Modeling an energy market with coupled collective heating and transport sector in high renewable energy sources penetration

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Overview

Nowadays, the world is facing problems related to climate change and the pollution of the natural environment, which are partially caused by the emission of toxic compounds and CO2 from the combustion of fossil fuels. Due to the fact that the natural resources of fossil fuels have been exploited for many years, such resources have been also reduced quite dramatically. The abovementioned facts determine that there is a need to conduct research which will demonstrate the technological and socio-economical possibilities of transforming energy systems and parts of transport system from fossil fuels into renewable energy sources [hereinafter referred to as: RES]. Currently, most of the energy systems in the world are based on fossil fuels. However, the possibilities of supplying the energy system with renewable energy sources have been discussed in the literature for many years. At the beginning of this century, a lot of researchers were of the opinion that renewable energy sources could cover only a few percent of the energy needs of a country the size of Germany. Afterwards, when renewable energy sources became constantly present on the day-ahead markets, it was examined whether wind energy could take part in balancing markets (following the day-ahead markets). Nowadays, the participation of this energy source is becoming reality (T. Gomez and R. Escobra, 2014). Many regions, not only in Europe, are currently introducing plans to modernize energy systems in order to cover most of the demand for electricity by RES within several or several dozens of years (Costa Rica 100% until 2021, Denmark 100% until 2050, Sri Lanka until 2030) (M. Willenbacher, 2017).

The use of renewable sources in classical energy systems does not always imply that the entire system needs to be reconstructed. It is possible to supply the system with up to 25% of energy coming from fluctuating renewable sources without major system modifications. However, problems arise only if one wants to create a system powered almost in 100% from renewable sources in which the majority of energy comes from fluctuating sources of renewable energy, such as solar, wind or wave energy. From the system operator's point of view, what is the ideal source of renewable energy are hydroelectric power plants the power of which can be freely modulated. In countries such as Norway, Brazil and Venezuela, more than 65% of energy comes from hydroelectric power plants (D. Gielen, 2012). Unfortunately, most countries, due to their geographical location and climate, are forced to seek other renewable energy sources which are not as stable as hydroelectric power plants. Systems powered mostly by fluctuating sources require the system operator to search for methods to compensate power fluctuations.

These considerations raise a number of questions related to the impact of modern technologies used to obtain electricity from RES on the nature and structure of the electricity market, both in Europe and worldwide.
These questions formed the basis for conducting research on the idea of supplying a selected region with high RES participation, taking into account cost and environmental efficiencies for the entire energy system. Further, the analysis of the subject indicated the need to conduct research on correlations which derive from integrating collective heating and transport systems with an electricity system in order to optimize the functioning of the entire energy market.

The issue, as outlined above, determines the objectives of this research, *i.e.* exploring the possibility of supplying a selected region with high renewable energy sources participation, identifying correlations between the integration of a supply system powered by RSE with collective heating and transport sector.

Furthermore, in order to perform the research and to achieve its objectives, the spatial and temporal scope of the analysis as well as the sources and research methods had to be determined. The spatial scope refers primarily to the empirical part of the research and concerns Poland, however, supported by data from all over Europe. The conducted research focuses on the economic analysis from the perspective of electricity end-users and does not encompass legal and political aspects. Further, the temporal scope covers the years 2005-2015, which is related to

the temporal scope of data available in secondary sources. In particular, it encompasses data from national energy operators, materials made available by statistical offices and the International Renewable Energy Agency. The research is based on foreign and domestic literature addressing the subject of renewable energy sources and related to the market of renewable energy. Nevertheless, these two issues are usually discussed separately, whereas existing studies on the energy systems powered in its entirety by renewable energy sources concern only a narrow scope of research and do not exhaust the subject matter.

Methods

This research was carried out through a combination of quantitative and qualitative methods. Quantitative analysis applied agent-based modelling, a method supported by extensive qualitative research. In order to forecast the input data for the model, such as demand or variable environmental parameters on the basis of historical data, Idat-Matlab functions based on *inter alia* ARIMA models were used.

Results

An extensive literature analysis and own simulations of functioning of electricity markets models in Matlab, Homer Energy and Energy Plan, resulted in presenting two models of transformation of the classical energy system. The first model preserves the dominance of large energy producers as main energy suppliers, while the second (reverse) model assumes that the energy producer is also the recipient of this energy, hence, the role of the system operator is reduced to ensuring system stability and production balancing.

Conclusions

The conducted research has indicated that renewable energy systems demonstrate greater cost and environmental competitiveness than conventional energy systems. Furthermore, it has been shown that the integration of collective heating and transport systems with the energy system has a positive impact on the efficiency of the entire system by reducing primary energy demand and decreasing carbon dioxide emissions.

References

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