Demand Response and Optimal Sizing of Hybrid Renewable Energy Systems

Fatma Zohra Dekhandji, Mouould Bouaraki, Nadhir Zaidi and Abdelmadjid Recioui
Laboratory Signals and Systems, Institute of Electrical and Electronic Engineering,
University M'hamed Bougara of Boumerdes, Avenue de l'indépendance, 35000.
Boumerdes, Algeria.
E-mail: fzdekhandji@yahoo.fr

Abstract— **Energy is a vital and essential element of our modern world. Its importance lies in the development process and its close association with sustainable development. This matter stimulated the search need for renewable energy resources, which are environmentally friendly to reduce environmental pollution on one hand, and reduce the pressure on the traditional energy use on the other hand. In this work, a design optimization of a system to illustrate energy management including renewable energy is done using Homer. Next, the system is simulated and tested using LABVIEW. The goal is to verify the adequacy of the designed system and its real life applicability.**

Keywords-Smart grids;demand response, renewable energies, HOMER, optimization.

I. INTRODUCTION

In recent years, there has been an proliferating rise in energy demand due to the economic growth in the industrialized countries, the increase in industry rates and the improvement of the technologies, the development in various fields and the rising oil prices [1-2]. For that, countries have no choice just to look for new energy sources, clean and cheap, especially as concerns over global warming and climate change persist. As a consequence, a considerable growth in using renewable energy resources has been observed [1-16].

Particularly, solar and wind energy are infinite, site-dependent, clean and high potential sources for alternative energy production [1-2]. Hybrid energy systems are the best suited to reduce dependence on fossil fuel using available wind speed and solar radiations [1-16]. The integration of renewable energy sources is not a straightforward operation but it needs a techno-economical analysis and requires the data of the renewable resources [9].

Sizing hybrid systems has been in the last two decades a large research field and many methods have been suggested to solve that problem. Particularly, research is carrying on the modeling accuracy of the component of the hybrid system and the followed power management strategies. The control strategy is the heart beating of any algorithm subjected to optimize a hybrid system, in 1996 Barley and Winn improved the control strategies model of introducing new parameters that have become of great importance in the control strategies of the software tools HYBRID2, HOMER and HOGA [9,16].

HOMER (Hybrid Optimization Model for Electric Renewables), developed by NREL (National Renewable Energy Laboratory in USA), is the most-used optimization software for hybrid systems. It uses a predictive control strategy where the charging of the batteries depends on the prediction of the demand and the energy expected to be generated by means of renewable sources, with this strategy, the energy loss from the renewable energies tends to decrease. Usually, the optimum design is carried out minimizing the Net Present Cost (NPC: investment costs plus the discounted present values of all future costs during the lifetime of the system) or by minimizing the Cost of Energy (COE: total cost of the entire hybrid system divided by the energy supplied by the hybrid system), the results obtained by each used tool will be evaluated by that economic criterion [5].

The goal of this paper is to illustrate the benefits of energy management including the renewable energies. It depicts a design optimization model by Homer software. The simulation and testing of the energy management system including the renewable energy sources is performed in LABVIEW software.

II. THE DEMAND-RESPONSE CHALLENGE

Demand response provides an opportunity for consumers to play a significant role in the operation of the electric grid by reducing or shifting their electricity usage during peak periods in response to time-based rates or other forms of financial incentives.

Some electric system planners and operators as resource options for balancing supply and demand are using demand response programs that can lower the electricity cost in wholesale markets, and in turn, lead to lower retail rates.
The electric power industry considers DR programs as an increasingly valuable resource option whose capabilities and potential impacts are expanded by grid modernization efforts. For example, sensors can perceive peak load problems and utilize automatic switching to divert or reduce power in strategic places, removing the chance of overload and the resulting power failure. Smart customer systems such as in-home displays or home-area-networks can make it easier for consumers to changes their behavior and reduce peak period consumption from information on their power consumption and costs. These programs also have the potential to help electricity providers save money through reductions in peak demand and the ability to defer construction of new power plants and power delivery systems [17].

Demand Response is a program that helps electricity customers monitor and manage their energy usage by

ISSN 2356-5608

allowing them to participate in electricity markets to respond to price changes through which customers reduce their electricity consumption in response to either high wholesale prices or system reliability risks.

