Study of the Different Structures of Hybrid Systems in Renewable Energies - A Review

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ABSTRACT

In the majority of isolated sites, the diesel generator is seen as the best solution for the electrification. For these sites, access to the electricity grid is either difficult or expensive. The rising price of fuel and the interest in reducing greenhouse gas emissions have led researchers to think otherwise: meeting the energy needs with minimal damage. Renewable energy sources (RES) have experienced a significant drop in the purchase price, making their use in these regions very advantageous compared to conventional sources. One of the barriers to scaling up renewable energy sources (RES) is the intermittency of these sources. The variability experienced by the resources (sun, wind, etc.) is not correlated with the load demand. For that there is always interest to couple several different sources and form what is called a hybrid system. This paper is a review of Hybrid Renewable Energy System (HRES) for electricity generation. It presents the operating mode, the different structure of the HRES and the sizing software used to evaluate the Hybrid Renewable System (HRS) behavior.

Keywords: Hybrid Renewable Energy System (HRES); Photovoltaic; Wind energy; Storage capacity**.**

1. INTRODUCTION

The power produced from renewable energy sources (RES) is characterized by its variability. The solution is to couple sources of supply and form a hybrid system (SH). A hybrid renewable energy system (SHER) is an electrical system, comprising more than one energy source, among which one at least is renewable [1]. In another word, a hybrid renewable energy system (SHER) is a system that combines two different technologies: one or more conventional energy sources,

and at least one renewable energy source. Hybrid energy systems are generally autonomous in this case storage capacity is necessary; this type is widespread in isolated sites.
The goal of a SHER is to meet the demand for a load from renewable sources, if there is a lack it is filled with conventional sources, while minimizing fuel consumption.

1.1 Classification

In the literature, several classifications have been proposed according to well-defined criteria. In what follows the classifications most used are presented.

1.1.1 Operating mode

Hybrid energy systems can be grouped into two categories. The first category includes hybrid systems that are connected to the grid; they operate in parallel with the network. These systems are connected to the network. In the second category we find the autonomous hybrid systems. These systems are isolated from the network.

1.1.2 Structure of the hybrid system

The structure of the hybrid system can be divided into three types of system:

- The presence or absence of conventional energy source

A hybrid system can contain a conventional power source such as a diesel generator, a gas turbine, or simply an entire plant for hybrid systems connected to the grid.

- The presence or absence of storage capacity

For autonomous hybrid systems, the presence of a storage device is necessary. In case of insufficient primary source, the storage satisfies the load. There is different means of storage; the most used are the rechargeable batteries, the flywheels of inertia...

- The renewable energy source used

The structure of a hybrid renewable energy system must include a renewable energy source, either a photovoltaic generator or a wind turbine or even a combination of its sources. The available energy potential (solar irradiation, wind speed, etc.) is very important for the choice of the source.

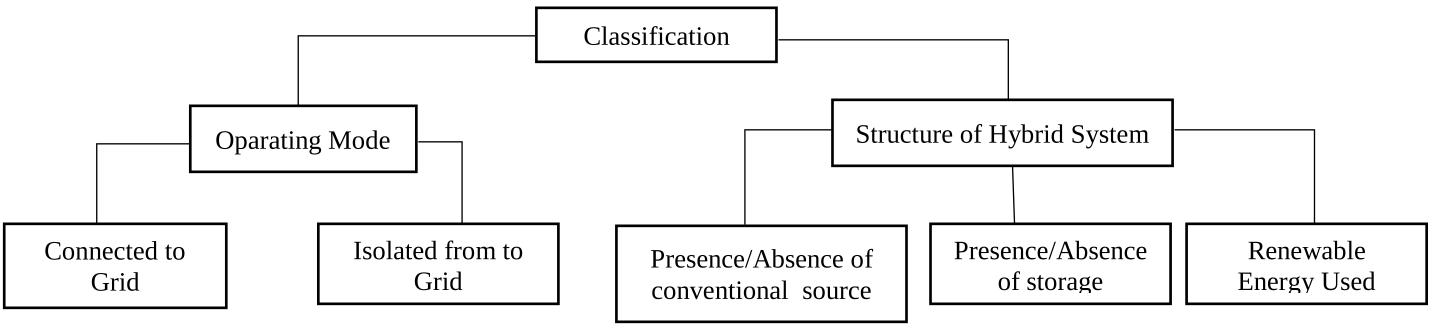

Fig. 1. *Classification of SHER [35]*

1.2.Optimization criteria for a hybrid system

For the sizing of a hybrid system, it is always advantageous to optimize the system so as to satisfy the demand of the load with a minimum cost.

