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OPTIMATE – a Modeling Breakthrough for Market Design Analysis to Test Massive Intermittent Generation Integration in Markets

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Abstract— **The paper presents the OPTIMATE simulator aiming at validating market design rules and testing new ones in the context of the integration of a massive amount of intermittent generation in the western European power system. The OPTIMATE platform is unique since it intends to replicate in a remarkably detailed manner how the sequence of electricity markets (day-ahead and intraday markets, balancing arrangement and imbalance settlements) works and how different players (thermal and renewable generators, consumers, portfolio managers, TSOs, etc) interact with each other with uncertainty on availability and level of generation and load. Different market design options can so be ranked thanks to the OPTIMATE platform using a set of indicators based on EU energy pillars, i.e., efficiency (generation costs and prices), climate policy (renewable production and CO2 emissions) and security of supply (frequency and level of load shedding).**

Index Terms—**Intermittent RES-E, market design, day-ahead, intraday, balancing, imbalance, power market model.**

I. INTRODUCTION

UNTIL recently, intermittent renewable generation in Europe has often been left out of organized electricity markets while benefiting from specific support schemes (in particular feed-in tariffs). Indeed, the impact of starting renewable generation on markets was marginal and hence there was no need for an adaptation of the market design. Yet, renewable technologies are now massively developed in Europe and the role of market designs becomes critical to ensure, under these new conditions, efficiency, climate policy and security of supply targets. It is therefore time to explore possible ways of integrating intermittent generation into the market, analyzing which market design options would be the most appropriate to accommodate large quantities of renewable energy.

The aim of this paper is to present the OPTIMATE platform. OPTIMATE is a numerical test platform created for the analysis of actual market designs and validation of new ones which may allow integrating massive intermittent generation dispersed in several regional power markets. OPTIMATE will therefore contribute to the construction of a pan-European electricity market adapted to climate policy and security of supply concerns.

The OPTIMATE platform is unique since it intends to replicate in a remarkably detailed manner how the sequence of electricity markets exactly works and how different players (generators, consumers, portfolio managers, renewable, TSOs, etc) interact with each other. OPTIMATE iterates day-ahead markets, intraday markets, reserves, balancing and imbalances mechanisms over the days and half-hours of a simulated year on a forty nine node network representing Europe (including mainly: Austria, Belgium, Czech Republic, France, Germany, Italy, Poland, Portugal, Spain, Scandinavia, Switzerland, the Netherlands and United Kingdom). At day-ahead, thanks to a learning by-doing procedure, the market players anticipate market prices over the different time frames in order to build bids and offers to the market and later establish their unit commitment of dispatchable equipments.

At each timeframe, load, intermittent generation and conventional generation availability forecasts vary (the closer to real time the more accurate the forecasts) making market players adapt their commitment and dispatch depending on contingencies. Within OPTIMATE, a large number of market design architectures can be modified and tested (e.g. renewable support schemes, balancing and imbalance rules, maximum prices, cross-border congestion management, etc.). Besides, the composition of portfolios, for each market player, can be adapted at will (e.g., inclusion or exclusion of renewable, of hydro-storage, etc.).

OPTIMATE can so study a large number of market rules

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on a representation of the western European power market in a large number of configurations of market player portfolios and of renewable integration. The OPTIMATE simulator is developed to rank different market design options. This is done by using a set of indicators based on EU energy pillars, i.e., efficiency (generation costs and prices), climate policy (renewable production and CO2 emissions) and security of supply (frequency and level of load shedding). The redistributive effects among agents from the change in market designs can also be evaluated. These analyses allow to highlight possible difficulties to implement it due to stakeholder opposition as well as provide recommendations on better market designs for the future.

The paper is organized as follows. Section II presents the state of the art about market design analysis to test the integration of massive amount of intermittent generation in the power market. Here, the goal is to highlight the major loopholes in the existing literature. Section III stands for the OPTIMATE simulator. The OPTIMATE process and key assumptions are detailed. Section IV proposes examples of questions to be studied relying on the OPTIMATE originality. Section V presents the key performance indicators allowing to compare different market designs. Finally, section VI concludes.