The Federal energy Regulatory Commission (FERC) of the United States defines the term DR as “changes in electric usage by demand side resources from their normal consumption patterns in response to changes in the electricity price over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized” [18].

The DR concept is similar to dynamic demand mechanisms that aim to manage customer electricity consumption in response to supply conditions for example, customer’s tendency to reduce their electricity consumption at critical times or in response to market prices. However, the difference is that demand response mechanisms meet direct demand and turn off, while dynamic demand devices tend to turn off fully when network pressure is detected.
In addition, the DR may include a reduction in the level of energy actually used or through the initiation of on-site power generation, which may or may not be parallel to the grid.

At the same time, the demand response system is one of the smart energy demand components includes the energy efficiency concept, home and building energy management, distributed renewable resources and the electric vehicles shipment [17].

Understanding and managing electric load is critical to participating in DR programs. Before we can manage the energy use, it is helpful to understand the energy demand (the sum of the various electric loads in our business at any given time) and how we are charged for that energy. Each utility charges its customers for energy amount they consume. In addition, commercial and industrial customers are also frequently billed for their peak demand, the highest rate at which the customer is using energy, generally measured in kilowatts (KW) over a one-hour period.

A load shape (known also as the load profile) is a graphical representation of how a customer uses electricity over the course of a day. The height of the graph at any point shows the customer’s peak demand; the area under the load shape is the amount of energy consumed, in kilowatt-hours (kWh), over a given time period.

When customers are billed for energy amount they use, they are often also billed for their demand magnitude, the maximum electricity amount of drawn from the grid at a single moment in time. This demand charge is usually based on the highest amount of demand registered during the billing period (the peak demand). Demand charges to the highest level achieved in preceding period (such as the previous six months). Because a demand ratchet can be a considerable percentage of the bill, C&I customers should peak demand whenever possible to reap the economic benefits.
Consumers, who manage their facility load profiles with a view to reducing their peak demand charges, are effectively undertaking their own DR program. It is entirely possible for consumers to practice their own DR program in response to conventional rate structure while participating in system operator or utility DR programs at the same time [19].

III. SIZING OF RENEWABLE ENERGY SYSTEMS

The optimal design for hybrid power systems is dependent and closely related to place of application. Therefore, the main objective of the present study is to determine the optimum solar/wind system that can provide the electricity needs in the research center **(CDER)** of Bouzareah, Algeria as average monthly consumptions. The system size and cost optimization is carried out based on the on-site measured data of wind and solar energy characteristics.

Bouzareah is a town located 8 km from the center of Algiers. It is considered as home to several major institutions. Among them, The Center for the Development of Renewable Energies (CDER) which holds world-leading scientific achievements in the field of solar power concentration over the African continent.

A. Solar and Wind data

Solar irradiance data and wind speed historical data were measured for one year by CDER, which belongs to Bouzereah. Table 1 shows the observed wind speed data during 2015 were obtained at 10 meters above ground level with an anemometer. These data were used to investigate the wind power potential of this region.
The highest monthly mean wind speed of 4.795 m/s occurred in April, while the lowest mean wind speed of 3.197 m/s occurred in October. The mean annual wind velocity was 3.839 m/s.
In addition, the table presents the estimated solar PV energy in (kWh/m2 day) of solar irradiance for horizontal surfaces: the highest monthly mean solar irradiation is recorded inJune as 7.200 KWh/ m^2 where the lowest is recorded in December as 2.150 KWh/ m^2.

Table 1 Monthly average of wind speed, solar irradiation and temperature in CDER of Bouzereah, Algeria. [28]

Month	Solar irradiation (KWh/m^2)	Wind speed (m/s)	Temperature (°C)
Jan.	2.480	3,600	10,930
Feb.	3.380	3,890	13,420
Ma.	4.590	4,100	15,540
Apr.	5.690	4,795	19,276
May	6.490	4,300	24,646
June	7.200	4,100	29,670
July	7.130	3,797	32,787
Aug.	6.440	3,496	32,554
Sept.	5.280	3,904	27,689
Oct.	3.820	3,197	21,648
Nov.	2.630	3,398	15,131
Dec.	2.150	3,495	11,618

ISSN 2356-5608

International Journal of Control, Energy and Electrical Engineering (CEEE)
Vol.7 pp.35-40

B. The load description

The study area consists of 20 houses each has a living area, kitchen, toilet and laundry area. The study will deal with one, two, three or four bedroom homes that are usually occupied.

