INCORPORATING UNIT COMMIMENT TECHNICAL FEATURES TO THE PAN-EUROPEAN HYBRID ELECTRCITY MARKET INTEGRATION ALGORITHM (EUPHEMIA)

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Overview

The European electricity markets' integration aims at the market coupling among interconnected power systems and the enhancement of market competitive forces. This process is facilitated by the adoption of a common clearing algorithm among European power exchanges: the Pan-European Hybrid Electricity Market Integration Algorithm (EUPHEMIA), which however lacks to capture critical technical features of the power systems, as done by the unit commitment problem. This paper presents an optimization-based framework for the optimal joint power and reserves market clearing algorithm, further utilizing the hourly offers module of the. In particular, through the formulation of a mixed integer linear programming model and employing an iterative approach, it determines the optimal power and reserves mix, the resulting market clearing prices, and it calculates the welfares of the market participants. The model incorporates intra-hourly power reserve constraints, as well as introduces new market products such as the linking-units option, aiming at supplying additional flexibility in the decision-making of the market participants. The model applicability has been assessed in the Greek power system and its interconnections with neighboring power systems in Southeast Europe. The proposed optimization framework can provide useful insights on the roadmap determination for the optimal generation and interconnection portfolios that address the new power market operating challenges of contemporary power systems subject to technical and economic constraints.

Methods

This paper presents an optimization-based framework for the optimal joint power and reserves market clearing algorithm, further utilizing the hourly offers module of the EUPHEMIA, the official clearing algorithm at a Pan-European level. In particular, through the formulation of a mixed integer linear programming model and employing an iterative approach, it determines the optimal power and reserves mix, the resulting market clearing prices, and it calculates the welfares of the market participants. As a consequence of the reserves' market incorporation, the design of the minimum income condition order has been modified to integrate the new sources of potential welfare. It examines also the impacts of a series of key operating characteristics of thermal units such as the minimum up and down times, as well as the consideration or not of each thermal unit's technical minimum in the market clearing process. Figure 1 provides the flowchart of the methodological solution framework.

The key decisions to be determined by the proposed optimization framework include: (i) the composition of the optimal power and reserves mix, (ii) the electricity trading, (iii) the resulting average system's marginal price and the market clearing prices per reserve type, and (iv) the welfares achieved by each market participant.

Therefore, the paper contributes to the relevant literature on the quantification of the impacts of different transmission capacities among interconnected power systems on a series of power systems operational and economic aspects. The main contributions and the prominent features of our work include: (i) incorporation of the interaction of power capacity reserves with an energy-only market, (ii) incorporation of the linking-units option facilitating the creation of a correlated unit's portfolio, (iii) incorporation of power reserve constraints satisfaction at an intra-hourly level, (iv) quantification of the impacts of key operational aspects of thermal units on the currently utilized economic-based market clearing algorithm, and (v) provision of price signals on potential investors for the optimal determination of investments in the power sector.

Results

An illustrated case study of the Greek power system has been selected so as to demonstrate the applicability of the proposed approach. The determination of the optimal clearing of a power exchange based on simple offers requires the implementation of energy system modelling for the whole energy system. Therefore, the proposed approach is useful in providing insights on the power scheduling decisions, incorporating post-optimization conditions with the use of an iterative algorithm, as part of an overall energy system modelling approach. The problem has been solved to global optimality making use of the ILOG CPLEX 12.6.0.0 solver incorporated in the General Algebraic Modeling System (GAMS) tool [28]. An integrality gap of 0% has been achieved in all cases. With the aim of investigating the impacts of a variety of aspects affecting the power market clearing process, and as a consequence the power system scheduling, several cases have been identified. The cases have been structured so as to examine technical, and economic factors influencing the resulting power and reserve mix, as well as the system's marginal price and the reserve market clearing price per type. Figure 2 depicts the total daily power mix for different cases and a representative day type.

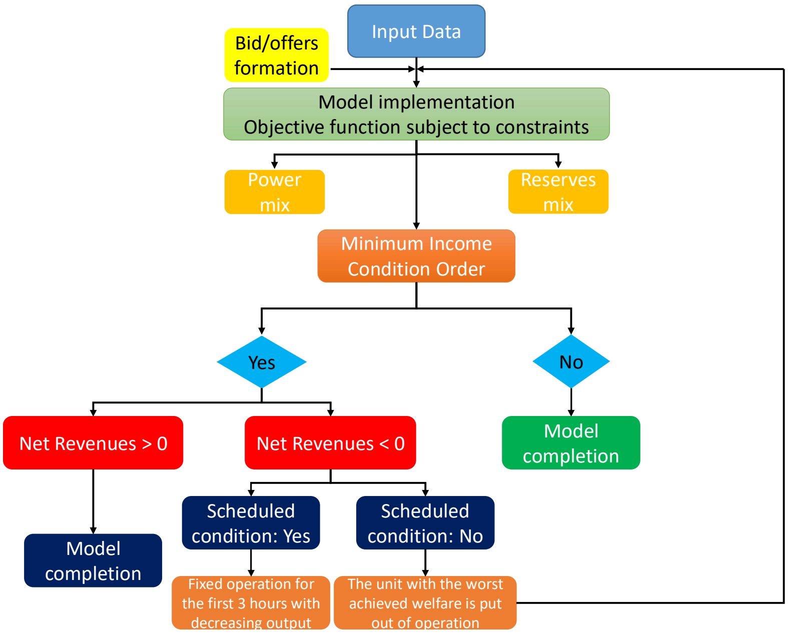

Figure 1: Flowchart of the methodological solution framework

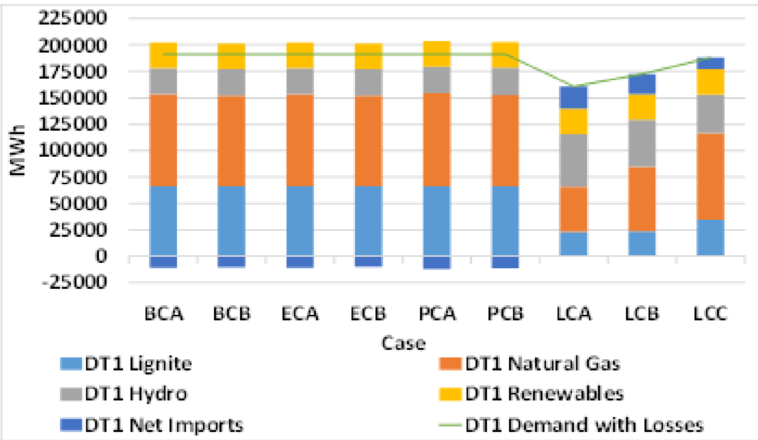

Figure 2: Total daily power mix per selected case and a representative day type (MWh)

Conclusions

The paper contributes to the relevant literature on the enhancement of the EUPHEMIA algorithm with the power reserve markets incorporation, satisfying the relevant constraints at both 15-min and 30-min level. The minimum income condition is also extended so as to integrate the reserves market clearing aspects into the revenues balance derived from the energy-only market. This addition provides a new space for strategy formation for the optimal management of electricity portfolios, adding new dimensions in the current market structure. Another important aspect of the proposed framework is that it introduces the concept of linking power units with one another, creating dynamic and flexible portfolios, facilitating their management, especially in the case of large power corporations, and providing additional degrees of freedom. Furthermore, the proposed methodological approach provides the basis for an analytical and systematic assessment of a series of key operating aspects of power units including the minimum up and down times, as well as the consideration or not of each thermal unit's technical minimum in the market clearing process.

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