Several criteria can be taken into account. The most important ones are:

- The cost of energy produced
- The probability of loss of the load (LPSP)

1.3.Sizing software

There is several sizing software. This software can see and evaluate the overall behavior of the system. We can quote the best known in this area:

• Hybrid2: developed by CEERE (center for energy efficiency and renewable energy). It allows the study of different hybrid systems. It is a tool for performing detailed, long-term economic analyzes on a wide variety of hybrid power systems. Hybrid2 is a probabilistic / temporal computer model, using time series for loads, wind speed, sunshine, temperature and the power system designed or selected by the user.

• HOMER (Hybrid Optimization Model for Electric Renewable): developed by NREL (national renewable
energy laboratory). It is a means for optimizing the design of micro-grids in all sectors of electricity, from public services in the villages to campuses and military bases connected to the network. HOMER integrates three powerful tools in single software, the engineering and the economy work side by side.

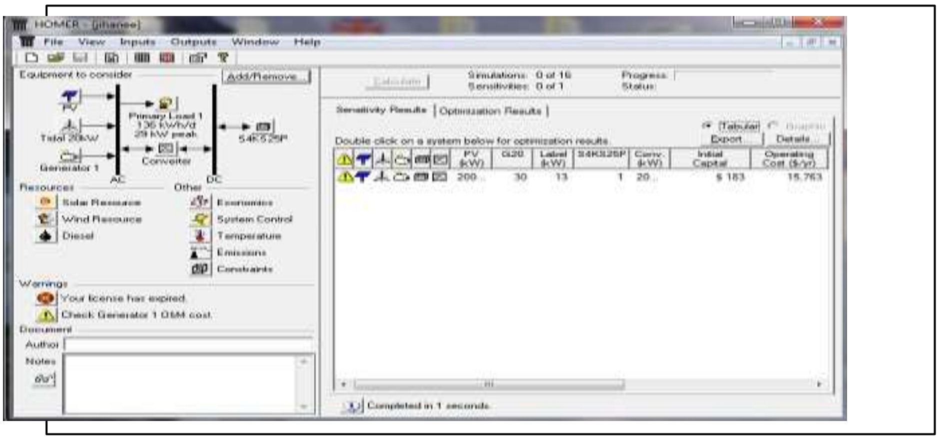

Fig. 2. *Preview of the HOMER software*

• RAPSIM (Remote Area Power Supply Simulator): This is free and open source micro-network simulation software for a better understanding of power flow behavior in smart micro-grids with renewable sources. It is able to simulate grid-connected or autonomous micro-grids with solar, wind or other renewable energy sources. The proposed software calculates the power generated by each source in the micro-array, and then performs a power flow analysis. This software is useful for the optimal placement of distributed production units in a micro-network.

2. STUDIES OF DIFFERENT STRUCTURES OF HYBRID SYSTEMS

2.1. Hybrid systems with a conventional energy source

2.1.1Photovoltaic systems with conventional source

These systems are located in sunny areas characterized by a warm climate. For example, there is Saudi Arabia [2, 3], where the authors studied the power supply of a house building, the Maldives [4], for a hybrid system connected to the electricity grid, and the Morocco [5]....

2.1.2Wind systems with conventional source

This type of system is widely used in windy sites such as islands and sea flanges. Research has been done for islands of different sizes: small as the Canary Islands [6], medium as Corsica [7] or large like England [8].

When the hybrid system operates in stand-alone mode, storage means are required: conventional by batteries [8]; or innovative by fuel cells [9].

