind are considered as the principal source. At the times when the wind and photovoltaic source is unable to supply the load demand. The diesel generator has been used as second energy source. The UC bank serves as a short duration power source to meet the excess power that cannot be satisfied by the PV and the wind system.

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

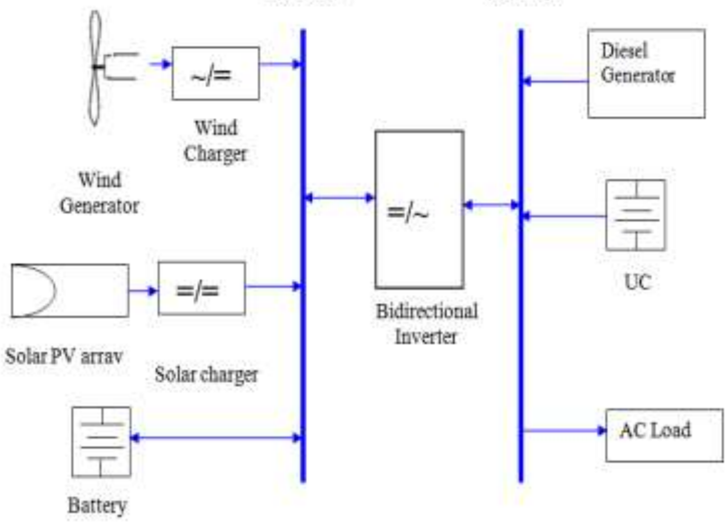
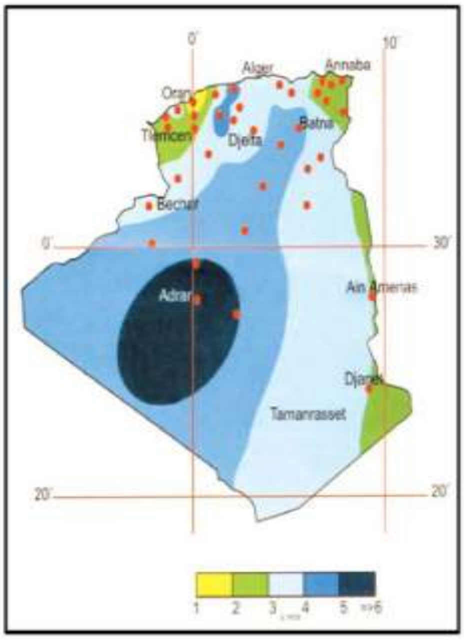


Fig. 1. Flow diagram illustrating wind/PV/diesel energy-hydrogen storage hybrid power generation system

WIND ENERGY

Algeria has a comprehensive plan to develop wind energy that can be achieved when the average wind speed is greater than 5-6 m / s. Studies of indigenous wind resources in Algeria performed by the Renewable Energy Development Centre (CDER) during recent years show that the climatic conditions in Algeria are favorable for wind energy utilization [3] [4] [5]. The wind resource has also been assessed by the developer, Sonelgaz, and at present, there are six pilot projects for electrification and telecommunication which are identified and quantified [6]. These are Bechar, Adrar, bordj Badji Mokhtar, Tindouf, Tamanrassat and Djanet. The annual average wind velocities in these six places are shown in Figure 2 .The region of Adrar receives the most wind in the country judging from the results of the preliminary survey. Evaluations of powers recoverable at heights from 10 to 50 mcould conclude in registering this region as a favorable site for the establishment of a windy farm. Other sites (North, High Plateaux) hide non-negligible energetic potentials (usable energy, Figure 3) [6] [7].



