AN OPTIMIZATION APPROACH FOR THE ECONOMIC DISPATCH PROBLEM INCORPORATING THE EFFECTS OF RETAIL POWER MARKETS

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Overview

The increasing interactions and interdependences of the wholesale and retail markets in the power sector has created the need for development of integrated approaches for the optimal portfolio management of vertically integrated utilities, aiming at drastically limiting their exposure to risk. The objective function to be optimized concerns the minimization of the total daily cost for the operation of a power system consisting of thermal, hydroelectric, and renewable power generating units, considering also its external interconnection, i.e., imports and exports, for a series of day types. More specifically, it is split into two types, namely cost and revenues components. The first part includes the hourly offers cost for thermal, nuclear, hydroelectric, and renewable power generating units, as well as the corresponding one for electricity imports and the block offers cost for thermal and nuclear power generating units. The proposed optimization framework can provide useful insights on the determination of the optimal generation and retail portfolios that address the new market operating challenges of contemporary power systems subject to technical and economic constraints.

Methods

The literature review has identified the increasing interactions and interdependences of the wholesale and retail power markets. Although there are numerous of papers examining the linkage among wholesale and retail market, there is lack of integrated approaches, especially related to the optimal portfolio management of vertically integrated utilities, aiming at drastically limiting their exposure to the risk. This stands as the aim of the paper. Figure 1 depicts the superstructure of the proposed optimization framework for the solution of the economic dispatch problem, based on advanced computational techniques. This work presents a mixed integer linear programming (MILP) model for the optimal clearing of a wholesale power market including market products widely used in power exchanges such as block and hourly orders, calculating also the economic balance of vertically integrated utilities participating in retail markets. By considering a wide range of technology options in the wholesale market including fossil fuel-based thermal units incorporating or not carbon capture and sequestration capability (CCS), nuclear power, renewable energy, electricity trading and storage options, as well as different types of consumers in the retail market (low, medium and high voltage), the model determines the optimal electricity generation mix, the system's marginal price and its environmental performance, as well as the net economic position of each power utility in both wholesale and retail markets. A series of sensitivity analyses has been conducted to investigate the influence of several economic, technical and political parameters in the operational scheduling and financial planning of each company. The model applicability has been assessed in an illustrative case study of a medium-sized power system considering also its interconnections with neighboring power systems. The problem is to be solved to global optimality making use of the ILOG CPLEX 12.6.0.0 solver incorporated in the General Algebraic Modeling System (GAMS) tool. An integrality gap of 0% has to be achieved in all cases.

Results

The key decisions to be determined by the mathematical model include: (i) electricity generation mix of the studied power system, (ii) system's marginal price, (iii) environmental performance, in terms of CO_2 emissions, as well as (iv) net economic position of each power utility in both wholesale and retail markets.

Therefore, the paper contributes to the relevant literature on providing a methodological framework for an integrated assessment of both wholesale and retail markets of the power sector, incorporating simultaneously all the contemporary market products currently utilized in power exchanges (block and hourly orders). The main contributions and the prominent features of our work include: (i) incorporation of the interaction and interdependence of wholesale and retail power markets within the context of contemporary power exchanges, (ii) quantification of the impacts of a series of economic, political, and technical aspects in the implemented decision-making, and (iii) provision of price signals on potential investors for the optimal determination of investments in both markets of the power industry.

Conclusions

The introduction of market competition in the power industry has turned the integration of wholesale and retail markets into a challenging task, requiring proper design and effective management in order for the market participants to adapt to inherent variabilities and potential price fluctuations. It is expected that a balanced portfolio in both wholesale and retail markets is of utmost importance for the economic viability of electricity enterprises, providing secure and safe risk hedging in a variety of volatile circumstances. Not surprisingly, an electricity company which is net buyer, namely its share in the retail market is higher than its corresponding share in the wholesale market, favors from low system's marginal prices in the wholesale market, while when an electricity company is net consumer, namely it exceeds its corresponding share in the retail market, favors from high system's marginal prices in the wholesale market. As a consequence, the degree of each company's exposure in each market requires systematic calculation and optimal portfolio management. Given the generating portfolio of each power enterprise and its profit margin goal, the selection of each type of demand representation, determined by the objective, the economic size and the organization structure of each electricity company, influences its financial sheet to a significant extent.

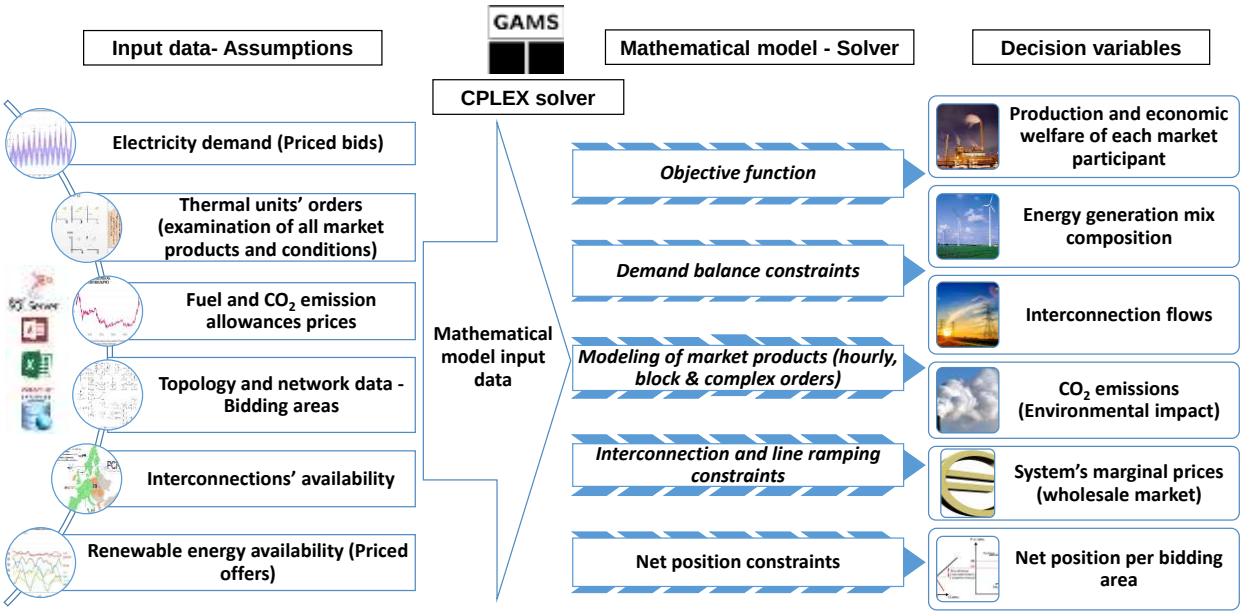

Figure 1: Flowchart of the methodological solution framework for the market clearing of power exchanges.

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