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Overview: Using Hybrid Energy System for Electricity Production Based on the Optimization Methods

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Highlights

- Literature review on the optimization approaches based on the hybrid power producer.
- A detailed demonstration of different configuration energy systems and hybrid power systems.
- Several optimization approaches have been suggested for different power systems.
- Discussion of hybrid energy system regarding the optimization method and simulation software.

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Abstract

Renewable energy systems are mostly used in the world due to their inexhaustible and non-polluting production. As a result of a large utilization of these energy sources in different areas, the electricity production rate is increasing every day. Previous studies clarified uses, modeling, configuration, energy management operation, and optimization objectives based on different energy sources. For this reason, this paper focuses on an overview of multi energy systems as renewable and conventional power sources with the integration of an energy storage system coupled to the on-off electrical network. Furthermore, a survey is done regarding global energy production, configuration energy systems, energy storage systems, power management strategies, and optimization methods based on different hybrid energy systems. Multiple optimization approaches have been implemented to reach the global best solution for the hybrid power systems. To ensure the best optimization result, it is preferable to take hybrid optimization methods into consideration. These methods have been invented recently and have proved their efficacy and performance mainly in power systems.

1. INTRODUCTION

Production energy by renewable energy sources has expanded in several fields such as industrial, agricultural, domestic, and popular sectors because they can meet the energy demand. Among these sources, solar and wind energy systems are mainly used in the world to generate electrical energy by considering climatic conditions. To ensure energy efficiency, it is preferable to use a hybrid energy system than a single source. Combination of multi energy sources has a great benefit regarding the cost, sizing, reliability, efficacy, and performance [1, 2].

In [3], the authors focused on the sizing of the hybrid energy system constituting a solar panel and battery energy system to supply an autonomous site. The authors in [4] proposed an investigation of various photovoltaic (PV)/Wind hybrid energy systems to generate electrical power. A comparative study has been done concerning system cost and configuration systems efficacy. Similar directions have been presented [5-10] to clarify different hybrid energy system analyses. The main purposes of these works have been established on the sizing, system cost, modeling, configuration, planning, strategy management, control, and optimization methods for different energy system producers. Faccio et al. [11] applied a survey

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comprising a PV/Wind /battery energy system supplying an isolated site. This study is based on the optimization of some parameters such as the cost, reliability index as loss of power supply probability (LPSP) and energy index, battery's state of charge, and other factors with the aim of showing the performance of integration of hybrid energy system. An overview have been introduced in [12] based on solar panel, diesel turbine generator and energy storage system. This study aimed to solve optimization issues and selected the optimum solutions. A new conception in [13] presented a techno-economic investigation of the rooftop photovoltaic system connected to the grid and concentrated on the educational building sector. The principal purposes of this study are to obtain a minimum cost of energy, reduce greenhouse gas emissions, and control the interruption of the grid in the building. Dawoud et al. [14] suggested an examination concerning the optimization approaches. The authors discussed the optimization of the actual tendency of the hybrid energy system attached to the micro-grid. In this analysis, artificial intelligence method was given a weighty optimization for the microgrid without an outspread long-period meteorological data. A novel survey achieved in [15] took into consideration the energy management problem in microgrid by implementing various optimization methods. Mainly, this study is based on the prevision, request management, financial dispatch, and unit engagement. The authors in [16] presented an analysis on multi viewpoint of energy surveillance focusing on energy efficiency, evaluation, optimization, and energy management approaches. This research has shown that energy production plays an important role in the economy, efficiency and performance through the different methods applied. In addition, extensive research has been conducted on various hybrid energy systems [17 -19]. The contribution of these studies is to obtain solutions to emerging issues such as sizing, control, performance, technology, economics, environment, modeling, optimization and energy management in order to improve distribution electricity generation and meet the energy deficit. Consequently, metaheuristic optimization methods have been used in the literature to attain the optimal values.

This paper offers a review study on optimization approaches. The aim of this analysis is to provide the reader with information on how to choose an effective optimization method to reach the optimal solution. Furthermore, a discussion on power system distribution based hybrid energy system with energy storage technology connected to the on-off power grid is included. This examination is based on energy management strategies and optimization approaches, in which various algorithms have been employed with respect to the requested issues. Integration of a hybrid power system to provide electricity has great benefits such as eliminating energy deficiency and increasing the performance and reliability of the generation system. Various classical and recent optimization methods have been applied in previous works to solve problems concerning electric power systems. An explanation will depicted in this paper to demonstrate the performance and durability of these methods mainly in the running time and optimization solutions (local/global).

2. WORLD ENERGY CONSUMPTION

World energy consumption is increasing by around 2.3% per year. It is predicted that the world's energy consumption to be 53% since 2008 until 2035, which Figure 1 demonstrates the durable energy demand in the world [20].

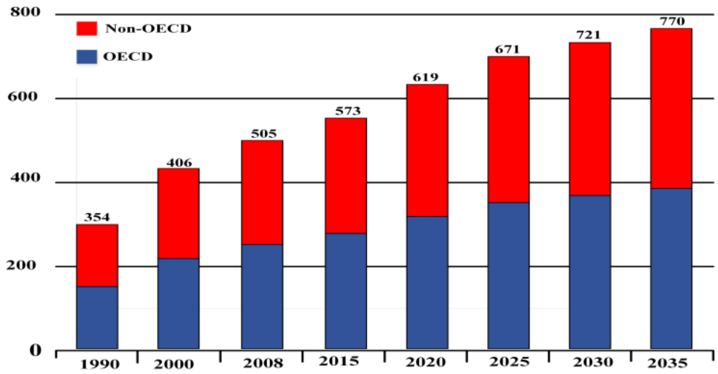

Figure 1. *World energy demand [20]*

Recently, global energy consumption statistics have proven that conventional energies such as (gas, coal, fossil fuel, etc....) are still dominant in the production of electricity despite the appearance of renewable energies. Furthermore, most of the countries in the world are decreasing the use of conventional energies and have replaced it with the renewable energies because these energies are free and not emit greenhouse gases.

Figure 2 explains the electrical energy production between fossil fuel and renewable energy from 2010-2020. Due to the emergence of the coronavirus epidemic, current information on world energy production in 2021 is not yet available.

