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Market coupling feasibility between a power pool and a power exchange

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ABSTRACT

The integration of the spot electricity markets in Europe shall lead to multi-area power exchanges that will substitute the local markets. In view of the "target model" that will be enforced in all European markets and the forthcoming coupling/integration of the Greek with the Italian electricity market, a volume-based market coupling between a power exchange (PX) and a power pool is implemented in this paper. The pros and cons of this approach are quantified, and the attained results are compared with the results of a single market splitting approach, in terms of pricing, overall social welfare and computational time.

1. Introduction

The cross-border exchanges in the European markets have increased, following the wholesale electricity price differences among them, leading to extended use of the respective interconnections, and thus to congestions. Cross-border capacity is becoming a scarce commodity that should be allocated in a market-based and transparent way. The route towards an efficient cross-border congestion management in Europe leads to the creation of a truly competitive Internal Electricity Market (IEM), which requires the full integration of the participating national and regional markets.

The bulk of transactions in Europe is settled on over-the-counter (OTC) markets, which usually co-exist with voluntary Power Exchanges (unbundled systems). The Greek wholesale electricity market design follows the integrated system approach [1], which is based around the operation of a mandatory pool solving a unit commitment problem with co-optimization of energy and reserves. The day-ahead optimization problem takes into account system constraints (inter-zonal flows and reserve requirements), as well as all unit technical constraints (technical minimum constraint, minimum up/down times, the unit reserve capabilities, start-up and shut-down sequence constraints, etc.). This diversity in the market design is a great challenge for Greece, to find a way of coupling with the European markets, without altering the basic features of its market scheme, considering that the European lobbying is far more powerful and strongly influencing the design of the Framework Guidelines and market coupling initiatives.

Many researchers have already studied the market coupling solutions, namely price-coupling and volume-coupling [2–8], applied mainly in the Central-Western European region. However, the current literature addresses the problem of market coupling between PXs; to the best of the authors' knowledge, there is no literature referring to market coupling between markets with significant diversity in their design.

In this paper the development of loose volume-coupling between a power pool and a Power Exchange at the day-ahead stage is studied, in view of the forthcoming coupling between the Greek and Italian wholesale electricity markets. Since the market design of the two markets is completely different, in terms of the day-ahead optimization problem solved, the only feasible solution would be the volume-based coupling. Thus, this approach is initially studied here. The results of this analysis give valuable insight for alternative feasible solutions that could be applied in such cases, respecting completely the market rules in each national regulatory framework.

The innovative features of this analysis as compared to the current literature are the following:

(a) The volume-based market coupling between a power pool and a PX is studied, considering that volume-coupling has been

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Nomenclature

Indices and sets

$a \in \mathcal{A}$ set of bidding areas in Europe

$f \in \mathcal{F}$ set of steps of the priced energy offer or priced load declaration, where $\mathcal{F} = \mathcal{F}^I \cup \mathcal{F}^J = (\mathcal{F}^g \cup \mathcal{F}^{imp}) \cup (\mathcal{F}^{load} \cup \mathcal{F}^{\exp})$, $\mathcal{F}^g$: set of steps of the generating units' priced energy offer, $\mathcal{F}^{imp}$: set of steps of the import agents' priced energy offer, $\mathcal{F}^{load}$: set of steps of the demand's priced load declarations, $\mathcal{F}^{\exp}$: set of steps of the export agents' priced load declarations

$i \in I$ set of generating units and import agents where $I = I^g \cup I^{imp}$, I^g: set of generating units and I^{imp}: set of import agents

$j \in \mathcal{J}$ set of demand entities and export agents where $\mathcal{J} = \mathcal{J}^{load} \cup \mathcal{J}^{\exp}$, $\mathcal{J}^{load}$: set of demand entities and $\mathcal{J}^{\exp}$: set of export agents

$m \in \mathcal{M}$ set of reserves types (primary-up, primary-down, secondary-up, secondary-down, tertiary spinning, tertiary non-spinning)

$t \in \mathcal{T}$ set of dispatch or trading periods of the trading day; typically, the dispatch period is equal to one hour