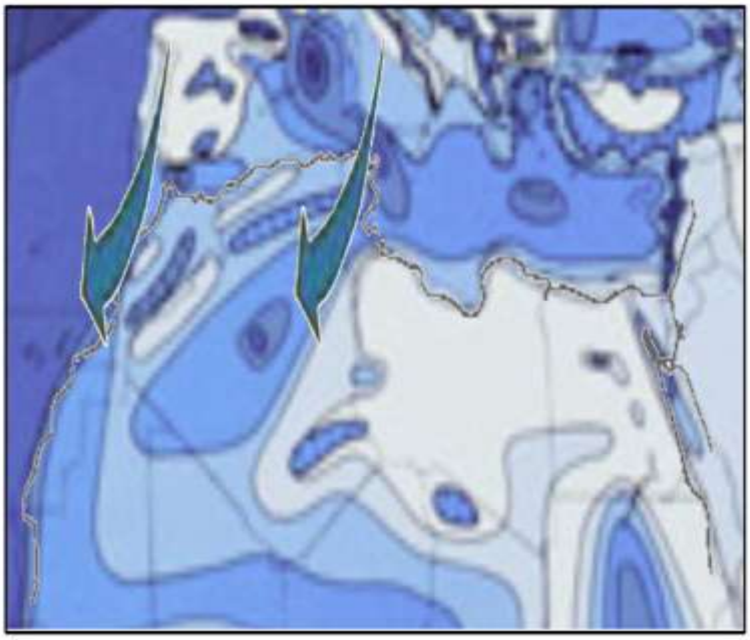


Fig. 2. Fig. 3. Wind chart of Algeria.

Wind energy conversion subsystem (WECS)

The block diagram of the wind energy system adopted in this paper is shown in fig.2. It consists of a horizontal axis wind turbine compiled to a permanent magnet synchronous generator (PMSG). A detailed description of the wind model can be found in [14]. The system is designed to achieve maximum power tracking (MPT) and output voltage regulation within a wide range of wind speed variation by means of MPPT block.

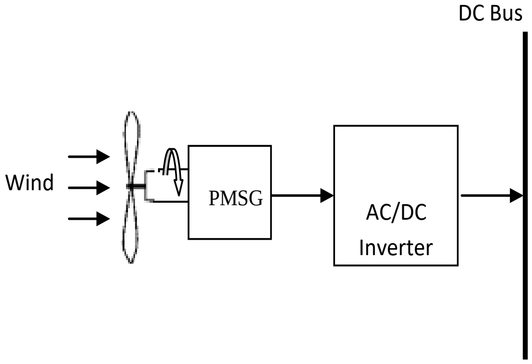


Fig 4. Wind generation system configuration.

Wind turbine model

The power extracted from the wind is given by [4]:

$$P_t = \frac{1}{2}\rho A C_p v^3 \tag{1}$$

Where:

ρ : is the air density in (Kg/m3).

A: is the area swept by the rotor blades in (m2).

ν: is the wind velocity in (m/s).

Cp: is called the power coefficient or the rotor efficiency and is function of tip speed ration and pitch angle.

The tip speed ration is defined as:

$$\lambda = \frac{\Omega R}{v} \tag{2}$$

Where:

Ω: is the rotational speed of the wind turbine in (rad/s).

R: is the blade radius in (m).

Manufactures usually give an experimental relationship between Cp and λ parameters, for several values of the rotation speed Ω. In order to evaluate the Cp coefficient, interpolation functions are used to approximate this experimental relationship, within each range of instantaneous values of λ. From this process, the following expressions result:

$$C_p = -v^3(0.12992\lambda^3 - 0.11681\lambda^2 + 0.45406\lambda) \tag{3}$$

The mechanical system is represented by the following equation:

$$J\frac{d\Omega}{dt} = T_m - T_{em} - f\Omega \tag{4}$$

Where:

J: is the total inertia which appears on the shaft of the generator in (Kg.m2).

Tm: is the mechanical torque in (N.m).

Tem: is the electromagnetic torque in (N.m).

Ω: is the rotational speed of the wind turbine in (rad/s).

f: is a viscous friction coefficient in (N.m.s.rad-1).

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

Permanent magnet synchronous generator (PMSG)

The space vector theory of the space vector gives the dynamic equation of the stator currents as follows:

$$\frac{dI_{sd}}{dt}=\frac{1}{L_d}(V_{sd}-R_sI_{sd}+p\Omega L_q I_{sq}) \quad (5)$$

$$\frac{dI_{sq}}{dt}=\frac{1}{L_q}(V_{sq}-R_sI_{sq}-pL_{sd}I_{sd}\Omega-p\Omega\Phi_m) \quad (6)$$

Where:

Rs: is the phase resistance of the stator wind in (Ω).
Ld and Lq are the d-q stator inductances respectively in (H).
Φ_m: is the flux of the permanent magnetic in (Wb).
Vsd and Vsq: are the d-q components of the stator voltage respectively in (V).
Isd and Isq: are the d-q components of the stator currents respectively in (A).
P: is the number of pairs of poles.
The electromagnetic torque is given by:

$$T_{em}=p(\Phi_m I_{sq}+(L_d-L_q)I_{sd}I_{sq}) \quad (7)$$

SOLAR ENERGY

The history of using solar energy in Algeria backs to 1954 with the solar furnace built by the French for ceramic fabrication purpose [8].

