Renewable and Sustainable Energy Reviews 77 (2017) 297–317

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

Renewable energy: Present research and future scope of Artificial Intelligence

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ARTICLE INFO

Keywords:
Renewable energy
Wind energy
Solar energy
Geothermal energy
Hydro energy
Ocean energy
Bioenergy
Hydrogen energy
Hybrid renewable energy
Artificial Intelligence

ABSTRACT

The existence of sunlight, air and other resources on earth must be used in an appropriate way for human welfare while still protecting the environment and its living creatures. The exploitation of sunlight and air as a substantial Renewable Energy (RE) source is an important research and development domain over past few years. The present and future overtaking in RE mainly comprises of (i) the development of novel technology for optimum production from the available natural resources (ii) environmental awareness, and (iii) the better management and distribution system. Like other domains (food, health, accommodation, safety, etc.), Artificial Intelligence (AI) could assist in achieving the future goals of the RE. Statistical and biologically inspired AI methods have been implemented in several studies to achieve common and future aims of the RE. The present study summarizes the review of reviews and the state-of-the-art research outcomes related to wind energy, solar energy, geothermal energy, hydro energy, ocean energy, bioenergy, hydrogen energy, and hybrid energy. Particularly, the role of single and hybrid AI approaches in research and development of the previously mentioned sources of RE will be comprehensively reviewed.

1. Introduction

Currently, the world economy is inherently dependent on the effective ways of electrical power generation, appropriate management and distribution [1–3]. The conventional approaches of energy production have a massive side effect on the global climate and climate changes. According to recently published reports by the International Energy Agency (IEA) "*Energy-related greenhouse gas (GHG) emissions would lead to considerable climate degradation with an average 6 °C global warming*" [4]. Consequently, the clean energy is the feasible solution to make the world safer and energy proficient. It is environment-friendly due to minimum CO_2 contamination, which is the basic measure of the greenhouse effect responsible for environmental degradation [5–7]. Research and development in the RE domain on both the governmental and public level will achieve better efficiency and guaranteed reimbursement in future demand of energy because of the simple and low cost of maintenance, durability and the unlimited sources [8–10]. The RE sources are also referred as alternative mainly due to their inconsistency to supply the demand uninterruptedly in some specific conditions [11]. Consequently, the performance improvement of alternative energy sources is inevitable to accomplish the future demand of energy in the world [12]. The latter can be achieved by addressing the constraints related to the design, efficiency, performance prediction of the existing RE system, and weather parameter estimation of the region, where the station is installed. The global energy consumption data in different fields, including the crude oil, oil products, natural gas, coal, and renewables, etc. are available in the Global Energy Statistical Yearbook by Enerdata [13]. According to their latest published information on 2015, the total production and consumption of energy in the world is rising year by year as shown in the Fig. 1(a). Fig. 1(b) represents the information of top ten countries in the world, having maximum consumption of energy in the year 2014. China has been the largest energy consuming country from 2009 to 2014, though a reduction of 7 million tons of oil equivalent (Mtoe) in the year 2014 compared to the year 2013 is noticed [13]. China and USA have energy consumption greater than 1000 Mtoe from 2000 to 2014.

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http://dx.doi.org/10.1016/j.rser.2017.04.018
Received 23 May 2016; Received in revised form 10 April 2017; Accepted 13 April 2017

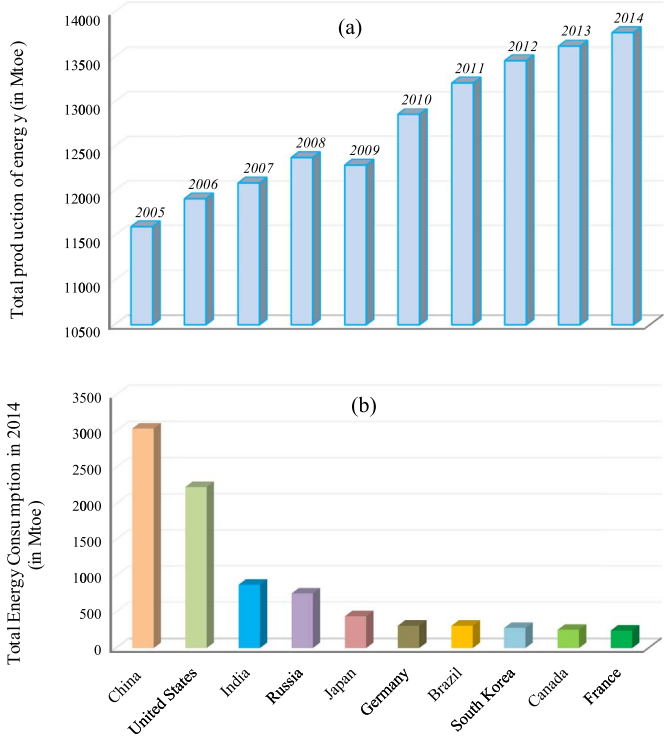

Fig. 1. (a) Total consumption of energy in last ten years (2005–2014) in the world, and (b) top ten countries with the maximum consumption of energy in the year 2014 [13].