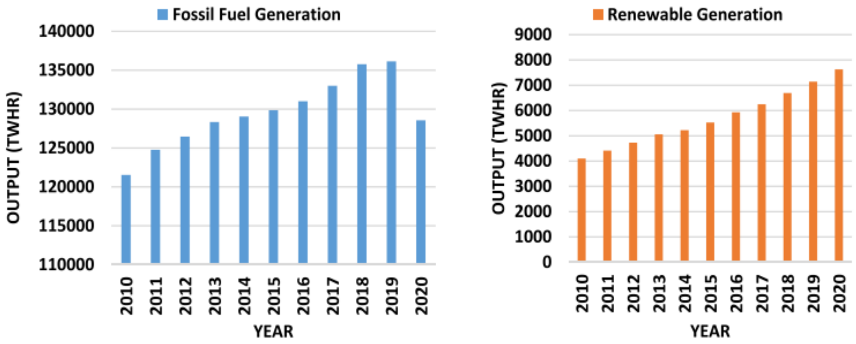

Figure 2. *Fossil fuel and renewable energy production development from year 2010-2020 [21]*

The difference between fossil fuel production and renewable energy reduced from the year 2010 to 2020, renewable energy production exceeded fossil fuel suppliers, mainly during the pandemic in 2020. It is considered that electricity production of residence areas might be provided through renewable energy systems in the future. Figure 3 clarifies the global renewable energy sources used for production from 2010-2020. In 2021 data, it is seen that overall renewable energy generation demonstrated an important increase between 2010-2020 from 4,098 TWh to 7,627 TWh [21].

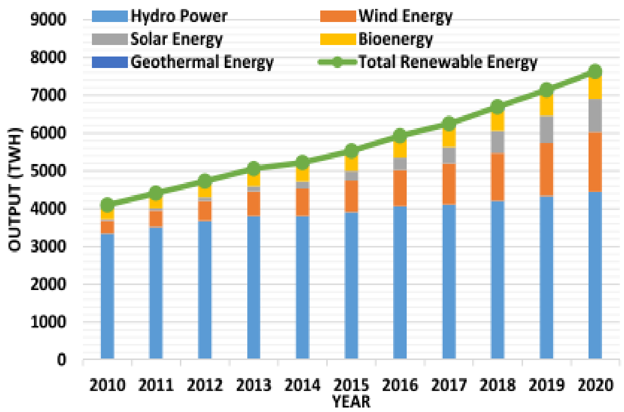

Figure 3. *Global renewable energy sources used from 2010-2020 [21]*

Renewable energy generation enables electrical installations to be made quickly and has made better progress in 2020. Renewable energy has a wide potential to decrease the costs and depends on the fossil fuel in the short and long period. Renewable installation is estimated at 320 GW around 8% in 2022. Hence, renewable power generation continues to increase in 2023 since solar energy extension cannot entirely recompense to mitigate hydropower and stable year-on-year wind accompaniments [22]. The total world energy production of renewable energy is depicted in Figure 4.

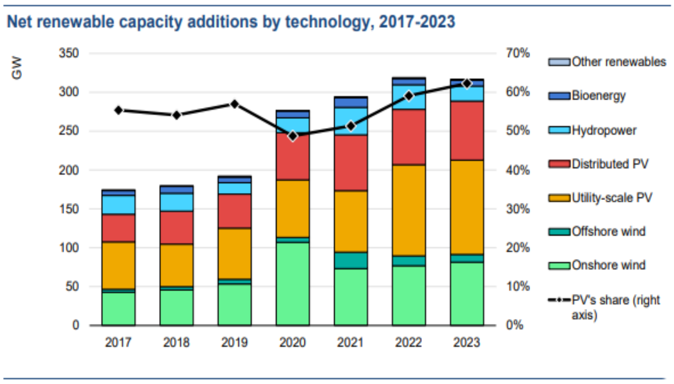

Figure 4. *Global energy production of renewable energy 2017-2023 [22]*

3. HYBRID ENERGY SYSTEM

Renewable energies are more consumable than conventional power systems although the power production is influenced by climatic and environmental conditions . The combination of multiple energy sources is known as a hybrid energy system, and its benefit is to guarantee the supply of electrical energy during energy production, increasing the efficiency and reliability of energy sources.

Hybrid energy system modeling is based on several aspects, such as studying the feasibility of sites, energy accessibility, technical, economic, and environmental factors. In this case, a sizing technique must be applied to accomplish the energy effectiveness of the system [2]. Mainly, the hybrid power system consists of renewable and non-renewable energy system, storage system, converters (AC/DC) and (DC/AC), load, grid as shown in Figure 5.

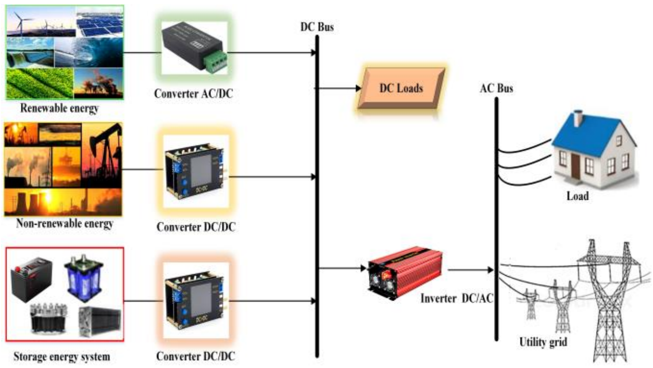

Figure 5. *Global schematic of hybrid power system*

3.1. Solar Energy

Solar system is the most renewable source in the world. The conversion of this system into electrical energy is generated through the sun. Actually, solar energy provides around 2% of the total electricity request [21]. It was produced at an installed power of approximately 139 GW in 2020. While the solar energy market is developing better in three countries -China, Vietnam and the United States- this energy source is also experiencing noticeable growth in other countries around the world [23].

In 2022, the total production of photovoltaic energy system achieved 120 GW [22]. Previous studies have integrated solar energy system in several sites to solve the optimization problem, as in [24]. The authors illustrated a techno-economic study of PV/ battery system connected to an on-off grid and applied different optimization methods to solve the proposed problem. Zhang et al. [25] discussed a grid related to the PV/battery/hydrogen system. Genetic method is used to enhance storage system sizes and strategy management parameters. An evolved operation management design in [26] aimed to obtain a minimum cost of grid-connected PV/battery energy system in South Africa, considering technical and economic criteria within certain process circumstance and constraints. ChaoMa et al. [27] defined the optimal power reassignation and sizing configuration of grid connected PV/hydrogen system generation. This novel study yielded the best results within the required objectives.