The insulation time over the quasi-totality of the national territory exceeds 2000 h annually and may reach 3900 h (high plains and Sahara). The daily obtained energy on a horizontal surface of 1m2 is of 5 kWh over the major part of the national territory or about 1700kWh/m2/year for the North and 2263kWh/m2/year for the South of the country (Figure 5) [13].

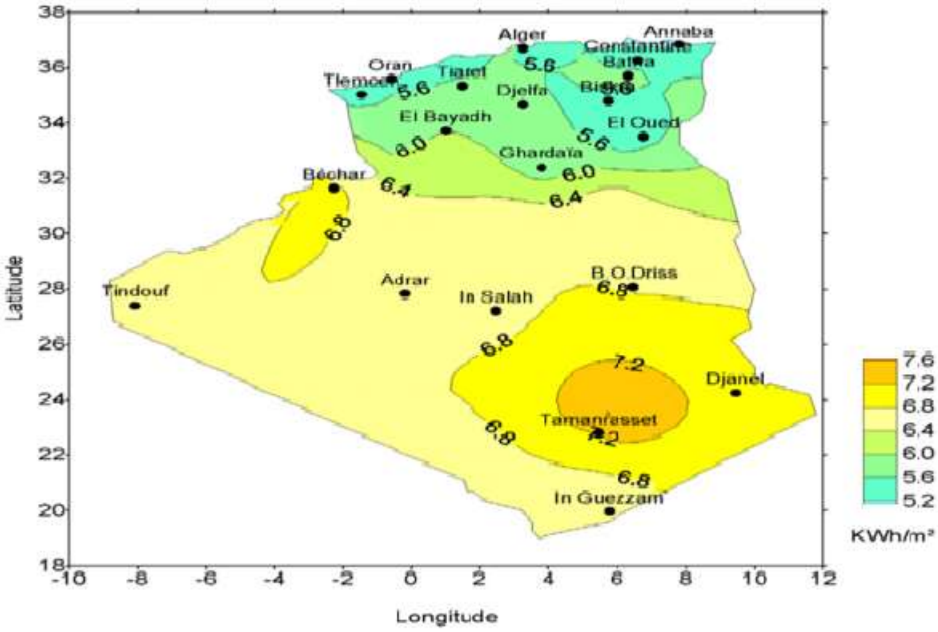


Fig. 5: Potential sites for solar electricity supply in the North Africa region and example of the overall daily exposure received (in kWh/m2/day) in Algeria.

Modelling for PV Cell/Module

The most commonly used model for a PV cell is the one-diode equivalent circuit as shown in Figure 6 [20], [28]. Since the shunt resistance Rsh is large, it normally can be neglected.

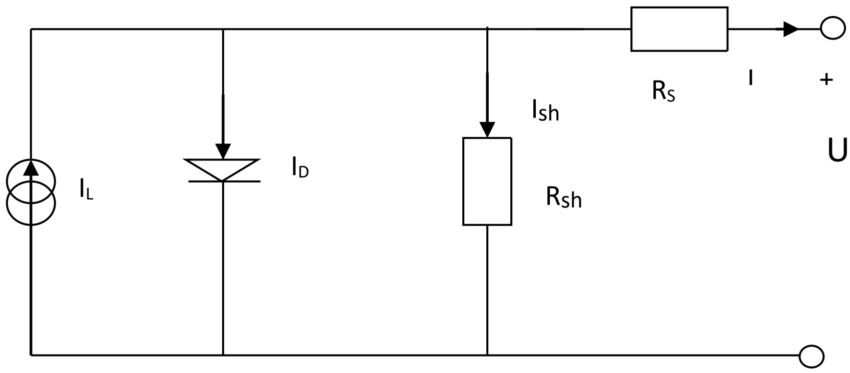


Fig. 6. One-diode equivalent circuit model for a PV cell

The relationship between the output voltage V and the load current I can be expressed as [9], [16], [17].