The typical relevant electrical loads are lighting, kitchen appliances (electric refrigerator, electric stove with oven and toaster), TV, computer, laptop computer, electric water heating and air conditioning to operate in approximately 8 months per year.

One of the programs that helps to know the technical and economic studies of hybrid systems, which was used in Algeria is Homer's software, which enables the combination of wind turbines, PV arrays, run-of-river hydro power, biomass power, internal combustion engine generators, micro turbines, batteries, and hydrogen storage, serving both electric and thermal loads.

The best feature of this program is the sensitivity analysis in addition to allowing guessing all costs such as initial capital and maintenance costs including pollution penalties. The optimization aims is to assess the economic and technical feasibility of a large technology options number, taking into account differences in technology costs and the energy resources availability.

C. The considered system

The system under consideration is a PV/Wind/Gasoline generator hybrid system as shown in Fig. 1. It consist of:

- ✓ Three (03) wind turbines from generic type that has a rated power of 3 KW AC. Each one has a 20 years lifetime with a 25 m as hub height. The typical power curve of these turbinesis shown in **Fig III.3**. The capital cost for one turbine is at 3900$ with the replacement assumed at the same price and the operation/maintenance costs at 100$/year.
- ✓ The Gasoline generator is a 2.61kW with a capital cost of 500$ and a lifetime of 5000 operating hours. Again replacement is assumed to be at the same price with the operation/maintenance costs at 0.03$/h. The fuel price is taken to be constant and it is 0.32$/Litter.
- ✓ Twenty-four (24) batteries from Lead Acid model that has a nominal voltage of 12V and a 1KWh as capacity. Their capital cost and replacement cost is considered fixe at 300$ and operating/maintenance cost of 10$/year.
- ✓ For DC/AC or AC/DC conversion, up to 5 items of 1kW converter is used. The capital cost of such a converter is fixed at 300$ and the same replacement price and no operating/maintenance costs. These have 15year lifetime and 90% efficiency.
- ✓ Two (02) PV panel from flat plate model that has a rated power of 200 KW AC. One has a capital cost of 3000$ with the replacement assumed at the same price and the operation/maintenance costs at 10$/year, and the second one has a capital cost of 5000$ with the replacement price of 4500$and the operation/maintenance costs at 20$/year.

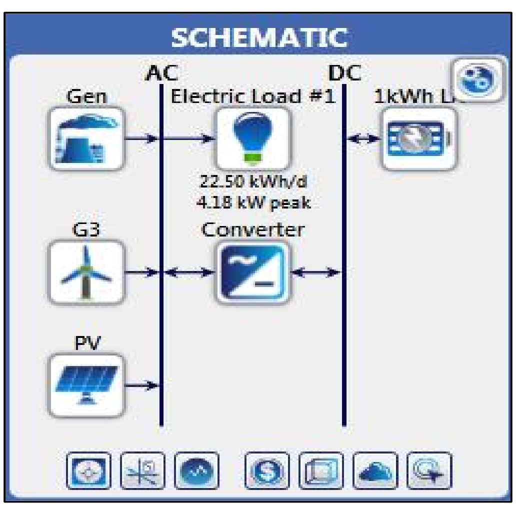


Fig. 1 The hybrid system considered for optimization

The load demand considered is for home consumption profile. The seasonal profile, which is presentedin Fig. 2, shows a relatively constant power demand over all the year.

The Fig. 3 represents the daily consumption. The chart shows that consumption increases during the day especially in the early morning, noon and night beginning when it starts to decline and negligible at night.

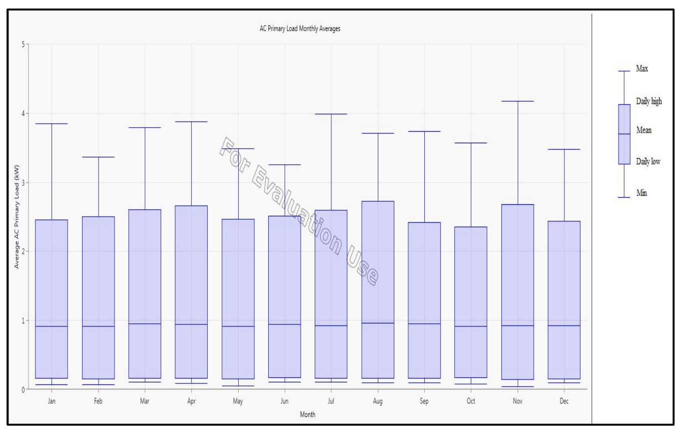


Fig. 2 the seasonal profile of the considered load.