3.2.Wind Turbine Energy

Wind system is the second main priority of electricity production among the renewable sources after hydropower [28], due to its comparatively simple and easy substructure, price efficiency, and advancement of technology [29]. The electrical energy production by the wind turbine system is made through the conversion of the wind kinetic energy. The output energy of this source is dependent on its weather condition, and its height, and is influenced by different temperatures.

The world wind energy market extended to 93 GW of novel installations in 2020, taking the entire capacity of onshore and offshore wind energy to 743 GW [30]. The USA and China have recorded a raise in wind energy installation. In [31], the authors presented a physics-informed optimization approach for modeling and controlling the wind turbine energy system connected to a standalone site with the aim to improving the energy efficacy of wind turbine. Zhang et al. [32] suggested a multi-objective optimization and configuration of wind turbine/solar energy system including energy storage system. Furthermore, different energy system configurations focus on the implementation of different operation managements. In [33, 34], an advanced work is presented that builds a grid-connected renewable energy system to solve multi-objective optimization approaches. Furthermore, an investigation of the economic and environmental perspectives was carried out. Daily planning of smart microgrid was proposed to solve multi-objective problems [35]. Moreover, all the disadvantages of the wind turbine system were considered to provide a good power consumption to the users.

3.3. Hydropower Energy

This type of energy source has a wide range of applications in the field of electricity. Hydroelectric power plants make it possible to generate electricity depending on the force of the water. This force depends either on the height of the waterfall (high or medium head power stations) or on the flow of rivers and streams.

The net worldwide production of hydropower reached 18 GW in 2020. Power extensions continued to grow moderately with 28 GW per year in 2021-2022 [22]. Some studies have applied hydroelectric power system to provide electric power to find solutions to the optimization problematic as mentioned in [36]. The authors offered an overview of the hydropower system based on the metaheuristic optimization methods. Hydropower energy was implemented as an energy storage system in [37, 38], named pumped storage hydropower. It has a wide potential that cause to identify the power flux and specify a model to evaluate all the outputs. Therefore, a modeling and optimization method was proposed to obtain solutions based on the required problems. Other researchers performed a hydropower system with a renewable power system combination where a new analysis was proposed to evaluate various criteria based on an improved optimization technique [39, 40].

3.4. Biomass Energy

Generation power from this source is done through a repeat cycle, which depends of plant, animal matter and materials as wood, organic waste, from forests and/or agriculture. This renewable source met 8.5 GW of the global production installation in 2019. It progressed at 7% per year between 2010 and 2021 and is still growing [22]. This power source generates energy that roughly doubles electricity production from 750 TWh (2.5% of total production) in 2021 to an estimated 1350 TWh (3.5% of total production) in 2030 [22].

Biomass energy has been combined in several studies with hybrid energy systems to supply electricity. Among the recent works, optimization problems were mainly focused in [41-45], where the authors proposed a new research on hybrid energy systems including biomass generator and energy storage system to supply an isolated site. Different problematics under various constraints were presented and an optimization approach was applied for all the objectives.

3.5. Geothermal Energy

Geothermal energy describes the heat from the earth's surface that is contained in the earth's crust or superficial layers. It comes in the form of steam or hot water tanks. This energy can be used for the production of heat for heating and the preparation of hot water. It is ecological, protecting the environment in the long run. It possible to produce different types of energy relating to the temperature of the heat drawn from the subsoil. Depending on the calories captured, the hot water is recovered for heating or air conditioning installations for use in the production of electricity [46].

Overall, world production of geothermal energy was estimated to be around 0.3 GW in 2020 and the total geothermal production to be around 16.5 GW in 2022. Previous works offered the use of geothermal source mostly in the heating and cooling thermal source for providing power. Furthermore, it is connected to a different energy system in various areas in order to solve the optimization problems. In [47-49], multi-objective problems have been posed concerning geothermal energy connected to a hybrid energy system to provide electric power. Optimization techniques have been used in the purpose to select the best results through different software simulation. To enhance the power efficacy, a new design model was planned in [50, 51], constituting a PV system, geothermal source, cooling and heating power system, considering energy storage system. Best results of optimization model were shown by the application of various algorithms.

3.6. Ocean Energy

Ocean renewable energy includes all the technologies making it possible to produce electricity from the various forces or resources of the marine environment: the swell, the currents, the tides, the temperature gradient between the warm surface waters, and the deep cold. Its global production reached to 400 GWh from 2019-2020. Ocean energy production is expected to increase by about 33% between 2020 and 2030, with no net emissions in 2050 and reaching 1 GW per year in 2030 [52].

Ocean energy was presented more in detail in the previous works to provide energy for different zones as in [53-57]. Almost all of these studies have introduced modeling and multi-objective optimization for hybrid energy systems under various constraints, using diverse optimization approaches to solve the intended issues.

3.7. Conventional Energy

Fossil fuels are the raw materials of the chemical industry and the most used sources of energy in the world. They supply more than 80% of the energy, far ahead of the nuclear energy and other energies (hydraulic, wind, solar). It refers to all non-renewable natural energy sources, such as coal, natural gas and oil, formed from plants and animals (biomass) living in the geological past. In 2022, the total coal consumption in the world was evaluated as 7% and was projected to reach 8 billion tons by 2021[22]. Recently, there has been a noticeable reduction in the use of conventional energy sources and their integration into the power system as an auxiliary source, in favor of the emergence of renewable energy sources to improve energy efficiency as mentioned in [58]. The authors suggested a hybrid energy system PV/wind/diesel/battery for supply residences in Saudi Arabia, and critical problems were simulated under Hybrid Optimization Model for Electric Renewables (HOMER) software. Several problems were posed in [59, 60] to expand the energy efficacy and solving optimization methods for the nuclear energy, renewable source and energy storage system. An enhanced multi-objective optimization was presented in [61] including hybrid energy system based on coal for mine industry. The results obtained have shown the performance and efficacy of the improved algorithm. Yang et al. [62] proposed a microgrid system containing renewable sources to provide power by means of shale oil. An improved Particle Swarm Optimization (PSO) algorithm has been employed to solve multi-objective optimization by HOMER software focusing on the sensibility analysis of the system.

