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Metaheuristic Algorithm to Find Optimal Sizing of Stand-Alone Hybrid Energy System in Remote Areas: A Review

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Abstract

In remote areas, electricity is provided by diesel generators, which have many disadvantages, such as their dependence entirely on fossil fuels that cause global warming due to emissions of harmful gases such as carbon dioxide, and the high maintenance cost of these generators, as well as the difficulty of transporting fossil fuels to them. Therefore, the world has tended to use renewable energy sources, due to their advantages such as their presence in all regions of the world, they do not emit harmful gases and their long life. However, renewable energy sources also have disadvantages such as high investment cost, and their intermittent nature because they depend on climate data. Therefore, the optimal sizing of these sources is considered an important factor to increase reliability, reduce emissions, reduce costs, and other goals. These problems can be solved by modern techniques, a metaheuristic algorithm that is more famous than traditional algorithms because it has good results and faster processing time. In this paper, we present a comprehensive review for used metaheuristic algorithms to find the optimal sizing of the energies used in the hybrid energy system (HES) for single and multi-objective optimization. Also, we review the main combinations of HES including their assessment parameters of economics, environmental, and reliability.

Keywords: Metaheuristic Algorithm, optimal sizing, standalone hybrid energy system

الخلاصة:

في المناطق النائية يتم توفير الكهرباء عن طريق مولدات الديزل، والتي لها العديد من السلبيات، مثل اعتمادها بشكل كامل على الوقود الأحفوري الذي يسبب ظاهرة الاحتباس الحراري بسبب انبعاثات الغازات الضارة مثل غاز ثاني أكسيد الكربون، وارتفاع تكلفة صيانة هذه المولدات، كذلك صعوبة نقل الوقود الأحفوري إليهم. ولذلك اتجه العالم إلى استخدام مصادر الطاقة المتجددة، لما لها من مميزات مثل تواجدها في جميع مناطق العالم، وعدم انبعاث غازات ضارة وعمرها الطويل. ومع ذلك، فإن مصادر الطاقة المتجددة لها أيضًا عيوب مثل ارتفاع تكلفة الاستثمار، وطبيعتها المتقطعة لأنها تعتمد على البيانات المناخية. ولذلك فإن الحجم الأمثل لهذه المصادر يعتبر عاملاً مهماً لزيادة الموثوقية وتقليل الانبعاثات وتقليل التكاليف وغيرها من الأهداف. يمكن حل هذه المشاكل عن طريق التقنيات الحديثة، وهي خوارزميات ال Metaheuristic التي تعتبر أكثر شهرة من الخوارزميات التقليدية لأنها تتمتع بنتائج جيدة ووقت معالجة أسرع. في هذا البحث، نقدم مراجعة شاملة لاستخدام خوارزميات ال Metaheuristic للعثور على الحجم الأمثل للطاقات المستخدمة في نظام الطاقة الهجين (HES) لتحسين الأهداف الفردية والمتعددة. كما نقوم أيضًا بمراجعة المجموعات الرئيسية لـ HES بما في ذلك معايير التقييم الخاصة بالاقتصاد والبيئة والموثوقية.

1. INTRODUCTION

Global demand for energy is expected to increase by 53% by 2035[1], the use of renewable sources of energy in recent years has continued to increase to help address acute energy and environmental problems, especially global warming [2,3]. Also, the special energy law, which was adopted in 2003, obliges energy producers to investigate cleaner forms of electricity generation to tackle global warming caused by greenhouse gases [4].

In recent years, an intensified global initiative has been made to develop renewable energy sources, and the related energy technologies are now recognized as a strategic field. New laws and initiatives to promote the use of clean energy technology have been implemented by governments around the world. These initiatives include supporting clean energy technology, increasing energy quality, and drawing up energy conservation strategies, along with their associated legislative acts [5-10]. The use of renewable energy is commonly regarded as a promising alternative to the traditional system of fossil fuels and is thus becoming increasingly attractive [11-16].

Currently, renewable energy production is growing annually, and most countries are aiming to achieve more than 15% of renewable energy production by 2020 [17-18]. However, the majority of renewable energy sources (RESs), such as solar and wind, are unusually unreliable and sporadic compared with traditional energies. Wind speed and solar irradiance can differ greatly for hours or days. Furthermore, low energy density is often seen as a significant downside for renewable energy sources. A single source of renewable energy is obviously insufficient to sustain a continuous source of energy to provide the load by electricity. [19-20]. According to the United States market for RESs, the U.S. Energy Information Administration renewable energy supply figures are shown in Figure (1) with the total energy produced from RESs rising. Meanwhile, solar and wind power have steadily increased the total annual renewable energy available [21]. The combination of one or more power sources may therefore supply the uninterrupted power, either through a grid-connected mode or a stand-alone mode, thus overcoming one system's shortages. A concept of hybrid energy systems (HES) that combines RESs with non-RESs has also become popular due to its high performance, high load factor, minimum cost, and low carbon emissions and acceptable in comparison with RESs only [22-27].