II. STATE OF THE ART ABOUT MARKET DESIGN ANALYSIS TO TEST MASSIVE INTERMITTENT GENERATION INTEGRATION IN MARKETS

The analysis of the integration of massive amount of intermittent generation in power systems has mainly relied on cost minimisation engineering techniques until now (see for instance [1]-[9]). While these techniques have been useful to understand the impact of intermittent generation on power systems, they have not allowed to simulate and to analyse the impact of different market designs and market player behaviours. Three main simplifying (generally implicit) assumptions were then used.

First, the market design was implicit in such studies. They then rely on cost minimization of all the market participants under the physical constraints of the system (i.e. the network constraints and the generators' constraints). It is then as if all the interconnected areas were perfectly coordinated, relying equivalently on either a single and perfect market or a centrally operated multi-area system. But the design of real markets is not always perfect and may distort the decision by the market participants and cost is then not always minimised. For instance, TSOs and power exchanges showed that ATC-based allocation of interconnection capacity was less efficient than flow-based allocation [3] (see also [4] and [9] about the benefit of implementing nodal pricing instead of an ATC-based allocation). It would then be relevant to estimate the effects of market designs distorting market participants decisions compared to a cost minimisation situation on the process of integration of intermittent generation.

The second simplifying assumption of studies is about the behaviour of market participants. As a consequence of the first simplifying assumptions, the market participants are expected to competitively behave and to be risk-neutral. In reality, some market participants may be more risk averse than others. For instance, the TSO may be less able to take risks because it may have strong undesired effect on the security of power supply, in particular when the production is more volatile because of the integration of intermittent generation. In reality, the power suppliers may not competitively behave and optimise their revenue, hoarding capacity or proposing prices above costs. These two behaviours (risk aversion and market manipulation) should be integrated in the analysis of the integration of intermittent generation in power system so that the results are realistic and take them into account.

It is noticeable that these assumptions were relaxed, at least to some extent, in the Tradewind [3] and EWIS [4] studies. They both include thermal production availability (i.e. generators tripping off events) and most importantly renewable production uncertainty and its effects on the thermal power stations programs and the need for intraday market so that they can reschedule at least cost. The weather data comes in successive timeframes, together with possible sudden conventional generator outages at real time. This scheme brings the most significant forecast errors in the model: standard deviation decreases as the timeframe goes closer to real time. It also captures the main rationale for intraday market quantities (otherwise ignored in a cost minimisation), which are the rescheduling to avoid imbalances as much as possible.

The third simplifying assumption of studies is the lack of representation of the sequential decision process in an electricity market. In particular, an extremely delicate problem of modelling a power market whose generation availability is uncertain is how to take into account the degree of flexibility of a conventional generation whose programme at DA may have to be contradicted several times at ID. This induces extra costs, for both marketers and TSOs, and in extreme cases impossibilities to adjust the overall system balance at real time (unless shedding load). The cost minimisation at ID timeframes cannot be done straightforwardly: time related constraints per unit and associated costs are to be modelled not only inside each timeframe, but also between timeframes. Not only the marketers' task of unit commitment is a source of complexity. The TSOs work for daily building of frequency reserve and cross-border limits to market depends also on the generation programming and then may impose its own constraints between successive timeframes. It is only a model integrating uncertainty about (renewable and thermal) generation, the repeated and interacting decisions of the market participants (marketers and TSOs) in the different timeframes (day-ahead, intraday and real time) and in interconnected areas that will allow to test integration in different market designs of massive intermittent energy. The Tradewind [5] and EWIS [6] studies studied these questions considering only the effect of building an intraday market. But, an extensive comparison of market designs from the day-ahead to the real time timeframe with regard to their ability to ease the integration of renewable energy has never been done to the authors' knowledge.

III. OPTIMATE INNOVATIVE APPROACH: MODULAR, STEPWISE & FEED-BACK

A. OPTIMATE goal

The OPTIMATE objective is to capture the effect of variants in market designs (rules), in particular on marketers' behaviour. Marketers are indeed not aiming at the overall cost minimisation but at their own portfolio benefit maximisation. They take opportunity of any flexibility authorised by market design, whose features are in Europe neither entirely uniform nor entirely coordinated between areas.