2.1.3Photovoltaic / wind / diesel systems

PV / W / diesel systems (photovoltaic / Wind / diesel) are widely used in sites that are characterized by high solar potential with a significant wind speed. The main goal is to reduce the amount of fuel consumed since renewable energy sources can provide a surplus of energy compared with one source.

2.2. Hybrid systems without conventional energy sources

These hybrid systems operate mostly in standalone mode in areas where access to the grid or fuel supply is expensive or even difficult.

2.2.1.Photovoltaic systems with storage

The photovoltaic installation must contain another source of energy, to satisfy the load demand during the night or if there is a lack of sunshine. This type of system is used to electrify houses [10], villages [11]. Some studies have studied the problem of modeling and analysis [12]; others have moved towards the issue of optimized sizing [10; 13]. The optimized parameter is either the cost of the energy produced, or the probability of loss of the load [14]; in both cases the objective is to ensure a continuous supply of the load with the lowest cost.

The presence of a storage capacity is necessary in an autonomous photovoltaic installation, to feed the load during periods of insufficient renewable source.

Research in the literature has studied the different types of storage: the ideal storage was treated in [10], however the author [15] used the batteries for storage and finally an electrolyser with hydrogen tank was presented [16].

2.2.2.Wind systems with storage

The interconnection of a wind generator with a storage device can be for two main reasons: the first is to play the role of the buffer for the case of a hybrid system linked to the electrical network, in other words to smooth the rapid variations of the power from the wind turbine [17]; the second role is to store energy in the long term for an autonomous system [18].

The storage modes used can be the batteries [18], an electrolyzer with hydrogen storage [19], or compressed air storage [20].

2.2.3.Hybrid photovoltaic / wind / storage systems

The systems previously presented have the major disadvantage of the lack of diversity of production sources; a single renewable source is used. This result in over-dimensioning of the components to ensure a continuous supply of the load, which generates a high initial investment and an increase in the price per kilowatt-hour produced. These obstacles can be overcome by adding a second source of energy [21].

Research in the literature studies existing systems [22], test benches [23] and theoretical work. The majority of the studies deal with the modeling and optimization of the hybrid system according to different criteria: minimum cost per kilowatt-hour produced [23,24], probability of loss of charge (LPSP) [25], or the study of the two criteria in a single case [26]. Most of the work uses evolutionary algorithms for optimization such as genetic algorithms [27] or optimization software like HOMER.

3. CLASSIFICATION OF THE HYBRID SYSTEM

Hybrid systems are used in several applications; their use is mainly to satisfy a load. Therefore we can make a ranking by power range:

Table 1. Classification according to power

Puissance (Kw)	Application
<5	Autonomous systems: telecommunication
10-250	Micro isolated networks: feeding an
>500	Large isolated networks

4. LITRATURE REVIEW ON OPTIMIZATION METHODS

4.1. Optimization using genetic algorithm(GA)

T.Senjyu and T.Funabashi (2007) made an optimal configuration of a hybrid system consisting of photovoltaic panels, wind turbines, batteries and a diesel generator. The system is located in OKINAWA where they took as case study three islands: Miyako, Kume and Tokashiki.The main purpose of the study is to minimize the cost of fuel used for diesel generator power and to integrate more and more renewable energies. Okinawa is located north of JAPAN; she has 40 islands. The energy requirement is covered by diesel generators which generates a very high cost of the energy produced and of course an increase in pollution.

Aware of the importance of green energy, a hybrid system is designed to meet the need for energy and to overcome the problem of intermittency of renewable sources. The optimization method used is the Genetic Algorithm (AG), taking as objective function the total cost. After simulation, the optimization algorithm gives the optimal number of PV modules, wind turbines and batteries. In all three islands studied the number of PV is zero, which shows that the cost of PV is higher compared to other sources.

Hongxing Yang and Zhaohong Fong (2007) have recommended a method to optimize a hybrid system (PV + wind + batteries). The method is based on AGs to achieve a global optimum that requires loss of power supply probability (LPSP) with a minimum cost. The decision variables are the number of PV modules, the number of wind turbines, and the number of batteries, slop angle and the height of the wind turbine. The proposed solution is applied to supply a telecommunication station.

