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Hybrid renewable microgrid optimization techniques: A review

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ABSTRACT

Power resulted form solar photo voltaic and wind turbine generators are reliant on the climate variations. Both the wind and solar systems are non-reliable if there are insufficient capacity storage units like storage batteries or backup units like diesel generators. The microgrids reliability increases when both systems (wind turbine and photo voltaic) are combined with the storage devices. The sufficient storage batteries bank capacity are needed to feed the load demands with power in cloudy and non-windy days. So the optimal placing of the components assigns to the required parts of hybrid microgrid. Also, this study reviews new ways of energy practice of hybrid sources. It presents the physical modelling of the renewable energy resources with numerous methodologies and principles of the optimization for the hybrid networks. Additionally, the hybrid sources are gaining popular and fame in the environmental crises and current scenario of energies. Based on this study, it has introduced a global survey on the present condition of optimization techniques especially that related to the isolated microgrid in the presented literature. The current trend of optimization for hybrid renewable sources demonstrations that artificial intelligence provides worthy optimization for the microgrid operations without an extensive long-term weather data.

1. Introduction

Energy has a creative role for social and economic developments all over the world. Nowadays, the worldwide energy demands are supplied using fossil fuels considering diesel depletion, growing inhabitants and increasing load requirements. The electrical power generations have gone into a new evolution phase which is highly characterized by growing what concerned with weather variations, a transition from a hydrocarbon-based economy, and the effective deployment of the energies [1–4].

Fossil fuels which represented in coal, oils and natural gasses, are the principal energy sources of the world. The dependence on fossil fuels in the 20th century decreased heavily the natural reserve of them. Most three RESs used widely are hydropower, WTG and SPV. RESs are considered as the important alternative sources, so they are selected in many countries. The hybrid systems can be SPV, WTG and hydropower or the mix of these units. Such systems have the backup units like a diesel engine and/or storage batteries to feed a peak hour demand. The characteristics of RES have been introduced in Table 1. Recently, to make an efficient usage of electrical energy, there is a great interest in optimizing a design of urban settlements by the exploitation of ordinary sources of energy like SPV, WTG systems and developments of building management. From the level of generation station to the level of a customer, a renewable distributed generation is allowed to help in an effective usage of the consumer energy, and for reaching to the intelligent demands response [5,6].

Most of RES such as SPV and WTG are clean and environment-friendly. Many researchers have been performed studies which concerning with the hybrid SPV–WTG microgrid. From the investigation, it has been confirmed that the HRES gives a good performance and a lower cost compared to the individual SPV or WTG system [7–10]. However, the hybrid SPV and WTG still has less disadvantages in comparison with the conventional sources if it is not designed in an accurate way. For example, the irregular nature of wind speeds and solar radiation which cause power fluctuations can be treated by using storage units like storage battery bank. These batteries can store extra power and supply loads with power in a case of occurring shortage [11]. Adding the storage batteries also support to avoid the SPV and WTG sources to be oversize. However, when the storage batteries have charged to its maximum value, and there is still excess power has been lost from the generation units which have to be avoided somewhere. Diminishing this unutilized excess power could lead to decrease a Cost of Energy (COE) [12]. Hence, the optimal capacity of each RES is necessary for confirming the actual load that is accommodated.

The electrical energy generation by the alternative sources such as WTG and SPV, have developed more attractive attention and are widely

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Table 1
Characteristics of renewable system.

Advantages	*Disadvantages*
Renewable energy is well renewable resources free like the sun and the wind as a fuel.	RES relies heavily upon the climate for sources of supply: rain, the wind, and the sunshine,...etc.
Economic Benefits: RES is cheaper in fuel consumption, and Operation and Maintenance (O & M) Requirement is low	Large Capital Cost: Initial investments are quite high in case of building RE plants.
Environmental Benefits:	Difficult to produce a large amount of energy as those created by coal stations
No pollution or waste natural resources	
Reliable Energy Source: solar and wind plants are distributed over all geographical region and climate disruptions in one region will not cut off power to any area.	To meet up the large amounts of electricity produced by fossil fuels, large amount of SPV panels and WTG farms need to be set up

utilized for replacing fossil fuels in the process of electrical energy since the 1970s because of the crisis oil. Nevertheless, such alternative energy units have a slow development and the conversion into a new phase of evolution in the power generation sector seems to be complex tasks because of different insights of problems. The environmental and economic issues not only sufficient reasons but there are other reasons such as social and psychological impacts on people's behavior. Moreover, new directions of technology for the energy productions from alternative sources have tested a considerable development to improve the microgrid efficiency and electric power generation reliability nets in alternative sources which consist of the practice of information and communications technology. In this way, the electrical company is developed to be more dynamical and flexible and support distributed storage units [13]. However, as a stochastic nature in some of alternative energies such as SPV and WTG, the transition into low carbon society will require a non-single solution.