HES design is a very difficult with a lot number of parameters, so techniques of classical design techniques can yield unsatisfactory results [28]. In some studies HOMER software is used to evaluate the HES configuration. With HES streamlined, the HOMER program uses an enumerative technique in the search for the optimum configuration. The listing technology guarantees the best possible solution, but an extremely long processor time is required. The academic community and the industry have in recent years paid more attention to algorithms of optimization. These algorithms have been applied to many problems and have been extremely successful [29]. Metaheuristic algorithms are presently utilized as the main method for achieving optimal solutions to real optimization issues. Also, such methods majorly benefit from stochastic operators which distinguish them from deterministic algorithms that are reliably establishing solutions to certain problems utilizing comparable starting points. Also, there are many applications of engineering verifying the possibilities of the meta heuristic algorithms for the process of optimization. The meta-heuristic algorithms were classified as evolutionary algorithms (EAs), physics-based algorithms (PBA), and swarm-based algorithms (SBA) [30].

This article is organized into five parts. Section 2 offers general knowledge of hybrid energy systems. Section 3 summarizes the metrics used to assess energy system performance. The hybrid energy system sizing methodologies (meta heuristic algorithms) are included in Section 4. Section 5 Conclusion and Recommendations.

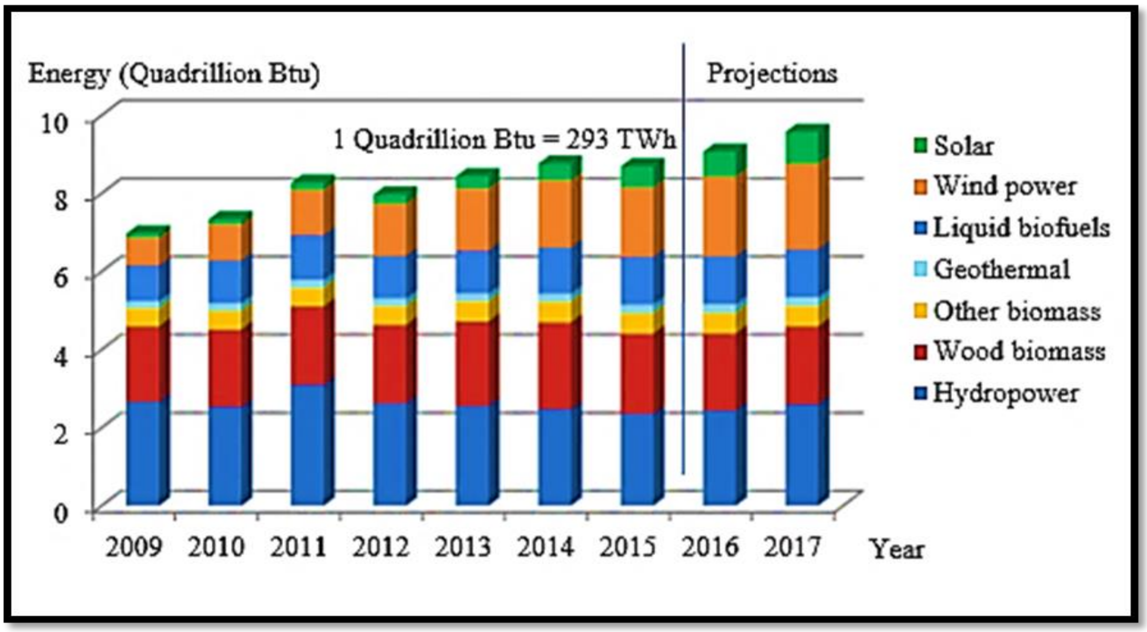

Fig.1 U.S. market use of RESs [21]

2. LITERATURE REVIEW

The metaheuristic algorithms could be categorized utilizing various criteria and this might be shown via their classification according to their features in terms of their memory usage, search path, the type regarding the used the exploration of the neighbourhood and the present number of the solutions which are transferred between iterations. In the literature, metaheuristic algorithms were categorized as population-based metaheuristics (PBM) and single-solution based metaheuristics (SSBM).

Typically, the latter was exploitative-oriented, whereas the former is more explorative-oriented. The meta-heuristic algorithms were classified as evolutionary algorithms (EAs) (inspired by normal evolutionary behaviours), physics-based algorithms (PBA), and swarm-based algorithms (SBA). A few evolutionary-inspired metaheuristic approaches were biogeography-based optimization (BBO), genetic programming (GP), differential evolution (DE), GA, probability-based incremental learning (PBIL), evolutionary programming (EP), and evolution strategy (ES). SBA was defined as the next category; these were inspired by living groups' behaviours [31–36].

A few of the major swarm-based approaches involve PSO (i.e. the particle swarm optimization) that has taken its inspiration from the social and individual behaviour of birds, while cuckoo search (CS) mimicks a distinctive egg-laying behaviour, ABC (i.e. the artificial bee colony) that has taken its inspiration from bee swarms' behaviour as they search for nourishment, also firefly algorithm (FA) that has taken its inspiration from properties of lights flashing from the firefly, WOA (Whale Optimization Algorithm) that mimicks the social behaviour of Humpback whales, and GWO (the Grey Wolf Optimizer) that mimicks grey wolves' behaviour as they hunt for prey [37-39].