$$I = I_L - I_D = I_L - I_0[\exp(\frac{U + IR_s}{\alpha}) - 1] \quad (8)$$

Where:
I_L: light current (A);
I_0: saturation current (A);
I: load current (A);
U: output voltage (V);
Rs: series resistance (r);
α: thermal voltage timing completion factor (V).
According to [7] and [8] the Light Current I_L can be calculated as:

$$I_L = \frac{\phi}{\phi_{ref}}[I_{Lref} + \mu_{SC}(T - T_{ref}] \quad (9)$$

Where:
Φ : irradiance (W/m^2);
Φ_{ref}: reference irradiance (1000 W/m^2 is used in this study);
$I_{L,ref}$: light current at the reference condition 1000W/m2 and 25 °C);
T : PV cell temperature (°C)
$T_{,ref}$: reference temperature (25 °C is used in this study);
μ_{SC} : temperature coefficient of the short-circuit current (A/°C).
The saturation current can be expressed in terms of its value at the reference condition as [18], [19]:

$$I_0 = I_{0ref}[\frac{T_{ref}}{T}]^3 \exp[\frac{e_{qap} N_s}{q\alpha_{ref}}(1 - \frac{T_{ref}}{T})] \quad (10)$$

Where:
$I_{0,ref}$: saturation current at the reference condition (A);
e_{gap}: band gap of the material;
N_s: number of cells in series of a PV module;
q: charge of an electron (C);
α_{ref}: the value of W at the reference condition.

DIESEL GENERATOR

Diesel generator sets convert fuel energy (diesel or bio-diesel) into mechanical energy by means of an internal combustion engine, and then into electric energy by means of an electric machine working as generator [20]

The main parts of a diesel generator are: the internal combustion engine, usually air- or water-cooled; the electric generator usually of synchronous type; the mechanical coupling; the support chassis; the battery for generator start-up; the fuel tank; the starter motor; the command panel, etc.

The diesel generator sets are usually designed to run at 3000 rpm or 1500 rpm at a frequency of 50 Hz. The primary movers are internal combustion engines equipped with mechanical regulators to keep the imposed speed, integrated in the injection pump and adjusted to obtain an output frequency of about 52 Hz without load and 50 Hz for rated load [20].

A detailed modeling of the diesel generator is found in [20].

ULTRA CAPACITOR BANK

Ultra capacitors or electrochemical double layer capacitors take advantage of the charge stored in their electrochemical double layer and provide high capacities. Thanks to their capacity, ultra capacitors can store an higher amount of energy than conventional capacitors. Moreover, ultra capacitors are currently available on the market with capacitance ranges up to 2700F for a voltage of 2 to 3V; they can release energy at high or low rate [21], [28].

The classical equivalent circuit of the UC unit, shown in Figure 7, consists of a capacitance (C), an equivalent series resistance (ESR) representing the charging and discharging resistance and an equivalent parallel resistance (EPR) representing the self-discharging losses [22], [23].

The EPR models leakage effects and influences long-term energy storage performance of the UC [24], [25].

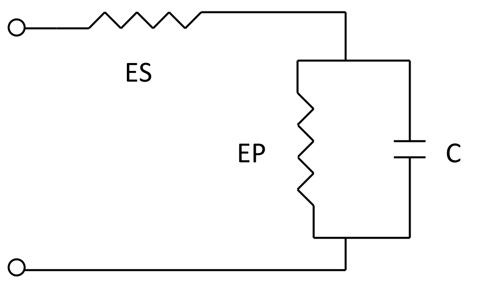


Fig. 7. Classical equivalent model for the UC unit.

The state of charge of the UC can be described as a percent age of the rated energy capacity, which depends on the terminal output voltage. The energy flowing out from the UC is directly deter mined by the capacitance and the voltage change as expressed in Eq11, [23],[27].

$$E = \frac{1}{2} C (V_i^2 - V_f^2) \quad (11)$$

Where:
V_i: initial voltage.
V_f: final voltage.

