Energy 116 (2016) 329–340

Contents lists available at ScienceDirect

Energy

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

Issues and solutions relating to Hungary's electricity system

Viktor Miklós Kiss [a,*], Zsolt Hetesi [b], Tibor Kiss [a]

[a] Faculty of Business and Economics, University of Pécs (PTE), Rákóczi út 80, HU-7622 Pécs, Hungary
[b] National University of Public Service (NKE), Ludovika tér 2, HU-1083 Budapest, Hungary

ARTICLE INFO

Article history:
Received 12 April 2016
Received in revised form
23 September 2016
Accepted 25 September 2016

Keywords:
Energy system
Electric power system
Sustainability
Simulation
Modelling

ABSTRACT

The great majority of Hungarian electricity generating system's capacity is obsolete and needs to be replaced. Current production is dominated by nuclear power and coal, whilst depending heavily on imported electricity to cover demand. Official plans for the future envisage scenarios also greatly dependent on fossil fuels and/or imported electricity. Currently, there are no specific plans for the large-scale introduction of renewable energy sources or energy independence. This paper shows that it is possible – with no significant change in structure – to develop an electricity power system for the country using a significant amount (25–30%) of renewable sources, which is less dependent on non-domestic sources for generation and which is more environment friendly than the official, forecast scenarios.

1. Introduction

Hungary is facing major challenges over the next decades if it wishes to supply its own electricity needs in a secure, economical and environment friendly way. Due to the fact that practically all of its large[1] (≥50 MW (megawatt)) power plants are to be retired within 15 years, there will inevitably be major changes in the country's system.

The Hungarian TSO (Transmission System Operator) analyses the situation on a yearly basis and publishes the results. The two basic scenarios they have built for the next decades could have significant dangers both environmentally and in terms of energy security. The proposed proportion of renewable sources is extremely low compared to most other European Union countries, and the scenarios are heavily reliant on non-domestic sources.

The current study aims to prove that the country is in a situation where a secure and environment friendly electric power system can be developed in future decades without having to significantly restructure the electric power system, and that the implementation of such a system is economically comparable to other scenarios. It will do so by simulating and comparing the different paths for the Hungarian system over the coming years.

The method generally used for evaluating different paths for energy systems is scenario based modelling. Major publications which incorporate electric power, heating/cooling and transportation into their respective country-size energy system models include Lund and Mathiesen who explored the possibility of a 100% renewable energy system (including electricity, heat and transportation) in Denmark by 2050 with an intermediate step (50% renewable by 2030) in between [1]. Ćosić et al. conducted a similar research for Macedonia with the same time frame (2030 and 2050) and renewable energy penetration (50% and 100%) [2]. Some country-size analyses focus on the effect of one particular energy source within the energy system. Novosel et al. recently published an article researching the possibilities for reverse osmosis desalination for Jordan [3]. The effects of a nuclear reduction strategy were researched by Gota et al. for Romania [4].

Some models lay down the foundation for a detailed analysis of a country's energy system. Connolly et al. [5] develop a simulation model of the current (2007) system of Ireland for the purpose of serving as a base for future analysis. Sáfián [6] conducted a similar research for the 2009 energy system of Hungary, which is a sound initial step and a stimulus for further analysis. The current study takes the idea one step further and creates specific future state scenarios.

Publications – similarly to the current study - focusing solely on the electric power system of a country include the research of Mason et al. on the possibility of reducing the fossil-fuelled

* Corresponding author.
E-mail addresses: kissv@ktk.pte.hu (V.M. Kiss), hetesi.zsolt@uni-nke.hu (Z. Hetesi), kisst@ktk.pte.hu (T. Kiss).

[1] Throughout the paper, the units with a capacity ≥50 MW will be referred to as *large* power plants and units with a capacity <50 MW as *small* power plants.

http://dx.doi.org/10.1016/j.energy.2016.09.121
0360-5442/

electricity generation of New Zealand and replacing it with renewable sources, such as wind and geothermal heat [7]. Krajacic et al. created a model with a similar goal for Portugal, where they researched the possibilities to replace the high proportion of imported oil and gas within the country's energy system with renewable sources [8]. Elliston et al. conducted a research for Australia, where they explored the technological options for the transition to a 100% renewable based electricity supply [9]. A recent study – published by Cho and Kim - discusses the feasibility and potential impact of establishing a renewable source based electricity supply system for Korea [10].

As the short literature review shows, the transition from traditional, dominantly fossil-fuel based electricity generation to a more renewable and flexibly based system is a very timely question. Due to the fact that Hungary is looking at a major transition in its electric power system, developing a model in line with the leading literature and detailed analysis seems essential.