3.8. Energy Storage System

Energy storage technology allows energy to be stored when there is no requirement by the power system producer. Most of the energy storage technologies used are electrical, thermal and gas, but other storage techniques such as electrochemical, mechanical and chemical have also been developed [63].

Integration of hybrid energy system in an electric power system needs to include an energy storage system to ensure the power consumption. In this context, most of the studies have clarified the combination of different energy storage types in power system as cited in [64], a planning of grid connected hybrid energy storage system as (battery/supercapacitor), renewable sources and load requirements. This investigation is affected through deterministic and stochastic optimization plan. Modeling, management operation strategies and optimization survey was presented in [65] for the (PV/wind/fuel cell/battery) energy system connected to the on/off grid in Thailand. Authors in [66] examined the optimization and sizing of hybrid energy system integrating wind turbine, electrical grid and various hybrid energy storage system to provide power in regional sites. Several optimization methods were applied with a comparative study regarding the optimization approaches to select the optimal value. Bakhshaei et al. [67] proposed a hybrid solar and Pumped Hydro Storage (PHS) energy system connected to the grid with the aim purchasing electricity from other grids. A new enhanced optimization method was implemented to minimize the system price, and the results proved the performance of the optimization technique. A techno-economic optimization of hole thermal energy storage system was proposed in [68]. The optimization model was carried out based on the energy management operation as storage energy that recycles heat through the combination of cooling and solar power generation, and the best results for the optimization problems were obtained. Global diagram of hybrid energy system is shown in Figure 6.

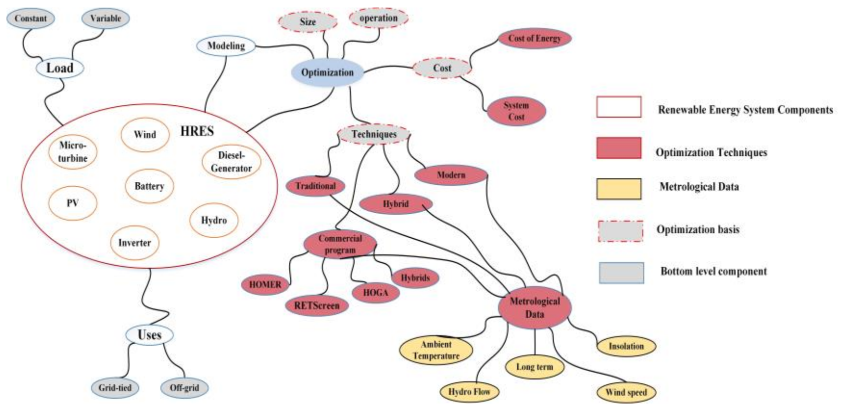

Figure 6. *Global diagram of hybrid energy system [20]*

To model hybrid energy system , some parameters need to be taken into account. Parameter choice is the main phase in modeling hybrid energy system especially in rural areas, according to some criteria such as economic, technical, environmental and social [69].

4. ENERGY SYSTEM CONFIGURATION

There are various modes to incorporate more energy sources to establish a hybrid energy system. Among these methods, there are three essential basic modes that must be taken into consideration as direct current (DC) coupled, alternative current (AC) coupled,and hybrid coupled. The AC coupled configuration system is divided into power frequency PF-AC coupled and high frequency HF-AC coupled [70, 71].

4.1. DC Coupled Configuration System

The circuit can provide power to the AC loads (50 or 60 Hz), or be connected to the grid via an inverter DC/AC, which can be controlled to permit bidirectional power flow [72], which Figure 7 demonstrates a block diagram of this configuration.

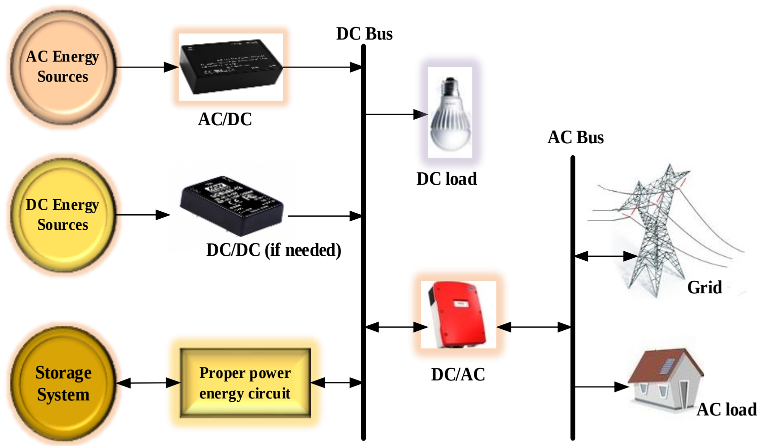

Figure 7. *Diagram of DC-Coupled Hybrid Energy System Configuration [70]*

4.2. AC Coupled Configuration System

This configuration mode is categorized into two types as PF-AC coupled and HF-AC coupled systems. This coupling type has been applied mainly in implementation with HF-AC loads (e.g.400Hz) [73-75].The description of these system configurations is shown in Figure 8 (a, b).