A few studies provided a novel swarm intelligence (SI) category, which referred to the socially inspired meta-heuristic algorithms. Also, approaches which belong to such category were inspired by cultural and social interactions identified in the behaviours of humans, while major algorithms in this category involve Teaching Learning Based Optimization (TLBO), Human mental search (HMS), Socio Evolution & Learning Optimization Algorithm (SELO), Artificial Memory Optimization (AMO), and Cultural Evolution Algorithm (CEA), while physics-based approaches are mimicking nature's physical procedures. The major algorithms in such categories involve mine blast (MB), gravitational search algorithm (GSA), water cycle (WC), simulated annealing (SA), and Lightning Attachment Procedure Optimization (LAPO) [40-43].

Figure. (7) shows Metaheuristics classification based on a variety of solutions.

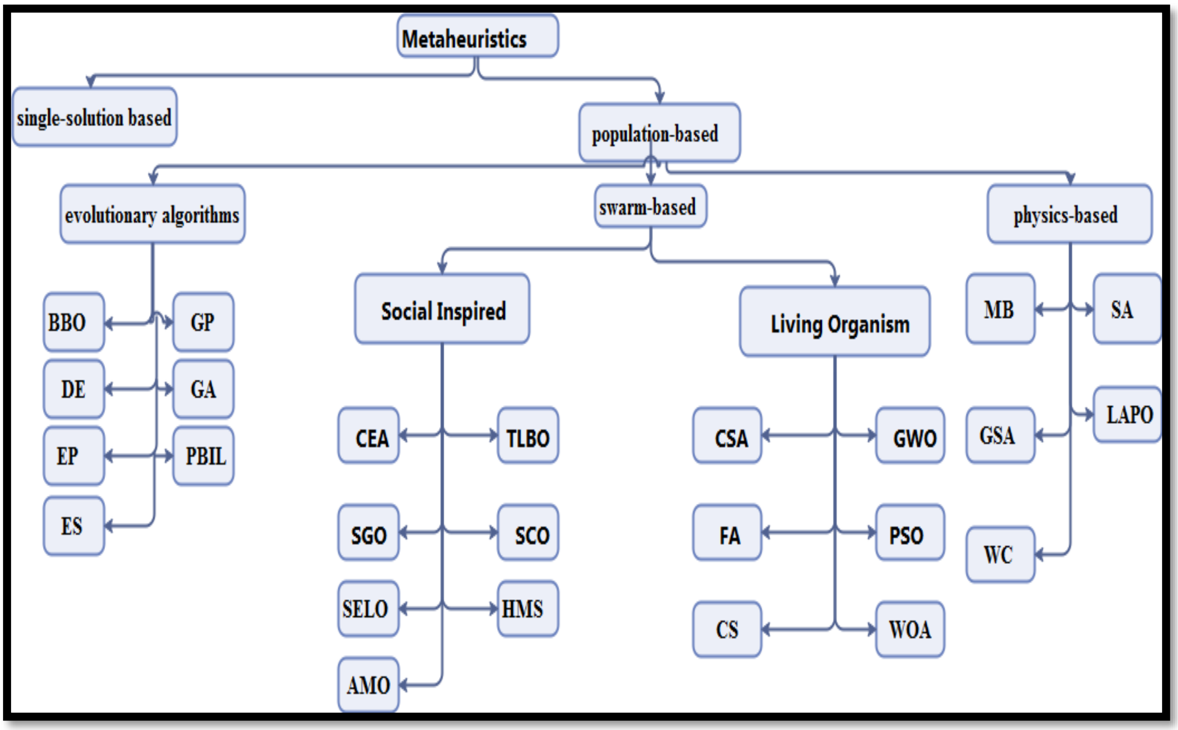

Fig.2 Metaheuristics classification based on a variety of solutions

The optimization is divided into a single as well as multi-objective optimization. The former depends on individual complete ordering. In the latter, there are infinite in equivalent partial orderings. Multi-objective optimization is classified into various methods As follows; Scalarization, weighting sum, e-constraint, goal programming, evolutionary, direct search, genetic, and Pareto optimality are among the methods used in search optimization. Figure (8) shows both multi- and single-objective optimization. [44].