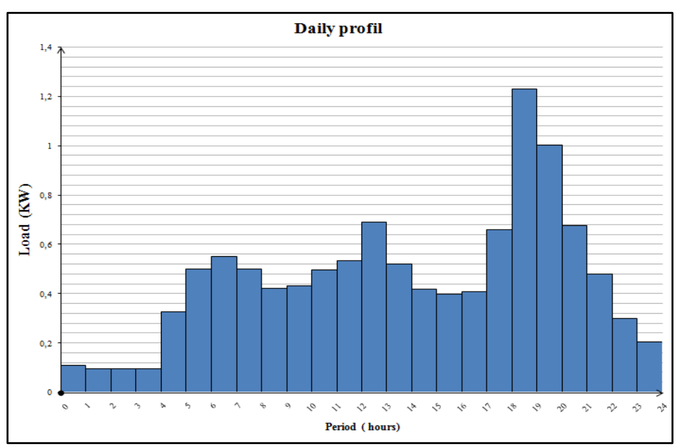
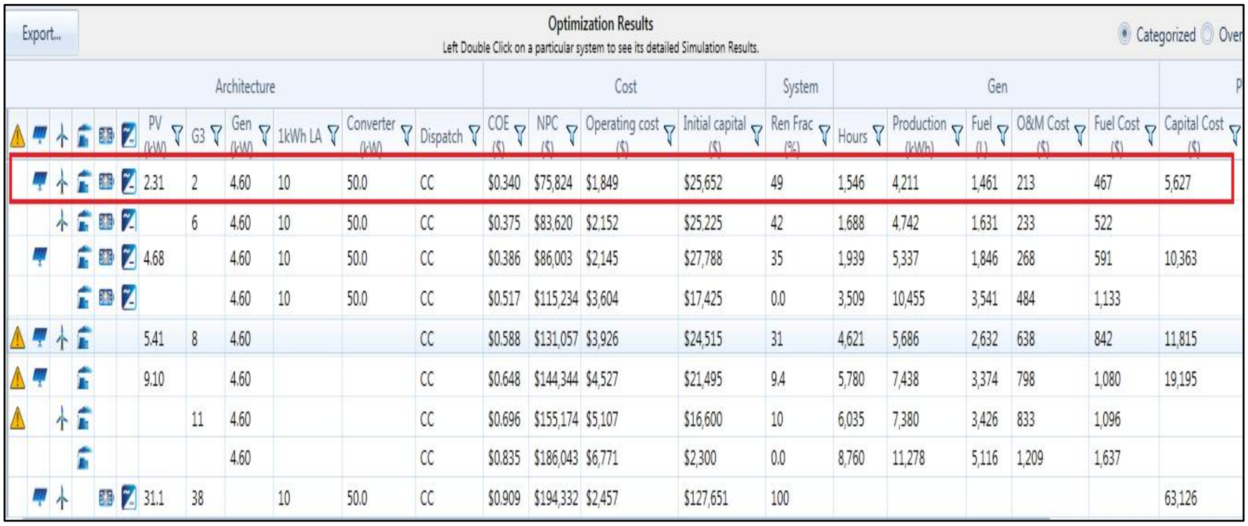


Fig. 3 The daily consumption of the considered load.

ISSN 2356-5608

International Journal of Control, Energy and Electrical Engineering (CEEE)
Vol.7 pp.35-40



Optimization Results
Left Double Click on a particular system to see its detailed Simulation Results.