Parameters

C_{ift}, Q_{ift} price-quantity pair of step f of priced energy offer of unit or import agent i in dispatch period t, in €/MWh and MWh, respectively; it is supposed here that the import agents use explicitly acquired long-term Physical Transmission Rights (PTRs) through energy offers in the wholesale electricity market (not through bilateral contracts)

C_{jft}, Q_{jft} price-quantity pair of step f of priced load bid of load or export agent j in dispatch period t, in €/MWh and MWh, respectively; it is supposed here that the export agents use explicitly acquired long-term PTRs through energy offers in the wholesale electricity market (not through bilateral contracts)

C_{ft}^{PP}, Q_{ft}^{PP} price-quantity pair of step f of power pool's Net Export/Import Curve in dispatch period t, in €/MWh and MWh, respectively

C_{ft}^{PX}, Q_{ft}^{PX} price-quantity pair of step f of power exchange's Net Export/Import Curve in dispatch period t, in €/MWh and MWh, respectively

E_n incidence matrix, whose elements are equal to 1 for interconnections for which market coupling is performed; otherwise, in case of an explicit auctioning process for PTRs, the value of the elements is equal to 0.

$NTC_{nt}^{a,a'}$ Net Transfer Capacity (NTC) on the interconnection n from bidding area a to bidding area a' in trading period t, in MW

Q_t^* fixed additional export/import quantity derived from the market coupler procedure in trading period t, in MWh

RES_t total injection of Renewable Energy Sources (RES), including the mandatory hydro injections, in dispatch period t, in MWh

RC_{it}^m reserve offer of generation unit i for the procurement of reserve type m, in dispatch period t, in €/MW

SUC_i start-up cost of generating unit i, in €/start-up

SDC_i shut-down cost of generating unit i, in €/shut-down

Variables

q_{ift} cleared quantity of step f of the generating unit or import agent i priced energy offer in dispatch period t, in MWh

q_{jft} cleared quantity of step f of load or export agent j priced load bid in dispatch period t, in MWh

q_{ft}^{PP} cleared quantity of step f of the power pool's Net Export/Import Curve (in the volume-coupling clearing) in dispatch period t, in MWh

q_{ft}^{PX} cleared quantity of step f of the power exchange's Net Export/Import Curve (in the volume-coupling clearing) in dispatch period t, in MWh

$flow_t^{a,a'}$ flow in the interconnection connecting area a to area a' resulting from the implicit daily auction (in the volume-coupling clearing), in trading period t, in MW

p_{it} cleared energy quantity of generating unit i in dispatch period t in the day-ahead market, in MW

r_{it}^m contribution of unit i in reserve type m during dispatch period t, in MW

u_{it} binary variable which is equal to 1 if generating unit i is committed during dispatch period t

y_{it} binary variable which is equal to 1 if generating unit i starts-up at dispatch period t

z_{it} binary variable which is equal to 1 if generating unit i shuts-down at dispatch period t

Functions

$\mathbf{c}_{it}^{com}$ commitment cost (based on submitted techno-economic data) function comprising the start-up and shut-down cost of generating unit i in dispatch period t, in €

$\mathbf{c}_{it}^{g}$ energy offer function of generation unit i, in dispatch period t, in €

$\mathbf{c}_{it}^{imp}$ energy offer function from import agent i, in dispatch period t, in €

$\mathbf{c}_{it}^{res}$ reserve offer function, based on offer function and provision of reserves of unit i, in dispatch period t, in €

$\mathbf{u}_{jt}^{\exp}$ utility function of export agent j in dispatch period t, in €

$\mathbf{u}_{jt}^{load}$ utility function of demand entity j in dispatch period t, in €

promoted by Europex and ETSO as institutionally easier to implement and a viable alternative to price coupling [9].

(b) A central market splitting approach is implemented, respecting completely the special rules in each regulatory framework.

The attained results of the centralized market splitting approach are compared with the results of the decentralized volume-coupling approach in terms of pricing, overall social welfare and computational time.

2. Problem formulations

2.1. Power pool – unit commitment problem

As already stated in the previous section, the day-ahead markets are centrally organized either as power exchanges or as power pools. Under the power pool model, the respective Market Operator solves a complex optimization problem, where a