The real UC bank can be modeled by using multiple UC cells in parallel and series. The total resistance and capacitance of the UC bank are given by [26]:

$$R_{UCbank} = n_1 \frac{R_{ESR}}{n_2} \quad (12)$$

$$C_{UCbank} = n_2 \frac{C}{n_1} \quad (13)$$

Where:
n_1: number of capacitors in series.
n_2: number of UC branches in parallel.
R_{ESR}: equivalent series resistance.

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

The state-of-charge (SOC) of the ultra capacitor is defined as:

$$SOC = \frac{V_{oc}}{V_{\max}} \quad (14)$$

Where:

V_{oc}: is the open-circuit voltage of the ultra-capacitor.

V_{max}: is the maximum open-circuit voltage of the ultra-capacitor at full charge.

POWER MANAGEMENT STRATEGY

The figure below shows the flow chart of system management.

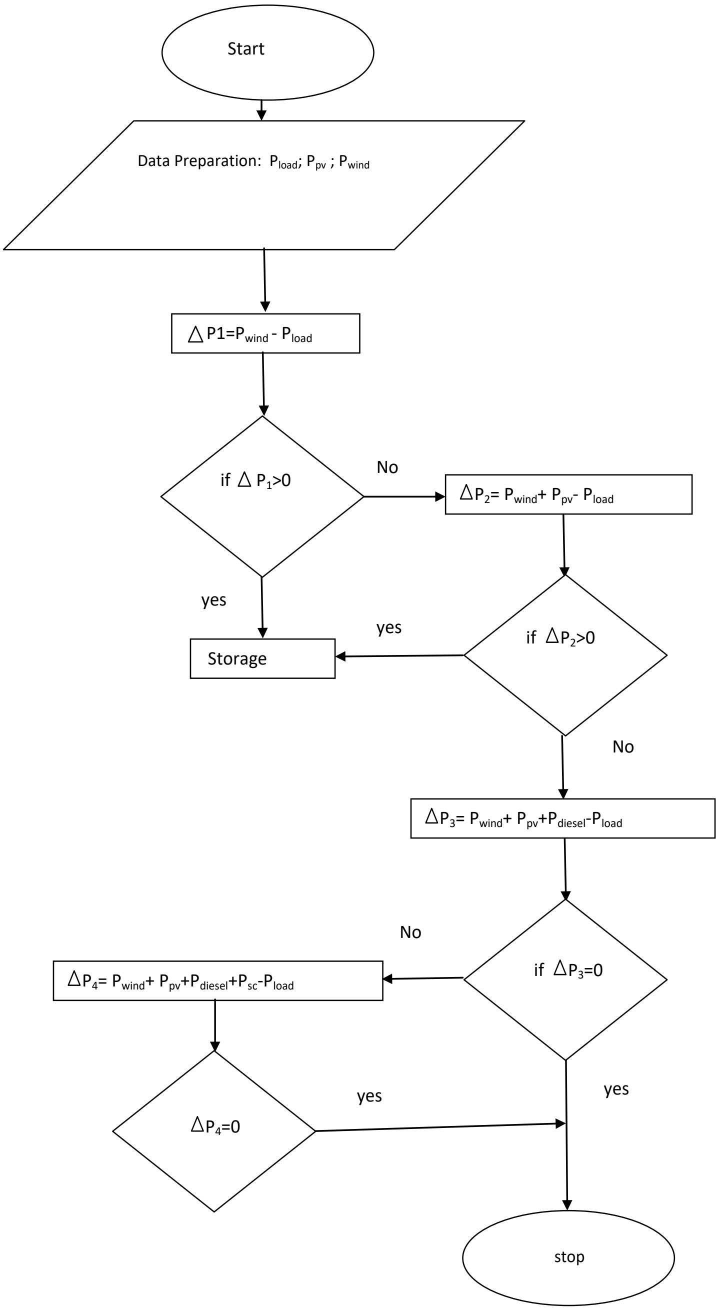


Figure 8. Flow chart of system management

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

SIMULATION RESULTS

Based on the component models given earlier, a simulation system for the proposed hybrid energy system has been developed in Matlab/Simulink.

Figure 9 shows in seconds Load power demand.