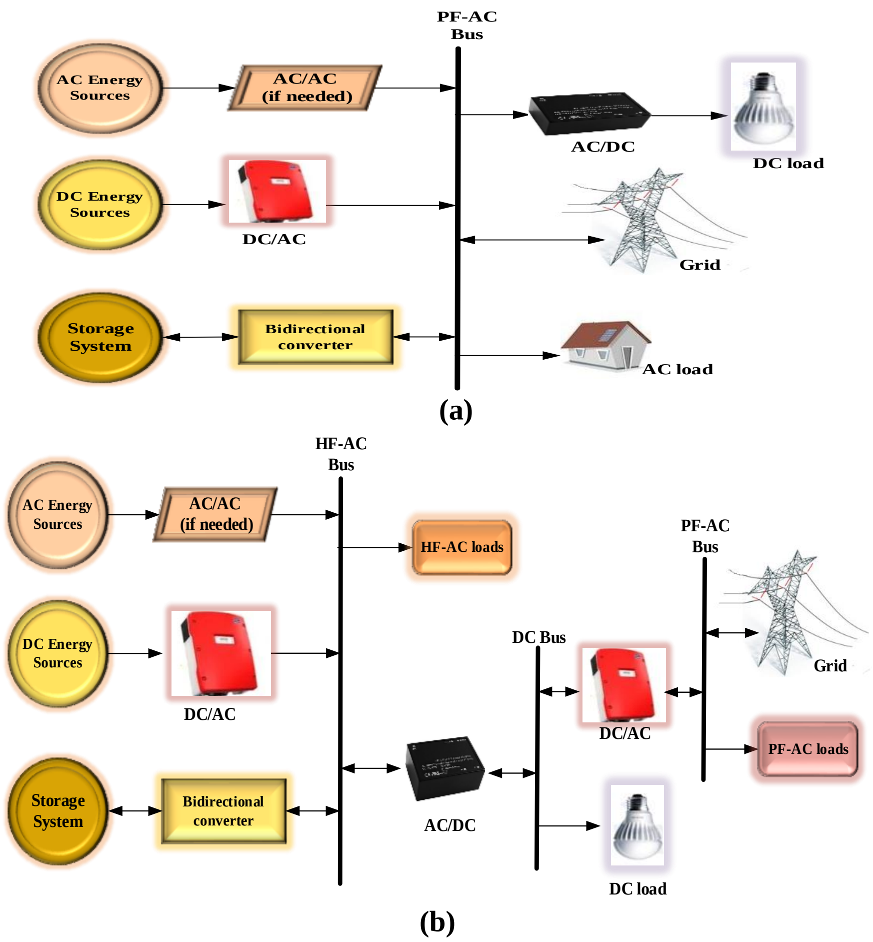

***Figure 8**. Diagram of AC-Coupled Hybrid Energy System Configurations:*
(a) PF-AC ;(b)HF-AC [70]

4.3. Hybrid Coupled Configuration System

In this hybrid coupling configuration system, a part of the energy sources can be connected directly without a supplementary electrical system. Consequently, this configuration system has better energy efficacy and the cheapest price.

The schematic diagram of this configuration is illustrated in Figure 9. It can be concluded that the power electronic system in Figures 8 and 9 are considered as modular construction units that will offer the systems extra suppleness, and extensive ability, decrease the transformation losses, and remove the use of converters in the coupling system.

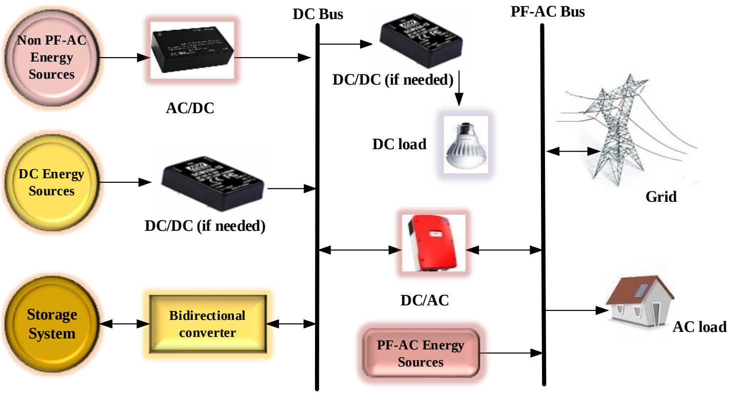

Figure 9. *Diagram of hybrid Coupled Energy system Configuration [70]*

5. ENERGY MANAGEMENT STRATEGY

The energy management process ensures great system efficiency and great reliability at minimum cost to ensure system supply and maximize system accomplishment. Power management operations are classified into three according to the purpose planning [76]: technical and economic objective strategies, and techno-economic objective strategy. Several energy management methods are applied for the grid connected hybrid energy system mode. Hence, the microgrid shall be controlled correctly when functioning on an independent mode to confirm a unified transition among modes of process and deliver steady voltage and frequency. Consequently, control strategy for microgrid is a defiance field that is being usually studied in order to discover the best appropriate depending on the necessities. The features of management energy control to accomplish in the microgrid environment are ensuring stability and the protection of the grid, power balance and transmission management, and synchronization between grid and power systems must be controlled through applying algorithms/controllers. Therefore, reliability and efficiency will be achieved for the power system [9]. These characteristics aim to adopt more complex regulation design than the conventional distribution networks regulation. In the characteristics of power grid, the grid does not check the management of production or storage units except their magnitude is demonstrative for the network. It is not easy to distinguish the most common control strategies as they mostly depend on the characteristics of the micro-grid. In the literature, some control strategies have been presented in order to implement the previously mentioned features based on a hierarchical configuration [77-79].

6. ENERGY SYSTEM OPTIMIZATION

To solve any optimization issue, the objective function must be determined, which is classified into two types as single objective function (SOO) and multi-objective function (MOO). Moreover, multi-objective optimization gives the best solution than the SOO in terms of reliability, economic and performance [80, 81].

Traditional methods can implement a single objective function. In contrast, modern approaches can employ a single or multi-objective function algorithm. Therefore, modern techniques are more efficient and give precise resolutions for the optimization process.

6.1. Hybrid Energy System Optimization Issue

Hybrid energy systems optimization issue can be classified as non-linear, non-convex, multi-objective in kind of discrete/ integer variables and non-linear/linear constraints [82]. The hybrid energy system sizing problem is expected to be multi-modes and so the total optimum resolve should be considered.

There are four main aspects that need to be clarified in order to design a hybrid energy system : decision variables, objective function, constraints, and optimization approaches [83].

6.2. Hybrid Energy Systems Based Optimization Approaches

This part comprises a discussion on the optimization methods used in the literature with the aim of solving energy system problems considering some criteria. Optimization techniques are generally classified into four methods i.e. traditional methods, modern (meta-heuristic) methods, hybrid methods and software tools for programming.

6.2.1. Traditional optimization methods

Deterministic approaches are categorized into several algorithms as iterative, mixed integer programming, probabilistic, graphical construction, numerical, and analytical. These methods allow the use of differential calculation in obtaining the optimum result. Due to the large number of explicative variables in the depletion optimization process, a large amount of time is required. In this context, the algorithm needs to be repeated various times by randomly selecting the initial condition. In rare studies using classical methods as in [84-87], the authors presented the optimal sizing of a hybrid energy system combining a hybrid energy storage system to provide electrical power. An iterative optimization process has been applied to minimize the system cost and ensure the reliability of the system. Optimization of various hybrid energy systems is very crucial, which the authors in [88-91] focused on reduce the overall system cost, achieve the system reliability, and grant the efficiency of energy production and system performance. The authors implemented deterministic optimization techniques as linear programming and improved linear programming to solve the optimization problems. Graphical construction classical optimization methods [92, 93] and probabilistic approaches [94, 95] were used to solve the optimization problems for the hybrid energy systems. An autonomous system constituted PV/battery energy system to feed a load in Oman [96]. The authors proposed a numerical optimization method to reduce the sizing and the cost of the system, in which the results obtained by Matlab software proved the efficacy of using the optimization approach.