The OPTIMATE simulator has been built to tackle the simplifying assumptions mentioned before and to mimic the actual functioning of electricity market. The complex interaction of marketers and TSOs in an electricity market cannot be simulated through an overall cost minimisation technique. Using tuning parameters in a cost minimisation process for market participants' behaviours and market design variants would not be robust enough. Marketers and TSOs indeed need to anticipate each other behaviour to take their own operational decisions, considering generation mix and forecast accuracy too. A more detailed model of market design and their variants and of market participants behaviours with uncertain availability must be purposely built.

B. OPTIMATE design

In order to build such an ambitious model, the design of OPTIMATE relies on three principles. First of all, OPTIMATE is modular. Second, the real time outcomes build in a stepwise process. Lastly, the interdependency of decisions by marketers and TSOs is dealt with a systematic assessment of reference forecast.

Modularity of OPTIMATE is obtained considering that the different markets in the different timeframes and the different decision processes by each market participants are designed as quasi-independent modules. Each module may then be fed by input assumptions or outputs from other modules.

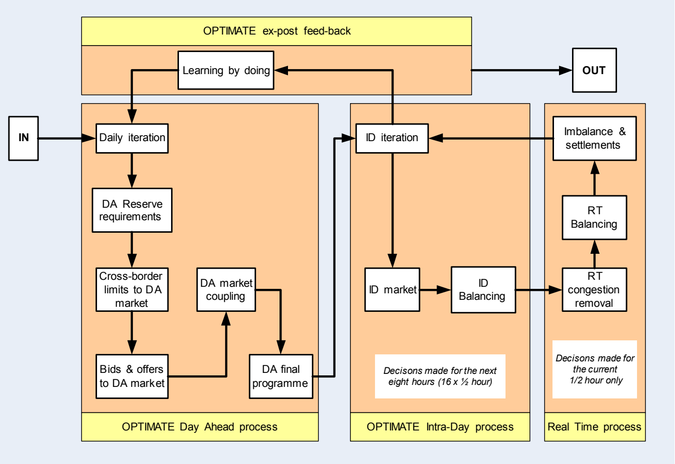

Fig. 1. Modules processing in OPTIMATE simulator

Fig. 1 then illustrates the general modules processing in OPTIMATE simulator. For each daily computation, the "daily iteration" module is fed in with reference input data and output from the learning by-doing modules (presented below). Its purpose is managing the daily iteration over the studied period (for instance a year). In the following, its outputs are processed into the "DA reserve requirements" module where the TSOs determine and reserve the required capacity amount in each control block. The TSOs then compute the cross-border capacity limits to be available day-ahead in the "cross-border limits to DA market" module. The marketers then calculate their bids and offers knowing cross-border capacities and generation capacity out of the market for reserves requirements into the "bids and offers to DA market" module. These bids and offers are then cleared in the "DA market coupling" module. Marketers deduce their DA final programme from the cleared volumes in the "DA final programme" module. Note that the sequence of modules represents how marketers and TSO interact currently on a daily basis.

The DA final programme is fed into the "ID iteration" module. This module is performed several times each day in accordance with the frequency of intraday market sessions defined in the market design. The market participants then build their expectation for the coming hours of the intraday market. In particular, the TSOs may update the cross-border capacities intraday compared to the cross-border capacities he issued day-ahead. The marketers then calculate their bids and offers from these cross-border capacities and their previous decisions. These bids and offers are then cleared. These three sets of actions (computation of ID cross-border capacity by TSOs, bids and offers calculation by marketers, and market clearing) are realised in the "ID market" module. The results are then fed into the "ID balancing" module where the marketers build their bids and offers for the balancing arrangement and where TSOs may decide to rely on delayed reserves to balance the system. Congestion appearing in real time is then dealt by TSOs in the "RT congestion removal" module. Each TSO then clears her "RT balancing" module and then the "Imbalance and settlements" module where the imbalances are computed and the marketers must pay for those.

The result is sent back to the "ID iteration" module to feed the ID and balancing modules of the coming hour and to feed also the "learning-by-doing" module. At last, the "learning-by-doing" module allows the marketers and the TSOs to adapt their behaviours in the following iterations by considering the market outcomes of their previous decisions. The TSOs and marketers have a reference forecast before each day and each timeframe within each day. The previously mentioned chicken and egg dilemma (TSOs needing the marketers schedules to compute the required reserves and transmission capacity and the marketers needing these inputs to compute their bids and so their programs) is tackled.