Thus, it can be deduced that the hybrid system that combines solar and wind generation units with storage means can decrease the fluctuation of these sources and reduce the storage capacity. A photovoltaic hybrid system, which uses PV energy combined with another energy source such as wind energy or diesel, is cheaper and more efficient than a photovoltaic system alone.

The designation of such system is complicated for several reasons:
• The uncertain nature of renewable sources
• The uncontrollable nature of the energy demand
• The non-linearity of the characteristics of the components.

R.Dufo-Lopez and J.L.Bernal-Augustin (2005) compared the system optimized by HOGA (Hybrid Optimization by Genetic Algorithm) with a photovoltaic system by itself, which was dimensioned based on classical methods. In this paper the authors presented an optimization method for a photovoltaic-diesel system using AGs (Goldberg, 1989).AGs is a successful choice for solving complex problems when other methods fail to provide an acceptable solution.

In the literature there are several programs that simulate a hybrid system like HYBRID2 (GREEN MANWELL, 1995) which was developed by NREL (National Renewable Energy Laboratory, USA) and TRNSYS which was developed by the University of Wisconsin. The point of weakness of this software is that they do not optimize the system.

4.2. Economic evaluation using HOMER

Asrari and Javidi (2012) made the economic evaluation of a hybrid system for the supply of electricity to an isolated village in Iran. The village named sheikh abouhassan is characterized by an average wind speed of 6.8m / s at 40m height and a daily irradiation average of 4.79KWh / m2 / day.

With this encouraging data, the demand for electricity from the site can largely be covered by renewable sources. The study is made using the HOMER as a tool for simulation and evaluation of different combinations of renewable sources.

4.3. Optimizations taking into account the degradation

O.Erdinc and M.Uzunoglu (2012) gave a new perspective of optimizing a hybrid system by taking into account the impact of hardware degradation. The optimal combination of the hybrid renewable energy system must ensure a balance between electricity demand and the cost of the system. For this, the "area based observer and focus" algorithm is proposed. The latter can be divided into two parts: area observation and focusing. They concluded that the degradation parameter has a strong impact on the cost of the energy produced.

4.4. Optimization by LPSP

DBNelson, MHNehrir and C.Wang (2005) made the economic evaluation of a hybrid system, including wind turbines, photovoltaic panels and fuel cell (FC), for the supply of a home away from the electrical grid. The study is done using the LPSP technique to determine the number of photovoltaic panel and the storage capacity.

T.Niknam and B.B.Firouzi (2009) proposed an algorithm for estimating the distribution status of renewable sources. The present algorithm can also estimate the load and output values of renewable sources.

The connection of renewable energies with the distribution network cannot work effectively without the means of control and optimization. So the estimate of the state of the network is important.

The algorithm used is PSO-NM; it is a combination of PSO (Particle Swarm Optimization) and NM (Nelder-Mead simplex search).

The results found are compared with other algorithms, which showed the effectiveness of this type of algorithm for similar studies.

5. CONCLUSION

In this paper we have presented a review for the different studies done in the literature related to Hybrid Renewable Energy System (HRES). Its highlights the important of hybrid Renewable energy sources, the most classification used and the system structure or configurations. The optimization issue is also presented as well as some critical challenges facing the deployment of alternative energy.

REFERENCES

[1] Lazarov V. D., Zarkov, Z., (2002). Monitoring of renewable energy sources hybrid system. Proceedings of International Conference ICATE'2002, Craiova/Baile Herculane, Romania, pp. 224229, 2002.

[2] Shaahid, S.M., Elhadidy, M.A., (2003). Opportunities for utilization of stand-alone hybrid (photovoltaic+diesel+battery) power systems in hot climates. Renewable Energy, vol. 28, pp. 1741– 1753, 2003.

[3] Shaahid, S.M., Elhadidy, M.A., (2004). Prospects of autonomous stand-alone hybrid (photovoltaic+diesel+battery) power systems in commercial applications in hot regions. Renewable Energy, vol. 29, pp. 165–177, 2004.