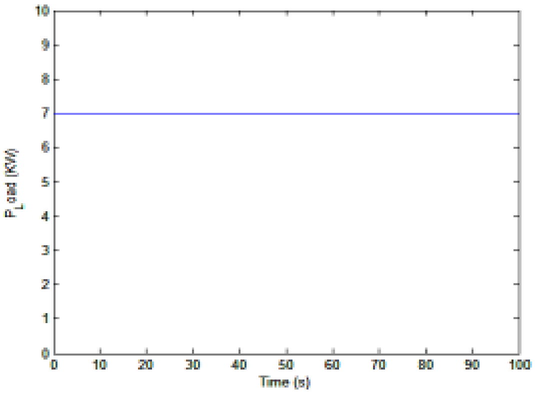


Fig. 9. Load power demand.

The power generated from photovoltaic generator is given in Figure 10.

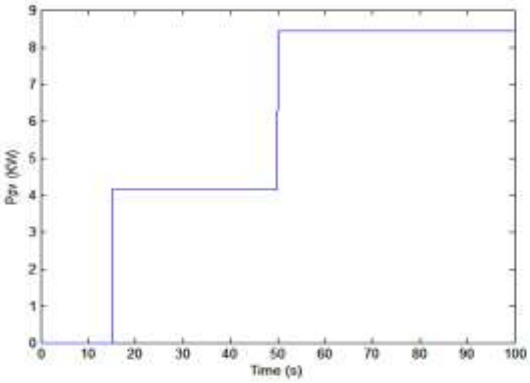


Fig. 10. Power from PV generator

The wind speed variation is presented on the Figure. 11.

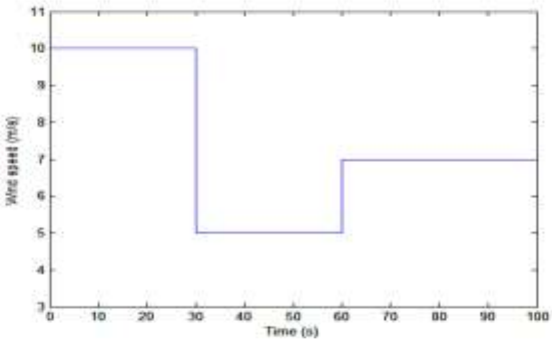


Fig. 11. Wind speed.

The output power from the wind energy conversion system is shown in Figure 12.

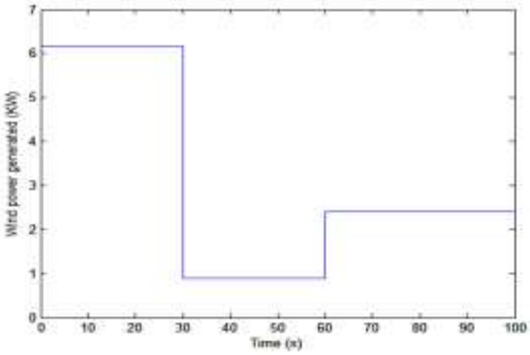


Fig. 12: Wind power generated.

Figure 13 shows the power output of the diesel generator.

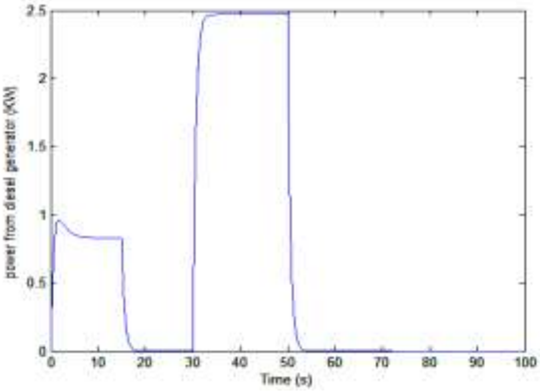


Fig. 13. Power from diesel generator

When the wind/PV hybrid system generated power from is not sufficient to supply the load demand (because of a drop in the wind speed (see Figure 14) and during in the small irradiation (see figure 11, for example between 30 and 50 s). Under this condition, diesel generator turns on to supply the power shortage and the UC bank serves as a short duration power source to meet the excess power that cannot be satisfied by the diesel generator because of their response t

