# Renewable Energy Hybrid Systems

Subjects: Engineering, Electrical & Electronic

Contributor: Juan Carlos León Gómez , Susana Estefany De León Aldaco , Jesus Aguayo Alquicira

Renewable energies are those sources of energy that can be obtained naturally without depleting the planet's resources. Hybrid renewable energy systems are those that combine two or more renewable energy sources to generate electricity.

hybrid renewable energy systems | battery energy storage system | optimization techniques | optimization algorithms

## 1. Introduction

Renewable energies are those sources of energy that can be obtained naturally without depleting the planet's resources. These sources include solar, wind, hydro, geothermal, biomass, and biofuels. Unlike non-renewable energies, such as oil, gas, and coal, which are finite and emit large amounts of greenhouse gases, renewable energies are cleaner and more sustainable. Additionally, the technologies to capture and utilize these energies have improved in recent years, making their use increasingly viable and economical. Renewable energies are a key solution to combating climate change and reducing dependence on fossil fuels [1]. By investing in these energy sources, jobs can be created and sustainable economic development can be promoted. In summary, renewable energies are a key alternative to ensure a cleaner and safer future for future generations.

Hybrid renewable energy systems are those that combine two or more renewable energy sources to generate electricity. These systems are especially useful in places where there is no access to the conventional electrical grid, or where the connection is limited or unstable [2]. An example of a hybrid system combines solar and wind energies. During the day, when the sun shines, solar panels generate electricity that is stored in batteries for later use. At night, when there is no sun, wind energy conversion systems (WECS) harness the wind to generate additional electricity and charge the batteries [3]. Another example of a hybrid system combines solar and hydro energies. During the day, solar panels generate electricity that is used to pump water from a river or lake to a dam. At night, when there is no sun, the water stored in the dam is released through a hydro turbine to generate additional electricity [4].

Hybrid renewable energy systems can be more efficient and reliable than systems that use a single energy source [5]. Additionally, they allow for a better use of available resources and reduce the cost of generated energy. For these reasons, hybrid systems are becoming increasingly popular worldwide, especially in rural or remote areas [6].

# 2. Renewable Energy Hybrid Systems

## 2.1. Composition of HRESs

The composition of the HRESs indicates the way in which the elements of the system will be distributed with the objective of reducing the conversion stages to reduce losses and the complexity of the control system. This is achieved without compromising the reliability and cost-effectiveness of the system.

