Applied Energy 221 (2018) 535–556

Contents lists available at ScienceDirect

Applied Energy

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

Computational tools for design, analysis, and management of residential energy systems

Khizir Mahmud[a,*], Uzma Amin[b], M.J. Hossain[b], Jayashri Ravishankar[a]

[a] School of Electrical Engineering and Telecommunications, University of New South Wales, NSW 2052, Australia
[b] School of Engineering, Macquarie University, NSW 2109, Australia

HIGHLIGHTS

- This paper thoroughly reviews computational tools for design, analysis, and management of residential energy systems.
- The tools are analyzed based on the conventional and CEN-CENELEC-ETSI Smart Grid Reference Architecture.
- Tools' availability, sources, typical applications, strengths, and limitations are discussed in detail.
- Necessary information is provided to help researchers to choose the right tools to meet specific objectives.

ARTICLE INFO

Keywords:
Building energy management
Computational tools
Domestic energy management software
Residential energy management tools
Residential energy modeling
Simulation software

ABSTRACT

Selecting an appropriate software tool for a particular energy-management system is a challenging task as there is little information available and several software tools to pick from. Each tool has its own strengths and limitations, and making a right choice is critical for accurate and feasible analyses. This paper reviews more than one hundred simulation software packages that are useful for residential-energy-management system analysis. The tools are analyzed based on the conventional and CEN-CENELEC-ETSI Smart Grid Reference Architecture. Additionally, tools' availability, sources, typical applications, strengths, and limitations are discussed. A case study on residential energy management and optimization is carried out to show the strengths and limitations of a certain computational tool. It is observed that none of the tools cover all the applications of residential energy systems, however necessary information is provided to help researchers to choose the right tools to meet specific objectives.

1. Introduction

Power generation, transmission, distribution, and the management of current power systems has been experiencing a significant change in recent years. Both aggregated and non-aggregated renewable-energy based power generators are replacing the bulky thermal power stations. At the same time transmission and distribution systems are becoming more complex, integrating distributed energy sources and grid-connected micro grids. Various non-conventional loads and sources like electric vehicles (EVs), and battery energy-storage systems (BESSs) are becoming a common part of the grid [1–4]. The future grid, alternatively known as the internet of energy (IoE), will facilitate plug-and-play features to integrate small-scale energy sources [4]. IoE customers, alternatively known as prosumers, will play the role of consumers and sellers simultaneously. Prosumers will utilize off-peak hours to store energy and sell it back during peak-load hours to optimize the electricity cost.

To get the full advantage of the energy devices and their plug-and-play capability, a robust energy-management system is necessary. Otherwise, uncontrolled loads and distributed energy sources may introduce power-quality degradation and instability to the grid. As power systems are becoming more disaggregated, it is important to manage the grid from the customers' premises. For example, customers in a high-rise building have a higher energy demand, which can be minimized by introducing building-attached renewable sources with battery storages, thereby optimizing the power consumption. Any effective energy management at the consumer point has a benefit for both consumers and the utility. Therefore, researches in residential energy systems, their economy, management and optimization are getting significant for power systems.

In residential-energy-systems research, the most common areas are load modeling and control, renewable energy integration, energy optimization, energy cost analysis, power quality analysis, home-to-grid

* Corresponding author.
E-mail address: khizir.mahmud@unsw.edu.au (K. Mahmud).

https://doi.org/10.1016/j.apenergy.2018.03.111
Received 28 November 2017; Received in revised form 15 February 2018; Accepted 26 March 2018
0306-2619/ © 2018 Elsevier Ltd. All rights reserved.

(H2G) bidirectional energy transfer analysis, and electrical protection systems analysis. It is important to analyze the energy modeling and management concept before its real implementation. However, the plethora of simulation software in the past decade has made it difficult for researchers to choose a particular tool appropriate to their research objective. Many researchers have reviewed the use of computational tools for various applications. These broadly cover the following: integration of renewable energy into various energy systems [1], integration of EV to grid [2,3], design and analysis of power systems [4], and hybrid renewable-energy systems [5]. However, none of the research focused on the tools related to residential energy systems. Residential energy management plays a pivotal role in power quality management, power regulation, load management, and grid efficiency enhancement, in power systems.