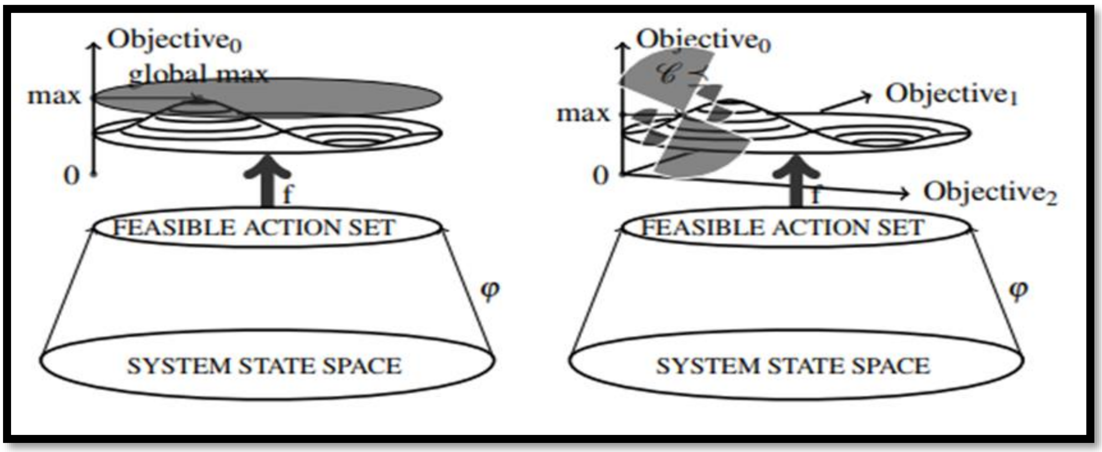

Fig.3 Single and Multi-objective optimization [44]

The meta-heuristic algorithms used to find ideal size for the HES for single objective or multiobjective in the following will review the studies that used meta-heuristic algorithms to find optimal sizing of the HES for single and multi-objective optimization.

In order to find the best size of a HES (BS -DG-PV) to electrify a small community in the south of Algeria, **Fodhil et al. (2016) [45]** employed PSO and the E-constraint technique. The lifespan of this research is one year. The ambient temperature and daily radiation for a year are combined to create the peak demand of 5 kW. They discovered that the optimal size with the lowest yearly cost is (76 PV at 4.12 kW, 48 BS at 5.76 kW, and 2 kW of DG), with a C^{Tot} of 3676 $ and total CO_2 emissions (CO_2^T) of 468 kg/year. They also discovered that raising CO_2^T emissions will lower C^{Tot} . **JOTY, et al. (2018) [46]** compared scenario PV-BS system by used GA algorithm with five scenarios; (PV-WT-BS), (WT-BS), (PV-BS-DG) system, (PV-WT-BS-DG) system ,and (WT-BS-DG) system to minimize COE, they found that (WT-BS) have COE of 1.06 $/kWh, while (PV-BS) system 0.3 $/kWh, (PV-BS-DG) system have COE of 0.223 $/kWh, (PV-WT-BS) system have COE of 0.3 $/kWh, (PV-WT-BS-DG) system have COE of 0.23 $/kWh.

Baygi , et al. (2018) [47] used Gray Wolf Optimizer to find optimal sizing of system consist of (PV-WT-BS-DG) to provide ten residual building located in Rafsanjan , Kerman, Ardabil, Iran .This study was single objective to minimize annual total cost of the system with reliability as constraint .The results of this algorithm compared with two algorithms (PSO) and (GA).The results show that (GOW) algorithm given optimal sizing of (PV-WT-BS-DG) with less annual total cost compared with rest algorithms**. N. Mars, et al.(2019) [48]** compares the results of the BAT algorithm with Homer and the particle swarm optimization (PSO) algorithm for. It demonstrates how the BAT algorithm finds the ideal size of a PV-wind hybrid energy system to meet the electricity needs of an offshore petroleum platform in Zarzis, and it does so with ease and at a lower cost. Subsequently, the findings demonstrate that ideal sizing, load supply level, and cost are significantly impacted by taking dependability characteristics into account. For the given hybrid system, the primary goal function is to minimize the annualized cost of the system (ACS). ACS operation Adding up the replacement cost (Cr), maintenance cost (Cm), and total capital cost .the results optimization (BAT) of number system component is Number of PV (15),number of WT is (0),number of battery (7) ,total cost is 9940$ in availability (100) $ and this result is better of (PSO) and HOMER.

W. M. Hamanah , et al.(2020) [49] Use Lightning search algorithm to compared between ten scenarios (PV-WT-BS-DG),(PV-WT-BS),(PV-BS-DG),(PV-WT-DG),(PV-DG),((PV-BS),(WT-BS-DG),(WT-BS),(WT-DG), and (DG) to find optimal sizing. The objective of this study is to minimizing of the system .This study was for one year. The results show that (PV-WT-BS-DG) scenario is given less cost of rest senarios where was COE is 0.0629 ($/ kWh),then (PV-WT-DG) of (0.0688 $/kWh) ,then (WT-BS-DG) of (0.0724 $/kWh) , then (WT-DG) of (0.0805 4/kWh) ,then (PV-WT-BS) of (0.0908) ($/ kWh), and worse scenario is (DG) of (0.2204) ($/ kWh),and (PV-DG) scenario of (0.2470) ($/ kWh).The study was in the Dhahran area**. U.AKRAM, et al.(2018) [50]** compared six scenarios (PV-WT-BS-DG),(WT-BS-DG),(WT-DG),(PV-DG),(PV-WT-DG), and (PV-BS-DG) ,to find optimal sizing of standalone hybrid renewable energy by (PSO) algorithm for multi objective optimization to provide typical residential standalone micro grid. The multi objectives are (Total cost , CO2 emission ,and Dumb Energy).The study was for one year. The results show that (PV-WT-BS-DG) scenario is best scenario where give (more economical, less total cost and less co2 emission) and consider Environmentally friendly compared with rest scenarios **.**