Thanks to its modular, stepwise and learning-by-doing approach, the OPTIMATE process captures marketer's adaptation to market rules, as implemented by TSOs and power exchanges (implicitly bundled with the TSOs here). It is a real breakthrough: to our knowledge, nothing similar does currently exist. The successive interventions of TSOs (day-ahead: computation and reservation of reserve requirement computation of available cross-border capacity and market clearing; intraday: updated computation of cross-border capacity for the intraday market and the balancing arrangement, market clearing, balancing mechanism clearing and imbalance settlements), and marketers (computation of bids and offers and of final programs day-ahead; computation of bids and offers for intraday markets and for the balancing arrangements) are represented by the successive modules. This allows to test innovative market designs changing the rule of modules.

The OPTIMATE results then move away from the reference value because of two reasons. First, the market participants' anticipations of thermal generation availability and of the level of load and intermittent production are blurred by forecast errors, decreasing while approaching the real time operation (e.g. Fig. 2). Ideally, two market design variants should be compared with several draws on stochastic variables so that average comparative values could be computed. The second reason why the OPTIMATE results may deviate from the reference value is because market participants may change their behaviours. The economic signals they receive may indeed change with market design variants.

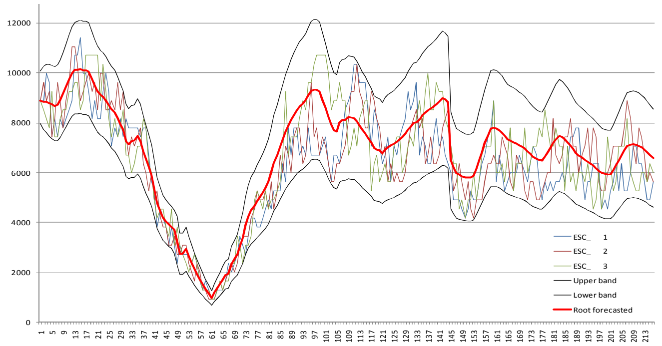

Fig. 2. Illustrations of deviations from reference values of wind power. The red line stands for wind forecasted and the black lines for the upper and lower values of wind production. The curves ESC_ 1, ESC_ 2 and ESC_ 3 stand for different possible wind productions from the same forecast.

All marketers share unique anticipative expectations and have a similar vision of risk adversity in the first version of the OPTIMATE simulator. Because of its modular design, the market participants' behaviors can be changed. In later versions, marketers and TSOs may have individual understanding of anticipative expectations and different risk aversions and even later on each marketer may also anticipate other marketers' behaviors (bridging the gap with the classical Cournot competition models).

In order to mitigate the influence of input data from the chosen reference data on the results, OPTIMATE will assess different sets of market rules considering the comparative efficiency of each variant. An additional work on the input data would be required to evaluate the absolute gains that some rules changes may generate.

C. The simulation platform architecture

In a first phase, the OPTIMATE platform will be accessible via a web client. It is then easier for the consortium members to use the platform for four reasons. First, the computations are centralized. Second, there is no compatibility problem between the platform and the operating systems. Third, the works by the different study holders are easy to schedule and can be run in parallel without consuming in-house IT resources. At last, the users have no need to update the software because the latest functional version is always available.

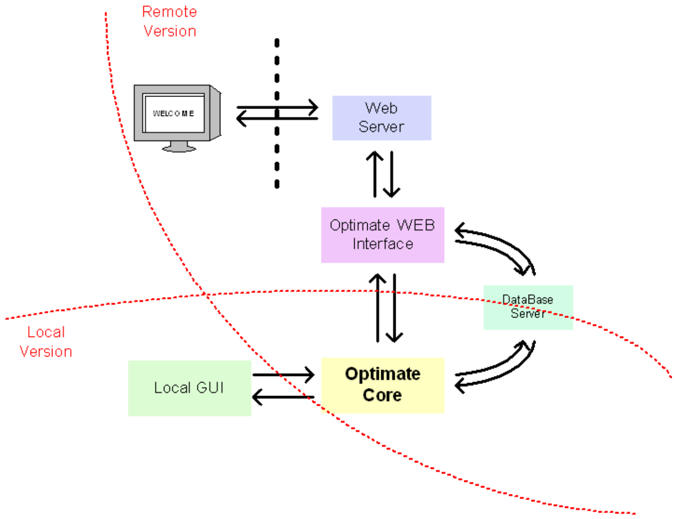

Fig. 3. The web-based and future local OPTIMATE platform architecture

In a second phase, the OPTIMATE simulator will be provided in a local version compatible with Windows and Linux.