6.2.2. Modern optimization methods

Usually, metaheuristic methods are used in combinatorial optimization, but also are encountered in continuous or mixed problems (problems with discrete and continuous variables). These methods have the aptitude to resolve small or large-scale power system processes. It has been considered a reliable approach, which has a small computational time with a fast convergence than the classical methods. It is recommended to use these techniques in different optimization fields. Various modern approaches have been applied for the hybrid power system to solve different optimization problems in mono or multi-objectives. In [97, 98], the authors proposed a multi-objective optimization of hybrid energy system to select the optimal solution under considering different constraints. A Multi-Objective Particle Swarm Optimization (MOPSO) was used [99,100] for load and grid connected hybrid energy system, in which an energy management operation was applied with some constraints to obtain the best configuration system. In [101], the authors presented a Fuzzy multi-objective optimization of a grid connected hybrid energy system feeding a load. Imperial Competitive Algorithm (ICA) was applied to the system to the solve optimization problem and respond to all criteria. An optimal sizing was studied for the hybrid energy system to supply the load demand in [102].

For resolving the optimization problem, some methods were applied as Particle Swarm Optimization (PSO), Tabu Search (TS), Simulated Annealing (SA), and Harmony Search (HS). Hence, the results obtained confirm the performance of PSO than the others algorithms in terms of reducing the system cost. Artificial intelligence was used in [103,104] such as Artificial Neural Network and Fuzzy Harmony Search algorithms. These algorithms were employed to reach the optimal solution regarding the posed optimization problems for the AC load. Genetic Algorithm (GA) was used in [105] to select the best configuration of hybrid energy system supplying a residence load. New and developed metaheuristic methods were investigated in the literature to enhance all the optimization problems. In [106], the work was based on the mine blast algorithm to obtain an optimal sizing with a minimum cost for the hybrid power system to feed an isolated site in Egypt. A comparative analysis was done with other methods as PSO, cuckoo search (CS) and artificial bee colony (ABC) to demonstrate the efficiency of the Mine Blast Algorithm. Shi et al. [107] employed a multi-objective of Line-Up Competition Algorithm (MLUCA), which is based on energy storage system as battery to prove its role in the power system, and accordingly applied it for PV/Wind/Diesel power system. An intelligent metaheuristic method inspired by honeybees as Artificial Bee Swarm Optimization (ABSO) was presented in [108]. The problems of optimization methods for an autonomous site connected to a PV/Wind/FC system were presented. A developed Fruit Fly Optimization Algorithm (IFOA) was applied in [109] to reduce the entire price and the CO2 emission of the hybrid energy system. Best results were obtained, which prove the efficacy of the optimization method and the performance of the system. Different hybrid energy system configurations were studied to provide electrical power and various optimization algorithms were employed [110-116] by means of Whale Optimization Algorithm (WOA), Improved Artificial Ecosystem Optimization (IAEO), Improved Salp Swarm Optimization Algorithm (ISSOA), Jaya Algorithm (JA), Crow Search Algorithm (CSA), Farmland Fertility Algorithm (FFA), and Improved Sine-Cosine Algorithm (ISCA). These studies allow to extract the best energy system configuration through the best optimization algorithm considering various optimization problems and constraints. The authors in [117,118] used an Improved Differential Search Algorithm (IDSA) and Shuffled Bat algorithm to find the optimal value of the sizing and locations of distribution generation in radial distribution system. A techno-economic optimization issues were solved through Pareto method and the results demonstrated the efficiency of the developed algorithm. Various optimization objectives with different criterion were depicted in [119] concerning the hybrid energy system to attain the optimal solution which is solved via Evolutionary Algorithm (EA). Kaabeche and Bakelli [120] offered a stand-alone PV/Wind system by using several energy storage systems. They used new meta-heuristic methods to solve the optimization problems about the reliability, cost, sizing, ect. with Ant Lion Optimizer Algorithm (ALO), Grey Wolf Optimizer algorithm (GWO), Krill Herd algorithm (KH),and JAYA Algorithm (JA). The simulation results indicated that the JA method obtained the best configuration energy system for the different types of energy storage system and achieved the optimal solution compared to other optimization methods.

6.2.3. Hybrid optimization methods

The combination of multiple optimization algorithms is often referred to as a hybrid method (traditional and/or modern). These hybrid methods have proved their performance in the literature to solve various optimization issues mainly for the hybrid power system. Recently, an improved evolutionary algorithm called Flower Pollination Algorithm (FPA) and Simulated Annealing (SA) have been proposed to improve the hybrid methods according to specific research [121]. The authors applied this hybrid algorithm to solve the optimization problems for the hybrid energy system supply power to an autonomous site situated in Iran. The authors in [122] suggested a new model of (PV/Wind/Battery) system to satisfy the power demand to a water desalination unit located in an isolated area. In order to answer all the optimization queries, a hybrid algorithm of Harmony Search-Chaotic Search (HS/CS) was used to reach the optimum values for the hybrid energy system. Kefayat et al. [123] introduced a hybrid Ant Colony Optimization-Artificial Bee Colony (ACO-ABC) method to obtain optimal sizing, placement, and other optimization objectives of distributed energy sources. A competent hybrid method called Big Bang-Big Crunch (HBB-BC) was applied in [124]. This approach proved its efficacy achieving the global optimum solution for the power system and fulfilled the energy demand. The authors in [125,126] investigated the optimal sizing of a hybrid power system constituted by solar panel, wind turbine, diesel/biodiesel generators and energy storage system as batteries, and fuelcell to supply a standalone system. Effective results were acheived