Ruiz, et al. (2018) [51] Used the Cut and Branch algorithm to determine optimal sizing of HES consisting of WT-PV-BS-DG, in the Colombian community of Uniguia, found in the state of Choco, to minimize CO_2^T , C^{Tot}, as objectives and LPSP as a constraint, this study was for one year. Also, a comparison software HOMER and Cut algorithm and , the weather information was gathered from NASA. Average load of 300 kW/h and max load 400 kW/h. They determined that the best sizing using Cut, Branch method is WT-PV-BS-DG, which gives a C^{Tot} of 1,090,600 $ with DG created at 37.8 (%). While ideal sizing by HOMER yields C^{Tot} of 1,144,600($ with DG produced at 71.74 (%). They also discovered that DG was the most often utilized energy source and that the Cut and Brunch algorithm outperformed HOMER. **Abba Lawan Bukar et al.(2019) [52]** compared between three algorithm (PSO), (CS), and Grasshopper Optimization Algorithm (GOA)) to determine the ideal system size consist of (PV-BS-WT-DG) to provide micro system of five homes in an off-grid area in Nigeria's Yobe State. The study was for multi objectives are to minimize total cost of the system and increase reliability of the system , and this study was for one year .The results shows that (GOA) best of (PSO) and (CS) where given less total cost of the system and more reliability. The result for optimal sizing of the system is consist of (PV-WT-BS-DG).

3.The HES architectures

Solar and wind power generation is growing and composes the world's fastest-growing technology. The estimated global wind and solar production in 2040 were 1,839 billion kWh, and solar power was 452 billion kWh. [53]. The main disadvantage of RESs, however, is their unpredictable and intermittent nature. This problem can be overcome by integrating different sources of energy to configure a hybrid energy system (HES) that can resolve problems of reliability and provide an environmentally friendly solution. Different energy sources like diesel generators and batteries should be integrated into HES to increase system stability and ease fluctuations. Most literature review studies used the wind turbine (WT), and photovoltaic cell (PV) as RESs integrated with the diesel generator (DG), and the battery storage (BS) [54]. The output power of the WT is dependent on instantaneous wind speed in the hub height, while the power output of the PV is dependent on the air temperature and solar radiation [55-62]. The important HES configurations in the previous study are as following:

3.1 PV-BS HES

Today, the installations of PV systems are increasing rapidly due to numerous factors, such as global warming concerns, energy protection, technical advances, and cost decreases. Stand-alone PV systems in Bicular are a very attractive and indispensable source of electricity for security cameras, road lights, electric signs, where some of them can be installed in remote or mountainous areas. [63]. For the stand-alone PV generation system, energy storage devices are needed. Battery charge and unload control with full photovoltaic power is the secret to improving the efficiency of the generating system [41]. A typical independent method, as illustrated in Fig. 5. includes a photovoltaic cell, DC-DC converter, energy storage system (battery rechargeable), and loading system [64]. In this configuration, the PV provides the load by the electricity, when found the solar radiation, the excess of the PV energy will charge the BS. When do not found the solar radiation the load demand will provide by the BS [65]. Figure (3) shows a block diagram of a PV-BS HES.

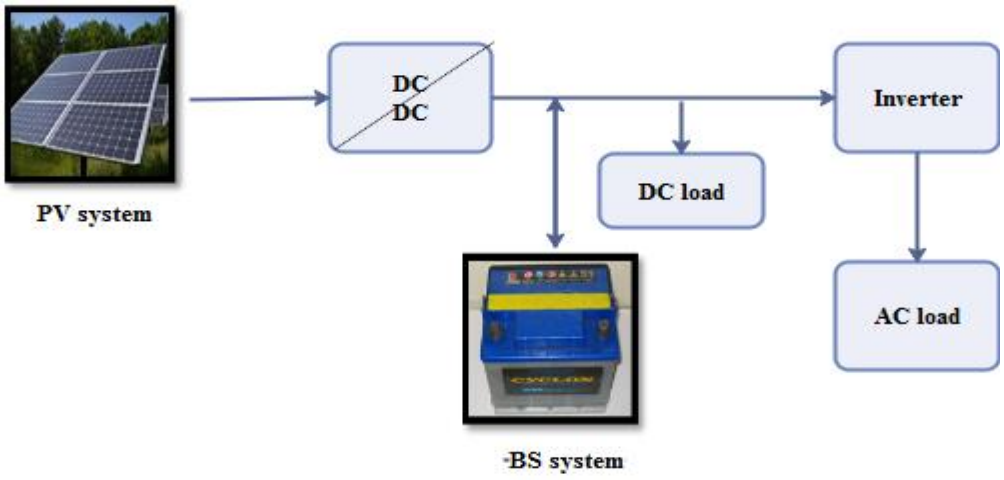

Fig.4 Block diagram of a PV–BS HES

3.2 WT-BS HES

The USA alone generates about 3 billion kilos of watt hours per year (which serves about one million people a year), primarily from the wind farms of California. The excess electricity generated is normally stored in batteries that can later be used if the wind speed below of the speed cut .WT should be combined with other sources, for instance PV or DG, in order to maintain the reliability of the system [66]. In this configuration, the WT provides the load by the electricity, when instantaneous wind speed in the hub height is greater than the cut-in wind speed and less than the cut-out wind speed. The excess energy of the WT will charge the BS, when the instantaneous wind speed is less than cut-in and greater than cut-out, the BS will charge the load demand by the electricity [67]. Figure (4) shows a diagram of a WT-BS HES.