Therefore, this paper provides an overview of the computational tools for the design, analysis, and management of residential energy systems. All the tools are systemically categorized based on their applications, functional capability, strengths, and limitations. A case study covering the overall areas of residential energy management has been carried out to show the strengths and limitations of a certain simulation tool. In this case study, the residential load is managed using battery-energy-storage systems and electric vehicles (EVs). The charging-discharging of the battery and EVs is controlled based on the load and the photovoltaic (PV) power generation to reduce the grid power demand. The pre-heating and pre-cooling demand is managed using the PV power, and the thermal-comfort satisfaction and dis-satisfaction index is analyzed based on that energy management. Additionally, the overall building design is optimized to enhance the energy efficiency. In this case study, it is observed that residential energy management is a wide area covering electrical loads, energy sources, renewable integration, HVAC, and the architectural design, and all these factors' effects should be considered for efficient energy management. However, none of the tools covers all these areas, as each tool has its own strengths and limitations. Therefore, in this paper, all the tools are categorized and analyzed based on their availability, applications, strengths, and limitations on the basis of both traditional and future smart-grid architecture. The goal of the paper is to help researchers to an easy selection of a specific tool appropriate to their research objective in the residential energy management domain.

2. Residential-energy-management systems analysis tool

2.1. List of residential energy systems tools

The simulation tools that are related to residential energy systems for modeling and analysis, optimization, management, economic analysis, and renewable energy integration are listed in Tables 1–5. Although the tools cover a wide range of applications, they are listed in separate tables because of their strength in a certain area. Each table is further segmented into tools' names, sources, availability, and common applications. Typical applications include load modeling and control, energy management, energy optimization, home-to-grid (H2G) power-transfer analysis and building energy economic analysis.

Although the tools listed in Tables 1–5 consider residential energy systems, some tools can cover energy systems on a bigger scale such as commercial places, schools, hospitals, markets; for example, BCHP Screening Tool, EZDOE, Commercial Building Energy Saver, ENERPASS, OptiMiser Commercial, MC4Suite, etc.

2.2. Capability of tools by applications

Some selected tools listed above in Tables 1–5 have been further classified in Table 6, based on the areas related to residential energy systems. The main areas are load modeling and control, energy management, energy optimization, impact of weather load analysis, home-to-grid (H2G) power-transfer analysis, energy economic analysis, renewable energy integration to grid analysis, switchgear and protection systems analysis, user interface with mobile applications, and comfort level calculations.

The areas in which the tools' capabilities are identified in Table 6, are -

- Load modeling and analysis including all electrical loads such as lights, fans, TV, refrigerators, dishwashers, ovens, vacuum cleaners, washing machines, electric appliances (hair dryer, charger, computer, iron, LED lights, strimmer). It also includes heating ventilation and air-conditioning (HVAC) systems.
- Load control and EMS (energy management systems) include residential load controlling and energy management by an existing or new control algorithm, or through a user-defined process.
- Weather-dependent load includes modeling and analysis of loads that are dependent on weather, and the impact of weather on loads.
- Renewable energy integration deals with tools that can model, analyze, and integrate renewable energy sources (PV, biomass) to residential energy systems.
- Energy optimization includes tools that help to obtain energy optimization solutions by applying optimization algorithms or they can provide multi-criteria based most economic/best design choices, compare energy performance and costs to optimize building performance.
- Economic analysis includes energy efficiency analysis considering economic impact of building-related selections and financial options and complex utility rates analysis.
- Power-quality analysis tools include tools that can analyze the residential power quality due to energy management, renewable energy integration, and the integration of new types of loads such as electric vehicles (EVs), batteries.
- H2G, alternatively known as home-to-grid bidirectional energy transfer includes tools that can model, analyze, and control the bidirectional energy transactions from home to the grid, either from a single home or aggregated homes.
- Switchgear and protection system tools can model and analyze power protection systems such as over-voltage, over-current, short circuit. at the residential point.
- EMS in current residential power systems, or EMS through the plug-and-play facility in the future internet-of-energy (IoE), will help users to monitor and control residential energy systems and appliances through user interfaces via mobile, iPad, laptop, etc. The tools which deal with these features have been included in the 'user interface' section.
- Comfort calculation includes tools that can calculate PMV (predicted mean Vote) and PDD (percentage of people Dissatisfied) following the standards of ASHRAE (American Society of Heating, Refrigeration and Air Conditioning Engineers) and ANSI/ASHRAE Standard 55-2010. It also includes Psychometric Charts to show thermal-comfort parameters such as humidity ratio, relative humidity, dry-bulb temperature.

A pictorial representation of the tools categorized based on their applications in Table 2 is in Fig. 1. All tools are color coded based on their availability, i.e. free, commercial, limited, and open source. Free tools are available to download and by all types of users. Commercial tools are not freely available, however most of the commercial tools offer a free demonstration version with limited features for a particular duration. Limited tools are only freely available for a particular organization, or a group of people. Open-source tools are freely available to download, use, and also to develop the source code.

2.3. Residential energy system tools based on the smart-grid architecture

In this section residential-energy system simulation tools have been classified based on the CEN-CENELEC-ETSI Smart Grid Architecture

Download English Version:

https://daneshyari.com/en/article/6680166

Download Persian Version:

https://daneshyari.com/article/6680166

Daneshyari.com