**Figure 1**, **Figure 2**, **Figure 3** and **Figure 4** illustrate the configurations used for these systems.

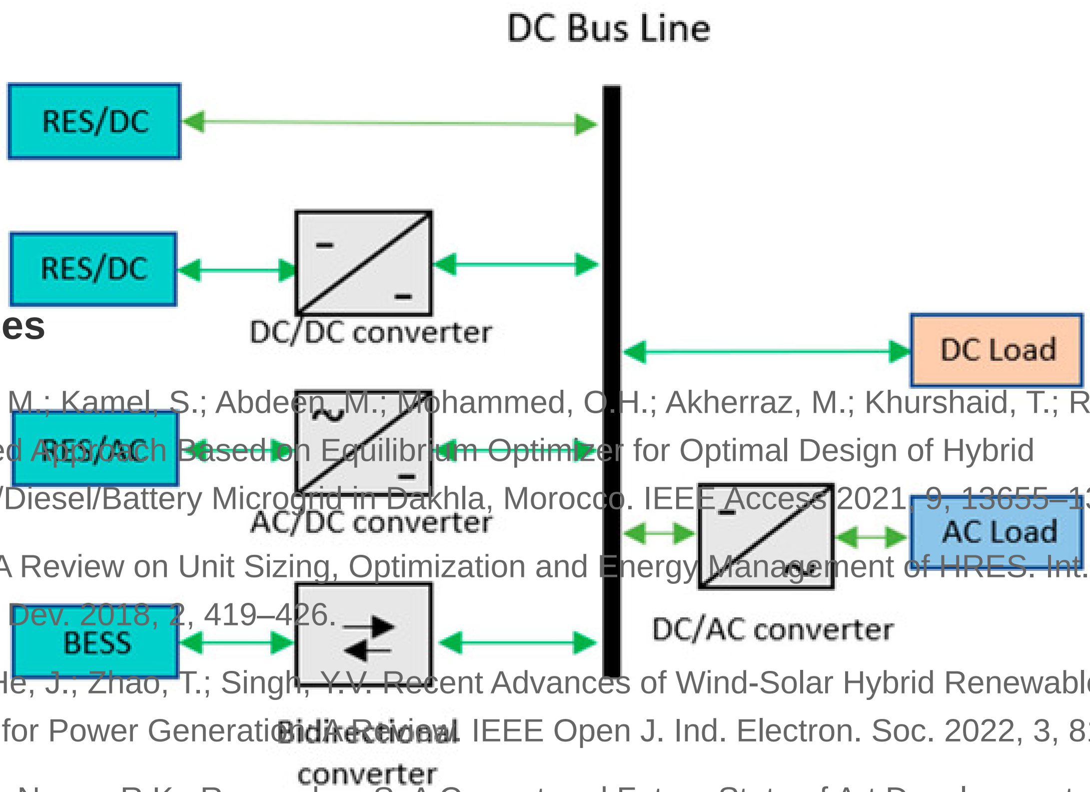


**Figure 1.** DC bus line configuration.

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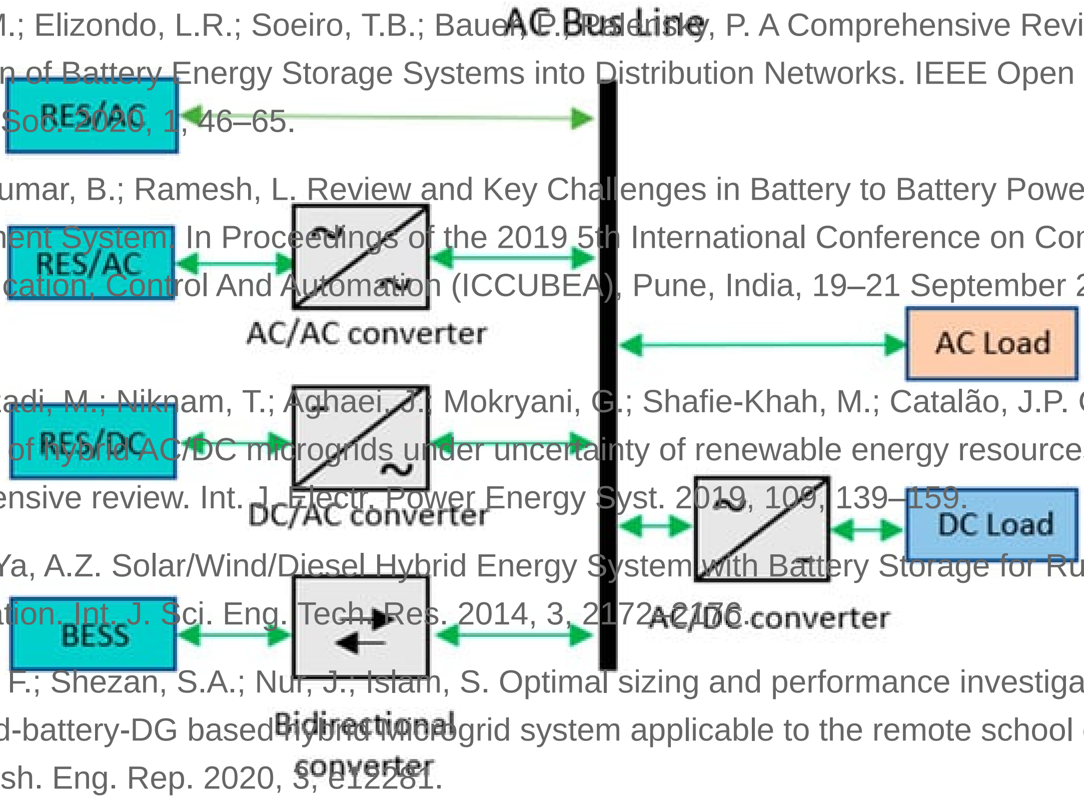


**Figure 2.** AC bus line configuration.

13. Ranjan, R.; Doda, D.K.; Lalwani, M.; Bundele, M. Simulation and Optimization of Solar Photovoltaic–Wind–Diesel Generator Stand-alone Hybrid System in Remote Village of Rajasthan, India. In International Conference on Artificial Intelligence: Advances and Applications 2019: Proceedings of ICAIAA 2019; Springer: Singapore, 2020; pp. 279–286.

