Long-term electric energy consumption forecasting via artificial cooperative search algorithm

CrossMark

S. Hr. Aghay Kaboli, J. Selvaraj, N.A. Rahim[*]

University Malaya Power Energy Dedicated Advanced Centre (UMPEDAC), Level 4, Wisma R&D UM, JalanPantai Baharu, 59990, Kuala Lumpur, Malaysia

A B S T R A C T

This study mathematically formulates the effects of socio-economic indicators (gross domestic production, population, stock index, export, and import) on Iran's electric energy consumption. The path-coefficient analysis is implemented on linear, quadratic, exponential, and logarithmic models to determine the optimized weighting factors. On this basis, artificial cooperative search algorithm is developed to provide better-fit solution and improve the accuracy of estimation. Artificial cooperative search algorithm is a recently developed evolutionary algorithm with high probability of finding optimal solution in complex optimization problems. This merit is provided by balancing exploitation of better results and exploration of the problem's search space through use of a single control parameter and two advanced crossover and mutation operators. To assess the applicability and accuracy of the proposed method, it is compared with genetic algorithm, particle swarm optimization, imperialist competitive algorithm, cuckoo search, simulated annealing, and differential evolution. The simulation results are validated by actual data sets obtained from 1992 until 2013. The results confirm the higher accuracy and reliability of the proposed method in electric power consumption forecasting as compared with other optimization methods. Future estimation of Iran's electric energy consumption is then projected up to 2030 according to three different scenarios.

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

Energy consumption forecasting has been always playing a vital role in planning and power system management. Accurate electric power consumption forecasting can provide reliable guidance for power grid operation and power construction planning, which is also important for the sustainable development of a country. The accuracy of electricity consumption forecasting directly impacts the effectiveness of energy trading, system reliability, O&M (operation and maintenance) costs, T&D (transmission and distribution) expanding and generators scheduling.

The accurate forecasting of electric energy consumption gives more realistic spectrum for future country's energy sources consumption to move towards sustainable development in a globalizing world. Electric energy consumption reflects the degree of economic development in a country and much evidence supports a causal relationship between economic growth and electric power consumption. Due to rapid development in developing countries,

their macroeconomic variables have rapid fluctuation and there are no stable trends for those variables. Subsequently rapid fluctuation on macroeconomic variables will result strong fluctuation in electric energy consumption. Hence, provide an accurate estimation of electric energy consumption to facilitate energy planning, formulating strategies and recommending energy policies with consideration of economic growth in the future is one of the most critical and challenging issue for electric utilities [1].

The statistical report on electric power industry conducted by ministry of energy [2] reveals that the electric energy consumption of Iran has been growing from 5.5 MTOE (94.35 KGOE per-capital) in 1992 to 22.64 MTOE (293.69 KGOE per-capital) in 2013 with the average growth rate of 7%. Fig. 1 indicates the compositions of gross power generation from 1992 until 2013. According to this report in 1992, 66.21%, 16.98%, 14.89% 1.91% of gross power generation composition had generated by steam, gas, hydro, and diesel turbines respectively. On that year, 30.5%, 24.94%, 20.73%, 18.25%, and 5.58% of total generation were for residential sector, public services, industries, grid loss (transmission loss plus power plants consumption), and agricultural sector respectively. The electricity sales to various consuming sectors from 1992 until 2013 are shown
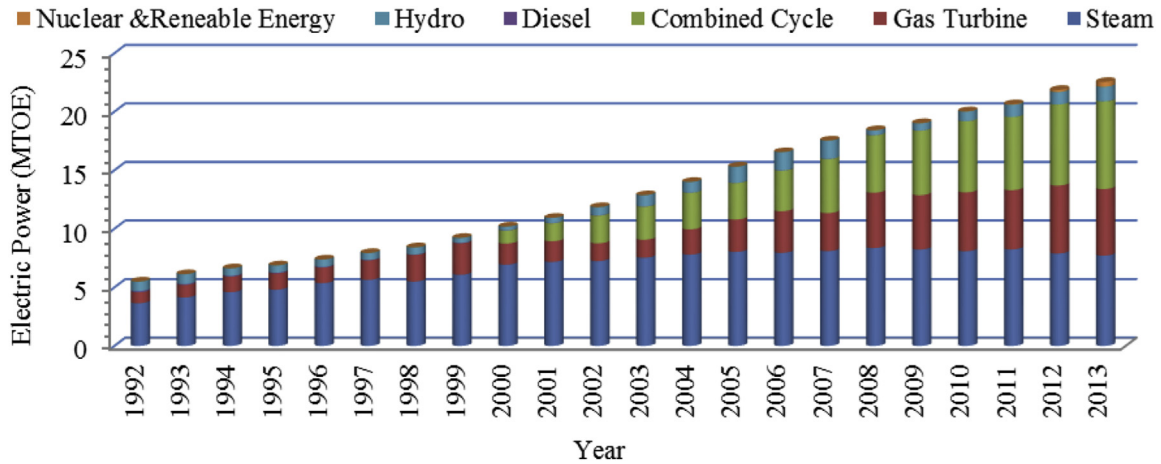

Fig. 1. Iran's composition of gross power generation from 1992 to 2013.

in Fig. 2.