based on Simulated Annealing (SA), Tabu Search (TS), Harmony Search SA-HS hybrid algorithms, and these algorithms demonstrated their performance compared to single SA, single TB or single HS methods. Zhou and Sun [127] implemented Simulated Annealing Particle Swarm Optimization (SAPSO) technique to accomplish the optimal value of the renewable energy sources related to the battery-supercapacitor energy storage system to provide electrical power. In [128], a developed hybrid meta-heuristic method (HGWOSCA) called Hybrid Grey Wolf Optimizer (GWO)-Sine Cosine Algorithm (SCA) was employed to extract the best configuration model of the studied hybrid energy system. Optimization results were compared to other techniques as SCA, GWO and PSO, and the novel method of HGWOSCA gave the best configuration system in terms of reliability and convergence. To ensure power efficiency produced by the renewable sources as solar energy and wind turbine, the authors in [129] took into account this viewpoint and introduced a hybrid Iterative-Pareto-Fuzzy (IPF) method to solve the optimization problems. An energy management operation is controlled based on the grid and hybrid energy generator to ensure power efficiency. The authors in [130,131] established hybrid algorithms such as Group Method of Data Handling Neural Network-Modified Fruit Fly Optimization Algorithm (GMDHMFOA) and Genetic Algorithm-Mixed Integer Linear Program (GA-MILP) to respond to all criteria posed in the optimization issues. Samy et al. [132] discussed the integration of the PV/Wind/fuelcell connected to the grid, and the power system produced energy to the load when the grid was not available to solve the power outages problem. A Hybrid Firefly-Harmony Search optimization technique (HFA/HS) was implemented and compared to the PSO algorithm to find a good optimal solution concerning the electricity price of purchasing and selling of the grid. In [133], a multi-objective optimization for a hybrid energy system connected to two modes in an autonomous site and in the power grid was introduced. The results of the optimization problems were shown via a developed algorithm based on Biogeography (BBO)-Particle Swarm Optimization (PSO), and this algorithm defined as a Greedy Particle Swarm and BBO algorithm (GPSBBO). Most of the research is based on photovoltaic and wind turbine systems, considering the battery energy storage system to supply power to an independent mode. As mentioned in the previous section, various hybrid optimization approaches are based on this energy system. Other new methods [134,135] have been developed such as Jaya (JA)-Teaching Learning Based Optimization (TLBO) JLBO and Flower Pollination Algorithm (FPA)-Simulated Annealing (SA) (FPA-SA) algorithms to solve the optimization problems. In addition, others hybrid techniques have been applied [136-140] to select the optimal sizing and placements of different distributed generation system. These hybrid methods are Biography Based Optimization (BBO)-Particle Swarm Optimization (PSO) (BBO-PSO), Artificial Bee Colony (ABC)-Cuckoo Search (CS) (ABC-CS), Multi-Objective Hybrid Big Bang (MOHBB)-Big Crunch (BC) (MOHBB-BC), Hybrid Nelder-Mead (HNM) - Cuckoo Search (CS) (HNMCS) and a novel Hybrid Grey Wolf Optimizer (HGWO) algorithm.
Moerever, for further clarity regarding traditional, modern and hybrid optimization techniques,a comparison is made for these methods and their performance is provided on the basis of advantages, disadvantages and techno-economic criteria in various aspects, as indicated in Table 1.

Table 1. *Comparison of Optimization methods*

Optimization methods	Advantages	Disadvantages	Techno-economic criteria	References
Traditional	-Can solve multi-objective function -Computational time is less -Give the same solution in each iteration -Need fewer objectives function	-Less precision in finding the global optimum -Need discrete and continuous probability methods -Linearity between variables -Limited optimization space	-Low flexibility -Speediness -Complex - Not set up to solve the no-linearity of multi-objective problems	[73-76] [85] [88-90]
Modern	-Precision in locating the global optimum solution -Fast convergence -Easy to implement	-Slow convergence rapidity -Give various solutions in each iteration	-System reliability is accomplished -System performance -High efficiency -Complex processing	[91-94] [97] [98-100] [122]

	-High accuracy in the simulation results	-Need more computational strength	program is needed	
Hybrid	-A great effectiveness -High strength and performance -Need less time -Rapid convergence	-Design system is complicated -Expanded solutions -Hard in achieving code	-High system reliability -Increase performance -Reducing time of optimization processing -Solve non-linearity optimization problems -Increase system lifetime -Minimize scope of system fail	[121-124] [128,129] [133] [136-140]

Traditional optimization methods have limited optimization space, contrariwise to the modern and hybrid methods. The modern technique has more computational strength and the hybrid method is treated as a complex design system.

The advantage of using techno-economic criteria to solve optimization problems through traditional, modern and hybrid techniques is that it can solve technical and economic factors respectively and achieve better characteristics in terms of system efficiency, performance and reliability. The economic criteria of these optimization methods are related to the system cost function. Hence, the technical criteria are related to some parameters such as energy production, lifetime, performance, stability, reliability and other factors.

6.2.4. Optimization software

In the recent years, a great growth of software and approaches have been employed to implement the optimization of the hybrid energy sources by using some models and criteria. For example, there are tools developed to evaluate the performance of the power system to help the designer investigate the combination of various energy sources.

The simulation is the best mutual practice, which offers more time and cost for the investigation and the valuation of hybrid power systems. Computer simulations are used computing optimum size with energy system cost of hybrid energy system for be able investigate for various sizing energy configurations.

Some drawbacks frequently discussed in the hybrid energy system modeling are system sizing and control scheme. As indicated in Table 2, common software tools were used to simulate the optimization objectives for the hybrid power system. These software are included to allow the user to easily design and select the optimal solution for various hybrid power sources available in the software's toolbox.

Table 2. *Different optimization software*

References	Software tool	Description
[141-149]	HOMER (Hybrid Optimization Model for Electric Renewables)	The authors have investigated different energy system configurations, in stand-alone and grid-connected systems to solve the techno-economic optimization problems. A sensitivity analysis is also taken into consideration for the overall hybrid power system
[150]	RHO (Receding Horizon Optimization)	Wang et al. have used RHO to select the optimal configuration of the PV/wind/diesel/Battery energy system in the purpose to obtain a minimum sizing with a less system cost

[144],[151,152]	Matlab/Simulink (Matrix Laboratory)	Matlab /Simulink is known and used mostly in various fields to solve the designing and program process. It allows the user to place different problems and find easy solutions using various toolboxes
[153-157]	TRNSYS (Transient Systems Simulation Program)	A review and analysis achievement have been made in these works, in which the TRNSYS tool is applied for several hybrid system configuration and compared to other software to find the optimal value of the techno-economic process
[158-167]	GAMS, HYDROGEMS, LINGO, GAMBIT-HOMER, LEAP, PREAD, ViPOR, H_2RES, ARENA RAPSODY, and further features software tools are implemented in [154]	Other software tools have been applied for most of the energy system resources connected/disconnected to the grid to generate power. Analysis, design, techno-economic optimization have been performed for different suggested system configuration

Various software for hybrid energy system optimization are known. These include Hybrid Optimization Model for Electric Renewables (HOMER) and Hybrid Optimization by Genetic Algorithms (HOGA) [168-170], hydrogen-based hybrid systems (HYBRID2) [171-174], Clean Energy Management Software (RETScreen) [175], ViPOR, SOLSIM and MATLAB as mentioned in [141]. The benefits of these tools is to aid the user to design, analyze and optimize different energy resources connected/disconnected to the grid, which ensure system performance. In this context, the majority of energy sources employed in most software are renewable energy, conventional energy, energy storage system, converter, inverter, load, DC bus related to the grid or in a stand-alone mode.