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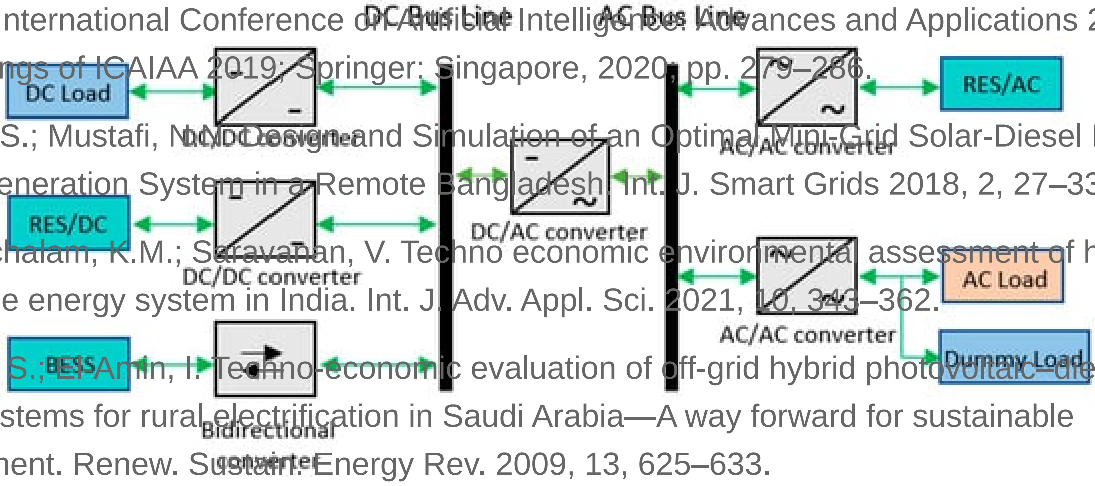


**Figure 3.** Isolated hybrid network.

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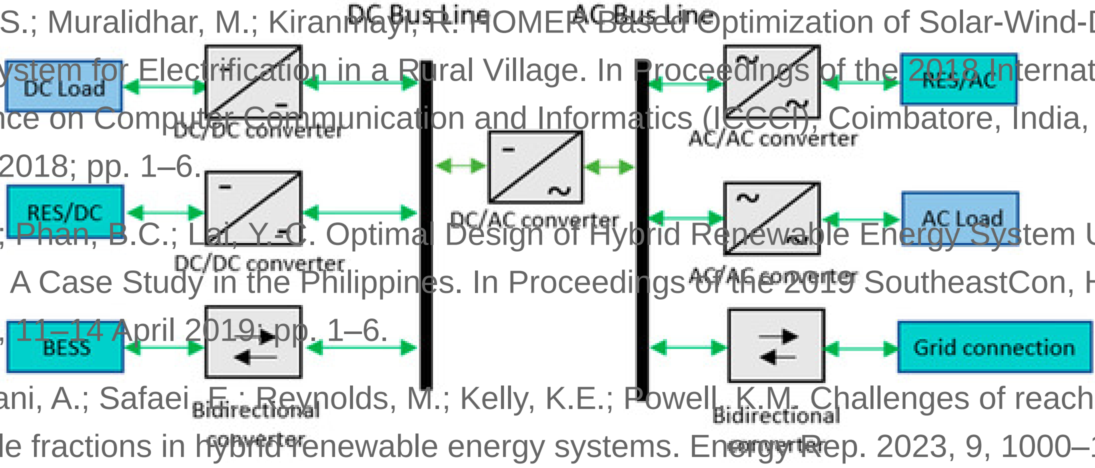


**Figure 4.** Connected hybrid network.

It can be seen in **Figure 5** that the most used generation sources are photovoltaic and WECS.