[4] van Sark, W.G.J.H.M., Lysen, E.H., Cocard, D., Beutin, P., Merlo, G.F., Mohanty, B., van den Akker, J., Razzak Idris, A., Firag, A., Waheed, A., Shaheed, A., Latheef, M., Wajeeh, A., (2006). The first PV-diesel hybrid system in the Maldives installed at Mandhoo Island. 21st European Photovoltaic Solar Energy Conference, 4-8 September 2006, Dresden, Germany, pp. 3039-3043, 2006.

[5] Muñoz, J., Narvarte, L., Lorenzo, E., (2004). First operating year of two village PV-diesel plants in the south of Morocco. 19th European Photovoltaic Solar Energy Conference, 7-11 June 2004, Paris, France, pp. 3462-3465, 2004.

[6] Carta, J.A., González, J., Gómez, C., (2003). Operating results of a wind-diesel system which supplies the full energy needs of an isolated village community in the Canary Islands. Solar Energy, vol. 74, pp. 53–63, 2003.

[7] Notton, G., Cristofari, C., Poggi, P., Musseli, M., (2001). Wind hybrid electrical supply system: behaviour simulation and sizing optimization.Wind Energy, vol. 4, pp. 43-59, 2001.

[8] Bowen, A.J., Cowie, M., Zakay, N., (2001). The performance of a remote wind-diesel power system. Renewable Energy, vol. 22, pp. 429–445, 2001.

[9] Garcia, R.S., Weisser, D., (2006). A wind-diesel system with hydrogen storage: Joint optimisation of design and dispatch. Renewable Energy, vol. 31, pp. 2296–2320, 2006.

[10] Mulder, G., De Ridder, F., Six D., (2010). Electricity storage for grid-connected household dwellings with PV panels. Solar Energy, vol. 84, pp. 1284-1293, 2010.

[11] Vosseler, I., Ramírez, E., Vallvé, X., Carreras, J.M., (2004). PV hybrid village electrification in Spain-6 years experience with multi-user solar hybrid grids. 19th European Photovoltaic Solar Energy Conference, 7-11 June 2004, Paris, France, pp. 3361-3364, 2004.

[12] Muselli, M., Notton, G., Poggi, P., Louche, A., (2000). PV-hybrid power systems sizing incorporating battery storage: analysis via simulation calculations. Renewable Energy, vol. 20, pp. 17, 2000.

[13] Kaushika, N.D., Gautam, N.K., Kaushik, K., (2005). Simulation model for sizing of stand-alone solar PV system with interconnected array. Solar Energy Materials & Solar Cells, vol. 85, pp. 499–519, 2005.

[14] Fragaki, A., Markvart, T., (2008). Stand-alone PV system design- Results using a new sizing approach. Renewable Energy, vol. 33, pp. 162– 167, 2008.Muhs, D. et al. (2003). *Roloff/Matek mechanical parts*, 16th ed. Wiesbaden: Vieweg Verlag,. 791 p. (In German). ISBN 3-528-07028-5.

[15] Zahedi, A., (1998). Development of an electrical model for a PV-battery system for performance prediction. Renewable Energy, vol. 15, pp.531-534, 1998.

[16] Busquet, S., Leroux, P., Albuisson, M., Gatt, P., Ménard, L., Mayer, D., Metkemeijer, R., (2004). PV/fuel cell hybrid systems perofrmance analysis and possible improvements. 19th European Photovoltaic Solar Energy Conference, 7-11 June 2004, Paris, France, pp. 2426-2429, 2004.

[17] Nouni, M.R., Mullick, S.C., Kandpal, T.C., (2007). Techno-economics of small wind electric generator projects for decentralized power supply in India. Energy Policy, vol. 35, pp. 2491–2506, 2007.

[18] Zini, G., Tartarini, P., (2010). Wind-hydrogen energy stand-alone system with carbon storage: Modeling and simulation. Renewable Energy, vol. 35, pp. 2461-2467, 2010.

[19] Ntziachristos, L., Kouridis, C., Samaras, Z., Pattas, K., 2005. A wind-power fuel-cell hybrid system study on the non-interconnected Aegean islands grid. Renewable Energy, vol. 30, pp. 1471–1487, 2005.