Iran as a developing country, which has the second largest population and economy in the MENA (Middle East and North Africa) region, has been subject to numerous perturbations on its economy. In recent decades, infrastructure limitations such as concerns about energy consumption, scarcity of resources, fluctuation of fuel price, fluctuation on electricity consumption patterns, economic crisis, and political issues in Iran have been forced the government to give high consideration to the electric energy consumption forecasting to prudently develop the power system. Hence, beyond year 2000, combined cycle, nuclear power plants, and renewable energy generators such as; wind, solar, solar thermal, geothermal, and biomass have been developed to redress the power system due to high-expected demand in the following years.

That electricity consumption trend of Iran has been changing gradually due to the increase in population, urban life, and economic growth. The portions of electric energy consumption have changed to 26.82%, 24.45%, 19.89%,13.28%, 12.57% and 2.99% for industries, residential, agricultures, grid loss, public services and exchanged electricity with neighboring countries respectively while 34.2%, 33.23%, 25.19%,5.52%, 1.84%, and 0.02% of the total power have been supplied with steam, combined cycle, gas, hydro,

renewable energy and diesel generators respectively in 2013. The outlook of electric energy consumption of Iran highlights that energy optimization strategy and systematic management of power system are a matter of sustainable development necessity due to variations in trend of electricity consumption.

This paper proposes ACS (artificial cooperative search) as an effective approach for long-term electric energy consumption modeling based on the structure of the socio-economic conditions of Iran, as a developing economy that has been subject to numerous perturbations. ACS is implemented to provide better-fit solution and improve the accuracy of estimation. Gross domestic product (GDP), population (POP), stock index (SI), import (IMP), and export (EXP) of goods and services in the last 22 years are considered as input variables of forecasting models while the observed electric energy consumption in that period are used for validation. In order to show the forecasting accuracy of the ACS, the obtained results by different models are compared with other metaheuristic methods that have been satisfactory applied for energy consumption forecasting.

The rest of paper is organized as follows: First, the literature review about different methodologies for long-term energy consumption forecasting is presented. Next, the basic concept and
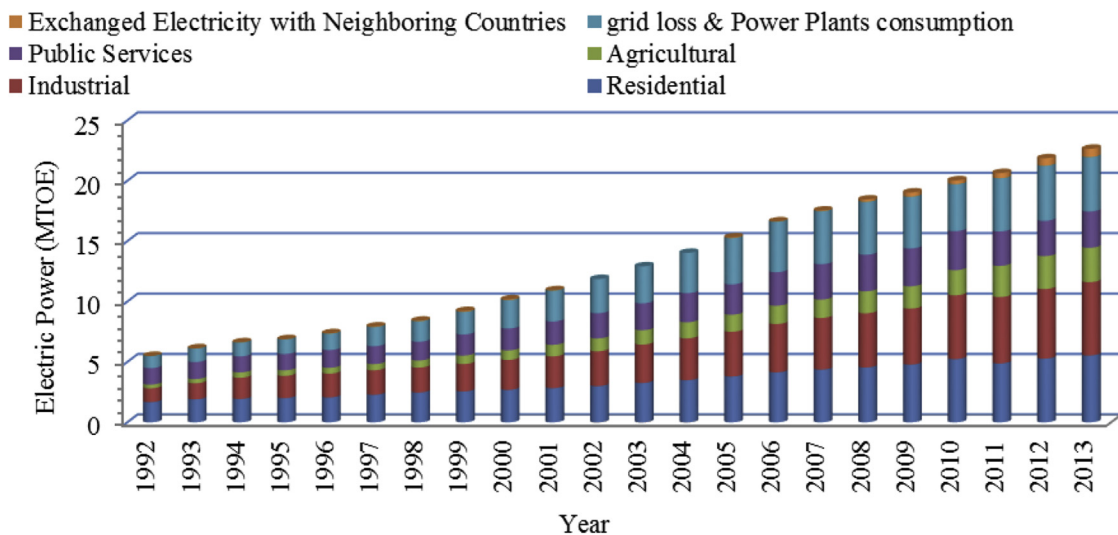

Fig. 2. Electricity sale to various consuming sectors in Iran from 1992 to 2013.