Computer Tools for Energy Systems

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Abstract This manuscript comprises a brief review of distinct tools that are used for analysing the renewable integration. Though numerous tools are used, a few are considered for explanatory purposes using the web sources of various tool developers. The details in this manuscript give the reader the necessary information to select and identify a suitable tool for renewable energy integration and its analysis for diverse objectives. This manuscript reveals that there is no tool exclusively which addresses all the problems that are related to renewable energy integration. Every objective has its own tool fulfilling its criterion. All the tools mentioned in this manuscript are related to typical applications for analysing the energy system from the state level to the national level. The details of the tools mentioned for analysis are looked at various factors like their energy sector, accounted technology, parameters, availability of tools, etc. Lastly, this manuscript provides information related to direct the decision-maker.

Keywords Energy tools · Renewable energy · Renewable energy integration · Power energy system

1 Introduction

The electrically powered industry plays its role in meeting the enormous demands of the nation. The experts predicted that the capital expansion for the infrastructure and the operations along with our set constraints are vital to the electric companies and utilities. The complexity increases at the time of operation so there is a tremendous need in improving the operation with the available tools. Usually, training facilities

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for the power system operation requires the hardware and software setup which are expensive in terms of growth are mainly because of distinct platforms integration. Years back, simulation has extensively adopted as a means to comprehend the power system operation and control. Today, computer-based tools for handling the problems on the specific application are a basic requirement. Efforts and expectations concerned with the tool designer is a sign of development. The software tool packages for energy systems are classified into two classes such as commercial software and academic aimed software which are well tested computationally and readily available in market following an all in one philosophy. In the face of their fullness, the aforementioned software can result cumbersome for academic purposes. More importantly, the commercial software does not allow the addition of new algorithms or alteration of source code. The flexibility and easy prototyping are the utmost crucial phases in academic purpose than the efficacy in computation. Then again, we have a variety of open-source academic research tools which are aimed at a particular aspect in analysing the power system. In the earlier era, quite a few high-level languages have become prevalent in academic purposes.

Only just, various challenges have arisen in present society such as change in climate, energy supply security, as well as economic slump. Consequently, the energy sector, exclusively renewable energy, is being beleaguered to combat these challenges concerned. In the 1970s, because of oil crisis, the interest has been focused considerably upon renewable utilisation. A vital element in this transfer of interest is to articulately show the technical analyses of how the implementation of renewable energy can be done, and its effect on other portions of the power system. For such technical analyses, computer-based tools give the creative solutions by modelling the predefined power systems. Creating novel tool is a time-consuming aspect for analysing each and every problem; hence, it would be highly feasible in accessing the existing tool. Nevertheless, when commencement of a study into the possibilities of renewable energy, it is hard to recognise which energy tool is the utmost appropriate for the study, even with existing literature. Renewable energy systems are relied on one or multiple sources. A hybrid renewable system comprises of two generating options based on units of renewable or fossil fuel or its combination. A few softwares are also developed based on hybrid technology of renewable energy to simplify its design and maximise its use. Therefore, this paper tells about the selection of an appropriate energy tool which provides a brief comparison of a few energy tools used for energy system as well as in distinct platforms of renewable energy.

2 Computer Tools for Energy System

A wide range of understanding is crucial about the features, shortcomings, usage and the choice for the available software tools for the academic studies. Experts have identified seven distinct types of tools such as simulation tool (it is mainly used for operating a given power system for given set of demands in power sector. The time steps in this tool are hourly over a time period of one year), scenario tool (it is the tool pertained to long-term scenario. The time steps for its functionality are one year which combines such one year into a series of years and finally a scenario), equilibrium tool (this tool is to brief the demand–supply behaviour, prices of the economy with the market and also it is to be identified whether the equilibrium is maintained), a top-down tool (it uses a macroeconomic data to find the growth in energy demand and also in the price of energy), a bottom-up tool (it is used for identifying and analysing various energy technologies along with the investment options and its alternatives), operation optimisation tool (it is used to optimise the given power system operation), investment optimisation tool (it is used to optimise the power system investments). In this section, a few tool features are reviewed individually. The tools information is described in the aspects of technology, cost, methodology, etc. Also, history and functionality are also presented for the tools.

2.1 AEOLIUS

In Germany at an institute for industrial production, this simulation tool has come into existence for the power plant dispatch [1]. The first version of the tool is still utilised to till date. The functionality is to analyse the high penetration rates influence of energy carriers which are of fluctuating nature. This tool is performed typically on an energy system with the time step of 15 min over a maximum of one year. Thermal generation and renewable energy technologies are the areas of simulation. It does not simulate the few areas like heat and transport in the energy system. In [2], combining PERSEUS-CERT, this tool analyses the effect of wind integration.