Architecture						Cost				System	Gen					
PV (kW)	G3	Gen (kW)	1kWh LA	Converter (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)	Ren Frac (%)	Hours	Production (kWh)	Fuel (L)	O&M Cost ($)	Fuel Cost ($)	Capital Cost ($)
2.31	2	4.60	10	50.0	CC	$0.340	$75,824	$1,849	$25,652	49	1,546	4,211	1,461	213	467	5,627
	6	4.60	10	50.0	CC	$0.375	$83,620	$2,152	$25,225	42	1,688	4,742	1,631	233	522	
4.68		4.60	10	50.0	CC	$0.386	$86,003	$2,145	$27,788	35	1,939	5,337	1,846	268	591	10,363
		4.60	10	50.0	CC	$0.517	$115,234	$3,604	$17,425	0.0	3,509	10,455	3,541	484	1,133	
5.41	8	4.60			CC	$0.588	$131,057	$3,926	$24,515	31	4,621	5,686	2,632	638	842	11,815
9.10		4.60			CC	$0.648	$144,344	$4,527	$21,495	9.4	5,780	7,438	3,374	798	1,080	19,195
	11	4.60			CC	$0.696	$155,174	$5,107	$16,600	10	6,035	7,380	3,426	833	1,096	
		4.60			CC	$0.835	$186,043	$6,771	$2,300	0.0	8,760	11,278	5,116	1,209	1,637	
31.1	38		10	50.0	CC	$0.909	$194,332	$2,457	$127,651	100						63,126

Fig. 4 the optimization results with the optimum systems ranked.

D. *Sizing results*

Once the specification described above is set in HOMER, it performs calculations to determine the best combination that meets the technical and economic requirements as shown in Fig. 4. In the system we simulated, Homer shows us that the optimal system is to combine PV panels with wind turbines and gasoline generators together with the battery bank and the converter.

IV. SYSTEM TESTING THROUGH SIMULATION

The application is about energy management including renewable energies, which means the grid will compensate the lack in energy in the peak load reduction when the energy demand exceeds the available energy by enabling the renewable energy sources.

As a small and simple presentation of the virtual life and virtual components, which will be integrated in the smart grid, we have represented that the grid contains five (05) houses, each house has its own used equipment that increases the energy consumption.

The results of the test being performed are presented using figures, which display the LABVIEW front panel of the developed system. We have tested five different cases:

Case one : The energy consumption is ordinary (Less than 40KWh). The green LED indicates normal consumption.

Case two : The energy consumption is medium (between 40KWh and 65KWh). The orange LED indicates that the consumption is increase and approaches the power getting from the Gasoline power station.

Case three : The energy consumption is high (between 70KWh and 80KWh). The red LED indicates that the consumption is greater that the power getting from the Gasoline power station and the blue LED indicates that the first stage of the Solar wind farm is activated.

Case four : The energy consumption is high (between 80KWh and 90 KWh). When the consumption is still rising, the blue LEDs indicate that the first and the second stages of the Solar wind farm are activated.

Case five: The energy consumption is high (Greater than 90 KWh). When the third stage of the Solar wind farm is activate, all LEDs are glowing in blue in order to compensate the peak load reduction.

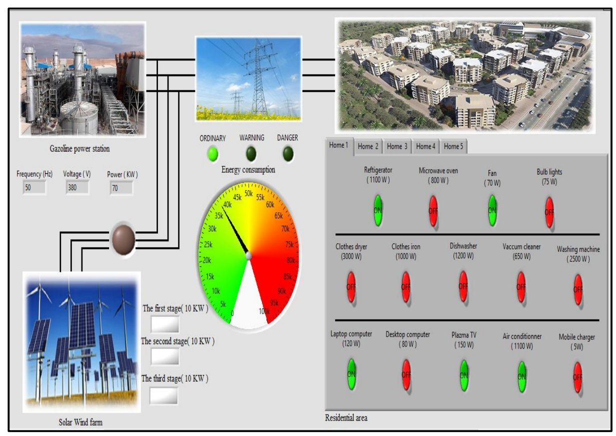


Fig. 5 the energy consumption is ordinary (Less than 40 kWh)

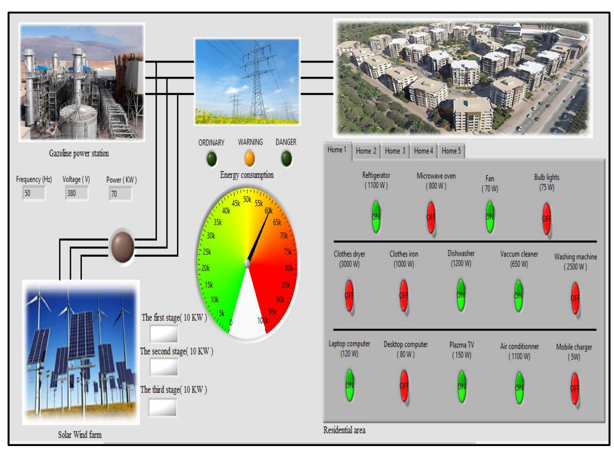


Fig . 6 the energy consumption is medium (between 40KWh and 65KWh)