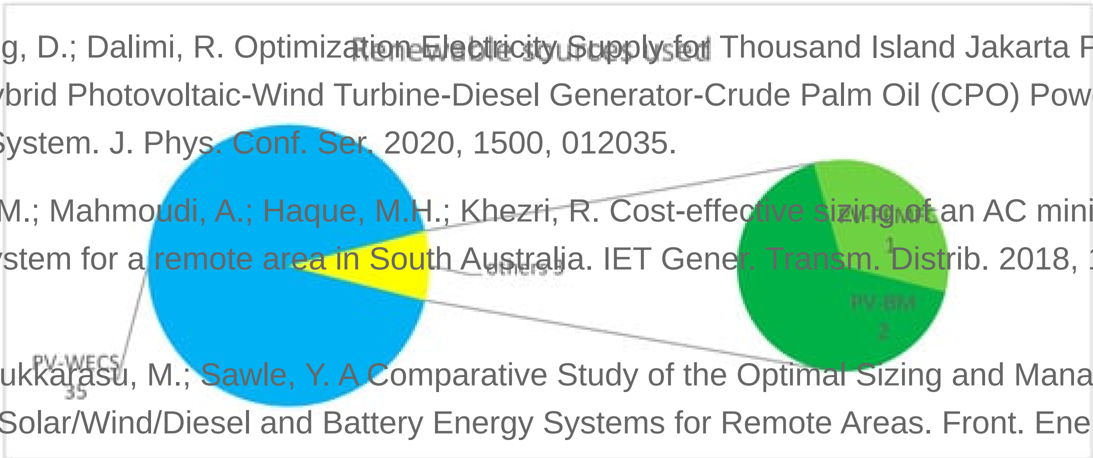


**Figure 5.** Number of articles according to the renewable sources used.

The HRES system can include a BESS (battery energy storage system) to improve reliability. The BESS stores electrical energy generated by renewable sources, such as solar panels or wind turbines, and uses it at times of high energy demand or when renewable energy generation is reduced due to weather factors. In summary, the BESS is a key part of the HRES system to ensure a reliable and sustainable energy supply. **Table 1** shows the most used BESSs, their advantages, and disadvantages.

**Table 1.** BESS types and advantages/disadvantages [5][7][8][9].

| BESS | Advantages | Disadvantages | Articles Related to BESS |
|---|---|---|---|
| Energy storage in compressed air (CAES) | Lower cost, low self-discharge, high service life. | High initial cost, large scale, there are geographical restrictions that limit the installation of the system. | Not found |

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economic analysis of an off-grid hybrid system for a remote island in Malaysia. Malawali island,

| BESS | Advantages | Disadvantages | Articles Related to BESS |
|---|---|---|---|
| Battery Ni–Cd | Low maintenance requirement, high energy density and high reliability. | This product has high costs and suffers from a phenomenon known as “battery memory”. | Not found |
| Battery lead–acid | This product has a medium energy density, low initial investment, and is widely available. In addition, it does not require a cell management system. | The characteristics of this product” include a low life cycle, low efficiency, ventilation requirements, and the need for proper disposal of used batteries. | [10][11][12][13][14][15][16][17][18][19][20][21] |
| Battery Li-ion | This product stands out for its high efficiency, high energy density, long life cycle, and relatively compact size. In addition, it is in an area where rapid technological advances are taking place. | The disadvantages of this product are its high initial capital costs due to the special packaging required and the potential risk of battery body rupture. | [22][23][24] |
| Hydrogen-based (HESS) | This product is almost contamination-free and has a wide power range. | This product includes low efficiency, low response time, high cost, and installation restrictions due to the hydrogen storage tank. | Not found |
| Supercapacitor (SESS) | It has high efficiency, long life cycle, and high power capacity. | It has a low energy density and a relatively high cost. | Not found |
| Flywheel (FESS) | It features high power capacity, long life cycle, and fast charging capability. | Disadvantages of this product include its high cost due to the need for a separate vacuum chamber, safety issues, high self-discharge, and high cost. | [25] |
| Gel batteries | This product is a good choice for applications that have high cyclic requirements due to its excellent recharge behavior, which gives it a long service life. | One of the disadvantages of gel batteries is that they have a lower current capacity compared to other battery technologies. They can be more expensive than some other battery technologies. | [26] |

These auxiliary sources are typically used when the main source cannot generate enough power to meet demand at times of high demand or when the main source is inactive or unreliable. Common examples of auxiliary generation sources are diesel or natural gas generators.

