Renewable and Sustainable Energy Reviews 32 (2014) 192–205

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

Review of software tools for hybrid renewable energy systems

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ARTICLE INFO

Article history:
Received 2 September 2013
Received in revised form
5 December 2013
Accepted 4 January 2014

Keywords:
Hybrid energy system
Simulation tools
Renewable energy
Solar energy
Wind energy

ABSTRACT

Hybrid energy systems are being utilized for supplying electrical energy in urban, rural and remote areas to overcome the intermittence of solar and wind resources. A hybrid renewable energy system incorporates two or more electricity generation options based on renewable energy or fossil fuel unit. The techno-economic analysis of the hybrid system is essential for the efficient utilization of renewable energy resources. Due to multiple generation systems, hybrid system analysis, is quite complex and requires to be analyzed thoroughly. This requires software tools for the design, analysis, optimization, and economic viability of the systems. In this paper, 19 softwares with their main features and current status are presented. The softwares studied are HOMER, Hybrid2, RETScreen, iHOGA, INSEL, TRNSYS, iGRHYSO, HYBRIDS, RAPSIM, SOMES, SOLSTOR, HySim, HybSim, IPSYS, HySys, Dymola/Modelica, ARES, SOLSIM, and HYBRID DESIGNER. The research work related to hybrid systems carried out using these softwares at different locations worldwide is also reviewed. The main objective of the paper is to provide the current status of these softwares to provide basic insight for a researcher to identify and utilize suitable tool for research and development studies of hybrid systems. The capabilities of different softwares are also highlighted. The limitations, availability and areas of further research have also been identified.

Contents

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http://dx.doi.org/10.1016/j.rser.2014.01.035

1. Introduction

Energy demand is increasing day by day due to increase in population, urbanization and rapid industrialization. This makes direct connection between energy use and quality of life. The fossil fuel resources, like coal, oil and gas, have limited reserves which results in continued fuel price hike which affects the economy of any country. Due to oil crisis of 1970s, considerable interest has resulted in utilizing renewable energy sources. Renewable energy is obtained from sun, wind, biomass, water, tides, ocean waves and geothermal heat.

Renewable energy systems are based on single source or multiple sources of renewable generators. Single source based renewable energy system incorporates only one electricity generation option based on wind/solar thermal/solar photovoltaic (PV)/hydro/biomass etc. along with appropriate energy storage and electronic systems. A hybrid energy system incorporates two or more electricity generation options based either on renewable energy unit or fossil fuel based unit like diesel–electric generator or a small gas-turbine along with energy storage and electronic devices. Several hybrid energy system configurations can be used for power generation like PV–wind–diesel systems, hydro–wind–PV-based systems, biomass–wind–PV installations, wind–PV based installation, PV–wind–hydrogen/fuel cell hybrid energy systems etc. Hybrid energy system has following main advantages in comparison to single source based system:

- Higher reliability
- Reduced energy storage capacity especially where different sources have complementary behavior.
- Better efficiency.
- Minimum levelized life-cycle electricity generation cost, when optimum design technique is used.

But in most cases due to lack of optimum designing or proper sizing, a hybrid energy system, is over-sized or not properly planned or designed, which makes installation cost high. The technical and economical analyses of a hybrid system are essential for the efficient utilization of renewable energy resources. Due to multiple generation systems, hybrid system solution is complex and requires to be analyzed thoroughly. This requires software tools and models which can be used for the design, analysis, optimization and economical planning. A number of softwares have been developed to assess the technical and economical potential of various hybrid renewable technologies to simplify the hybrid system design process and maximize the use of the renewable resources. In the study hybrid system analysis softwares are reviewed. The main objective of the paper is to provide a basic insight to a researcher to identify and utilize suitable software tool effectively, as per the requirements for research and development studies related to hybrid systems. In this study, applications and status of 19 softwares namely HOMER, Hybrid2, RETScreen, iHOGA, INSEL, TRNSYS, iGRHYSO, HYBRIDS, RAPSIM, SOMES, SOLSTOR, HySim, HybSim, IPSYS, HySys, Dymola/Modelica, ARES, SOLSIM, and Hybrid Designer are presented. A comparative analysis of these softwares along with literature review of research carried out using these softwares worldwide, are presented. The limitations, availability and areas of further research have also been identified. The analysis of a PV–battery and PV–wind–battery hybrid system is presented as case studies using HOMER and RETScreen.

The paper is organized as follows: Section 2 provides an overview of various software tools with their main features, Section 3 gives a literature survey of hybrid energy systems using some of the software tools, Section 4 deals with the case studies and conclusion is given in Section 5.

2. Software tools for hybrid system analysis

A comprehensive understanding is essential about available hybrid system models and software tools, their features, shortcomings, user need and choice for research studies. In this section, the main features of 19 softwares developed for hybrid system design are discussed along with a comparative analysis.

Turcotte et al. [1] classified the software tools related to hybrid systems in four categories: pre-feasibility, sizing, simulation and open architecture research tools. The prefeasibility tools are mainly used for rough sizing and a comprehensive financial analysis(e.g. RETScreen). The sizing tools are used for the determination of optimal size of each component of the system and provide detailed information about energy flows among various components (e.g. HOMER). In a simulation tool, the user has to specify the details of each component in order to get the detailed behavior of the system (e.g. HYBRID 2). In open architecture research tool, user is allowed to modify the algorithms and interactions of the individual components (e.g. TRNSYS). Klise and Stein [2] described various PV performance models, hybrid system performance models and battery storage models in a Sandia National Laboratory report. Arribas et al. [3] carried out a survey of ten existing software tools based on the availability, features and applications and presented guidelines and recommendations in a International Energy Agency (IEA) report. This report also categorized tools into four categories namely dimensioning, simulation, research and mini-grid design tools. Connolly et al. [4] surveyed 37 computer tools for analyzing integration of energy systems. The survey also includes three hybrid simulation tools HOMER, RETScreen and TRNSYS. The survey was carried out in collaboration with tool developers which included five components namely background information, users, tool properties,