D. Key specifications and critical assumptions

OPTIMATE relies on a stylistic model allowing to choose nearly any combination of day-ahead, intraday or balancing designs implemented in Europe. The following market design variants can be chosen (in different menus on the simulator interface) to be applied as a whole or per area.

- **RES support schemes**:
    - The RES support schemes can be implemented as a feed-in tariff or a market premium adding to the market price.
- **TSO behavior and congestion management model**:
    - The reserve requirements can be computed following the ENTSOE recommendations or the ENTSOE recommendations plus 25%.
    - The day-ahead capacity model can be either ATC-based or flow-based.
    - The TSOs can be more or less risk averse (in particular with regard uncertainty on cross-border flows from intermittent generation) when computing the cross-border capacity day-ahead.
    - The intraday cross-border capacity can be

    just updated or thoroughly recomputed.

- **DA and ID market design**:
    - The market clearing can be based on either portfolio or unit bidding by marketers.
    - Negative day-ahead prices can be allowed or not (for each market area) and different day-ahead price caps can be set in the different market areas.
    - The intraday market can be cleared thanks to continuous auctions or discrete auctions.
    - The intraday gate closure time ahead of real time can vary from one half-hour to four hours.
    - The intermittent generators may be allowed to participate to the provision of downward reserves.
- **Balancing mechanism design and imbalance pricing**:
    - The reserve procurement scheme can be based on either "German-like" fast tertiary reserves only or "French-like" delayed and fast tertiary reserves.
    - The balancing mechanism may be not coordinated, coordinated only among the Central Western European TSOs or coordinated among all the modeled TSOs.
    - The balancing regimes may rely on either marginal or pay-as-bid pricing.
    - The imbalance prices can be built on either marginal or average pricing and on either single or dual pricing.
    - At last, price caps and floors can be added on imbalance prices in relationship with day-ahead prices.

The studied area is Europe in its assumed 2015 configurations. The generation units are standardized (being either nuclear, gas-fired, coal-fired, hydro, wind power or photovoltaic with possibly different characteristics in different countries). Generators are individually modeled (i.e. with no aggregation). However, the European network is simplified. The main focus is then on the geographic area of the consortium members. The EHV nodes are then aggregated into clusters, defined to mitigate discrepancies on critical branches. A 49-node network then represents the studied area (see Fig. 4; the red lines stand for the critical branches where congestion may occur).

Besides all these possibilities, a few critical simplifying assumptions model the power system. The OPTIMATE simulator uses a DC lossless network. Network limits can never be trespassed in real time and load may then be curtailed if required. The shortest time granularity is 30 minutes. Forward contracts are ignored and so every transaction takes place either day-ahead, intraday or in real time. The TSOs are jointly in charge of the overall congestion management (day-ahead, intraday and in real time). However, each TSO is responsible for balancing its own area (relying on the balancing resources in her own area or thanks to coordinated resources depending on the implemented scheme).