## 2.2. HRES Sizing and Optimization

HRES optimization criteria can be divided into two categories: economic and reliability, and the selection of each depends on the research objectives and the desired tolerance level [5]. Economic criteria refer to the cost or size of

technique. Int. J. Renew. Energy Technol. 2018, 9, 84.

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the system, while reliability criteria focus on ensuring the continuity of load power supply. **Table 2** and **Table 3** list the economic and reliability optimization criteria found in the literature, respectively, and identify the limitations that each may present.

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**Table 2.** Economic optimization criteria and constraints for HRESs [3][5].

| Criteria | Type | Limitations | Articles Related to the Criteria |
|---|---|---|---|
| Annual system cost (ACS) | Economic | The cost estimate does not consider the possible variation of the interest rate and inflation. | Not found |
| Net current cost (NPC) | Economic | It is not possible to take into account fluctuations in fuel prices (in case conventional energy sources are included) and uncertainties in the durability of system components such as batteries. | [1][6][11][12][13][14][15][16][17][18][19][21][23][24][25][26][27][28][29][30][31][32][33][34][35][36] |
| Cost of energy (COE) | Economic | The cost of recovering system components at the end of their useful life is not included. | [11][12][13][15][16][17][18][21][23][24][26][28][30][31][32][33][34][36][37][38][39][40] |
| Levelized cost of energy (LCOE) | Economic | The cost estimation tool does not take into account external factors, such as volatility in fossil fuel prices and inflation. | [1][19][22][24][25][27][29][41] |
| Total net current cost (TNPC) | Economic | Changes in the cost of energy are not taken into account. | Not found |
| Life cycle cost (LCC) | Economic | Cost estimation is complicated by the difficulty of accurately predicting acquisition, operation, and long-term maintenance costs, which can affect the accuracy of the life cycle cost (LCC) analysis. | [26][42][43] |
| Cost of loss of battery life (LLCB) | Economic | Reduced battery performance as the battery ages is not included in the evaluation. | Not found |

**Table 3.** Optimization criteria (reliability) and limitations for HRESs [3][5].

| Criteria | Type | Limitations | Articles Related to the Criteria |
|---|---|---|---|
| Probability of loss of power supply (LPSP) | Reliability | It is defined for a specific load profile and does not take into account variations in that load profile. | [1][28][39][40][41][44] |
| Expected energy not supplied (EENS) | Reliability | The potential impact of variation in load demand is not taken into account. | Not found |

| Criteria | Type | Limitations | Articles Related to the Criteria |
|---|---|---|---|
| Level of autonomy (LA) | Reliability | Normalized-to-total annual energy demand. | Not found |
| La probabilidad de pérdida de carga (LLP) | Reliability | A limitation in the assessment of power supply reliability is that long-duration load loss (LLP) only measures the probability of power supply interruption and does not provide a complete assessment of the reliability of the power system as a whole. | [32] |
| Deficiency in probability of power supply (DPSP) | reliability | For EPG < EL, it is the same as LPSP. | Not found |

### 2.3. Optimization Algorithms

Three main categories of techniques for optimizing hybrid renewable energy systems (HRESs) can be identified: artificial intelligence methods, iterative methods, and software tools. Artificial intelligence methods include various techniques such as genetic algorithm (GA), particle swarm optimizer (PSO), Tabu search (TS), simulated annealing (SA), harmonic search (HS), and others. On the other hand, iterative methods may include electric bee colony system (ESCA), power PA algorithm (POPA), and generic algorithms (GA), among others. In addition, there are software tools such as the transient energy systems simulator (TRNSYS), the hybrid optimization model for electric renewable energy (HOMER), and Hybrid2, each with its underlying optimization technique [45].

## 3. Summary

With improvements in the research and development of solar and wind technologies, the cost of renewable energy sources is expected to decrease in contrast to the annual increase in the cost of conventional energy resources. Therefore, this hybrid system will be more economical in the future and it is also likely that the environmental benefits will encourage its use and acceptance. In addition, the inclusion of artificial intelligence in energy management is expected to further improve the performance of the hybrid system in the near future. Optimal resource allocation according to load demand and renewable resource forecasting can significantly reduce system operating costs. The application of advanced control techniques using a centralized controller also promises to improve the performance of modular hybrid power systems. Finally, the implementation of modern control techniques to monitor the operation of modular hybrid energy systems can further optimize the use of renewable resources and improve energy management.