Most of the countries in the world, including the top ten listed in Fig. 1(b) were trying to include RE as a major constituent of their total energy production. RE sources in China are showing increasing in growth, but their preliminary predictions are not even close to being fully used. Republic of China RE Law and associated conventions have encouraged the additional utilization of RE resources [14]. The similar trend is also followed by many small developing countries like (i) Former Yugoslav Republic of Macedonia (FYROM), where the first wind power plant was completely installed and operating successfully with the total capacity of around 50 MW in 2014, the projected annual production is about 125 GW/h to supply the need of 60,000 people (total population of the country is about 2.1 million) [15]; (ii) Uruguay (population 3.4 million) is producing 94.5% of its energy demands from renewables [16]; (iii) Costa Rica (population 4.8 million) is using maximum renewable and target 100% renewables for the power production by 2021. The European Union (EU) regulations on the RE decided to achieve a target of 20% of RE production in the total energy consumption of EU by 2020 and 27% by 2030 [17]. Fig. 2 exhibits the share of renewables in electricity production by top ten

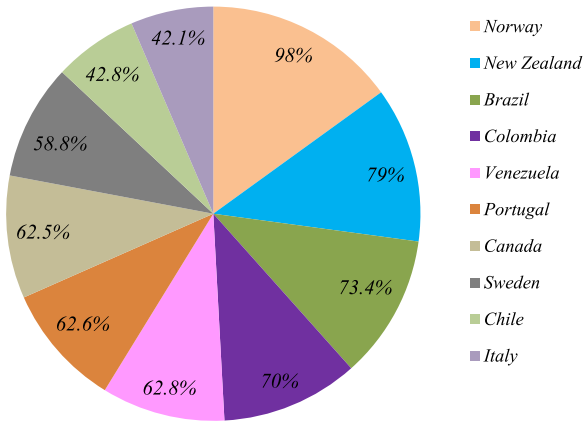

Fig. 2. A contribution of renewables in electricity production in the year 2014 [13].

countries in the world for the year 2014, from which it is obvious that the world is focusing additional attention on the alternative ways of energy production [13]. The research and development in the RE have been in full swing within the past few years. A total of 24248 research reports was published in the literature by the numerous research groups worldwide, focusing on the different issues related to the RE domain in between the years 2012–2014 [18]. It results in a total citation count of 144911 [18]. Fig. 3(a) shows the total number of publications related to the RE sustainability and environment in top ten scientific journals in between the years 2012–2014. The citation counts of top ten scientific journals in the similar period of time are represented in the Fig. 3(b). The advancement in the RE domain specifically in the sources, county-wise application, future use, environmental effect, production methods, storage, management, distribution, allied policies and limited technical limitations, etc. are detailed in several review reports [7–12,19–35] available in the literature. The most prioritized research in RE domain includes: life cycle assessment (LCA) [27,36–40], search and analysis of novel sources [41–45], social, economic and environmental effects [46–48], effective storage and relocation system [49–51], planning and design of grid integration and supply systems [52–54], electrification in rural area of developing countries [55–57], data acquisition and monitoring systems [58–61], country and region wise assessment of development and availability [23,35,62–70] and many more. Decision systems have been developed for several aspects of RE such as in the evaluation of prospective, using geographical information system (GIS) database [71], structuring of projects [72], planning for diffusion [73], and selection of project [74].

Optimization in RE is reported in several studies, like in control strategy for hydrogen storage [75], a community-based hybrid system [76], configuration of power generating system [77,78], scheduling of micro-grid [79]. Besides that, simulation and optimization of hybrid RE system, including the solar, wind, and other sources are designed and evaluated [80–82], modeling for high percentage of combined heat and power production (CHF) and wind power [83], solar radiation modeling [84], induction generator [85] are also described.

Adaptability in any field is always mandatory for additional advancement with the passage of time; it is also true for the RE. Since the scope of technology is developing day by day, the application of the previous becomes an essential part of each of the research and development domain currently. Specifically, the use of a machine which acts intelligently to tackle the problems is preferred in most of the research domains. Artificial Intelligence (AI) focuses mainly on developing intelligent machines and software for specific problems [86]. It has countless applications in most of the research domains, including the food, health, safety, education, business, agriculture, art, etc. [87]. AI also plays a substantial role in the advancement of RE. Importance of AI in RE specifically in solar radiation and wind speed prediction, prediction of energy intake of a solar building and heating loads of buildings, modeling of room heater, load and short-term electric power forecasting, sizing photovoltaic systems, wind and solar power modeling and forecasting, electrical load prediction of the city and supermarkets, etc. is summarized in the studies [88–95]. Though most of the previous reports cover the application of artificial neural network (ANN) based approaches in RE, therefore the main focus of the present study is to review the applications of different AI techniques including the ANN, applied in the RE in recent few years. Precisely, the performance of AI methods in the progress of Wind Energy, Solar Energy and other significant sources of RE is detailed. Besides, the impact of hybrid AI approaches in single and hybrid RE system have been thoroughly discussed and summarized.

2. Significant renewable energy sources

RE types, according to the source of generation, mainly include wind energy, solar energy, hydro energy, geothermal energy, bioenergy, ocean energy, hydrogen energy, hybrid RE, etc. [1–5]. A schematic diagram