2. The scope of the article

The primary goal of the article is to develop a model for the electricity system of Hungary, which is capable of analysing future scenarios. The developed model is used to simulate the current plans of Hungary regarding the future of their electric power system and an alternative system developed by the authors, which seeks to model a conservative, realistically possible scheme inclusion of renewable energy sources.

The results are evaluated and compared in terms of the security of electricity supply, their effect on the environment, and their economic feasibility. The security of supply will be evaluated by the amount of domestic versus foreign sources for electricity production and the renewable energy share within the system. Their effect on the environment will be compared by their respective emission intensity (gCO2 eq./kWh-e) and a detailed evaluation discussing investment; operation and fuel costs of the scenarios will provide the basis for comparison in terms of economic feasibility. A sensitivity analysis will be conducted in relation to changes in electricity demand and CO2 prices.

The study would like to show that it is possible to include a significant amount of domestic and renewable energy sources in the Hungarian electric power system without performing major changes within the structure of the system - and also that this would improve the energy security of the country, have a lower negative impact on the environment, and would be comparable to other (fossil fuel-based) scenarios financially.

3. Hungary's current electric power system

Most of the large power plants operating in Hungary are basically at least forty years old, the majority having been built in the 1960s and 1970s. There are, nevertheless, a few new, relatively modern blocks installed at various existing plants, and some peaking power plants are relatively new (post-2000). Please refer to Table 1 for the details of the country's production capacities. The data are from the latest year for which data were available (2013).

According to the Hungarian TSO [11] there were only two power plants where the yearly capacity factor exceeded 63.8%[2] and could be considered to be a base load power plant. The two power plants were the nuclear power plant in Paks and a coal fired power plant in the Mátra Hills. Although the share of the total capacity of natural gas fired plants in the country is around 60%, these capacities are rarely used and their use is continuously decreasing. In 2014 only 6.7% [12] of the total electricity consumed in Hungary was produced by domestic plants using natural gas, and most of that was produced by CHP (Combined Heat and Power) plants which primarily serve a district heating demand. The severity of the situation for natural gas-fired plants is shown in Fig. 1, where it is clear that their production is gradually being substituted by imported electricity. Even the newly (2011) built 433 MW power plant in Gönyű - which theoretically could reach a 59% efficiency [13] - was being operated on a low, 7.4%, capacity factor in 2014 [11].

The main reason for this trend lies is the nature of the European Network of Transmission System Operators for electricity (ENTSO): It seems that natural gas fired plants are currently not competitive economically. This is not a Hungarian phenomenon, and the decreasing involvement of natural gas fired plants for electricity production is visible in the whole of the ENTSO system. The total share of natural gas in the system has dropped from 16.0% in 2010 to 11.0% in 2014 [12]. The fact which makes Hungary's case special, is that around 60% of the country's capacities are natural gas-fired plants, and if they cannot be economically powered, the country turns to imports, which, consequently, supplied more than one third (33.9%) of the countries consumption in 2014 [12]. This puts Hungary 4th on the list of net importers compared to total consumption in the ENTSO system. Only Luxembourg (75.7%), Lithuania (71.5%) and the Former Yugoslav Republic of Macedonia (34.7%) have a bigger share of their consumption of electricity originating abroad [12]. Although relying greatly on imported electricity is not necessarily a problem, the fact that Hungary has a total electricity generating capacity which is more than 140% of the maximum load for the country (9127 MW to 6419 MW in 2014 [11]), it raises questions.

The answer lies in the structure of the 9127 MW capacity. Most of the large power plants are obsolete, and gradually being demoted into the tertiary reserve capacities and ultimately being retired. Most of this will happen in the next 15 years, which could result in the need to build a significant new capacities in order to comply with capacity regulations.

3.1. The case of Paks and Paks II nuclear plants

Paks in a small city located in the central area of the country, on the banks of the Danube. It is best known for having the sole nuclear power plant in the country, operating four reactors with a total capacity of 2000 MW. The power plant - in operation from 1982 - was always a major contributor to the domestic power system and is now responsible for approximately 50–55% of the total domestic electricity production. It recently had its operating license extended until 2035. Hungary, however, will not lack a nuclear power plant after that date, since the country has signed an inter-governmental agreement to build new blocks for the nuclear power plant, named Paks II., which will consists of two 1200 MW reactors for a combined capacity of 2400 MW. Their commercial operation is planned to be started around 2025 [14]. Although this date might easily be delayed, it is possible that Hungary will operate a total of 4400 MW of nuclear capacity for a couple of years. It is very difficult to predict the potential length of the overlap period, and so our research focuses on the time period (starting from approximately 2030) when there is to be only one nuclear power plant in operation.

4. Future plans

This chapter analyses the current plans of Hungary regarding their electric power system for the next decades, and the analysis considers both the demand and the supply sides using the plans developed by the national TSO, the National Energy Strategy [15],

[2] Hungarian threshold for base load power plants.