2.2 BALMOREL

This tool mostly emphasises on CHP. Since 2000, this tool development and maintenance is an open source [3]. GAMS' modelling is the formulated language for the tool. To till date, we have ten distinct versions. To perform the analyses with this tool, at least a week's training is a prerequisite. It has a flexible time aspect. It can simulate heat but not transport of the energy system. This tool has been applied to many projects across the globe [4–11].

2.3 BCHP Screening Tool

This tool is for evaluating the power systems in the aspect of saving. It was industrialised in the USA by Oak Ridge National Laboratory [12]. To till date two versions were released. Based on the earlier experience with this tool, it needs nearly two weeks of training to upgrade from basic analysis to advanced analysis. It is particularly designed for the study of commercial buildings. The database is inbuilt for this tool. It is mainly focussed on single project investigations so large-scale models of electricity are not modelled. The tool is well thought-out to achieve the parametric studies amongst a baseline building, naturally a conventional building deprived of a CHP system, and up to 25 other CHP scenarios.

2.4 COMPOSE

Compare Options for Sustainable Energy is a tool based on evaluating a techno-economic energy project which is brought by Aalborg University in Denmark [13]. This tool's purpose is to assess the projects which support the intermittency of cost distribution and the profits under ambiguity. The current version of this tool can be downloaded at free of cost. A minimum of three to four days' training in this tool is a prerequisite. It is a user-defined system and a single project investigator. The main focus is deliberately on cogeneration. Uncertainties by the user defined may allow wide range of risks. It uses a one-hour time step over a number of years which are user defined. It also mainly focusses on framework modelling. In analysing the aids of energy storage and relocation options, this tool can be used.

2.5 E4cast

This tool is mainly developed by the Australian Bureau of Agricultural and Resource Economics (ABARE) for the Australian power system for its long-term projects [14]. Since the year of inception, the tool is regularly updated. The software is not for sale in its place, and the customers are supposed to pay for the analysis at a rate of AU$1500 per day. The time step for this tool is up to a maximum of 30 years. Naturally, this tool is used for simulating the future energy requirements within the Australian power system and recognises how these can be met. It has also used by the climate change department of Australia to assess the impacts of the various policies on emissions and renewables.

2.6 EMCAS

Electricity Market Complex Adaptive System uses a new modelling method for simulating the power system [15]. This tool was initiated in 2002 in the USA and Argonne National Laboratory is the one which updates to the latest version regularly. This tool is utilised approximately in twenty countries by the universities, transmission and power companies and also by various system operators. To obtain knowledge about this tool, a minimum of three weeks is a prerequisite to reach advanced analysis. Maximum of one hour is required to complete the entire analysis. Also, it is used to investigate the possible impacts in the aspects of operation and economic of various events in power system. This tool also has the ability to analyse the energy system investments and issues based on expansion by using a multi-agent-based profit maximisation method.

2.7 EMINENT

To allow new solutions faster in the market, this tool has come into existence. It was developed by the Netherlands organisation for applied scientific research in the Netherlands in the year 2005 [16]. As the tool is not developed up to the mark, the access is limited. Nearly, a month's training is required to learn the tool. It has an inbuilt database and assessment tool for evaluating new solutions for the new technologies of power systems. This tool constitutes two databases such as one from the national energy and the other which contains main information about the projects that are under development. It has capability in assessing a technology in financial environment. In [17, 18] we can find the overview, case studies and its comparison with other tools.

2.8 EMPS

EFI's Multi-area Power-market Simulator is a consistent refinement of SINTEF Energy Research in Norway [19]. Its development is done since 1975. Its tool mainly meant for optimised power system operation of hydrosources and thermal sources. In addition to thermal generation technology, the renewables are also one. Over the years to till date, we have up to ten versions updated and cumbersome of users have brought it. Minimum of a month's training is required for doing an advanced analysis with this tool. This tool has two parts, the first one is the strategic evaluation part and the other is simulation part. The time step for this tool is a week and the analysis can be carried out up to a period of 25 years. In [20–24], various case studies are undertaken using this tool.

2.9 Energy PLAN

Since 1999 at Aalborg University, Denmark, this tool has been continuously developed and maintained [25]. As it is easy to download, we can find a greater number of users with the latest updated versions. The period of learning this tool is up to a month and may extend based on the level of complexity. It is a user-friendly tool and the main purpose is to assist the design of energy planning strategy by simulation of the whole power system. Mostly, all the areas in the electric sector can be modelled by this tool. This tool optimises the given system operation as opposed to tools where the investments of the energy system have been optimised. Numerical analysis is done by this tool in electrical sector in large-scale integration of renewables in various countries like Estonia, Poland, Spain Germany and the UK [26, 27].