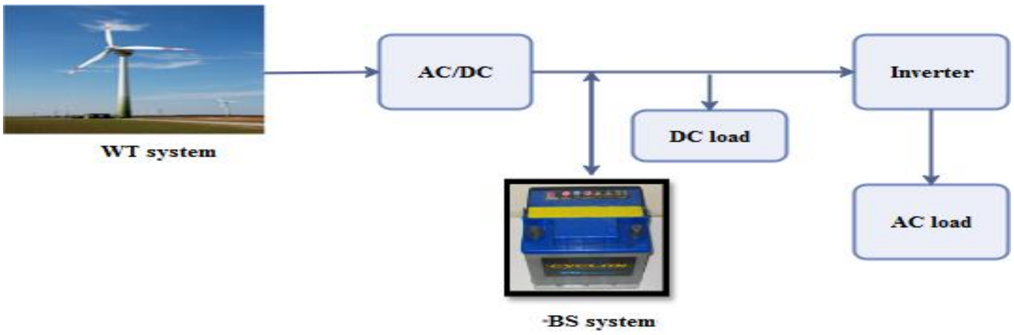

Fig.5 Block diagram of a WT–BS HES

3.3 WT-PV-BS HES

This system uses three power supply systems, each capable of working independently to ensure availability for joint load demand [68].In this configuration note that the WT-PV system will provide the load demand by electricity when wind speed in target height is greater than the cut-in, solar radiation is available, and renewable energy is greater or equal loss & load, but when wind speed in target height is less than cut-in wind speed, and solar radiation is not available it will provide load demand by the BS. When wind speed in target height is greater than cut-in wind speed, solar radiation is available and renewable energy is less than load & loss the load demand will be provided by the WT- PV-BS system. Excess energy will charge the BS. When there is an excess of renewable energy and LCB in maximum will be dump energy [69-74]. Figure (5) shows a block diagram of a WT-PV-BS HES.

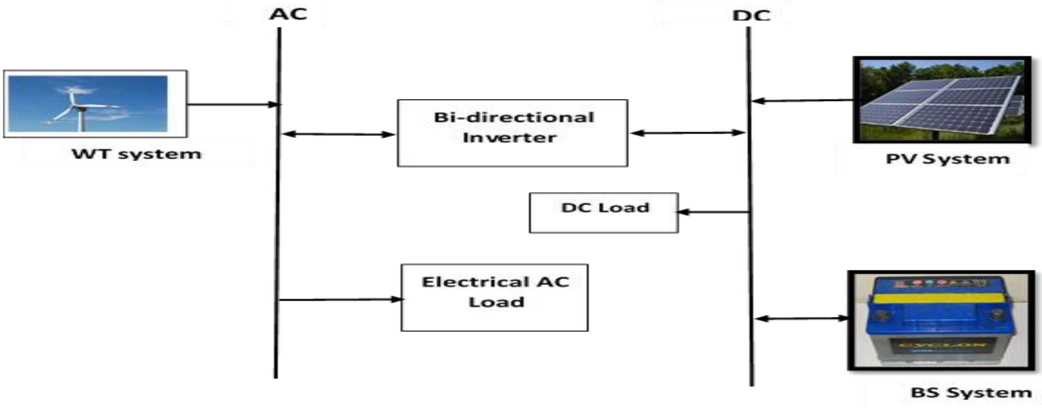

Fig.6 Block diagram of a WT–PV–BS HES

3.4 WT-PV-BS-DG HES

In this scenario note that the WT-PV system will provide the load demand by electricity when wind speed in target height is greater than the cut-in , solar radiation is available, and renewable energy is greater or equal to load & demand, but when wind speed in target height is less than cut-in wind speed, solar radiation is not available it will provide load demand by battery storage. When wind speed in target height is greater than cut-in wind speed, solar radiation is available and renewable energy is less than load &loss

the load demand will be provided by the PV-WT-BS system. Excess energy will charge the BS. When there is an excess of renewable energy and LCB in maximum will be dump energy but when LCB in minimum and there is a deficit of the renewable energy, DG will run with maximum output power to cover a deficit [75-77]. Figure (6) shows a block diagram of a WT-PV-BS-DG HES.

