Integration of renewable energies in North Africa to supply European electricity markets

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(1) Overview

Up to now, the North African electricity markets are characterized by a dominant conventional power generation a weak interconnection between the individual markets. A liberalization process of the electricity markets to create more efficient and cost effective supply structures has been started slowly in the last years, although the pressure of a strong demand increase and a large volume of infrastructure investments to modernize the current electricity systems exist in all countries of the region. In 2010, the share of electricity produced by renewable sources such as wind, solar and hydro was approximately 7% in the North African countries. Most of this renewable electricity production comes from hydro power plants in Egypt and Morocco. Nevertheless, ambitious targets to increase the share of renewable energy sources, mainly from wind power plants, photovoltaic systems (PV) and concentrated solar power plants (CSP) with thermal energy storage are set to shares of 20 to 40% in the timeframe of 2020 to 2030 [1]. Additionally, there is the vision to export electricity from renewable energy sources to Europe [2]. In this context the question arises, how much and to what price the electric energy can be generated from renewable energy technologies and exported to Europe, how much will be used for own consumption and to which extent do the regional electricity grids in North Africa have to be extended and connected for optimization and to balance out fluctuations in generation. For Europe, the option to import electricity from North Africa is still a question about technology choice and costs of electricity under the overall conditions of higher investment risks and political stability in the region.

(2) Methods

A two-step approach combining an optimized investment planning model for new power plant capacities and an optimal operation dispatch was developed to cover the design of the existing electricity market in North Africa and the need for a future interconnected Mediterranean electricity production. As a key issue this modeling approach includes the existing conventional power plant system in the analysis and connects it with a high-resolution simulation of renewable energy generation. Also grid extensions between local areas via HVDC lines and the intercontinental transport via HVDC lines to Southern Europe have been linked with the investment model. Therefore, two models based on linear programming were developed. To analyze the future hourly electricity generation for export and its costs, the models use different strategies to optimize the electricity generation in North Africa which is exchanged with Europe: (1) surplus electricity is exported; (2) electricity below a certain generation price is exported; (3) hypothesized demand loads of Europe are considered.

Each country of North Africa was divided into three to seven regions by using political regions and connected areas. With this approach, the effects of exchanging electricity of one region with its neighbor regions are analyzed. All existing high voltage transmission lines between two regions are included in the database of current infrastructure and the maximum net transfer capacity between the regions was obtained. All generation capacities are indexed to one region by considering their geographic location.

The objective function of the model minimizes the annual system costs by considering external revenues by exporting electricity to Europe.

(3) Results

Electricity generation in North Africa will require more operational management as hourly operation will be effected by a strong fluctuating power generation. Higher shares of fluctuating wind and solar energy will influence the operation mode of conventional power plants strongly (see Figure 1). Electricity exchange between regions and countries was assumed which will lower the effect of the fluctuating generation. In Figure 1, it can be seen that the generation from coal and combined cycle power plants has to follow the demand, mainly during evening hours after the sunset. A few days are strongly influenced by high wind generation, as it can be seen at day 1 and 5.

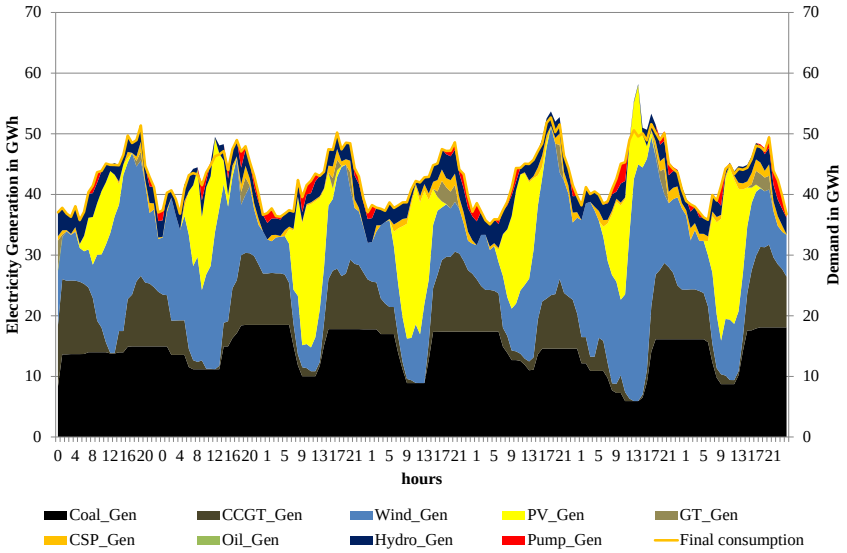

Figure 1: Hourly electricity generation in North Africa

Depending on the definition of each export case, the annual volume of exports varies significantly. The results show a high dependency between the amount of exported electricity and the market environment (different cases). Based on these results, first policy recommendation for designing a future electricity exchange between North Africa and Europe can be drawn.

Besides the effects of large capacity increase in terms of new power plants and transmission lines, this paper shows results regarding the point of time of electricity export. Electricity exports of each hour per day over the year 2050 are calculated by the model and summarized to analyze the daily distribution of potential imports in the EU. The analysis demonstrates that the electricity export could not meet a beneficial demand of Europe always. Particularly, larger amounts of electricity exports in cases (1 - surplus) and (2 - price) will appear during early afternoon. This might be in contrast to the assumption of case (3 – fixed demand) which asks for electricity imports in the EU during morning or evening hours. A comparison of case (3) with case (1) and (2) gives the higher costs when a specific demand in the EU is supplied by renewable energy sources in North Africa.

(4) Conclusions

A new optimization model was applied to the North African electricity market to analyze the effects of increasing shares of renewable energies in three export scenarios. The scenarios, applying different export strategies to Europe, were used to model the outcomes in a long-term horizon for the electricity system in North Africa in the year 2020 and 2032. With a large market deployment of renewable energies, mainly wind and PV, the electricity export from North Africa could be beneficial from a macro-economic view as the fluctuating electricity generation can be handled more easily in larger, interconnected areas. The first results of this modeling approach show large differences regarding the amount of exported electricity and the point of time when this electricity is transferred to Europe.

References

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