2.10 Energy PRO

The tool is a closed package of modelling, design, analysis and optimisation of fossils and renewables. EMD International A/S at Denmark industrialised this tool and also maintained by themselves [28]. From the inception of this tool, they have got over fifty versions. This package is a module chosen and used by sixteen countries with approximately a hundred users. Minimum of one-day training is used to learn this tool. This tool specialises mostly in thermal plant studies. It also involves models pertaining to heating sector but not in the technology of transport. It takes a minute time step for a duration of 40 years maximum for carrying out the analysis. Today, this tool is used for analysing the CHP plants at fixed tariffs [29] and also stimulates the compressed air energy storage in the spot market. Also, in [30, 31], analysis about heating and optimal sizing on the spot market is carried out.

2.11 ENPEP-BALANCE

The tool was established by Argonne National Laboratory in the USA in the year 1999. The nonlinear software matches the power demand with the existing resources and technologies. Approximately, this tool is used by fifty countries all over the world. In [32], this tool can be freely accessed. For learning this tool in a basic and advanced way, a person requires a period of two weeks. This tool is simulated based on market to determine the price changing and energy demand levels in the power market. The detailed analysis is done on annual basics to an extent of 75 years maximum. This tool depends on a decentralised process of decision making in the power sector. All types of generations can be simulated along with the financial aspects. Simultaneously, this tool finds the supply intersection and energy demand curves for all forms of energy in the network. The tool also services the iterative technique for a solution which is within the user-defined convergence tolerance. In [33, 34], a few case studies are mentioned.

2.12 GTMax

The Generation and Transmission Maximisation tool simulates the generating units dispatch and economic trading amongst the utilities with a network representation of grid [35]. In 1995 at Argonne National Laboratory, USA, this tool was established, and also, this is used in twenty-five countries across the globe. The price can be known only by contacting them. According to the expert's knowledge, learning the tool needs a week's training and also to adopt the advanced feature's implementation. The loads located at various locations can be served by this tool. All the technologies can be simulated by this tool. Also, in [36–39], this tool has a numerous investigation.

2.13 H2RES

This simulation tool mainly stimulates the renewable sources integration into power system. It was industrialised in the year 2000 by the amalgamation of Instituto Superior Tecnico in Lisbon, Portugal, and the University of Zagreb, Croatia [40]. To get an expertise in this tool, two months are a prerequisite, and also, this tool is used internally for research rather than external usage. This tool has been explicitly designed for renewable integration when operated at standalone condition. It can aid as a renewable planning tool along with the larger power systems. The tool considers all thermal generations but not nuclear and also it considers all renewable generations leaving tidal as exception. All the storage and conversion technologies are considered in this tool except compressed air energy storage. Using the criteria of satisfactory proportion of intermittent and renewable electricity in energy systems, this tool integrates as much as possible renewable and intermittent energy into the power system. The financial aspect is not included in this tool which may be added later. Finally, numerous investigations are done by various countries by this tool [41–43].

2.14 HOMER

The HOMER is an accessible micro-power design tool which is brought up in the year 1992 by the National Renewable Energy Laboratory in the USA. To till date, it has reached forty-two updated versions which have access [44]. Experts state the tool has used by thirty-two thousand people who learnt this tool in the span of one day. This tool simulates and optimises the system at standalone and grid-connected scenarios with various combinations of renewables. A few financial aspects are involved. It requires a time step of one minute for analysis considering a period of one year. It can also perform sensitivity analysis where the investigation can be done if there are any uncertainties in input variables. Finally, in [45, 46], various investigations are involved using HOMER as a software tool.

2.15 HYDROGEMS

As the name states, this software tool is based on hydrogen energy which is suitable for simulating the hydrogen energy system integration, specifically renewable-based standalone energy systems [47]. This tool is first developed in the year 1995 at the Institute for Energy Technology, and also, it was used in various research studies [48, 49]. Training of three months minimum is required for learning this tool. A period of one month is sufficient for the TRNSYS users. The performance analysis can be done in multiple time steps. These tool components are based on various streams of engineering like electrical, mechanical and heat transfer engineering. The pragmatic parts of this tool are designed to find the possible parameters based on the available data in the literature. This tool is accounted for the financial aspects also. This tool is used to analyse the operation of various renewable sources in standalone system as well as the simulation is also done based on hydrogen-based renewable energy [48, 49].

3 Conclusion

This research work achieves high efficiency in all aspects of information and technology. This will be applied in typical applications. The implemented proposed tool provides numerous effective and efficient information and especially for energy tool. Energy tool is used evidently and it is accessible in terms of region, analysis, technologies and objectives.

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