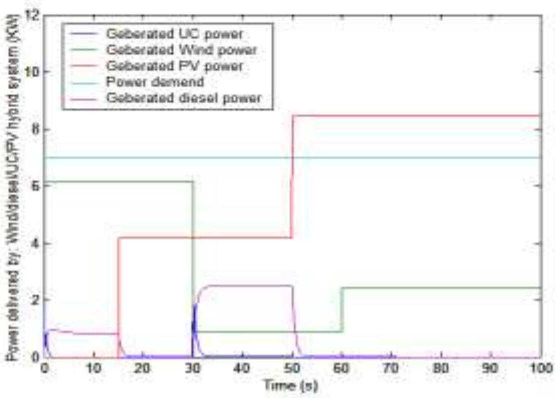


Fig. 14: Power delivered by: Wind/diesel/UC/PV hybrid system

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

The power storage by the Wind/diesel/UC/PV hybrid system is show in figure 15

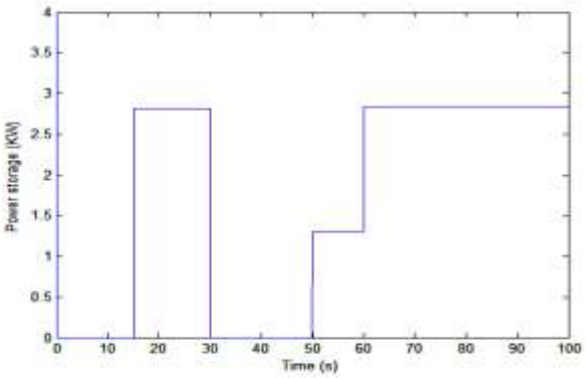


Fig. 15: Power storage by: Wind/diesel/UC/PV hybrid system

CONCLUSION

In this paper, a hybrid wind/FC/UC System Performance is proposed;
The photovoltaic (PV), wind turbine system, ultra-capacitor, diesel generator system and their component are modeling and smiling used MATLAB/SIMULINK.
The results show also the excellent performance of the hybrid topology proposed. The UC bank serves as a short duration power source to meet the excess power that cannot be satisfied by the photovoltaic wind hybrid system or the diesel generator.

REFERENCES

[1] Xue Li, , Vasu D. Chakravarthy, , Bin Wang, and Zhiqiang Wu, "Spreading Code Design of Adaptive Non-Contiguous SOFDM for Dynamic Spectrum Access" in IEEE JOURNAL OF SELECTED TOPICS IN SIGNAL PROCESSING, VOL. 5, NO. 1, FEBRUARY 2011
[2] A. Agus Setiawan, Y. Zhao, R. Sunsanto lee, and V. Chem, "Desigen of Hybrid Power System with Reverse Osmosis Desalination Plant for Maldivers,". DESALINATION, 122:144-15, NAYAR 2008.
[3] A Hazed A, "chnical Analysis of an Electric. Power System Consisting of Solar PV Energy. Wind Power and Hydrogen Fuel Cell," in proc power Energeting Conferance. AUPIC. PP, S. 1,MAY 2007.
[4] H. Koinuma, A. Boudghene Stambouli, "Current status and future plan of SATREPS-SSERC (Sahara Solar Energy Research Center) project". 3rd AASEF (3rd Asia-Arab Sustainable Energy Forum) Jointly with 5th International SSB Workshop, Hirosaki, Aomori, Japan, , s. 6-8 MAY 2013.
[5] A. Boudghene. Stambouli, Z. Khiat, S. Flazi, Y. Kitamura, "A review on the renewable energy development in Algeria: Current perspective, energy scenario and sustainability issues". Renewable and Sustainable Energy Reviews Vol 16, , s. 4445–4460. 2012.
[6] L, Fernandes, P. Ferreira, "Renewable energy scenarios in the Portuguese electricity system". Energy 2014; 69, s. 5 1e 7. http://dx.doi.org/10.1016/ j.energy. 02, s. 098. 2014.
[7] MEM. http: //www.mem-algeria. org/ fr /enr/ carte vents.htm. 2005.
[8] Koinuma H., Kurokawa K., Kitazawa K., Fujioka H., Sumiya M., Furuya Y.: "Oxide initiative to make the dream of 'Sahara Solar Breeder Plan' come true. 17th international workshop on oxide electronics, Awajishima, Japan..WOE-17 Abst. s. 100530. 2010.
[9] Fergani S., SiAli M., Flazi S., Stambouli Boudghene A.: "Optimization of solar source based net-work". International Conferenceon Renewable Energiesand Power Quality (ICREPQ'14) Cordoba (Spain). Renew Energy Power QualJ (REPQJ), s. 2172-038X 12,.2014.
[10] Fergani S., SiAli M , Flazi S., Stambouli Boudghene A.: "Solar source based net- work, optimal generator position & economic cables sections". Grand renew- able energy Proceedings, July27–August1., 2014.
[11] Fergani S., Flazi S, Boudghene Stambouli A., Mokhtaria S .: Optimization of distribution net -works supplied by photovoltaic sources, using a new optimal loads distribution center method" .Renewable and Sustainable Energy Reviews 56, 2016, s. 8875–892.

