Renewable and Sustainable Energy Reviews 62 (2016) 609–620

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Optimal planning of hybrid renewable energy systems using HOMER: A review

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ARTICLE INFO

Article history:
Received 11 June 2014
Received in revised form
29 December 2015
Accepted 3 May 2016

Keywords:
Hybrid renewable energy system
HOMER
Optimal sizing

ABSTRACT

World energy consumption is rising due to population growth and increasing industrialization. Traditional energy resources cannot meet these requirements with notice to their challenges, e.g., greenhouse gas emission and high lifecycle costs. Renewable energy resources are the appropriate alternatives for traditional resources to meet the increasing energy consumption, especially in electricity sector. Integration of renewable energy resources with traditional fossil-based resources besides storages creates Hybrid Renewable Energy Systems (HRESs). To access minimum investment and operation costs and also meet the technical and emission constraints, optimal size of HRES's equipment should be determined. One of the most powerful tools for this purpose is Hybrid Optimization Model for Electric Renewables (HOMER) software that was developed by National Renewable Energy Laboratory (NREL), United States. This software has widely been used by many researchers around the world. In this paper a review of the state-of-the-art of researches, which use HOMER for optimal planning of HRES, is presented.

Contents

Abbreviations: EML, electrical machinery laboratory; TGS, thermal generation station; DRC, Democratic Republic of Congo; UAE, United Arab Emirates; K.S.A., Kingdom of Saudi Arabia; UK, United Kingdom; MACS, maximum annual capacity shortage; USA, United State of America; MREF, minimum renewable energy fraction; WEOR, wind energy operating reserve; PVEOR, PV energy operating reserve.

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http://dx.doi.org/10.1016/j.rser.2016.05.039
1364-0321/

1. Introduction

In recent years, population growth and technology development have resulted in increasing energy consumption, especially in electricity sector. Moreover, there are many rural and remote areas particularly in developing countries which have no access to electricity. In order to solve these problems, electricity generation should be increased. Nowadays, a large percentage of the world electricity is supplied by fossil fuel resources. However, these resources cannot meet the future electricity requirements because of their economic and environmental problems. Renewable energy resources have become efficient alternatives for fossil fuel resources. However, when these resources are used to supply the local loads individually, many problems are created such as high investment costs and low security of supply because of intermittent and uncertain nature of them. To solve these problems a new concept, namely Hybrid Renewable Energy Systems (HRESs) has emerged [1]. HRES is a combination of renewable, traditional energy resources, and energy storages to meet the load locally in both grid connected and standalone modes. HRESs are used in standalone mode in remote and rural areas. In this mode, due to uncertain nature of renewable resources, traditional energy resources and energy storages can be used as the back-up resources for them. In fact, during the periods in which the output of renewable resources is not enough to meet the load, remaining part of the load can be supplied by the back-up resources. On the other hand, when the renewable resources have extra generation, the excess energy can be absorbed by the energy storages. Therefore, HRESs have more reliability than only renewable energy systems in standalone mode. HRESs are used in grid connected mode in some places such as universities, hospitals, factories, and town. In this mode, when the grid electricity prices are low, the HRES meets the load from the grid and charges the energy storages with renewable resources. Then, during the periods in which the grid electricity prices are high, the HRES meets the load with its resources and sells the extra energy to the grid. In this manner, energy storages are discharged to meet the load or to sell energy to the grid. In this mode HRESs have more economical than only renewable energy systems. Therefore, HRES provides some advantages, e.g., increasing penetration of renewable energy resources, decreasing Cost of Energy (CoE), reduction of greenhouse gas emission, and providing access to electricity for people in remote and rural areas. These advantages meet all three criteria of Sustainable Development (SD) including economic, environmental, and social aspects.

One of the important issues in HRES is optimal planning of its component, e.g., number of Wind Turbines (WTs), Photo-Voltaic (PV) arrays, batteries, and capacity of generators and converters so that the objective functions are minimized/maximized and all constraints are satisfied. For this purpose, many software and optimization approaches are proposed in the literature. There are appropriate papers that have reviewed optimal planning and operation techniques of HRES from different viewpoints [1–9]. Different optimization methods and modeling of HRESs' component are described in [2]. Design and control techniques reported in the literature to simulate and optimize the stand-alone HRES are reviewed in [3]. Optimization tools and techniques which are used for optimal design of HRESs are reviewed in [5]. Ref. [7] reviews the different aspects of optimal design of HRESs only including WT, PV, battery, and converter. Different studies on HRES in both grid-connected and standalone modes including planning criteria, optimization techniques, energy management, and various configurations are reviewed in [8,9].

One of the most powerful tools for optimal sizing of HRESs' equipment is Hybrid Optimization Model for Electric Renewables (HOMER) software that was developed by National Renewable Energy Laboratory (NREL), United States [10]. Although HOMER software is used in many studies, a brief description is presented on it in review papers [1–9]. Therefore, an article is needed that comprehensively reviews the papers which used HOMER for optimal planning of HRESs which is the main objective of this paper. This review will be useful for researchers who intend to use HOMER for planning of HRES in their regions. It provides the required information about planning of HRES simulated with HOMER such as what components are considered in HRESs? How they are used in stand-alone or grid connected modes? And what uncertain parameters are considered in the articles?

The reminder of the paper is organized as follows. Description of HOMER software is presented in Section 2. Equipment modeled in HOMER and considered in the literature is compared in Section 3. Sensitivity analysis on different uncertain parameters in the articles is reviewed in Section 4. Section 5 presents the discussion on HOMER's outputs. Finally, conclusion is presented in Section 6.

2. HOMER software description

HOMER software is a powerful tool for designing and planning of HRES in order to determine optimal size of its components through carrying out the techno-economic analysis. Many resources such as WT, PV array, fuel cells, small hydropower, biomass, converter, batteries, and conventional generators are modeled in HOMER. HOMER also considers HRES in grid-connected and stand-alone modes. Fig. 1 shows the typical configuration of HRES designed in HOMER. Required input data for simulation with HOMER and also a comprehensive framework to show how optimal sizes of HRES's equipment is determined by HOMER are described in this section.

2.1. Input data

HOMER requires six types of data for simulation and optimization including meteorological data, load profile, equipment characteristics, search space, economic and technical data. These data are described in details in the following subsections.

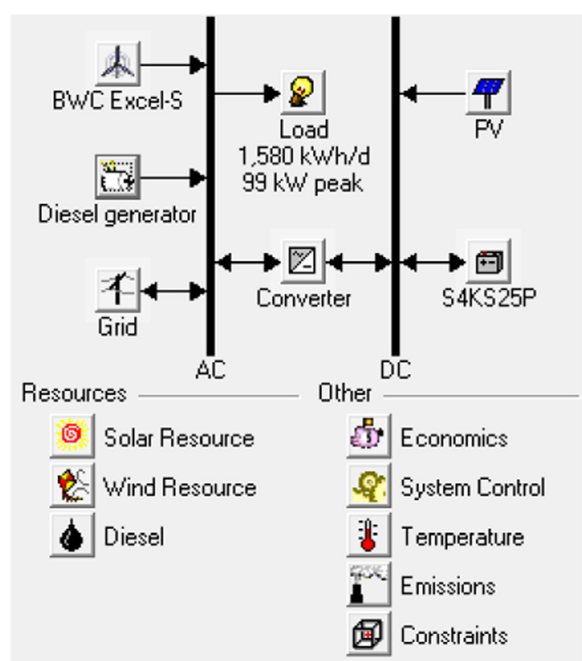

Fig. 1. Typical schematic of a HRES in HOMER.