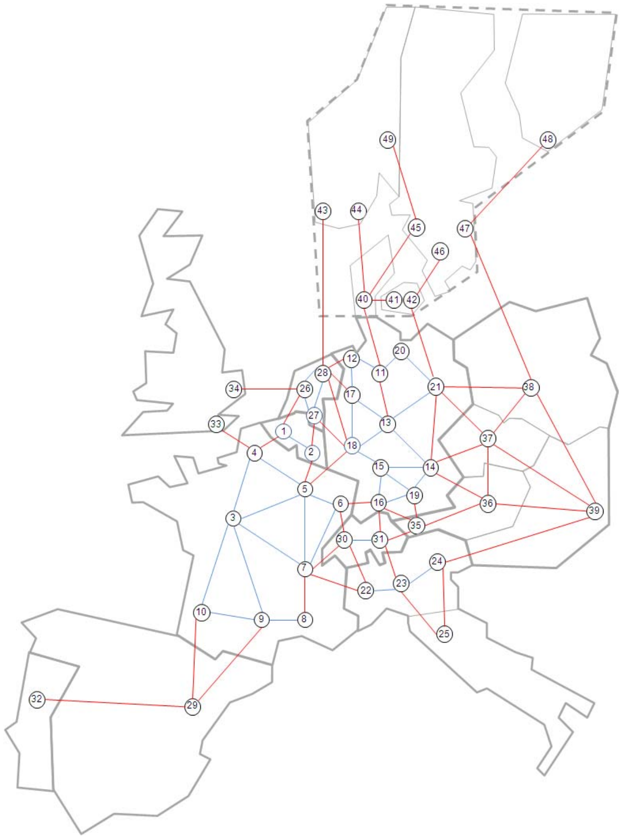

Fig. 4 OPTIMATE model for the European network

IV. SOME CONTROVERSIAL QUESTIONS WHOSE EFFECT OPTIMATE WILL QUANTIFY

The details modelled in the OPTIMATE simulator allows to perform studies with more diversified topics. The OPTIMATE consortium members are nevertheless interested in three topics in particular, first in the effects of market rules on the integration of RES, second in the effects of network modeling and its management coordination on the RES integration and third, in the impact of the variants of RES support schemes on their integration in the market.

A. Day-ahead, intraday and balancing market designs

The market designs alone (without considering its interactions with the support schemes) may impact the integration of renewable intermittent generators into the market. The respective moments of day-ahead and intraday gate closures are expected to influence the cost of integrating RES. Besides, the OPTIMATE simulator can evaluate whether there are interactions between the day-ahead and intraday gate closures times and the design of intraday market (either continuous or discrete). The OPTIMATE platform can also estimate how the liquidity of intraday markets and the non-linearities introduced by (upper or lower) price boundaries may modify the cost of integration of renewable generation.

The design of balancing arrangements and imbalance settlements has obviously an impact on the integration of intermittent generation too. The OPTIMATE model is able to simulate the effects of reliance on balancing pooling, increase in reserve requirements, or fast tertiary reserves only or with delayed reserves too. Considering a change in some generators dynamic constraints, OPTIMATE can also evaluate the benefits of retrofitting some inflexible generators (like coal-fired ones).

B. Congestion management model

Congestion management is a topic of market design in itself. The way the TSOs compute the available cross-border capacity influences market transactions. For instance, the results of a recent study by TSOs and power exchanges [3] show that efficiency and cross-border exchanges may significantly increase with the forthcoming implementation of the flow-based allocation of cross-border capacity.

The computation of cross-border capacity will consequently impact the integration of renewable generation. It is then expected that going from an ATC-based allocation to a flow-based allocation of transmission capacity will ease the integration of intermittent renewable. Similarly, a full recomputation of cross-border capacity intraday instead of a simple update is expected to leave more cross-border transmission capacity to the market, increase cross-border exchange, in particular when a high amount of intermittent RES is integrated. The TSOs may also be more risk averse with an increasing share of uncertain production because they may face more volatile power flows. The OPTIMATE simulator is able to test these design rules thanks to a parameterization of the “cross-border limits to DA market” module and of the “ID market” module.

At last, there may also be interaction between the computation of cross-border capacity (day-ahead in particular) and the computation of reserve requirements. In case of reserve pooling, it would logically be required to reserve transmission capacity for cross-border reserve exchanges. This combination can be tested in the OPTIMATE platform choosing whether reserves are pooled or not and whether critical branches limits are taken into account in the reserve requirements computation.

C. Variants of RES-E support schemes

The RES support schemes and its interactions with specific market rules may also impact the integration of intermittent generation in the market. Market premium forces the renewable generators to be integrated in the market (both in the day-ahead and intraday timeframes). Inversely, feed-in tariffs give the renewable generators a priority over the other technologies, whatever it may cost. The support schemes will then impact of the activity on the day-ahead and intraday markets and on the cross-border exchanges that the OPTIMATE platform can measure.

There may also be interactions between the support schemes and the balancing responsibility. The OPTIMATE simulator is indeed able to evaluate whether it is more efficient to combine feed-in tariffs with balancing responsibility to intermittent generators or not. OPTIMATE is also able to compute whether there are beneficial interactions between the RES support schemes (either premium-based or fully subsidized) and the definition of imbalances prices (single versus dual pricing and average versus marginal pricing).