[12] Malwé B H., Noë D., Yamigno D., Njoya M M Y., Gambo B., Crépin KT.: "Reducing electrical energy losses in photovoltaic source distribution networks". Int JBasicApplSci,;. 257–62. s 3(3)2014.

[13] Algeria energy report, /http://endofcrudeoil. Blog spot.com , 03,2012 . // algeria - energy-report. html S; 2012.

[14] Ait Mimoune H., Stambouli A B., Flazi S H.: " A review on the water and energy sectors in Algeria. Current forecasts, scenario and sustainability issues" Renewable and Sustainable Energy Reviews, s. 261–276. 41,2015.

[15] Eminoglu U.: "Modelling and Application of Wind Turbine Generating Systems(WTGS) to. Distribution Systems". In J Renewable Eneergy, s. 2474-2483. 34, 2009.

[16] Meharrar A., tioursi ., Hatti M., Stambouli A B.: "A variable speed wind generator maximum power traking passed on adaptative neuro-fuzzy inference system". J Expert Systems with Applications, s.7659-7664 . 38, 2011.

[17] Ulleberg Ø., MØRNER S O. :TRNSYS simulation models for solar -hydrogen systems. Solar energy, s. 271-279. Vol.59, No. 4-6, 1997.

[18] Wang C., "Modeling and control of hybrid Wind/Photovoltaic/Fuel distributed generation systeme". Doctor of philosophy dissertation. MONTANA STATE UNIVERSITY Bozeman, Montana July 2006.

[19] Ulleberg Ø., "Stand-Alone Power Systems for the Future: Optimal Design, Operation & Control of Solar-Hydrogen Energy Systems". Ph.D. Dissertation, Norwegian University of Science and Technology, Trondheim, 1998.

[20] Townsend T U."A Method for Estimating the Long-Term Performance of Direct-Coupled Photovoltaic Systems", MS thesis, University Of Wisconsin – Madison, 1989.

[21] Tudorache T., Roman. C. "The Numerical Modeling of Transient Regimes of Diesel Generator Sets", Acta Polytechnica Hungarica, s.Vol.7, No 2, 2010.

[22] Kisacikoglu MC., Uzunoglu MC ., Alam M. "Load sharing usingfuzzy logic control in a fuel cell/ultracapacitor hybrid vehicle"; in Int J hydrogen energy, s. 497–1507. 34,2009.

[23] Zhang X., A Masrur and D., Danis zewski. "Wavelet based power management of hybrid electric vehicles with multiple onboard power sources", in J Power Sources, 185, s. 1533-1543. 2008.

[24] Spyker R L., Nelms R M. " Analysis of double-layer capacitors supplying constant power loads", in IEEE Trans Aerosp Electron Syst, s. 1439–1443. 36 (4), 2000.

[25] Spyker R L., Nelms R M. "Classical equivalent circuit Parameters for a Double-Layer Capacitor" in IEEE Trans. onAerospace and Electronic Systems, , s. 829-836. 36(3),2000.

[26] Kotsopoulos JL.,Duarte M., Hendrix A. "converter to interface ultra-capacitor energy storage to a fuel cell system. ", in IEEE International Symposium on Industrial Electronics, s. 827 –832. 2, 2004.

[27] Wenzhong G. " Veh. Technol. " in IEEE Trans.; s. 846–855. 54 (3),2000.

[28] Candusso. D, Rulličre. EE, and Toutain. E. "A Fuel Cell Hybrid Power Source for a Small Electric Vehicle", in Energy Renewable: Power Engineering, s. 85-92. 2001.