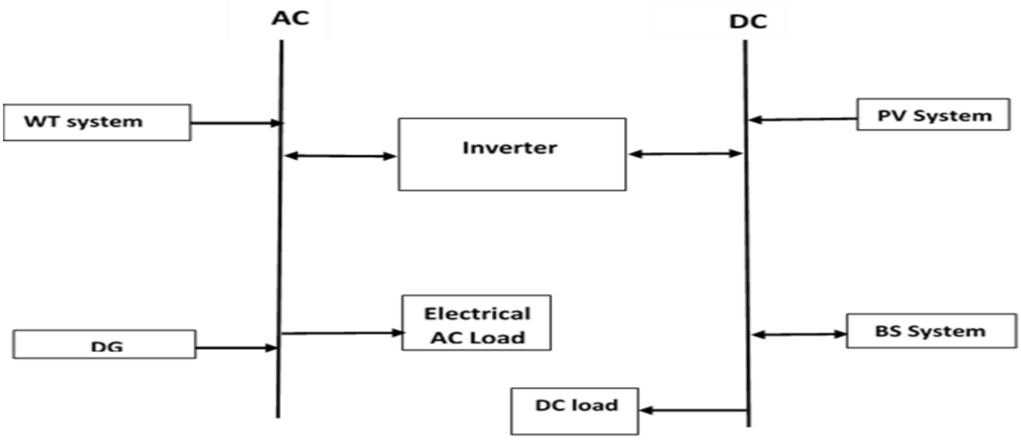

Fig.7 Block diagram of a WT–PV–BS-DG HES

3.5 Other HES

There are other HES that literature review studies have used to find the best sizing and the best composition that gives optimum attractive results, such as PV-DG, WT-DG, BS-DG, PV-BS-DG, WT-BS-DG, PV-WT, PV-WT-DG, or PV-WT-grid systems, etc. [78-95].

4. The HES metrics

To find the optimal sizing and combination of the HES many metrics will review as the total life cycle cost (C^{Tot}), cost of energy (COE), total CO_2 emissions (CO_2^T), total dump energy (D^T), probability Loss power supply (PLPS), and Renewable Energy Ratio (RER) were considered important the metrics that used in most the literature studies. The following will explain the metrics:

4.1 Total life cycle cost (C^{Tot})

Total life cycle cost represents the total cost of the system during the life of the project and it includes the initial total cost of the investment, the total maintenance cost, the total replacement cost, and the fuel total cost, given by Eq.1 [96-99]

$$C^{Tot} = C^I + C^M + C^R + C^F \qquad (1)$$

4.2 Cost of energy (COE)

The COE is the average cost per kilowatt-hour ($/kWh) of useful electrical energy produced by the system .It is calculated as follows [100-101]

$$COE = \frac{C^{Tot}}{\sum_1^n EL(t)} \qquad (2)$$

Where: EL(t) is demand energy by the load (Wh or kWh), and (n) is the project life cycle (hours).

4.3 Total CO_2 emissions (CO_2^T)

Cause emissions of carbon dioxide when operating the DG with a deficit in the RESs and the charging state of the BS is at the lowest level, which is an undesirable condition because it causes global warming. In time (t) CO2 emission calculated by Eq.3 [97-98]. Fuel consumption of the DG $fuel(t)$ in time (t) calculated by using Eq.4[102]

$$CO_2(t) = S_{CO2}(\frac{kg}{L}) \times Fuel(t)(\frac{L}{h}) \quad (3)$$

$$Fuel(t) = (0 \cdot 246 \times (P_{adg}) + 0 \cdot 08415 \times P_{rdg}) \quad (4)$$

where (P_{rdg}) is the rated power of the DG (kW), 0.246,0.08415 is constant factors (l/kW h) ,and P_{dg} is the average power output in time t of the DG (kW); S_{ECO2} Specific DG CO_2 per liter of fuel (as 2.7 kg / l), $CO_2(t)$ is emission CO_2 in time (t) (kg). $Fuel(t)$ is fuel consumption by the DG in time (t)(L).

The CO_2^T calculated by Eq.5

$$CO_2^T = \sum_{t=1}^{t=n} CO_2(t) \quad (5)$$

Where :CO_2^T are the total CO_2 emissions (kg)

4.4 Total dump energy (D^T)

This occurs when there is an excess of renewable energy and level charge of the BS (LCB) in the maximum. This condition is not desirable as there is energy wastage. The dump energy in time (t) can be calculated by using Eq.6 [96-97]

$$D(t) = Exess(t) \quad (6)$$

Where: $Exess(t)$ is the excess of the energy generated by the RESs when LCB is at maximum (Wh or kWh).

Where: $D(t)$ is the dump energy in time (t) (Wh or kWh)

D^T Calculated by using Eq.7 [74-75]

$$D^T = \sum_{t=1}^{t=n} D(t) \quad (7)$$

Where D^T is total dump energy (Wh or kWh)

4.5 Probability loss power supply (LPSP)

Because of stochastic wind speed, and solar radiation, it is assigned to test the reliability of the HES. The electrical power of the system is reliable if enough power can be supplied to the power for a certain duration. The ratio of all deficits energy demand energy by the load through the period considered can be described as $LPSP$ calculated by using Eq.8 [103-117]

$$LPSP = \frac{\sum_{t=1}^{t=n} E_D(t)}{\sum_{t=1}^{t=n} EL(t)} \quad (8)$$

Where: LPSP is probability loss power supply (%),E_D energy deficits in time (t) (Wh or kWh).