Fossil fuels can be replaced by means of alternative energy resources, the specialists forecast that will be integrated and essential for multi-HRESs which are working together such as hydro, geothermal, Biomass (BM), WTG, SPV, hydrogen and nuclear at key part of energy generation and customer level in reorganized RES [9,10,14]. When the energy system contains two energy supplies or more, it is called HRES. Sometimes these systems present the lowest costs and the highest reliability compared to the other systems which use only one renewable source. Therefore, the penetration of HRES into the energy market rest on main methodologies which can be utilized for designing these kinds of HERS in an optimally way. The optimization problems are discussed to select the “best” set of system components from a search space or set of possible solutions. This includes a selection of one optimization problem or more, an Objective Function (FC), and problem constraints.

The FC and constraints should be functions of single optimization variable or more. Additionally, the problem growths its complexity due to the non-linear characteristic answered in the system components, stochastic obtained ability in some RES (for example SPV and WTG), the considered constraints and optimization variables. Electric power has the vital role for the economic and the personal HRES. A known-engineered HRES has a good effect in cost, high reliable and improves a quality of life [15]. In most cases, SPV and WTG complement each other; however, both of systems are unpredictable as instantaneous fluctuation for wind speeds and solar radiation. The hybrid systems contain SPV-WTG and hydropower were realized by references [16,17] in the rural villages of Nepal. Reference [18] found out the characteristics for an isolated microgrid HRES and their effects which concerning with microgrid reliability. HRES is seriously reliant on its components. Therefore, an accurate modelling of every component for HRES delivers tools to recognize the performance of model in a good way, and aid to optimize HRES.

This paper reviews comprehensively the optimization criteria and various optimal sizing for HPS reliant on small SPV, WTG, hydropower and battery devices. For understanding in a clear way, Tables have displayed optimal designs and different optimization approaches. The Mathematical models, flow charts and Figures also have added wherever necessary. This paper will present a new trend of the world energy scenario, and develop the restraint on the energy load demand of the future with appropriate references. Also, the energy microgrid performance is usually evaluated by long series of time for climate or load demand profile which record the increase in the method calculus complexity. Several mathematical models like probabilistic approaches [19–21], the Artificial Neural Networks (ANNs) [21,22], the Genetic Algorithms (GAs) [22–24]and the Particle Swarm Optimization (PSO) [25,26] have been suggested to deal with the multi-FCs, non-linear characteristic response of models components and long time series for climate variables.

The aim of this study is to perform a brief overview of the present state of methodologies which is used for sizing HRES with the energy storage units for both standalone and grid connected systems.

This paper is organized into 12 sections. Section 2 delivers the hybrid RES architectures. Section 3 contains the world energy state. Section 4 provides the kinds of small power networks that includes two types grid connected and the remote operation. Section 5 presents HRES that contains SPV, WTG, hydropower station and biomass energy. Section 6 involves in the future of HRES. Section 7 presents the mathematical modelling of HRES. Section 8 contains the HRES expansions planning methods. Section 9 presents HRES optimization techniques. Section 10 provides the best design criteria of HRES. Section 11 includes the issues with HRES. Finally, Section 12 concludes the conclusions of this paper.

2. Hybrid RES architectures

The general HRES construction is demonstrated in Fig. 1. This type of energy systems is called “hybrid” because they include two RESs or more to feed a required electrical load, and a commonly AC load. It may also supply a DC load or both at the similar time. Energy sources may be renewable, conventional or energy storage units. In this approach, lacking some energy units are supplemented by strengthening the other sources in a natural or a controlled way. It can be demonstrated that despite being some alternative sources (such as SPV and WTG) unpredictable availability, they present complementary patterns [27,28]. HRES can operate grid connected or standalone microgrid.

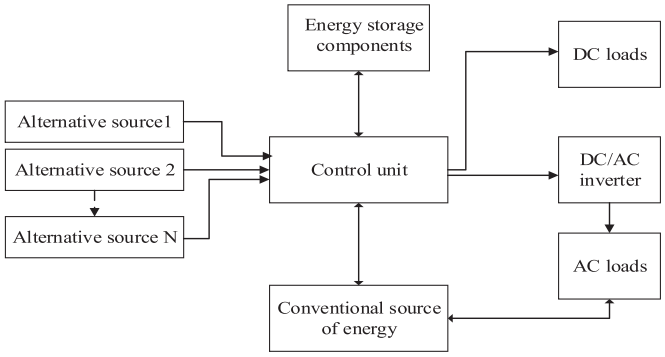

Fig. 1. General HRES architecture.