Among the software tools applied in the literature, such as HOMER, RETScreen, HOGA, HYBRIDS, HYBRID2, most modeling systems are based on some features related to runtime, simulation result, integrated energy sources, etc., and the major benefits and drawbacks of these software are shown in Table 3.

Table 3. *Comparison of the most used optimization software*

Software	Created by	Features	Drawbacks
HOMER (Hybrid Optimization Model for Electric Renewables)	National Renewable Energy Laboratory, USA in 1992	-Can perform a techno-economic investigation for every renewable energy sources, moreover, a diesel generator can be added with a battery or hydrogen storage energy system connected to the load or to the grid -Representation of the graphical results -Easy to use for the users	-Needs great computational time and great number of variables -Limitation of the program, it means that the user cannot choose the suitable components of system
RETScreen (Clean Energy Management Software)	National Resources Canada in 1996	-Easy to apply and based on the Excel software -Strong metrological database from NASA only -Can achieve an analyses techno-economic with a sensitivities study -Able to add other element but with respect some characteristics	-Non limited of the computational time -Limited choices of input data and for search, recuperation and conception characteristic

HOGA (Hybrid Optimization by Genetic Algorithms)	Electric Engineering Department of the University of Zaragoza (Spain)	-Can solve mono and multi-objective optimization problems using Genetic algorithm -Weak computational time -The user can select components from the existing of the hybrid energy system in the toolbox	-Sensitivity analysis is not performed -Quotidian load is limited
HYBRIDS	Solaris Homes	-Establish the potential of renewable part and estimating economic utilities based on the excel program -Need quotidian average load and environmental data predictable for each month in the year -Design of the renewable energy configuration can be developed -HYBRIDS is inclusive requires a great level of information of renewable energy system configurations	-No offer an optimal sizing -Simulate one energy system configuration per time
HYBRID2 (hydrogen-based hybrid systems)	University of Massachusetts and the National Renewable Energy Laboratory (USA)	-Can achieve optimal sizing of hybrid energy system -Analyze techno-economic -Time-step changes are taken in consideration through using probabilistic approach -Easy to perform the design and optimization of power system -Simulation are very precise	-Lower of flexibility of the software -Necessity a wide data set

7. DISCUSSION

A viewpoint analysis was presented in this paper concerning hybrid power systems based on the optimization methods. This investigation has treated several points mainly energy production data in the world, energy system types, hybrid energy system configuration, energy management operation, and optimization study.
Hybrid energy system is suggested in this examination because it is more beneficial than single source and can mitigating power deficiency. Hence, previous studies have been proved the integration of multiple energy sources for provide electric power, regarding to the energy durability, system reliability, economizing on energy costs, minimizing energy demand, reducing greenhouse gas emissions, and increase energy security. These systems are particularly useful in remote areas wherever the electricity grid is not available. It can be confirmed that using hybrid energy system is more advantageous than single source for electricity production and ensure energy demand.

Combination of hybrid energy system can be done through three modes, as mentioned in Figures 7, 8 and 9. Most of last searches have been introduced different energy system configurations, such as renewable energy, conventional energy, and energy storage system connected/disconnected to the grid.This combination between the hybrid energy system and the users (load/grid) needs to control power management flow, which discussed in the previous section.

Several optimization approaches (traditional-metaheuristic-hybrid) have been applied for the hybrid energy system, to solve various problems as sizing, system cost, CO_2 emission, reliability, energy cost, and life cycles duration, etc. A comparative study was illustrated in the Table 1 to clarify the merit, demerit, and techno-economic objectives of theses optimization methods.

An improve optimization software's have been used to find a techno-economic solution for the hybrid energy system, as depicted in the Table 2. The most software's implemented in the previous researches are mentioned in the Table 3, which a comparative analysis have been done to show the effectiveness and durability of theses software's in the optimization matters. This work was proposed a global survey about several optimization algorithms, applied in different electric power system, to solve various optimization issues under different constraints. A detail demonstration was presented several optimization problems posed in the literature, and solved by using different optimization approaches.

8. CONCLUSION

In this article, a discussion was carried out mainly considering a very important area in electric power generation based on the hybrid energy system. Integration of hybrid energy system to provide power has great benefits for the electric system, since can compensate energy deficit, assure reliability, efficacy and confidentiality. Energy production has been expanded in the most countries of the world, specifically renewable energy sources, which were installed approximately 320 GW in the last year. The combination of several renewable energy sources makes it possible to optimize in maximum as possible the electricity production systems, both from a technical and economic point of view.

There are three modes to coupled hybrid energy system, such as DC coupled, AC coupled and hybrid (DC/AC) system configurations. Power flow between the hybrid power system and the load/grid must be controlled, which an energy management technique will be implemented to realize a good energy management system.

An overview of using optimization approaches in different energy systems was presented in order to facilitate, to the reader to choose a good method to achieve an economic system. In addition, various developed optimization methods were demonstrated for different hybrid energy system configurations to provide power either to a stand-alone system, or to the grid. More optimization problems were posed under different constraints to obtain optimum solutions from technical, economic and environmental perspectives. Utilization of the optimization techniques to solve several problems, need to validate via a software tool, which an explanation was mentioned with a comparative analysis regarding the previous and most used software.

It can be concluded that hybrid optimization methods have been proved its performance in the literature than the other optimization methods in terms of efficacy, convergence, and running time. It is suggested that future work should focus on issues related to the use of energy storage technology in power systems, from several sides based on the optimization approaches.

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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