4.6 Renewable Energy Fraction (REF)

REF is the ratio between the energy drawn to the load from the DG to the energy drawn to the load from HES, and calculated by using Eq.9 [22]

$$REF = (1 - \sum_{t=1}^{t=n} \frac{EL,DG}{EL(t)}) \times 100 \quad (9)$$

Where: REF is the ratio between the energy drawn to the load from the DG to the energy drawn to the load from HES (%),EL,DG the energy drawn to the load from the DG (Wh or kWh).

5. Conclusion and Recommendations

5.1 Conclusion

This article offers a summary of the most current research work. The use of metaheuristic algorithms for multi and single-objective optimization to find optimal sizing and combination of the standalone hybrid energy system in remote areas; with a review of HES architectures, and important configurations that are used in literature review studies. It also reviews important the metrics to test optimal sizing of the HES used in most of the literature studies as the total life cycle cost (C^{Tot}), cost of energy (COE), total CO_2 emissions (CO_2^T), total dump energy (D^T), probability loss power supply (PLPS), and Renewable Energy Ratio (RER). From the literature review it is concluded as follows:

1. The first conclusion of this analysis is that, while many HES optimization approaches exist, a few have addressed the multi-objective optimization of stand-alone HES with metaheuristic algorithms.
2. Wind energy and solar energy are the most renewable sources of energy used in the design of independent hybrid systems.
3. Hybrid RESs are the best of single RESs giving more attractive results, such as minimum total cost of the system through the project life cycle, and high reliability.
4. Solar cells depend on solar radiation and temperature. The cell energy increases with increasing solar radiation and decreases with increasing temperature, while the turbine depends on wind speed.
5. Most studying relied on the equations written in this article for the purpose of calculating the best sizing of a standalone hybrid energy system.
6. GA, PSO, GWO, BAT algorithm, Lightning search algorithm, Cut and Branch algorithm,and GOA algorithms are the most common metaheuristic algorithms in previous studies that are used to find optimum sizing and composition of stand-alone HES in remote areas.
7. Most of the studies concluded that a PV-BS-WT-DG system gives more attractive results than used hybrid RESs.
8. Most of these studies are for just one year of evaluation.
9. Some of the research found that uses metaheuristic algorithms superior to the linear program as HOMER to find the ideal sizing of HES.
10. Most of the research concluded that the optimal sizing of HES is a mix of RESs (PV-WT) with storage system (BS) and non-renewable energy source (DG), but in this research, DG was used only to cover a deficit of RESs without charging the batteries.
11. Some of the research found that the energy costs decreased when the load size was greater (village population) also the implementation of HES is more economical than connecting villages to the power grid.
12. Most of the research does not use real data as temperature, wind speed, and solar radiation, Data is supported by software and NACA data.
13. Metaheuristic algorithms need to control parameters that help them to balance between global search and local search.
14. The total cost depends on the cost of materials, maintenance cost, and replacement cost.
15. A renewable energy system can operate without generators by relying on batteries, but the cost increases.
16. Studies over a long period are better than studies over one year... because the lifespan of solar cells is approximately 25 years.

5.2 Recommendations

In light of the conclusions stated above, some recommendations can be drawn:

1- Increase the number of studies using multi-purpose optimization by the metaheuristic algorithms to find the ideal combination and sizing of standalone HES.

2- Design a new algorithms that does not contain control parameters in order not to affect the search process and to make the design of the algorithm is less complex.
3- More studies are needed to make the lifespan of the study the same as the lifespan of RESs.
4- Use real data such as temperature, wind speed, and solar radiation.
5- The use of diesel generators to charge the BS will cover a deficit of RESs when the level charge of the BS in minimal.
6- Many factors affect the output energy of the PV, such as humidity and pollution, as well as the presence of factors, the affect on the output energy of the WT, such as air temperature and dust, that must be taken into consideration in future researches.
7- New studies to compare between split diesel generators and single big DG depending on the current prices.

Nomenclature

PV	Photovoltaic Cell
HES	Hybrid Energy System
RESs	Renewable Energy Sources
C^{Tot}	Total life cycle cost ($)
C^{I}	Initial total cost of the investment ($)
C^{M}	Total maintenance cost ($)
C^{R}	Total Replacement cost ($)
C^{F}	Total fuel cost ($)
COE	Cost of energy ($/kWh)
EL(t)	demand energy by the load (Wh or kWh)
n	life cycle of the project (hours)
CO_2^T	CO_2 emissions total (kg)
$CO_2(t)$	emission CO_2 in time (t) (kg).
S_{CO2}	Specific DG CO_2 of fuel per liter (kg/l)
DG	Diesel Generator

WT	Wind Turbine
Fuel(t)	fuel consumption by the DG in time (t)(L)
P_{rdg}	power of the DG (rated) (kW)
Padg	average power output of the DG in time t (kW)
D^T	Total dump energy (Wh or kWh)
D(t)	dump energy in time (t) (Wh or kWh)
LPSP	Probability Loss power supply (%)
DE(t)	energy deficits in time (t) (Wh or kWh)
REF	Renewable Energy Fraction (%)
EL, DG	energy drawn to the load from the DG (Wh or kWh).
LCB	Level charge of the BS (W)
BS	Battery Storage

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