[20] Zhou, T., (2009). Commande et Supervision Energétique d'un Générateur Hybride Actif Eolien incluant du Stockage sous forme d'Hydrogène et des Super-Condensateurs pour l'Intégration dans le Système Electrique d'un Micro Réseau. PhD thesis, Ecole Doctorale SPI 072, L2EP à l'Ecole Centrale de Lille, 2009.

[21] Diaf, S., Notton, G., Belhamel, M., Haddadi, M., Louche, A., (2008). Design and techno-economical optimization for hybrid PV/wind system under various meteorological conditions. Applied Energy, vol. 85, pp. 968–987, 2008.

[22] Sopian, K., Ibrahim, M.Z., Wan Daud, W.R., Othman, M.Y., Yatim, B., Amin, N., (2009). Performance of a PV–wind hybrid system for hydrogen production. Renewable Energy, vol. 34, pp. 1973-1978, 2009.

[23] Nandi, S.K., Ghosh, H.R., (2010). Prospect of wind-PV–battery hybrid power system as an alternative to grid extension in Bangladesh.Energy, vol. 35, pp. 3040-3047, 2010.

[24] Dali, M., Belhadj, J., Roboam, X., (2010). Hybrid solar-wind system with battery storage operating in grid–connected and standalone mode: Control and energy management - Experimental investigation. Energy, vol. 35, pp. 2587-2595, 2010.

[25] Ekren, O., Ekren, B.Y., (2008). Size optimization of a PV/wind hybrid energy conversion system with battery storage using response surface methodology. Applied Energy, vol. 85, pp. 1086–1101, 2008.

[26] Ekren, B.Y., Ekren, O., (2009). Simulation based size optimization of a PV/wind hybrid energy conversion system with battery storage. under various load and auxiliary energy conditions. Applied Energy, vol. 86, pp. 1387–1394, 2009.

[27] Koutroulis, E., Kolokotsa, D., Potirakis, A., Kalaitzakis, K., (2006). Methodology for optimal sizing of stand-alone photovoltaic/wind- generator systems using genetic algorithms. Solar Energy, vol. 80, pp. 1072–1088, 2006.

[28]] Senjyu, T., Hayashi, D., Yona, A., Urasaki, N., & Funabashi, T. (2007). Optimal configuration of power generating systems in isolated island with renewable energy. Renewable energy, 32(11), 1917-1933.

[29] Yang, H., Zhou, W., Lu, L., & Fang, Z. (2008). Optimal sizing method for stand-alone hybrid solar–wind system with LPSP technology by using genetic algorithm. Solar energy, 82(4), 354-367.

[30] Rodolfo Dufo_Lopez,José L.Bernal_Agustin.Design and control strategies of PV-Diesel systems using genetic algorithms.Solar Energy 79(2005)33-46.

[31] Arash Asrari,Abolfazl Ghasemi,Mohammed Hossein Javidi.Economic evaluation of hybrid renewable energy systems for rural electrification in Iran-A case study.Renewable and sustainable Energy Reviews 16(2012) 3123-3130.

[32] Erdinc, O., & Uzunoglu, M. (2012). A new perspective in optimum sizing of hybrid renewable energy systems: Consideration of component performance degradation issue. international journal of hydrogen energy, 37(14), 10479-10488.

[33] Nelson, D. B., Nehrir, M. H., & Wang, C. (2005, June). Unit sizing of stand-alone hybrid wind/PV/fuel cell power generation systems. In Power Engineering Society General Meeting, 2005. IEEE (pp. 2116-2122). IEEE.

[34] Niknam, T., & Firouzi, B. B. (2009). A practical algorithm for distribution state estimation including renewable energy sources. Renewable Energy, 34(11), 2309-2316.

[35] Jihane Kartite ,Mohamed Cherkaoui. (2018). Study of the different structures of hybrid systems in renewable energies: A review. Technologies and Materials for Renewable Energy, Environment and Sustainability, TMREES18, 19–21 September 2018, Athens, Greece.