OPTIMAL ELECTRIC POWER TRANSMISSION PLANNING TAKING ENVIRONMENTAL CONSTRAINTS INTO ACCOUNT

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Overview

The worldwide reconstruction of the electric power systems is taking place under increasing end-user energy demand, environmental changes and active trading markets. The realization of the common market in Europe as well as power supply improvements in other regions, are not possible without investments in the transmission sector. These investments can be either in new transmission lines or in line capability upgrades using new technologies, e.g. FACTS devices. This means that the transmission planning and analysis of electric power systems cannot remain the same as it was 10 or 20 years ago.

The generation sector and the energy balance is an important part of the electric power systems planning, but the present requirements in Europe and other places in the world call for new methods and tools to analyze the development of the electricity system, including the transmission and distribution systems. The topic is sensitive due to the fact that transmission investments create winners and losers. The following analysis is based on social welfare. The considered requirements are the environmental impact of energy consumption, the impact of the transmission capacity increment on the market, as well as the benefit or the deficit in social welfare.

The energy production is commonly associated with negative effects. Fossil fuel power plants are much cheaper and competitive than other types of power plants but not sustainable. They are the main sources of CO_2, NO_x, SO_2 and fine particles. Hence, a number of negative effects arise, with their costs not reflected in the electricity prices. These costs are known as external costs. They refer to environmental damages, health impacts and climate change respectively. The discussion how and whether it is possible to estimate the monetary values of external costs is not the subject of this paper, but how it is possible to consider them in the electric power transmission planning and operation. This paper, accordingly, emphasizes the compensation of transmission investments from the social benefit that arises from the internalization of external costs.

Methods

The analysis is based on Optimal Power Flow (OPF) as explained below. The OPF is capable to represent the characteristics of the modern liberalized electricity market and to support the market based system analysis. Furthermore, the OPF is able to combine conflicting and independent variables to the overall optimum. Hence it is applicable for solving problems of aggregation of conflicting interests in power systems, so called multi-objective optimization problems. Indeed multi-objective optimization methods attract more and more the attention of policy and decision makers due to the need for studying bigger, more complex and more realistic systems.

In this paper, the main criterion for electric power transmission investment planning is the maximization of social welfare when the external costs of production are internalized. The social benefit can be used further to compensate the required investments for the market enhancement.

The studied system is a model of a transnational European electricity network including the four countries Germany, Belgium, France and the Netherlands. The model includes 82 generation companies represented with step-wise marginal cost functions where the external costs have been internalized according to the mean values of power plants efficiencies. The loads are represented as mid-term linear demand functions for peak and off peak loadings. Subject to the above criteria and the collected data a priority project EL1 between France and Belgium will be evaluated.

Results

The results show that the internalization of external costs in that region promotes new entrants in the market, increases the dependencies between the participants, and to wit, leads to a more compact market environment.

Furthermore it causes a deficit in the social welfare which is much smaller than the total social benefit from the decrease of the fossil fuel power plants production. As a result France and Belgium, which are the involved parties in the priority project, benefit least from this investment, increasing the dependencies of the network participants even more. The paper will contain a detailed description of the above mentioned methods and their implementation, as well as an analytical documentation and evaluation of simulation results of the tested power system.

Conclusions

The latter analysis has been proposed for the evaluation of future transmission investments based on a social welfare analysis. As environmental constraints become more and more part of the energy systems operation, the above method can support decision makers in the planning of the future electricity system.

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