ISSN 2356-5608

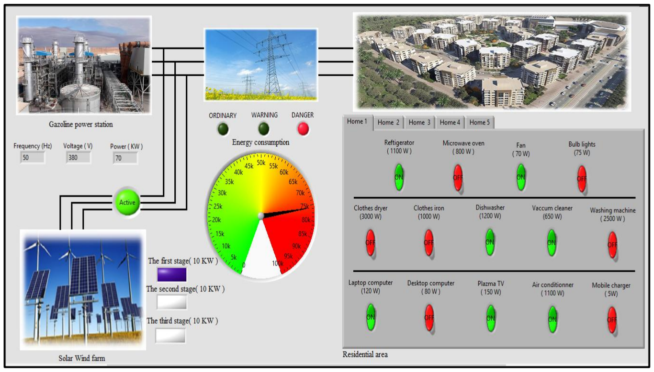


Fig. 7 the energy consumption is high (between 70KWh and 80KWh)

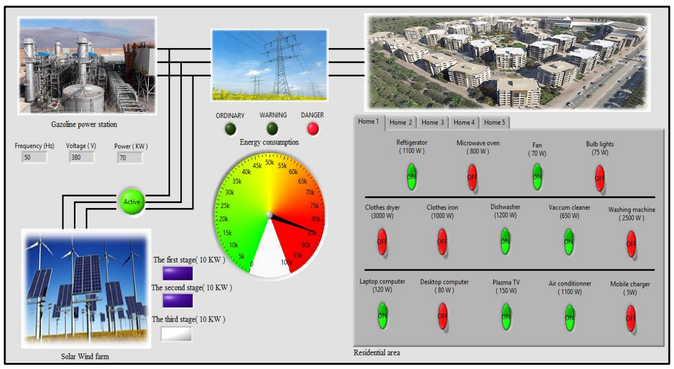


Fig. 8 the energy consumption is high (between 80KWh and 90 KWh)

Fig. 9 he energy consumption is high (Greater than 90 KWh)

The following points may be mentioned about the testing results:

- In the displayed figures, the gageis represented the energy consumption of controlled five houses and the three LEDs (ORDINARY – WARNING – DANGER)will indicate the occurrence of thepower on the grid, which is coming from the Gasoline power station and compared with the houses energy consumptions.
- We suppose that the Gasoline power station has a frequency of 50Hz, a peak voltage of 380 V and peak power of 70 KW.
- When the energy consumption is exceeded the power coming from the Gasoline power station, the Solar wind farm stages will active automatically and immediately to compensate this reduction.
- By testing the behavior of the developed system under different conditions (increase of the energy demand), the Solar wind farm was able to recognize the appropriate incompletion.
- When the Solar wind farm stages active, the LEDs indicators has the ability of indicating the correct stage of operation in all cases.
- The Solar wind farm energy increases when the energy consumptions is higherthan the Gasoline power.

V. CONCLUSIONS

In this paper, we have shown how renewable energies integrated to the grid can maintain the electric system in balance and how this integration is useful for both customers and utilities. We have divided our design of a hybrid system used solar and wind power energies in two parts: Homer software gave us the possible optimization and costing to our system and the second part which has been successfully developed based on LABVIEW software to test the demand response program.

By testing the behavior of the developed system under different conditions, the hybrid system has been able to satisfy the consumption. Finally, after the test, it can be noticed that the obtained results demonstrate the principle of integrating the renewable energies within the smart grid. Moreover, it can be concluded that this proposed scheme has the following advantages:

- Increasing the supply of renewable energy would allow us to replace carbon intensive energy sources andsignificantly reduce global warming emissions.
- In addition to jobs and economics benefits, the used of renewable energy make stable energy prices.

In the light of the results and observations obtained, one can make recommendations in a manner that deals with the promotion of the economics of renewable energies and appreciates their developmental role in rationalizing the context of economic growth, social stability and environmental balance.

REFERENCES

[1] Recioui A, Bentarzi H, Chellali F, Stand-alone system optimization and assessment of wind energy potential of a remote area in Algeria, International Symposium on Environment Friendly Energies in Electrical Applications, 2-4 November 2010.
[2] Farouk Chellali, Adballah Khellaf , Adel Belouchrani , Abdelmadjid Recioui ,"A contribution in the actualization of wind map of Algeria", Elsevier, Renewable and Sustainable Energy Reviews 15 (2011) 993–1002
[3] Rusawasatt Lutato, Minimising Excess energy in Sizing of Hybrid Renewable Power Systems, SCIE Journals, 2012.
[4] Kashefi Kaviani, et al ,Soft Computing in Green and Renewable Energy Systems, Springer, 2009
[5] HOMER energy modeling software. National Renewable energy laboratory. Available from: http://en.openei.org/wiki/HOMER.

ISSN 2356-5608

[6] Pei Yi Lim, Power Management Strategies for Off-Grid Hybrid Power Systems, Doctor of Philosophy of Curtin University, October 2011.
[7] Mohammadi M, Hosseinian SH, Gharehpetian GB, GA-based optimal sizing of microgrid and DG units under pool and hybrid electricity markets. Int J Elect Power Energy Syst 2012;35(1):83e92.
[8] Hanieh Borhanazad a, Saad Mekhilef a, Velappa Gounder Ganapathy b, Mostafa Modiri-Delshad, Ali Mirtaheri, “Optimization of micro-grid system using MOPSO Renewable Energy”, 71 (2014) 295e306
[9] Erdinc O, Uzunoglu M. Optimum design of hybrid renewable energy systems: overview of different approaches. Renew Sustain Energy Rev 2012;16(3): 1412e25.
[10] Luna-Rubio R, Trejo-Perea M, Vargas-V azquez D, Ríos-Moreno GJ. Optimal sizing of renewable hybrids energy systems: a review of methodologies. Sol Energy 2012;86(4) 1077e88.
[11] Bogdan, S. B. and Salameh, Z. M. Methodology for optimally sizing the combination of a battery bank and PV array in a wind/PV hybrid system. IEEE Transactions on Energy Conv. 11(2), 367-375, 1996
[12] Bin, A., Hongxing, Y., Shen, H., Xianbo, L, Computer aided design for PV/Wind hybrid system. Renewable Energy 28,1491-1512, 2003
[13]J. F. Manwell and J. G. McGowan, Lead acid battery storage model for hybrid energy systems, Solar Energy,(1993) Vol. 50, pp. 399–405.
[14] Said Diaf, Djamila Diaf, Mayouf Belhamel, Mourad Haddadi, Alain Louche, A methodology for optimal sizing of autonomous hybrid PV/wind system. Energy Policy, Elsevier, 2007, 35,pp.5708-5718.
[15] Kaabeche A, Belhamel M, Ibtiouen R. Techno-economic valuation and optimization of integrated photovoltaic/wind energy conversion system. Sol Energy 2011;85(10):2407e20.
[16] Deshmukh MK, Deshmukh SS. Modeling of hybrid renewable energy systems. Renew Sustain Energy Rev 2008;12(1):235e49.
[17] Clark W. Gellings, “Smart grid enabling energy efficiency and demand response”, August 21, 2009 by CRC Press Reference - 250 Pages ISBN 9781439815748 - CAT# N1011.
[18] Johanne Mose Entwistle, Kurt Nielsen and Tseganesh Wubale Tamirat, Designing a Market Solution for Rapid Demand Response in Kenya, A report from the EURO star project UMEME 24/7.
[19]DEMAND RESPONSE for Small to Midsize Business Customers, Reference guide, 2010 CEATI International.

Your Name	Title*	Affiliation	Research Field	Personal website
Fatma Zohra Dekhandji	Dr.	University of Boumerdes, Algeria	Power quality, machines	
Mouloud Bouaraki	Mr.	University of Boumerdes, Algeria	Renewable energies	
Nadhir Zaidi	Mr.	University of Boumerdes, Algeria	Master in Power engineering	
Abdelmadjid Recioui	Dr.	University of Boumerdes, Algeria	Telecommunications, optimization, smart grids	

ISSN 2356-5608