All the previous propositions are examples of OPTIMATE’s capabilities. The modular structure of the simulator allows to consider other questions, either from its forthcoming architecture, completing its existing modules or adding new modules. For instance, transparency issues could be considered, asking what would happen if additional information were published by TSO about reserve requirements and margins. It would also be possible to consider the effect of more demand flexibility on the overall integration of intermittent RES. It would also be possible to consider that market participants does not necessarily share the same expectation of uncertain variables, in particular the production level of intermittent generation and the availability of thermal generation (i.e. tripping off events of thermal generators).

V. ANALYSIS METHODOLOGY

The market integration of intermittent RES is a multidimensional problem, more precisely a four-dimensional problem because of the three pillars of the European energy policy (competition, decarbonization and security of supply) and the redistributive effects of change in design rules.

Of course, the integration of intermittent RES has an impact on the overall cost and efficiency of the power system for two reasons. First, these technologies have a zero marginal cost, which push the residual merit order to the right-hand side when they produce. Second, the system may then need more reserve to compensate for their intermittency. It may also impact the power system decarbonization. Some market designs may indeed imply a higher use of more CO2 emitting technologies or more curtailment of RES for instance. Besides, the integration of intermittent generation may increase concerns about the power security of supply. At last, reforms of the market always create winners and losers because of redistributive effects of change in market rules.

The tested market designs should then be considered following these fours dimensions, looking at adapted indicators. Efficiency could then be measured thanks to the classical definition of social welfare. Decarbonization could be measured by the share of renewable supplying load and the CO2 emissions by fossil-fueled technologies. The power security of supply could be evaluated both by the load shedding volume and by the real time reserve margin. Redistributive effects may be measured with consumers and producers surpluses (possibly detailed per technology) and TSOs costs (for balancing and congestion removal) and congestion rents from market coupling. More detailed indicators could also allow to detail the effects of market rules on production levels, cross-border exchanges and prices (in average and dispersion values) in specific areas. The

OPTIMATE simulator integrates these analytical computations.

VI. CONCLUSION

This paper presents a new simulation tool for operations of European power markets. The OPTIMATE simulator provides a geographical resolution of up to 10 nodes per country (Germany) to account for possible congestion. The paper explains the large range of market design options that can be reflected by the model. The most prominent ones among them are the option to choose between unit bidding and portfolio bidding, thus representing strategic behavior, the option to choose between different support schemes and numerous design parameters, e.g. regarding imbalance charges. In addition, a modular approach has been pursued for the simulator, i.e. different cases of day-ahead, intraday and balancing markets and actor's learning-by-doing horizons can be combined with each other. The OPTIMATE simulator is currently in the test phase. First results are expected to be analysed in the first semester 2012 and to be displayed by the end of the third quarter this year.

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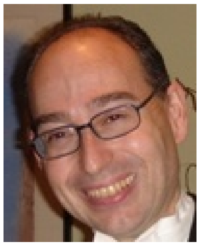
VIII. BIOGRAPHIES

Alexander Weber is with the department 'market processes' at EnBW Transportnetze AG, the TSO for the state of Baden-Württemberg, Germany. He is in charge of research on market design issues and the project OPTIMATE for EnBW TSO. He is mainly working on economic problems of the electricity sector with a current special interest in quantitative methods. He received his diploma in business administration with electrical engineering from Darmstadt University of Technology in 2010.

Jean-Michel Glachant has been Director of the Loyola de Palacio Energy Policy Programme and Florence School of Regulation from Autumn 2008 (and before professor at La Sorbonne and University Paris-Sud in France, and employed by the industry and private sector). He has been advisor of DG TREN, DG COMP & DG RESEARCH at the European Commission and of the French Energy Regulatory Commission (CRE). He is or has been coordinator or scientific advisor of several European research projects (SESSA, CESSA, Reliance, EU-DEEP, RefGov). He is a research partner in the CEEPR at MIT (USA), the EPRG at Cambridge University, and the EEI at the University of Leuven. His main research interests are the building of a common European energy policy (security of supply, renewable energy, energy efficiency, energy technology policy, and climate change policy), the achievement of the European energy internal market (design, regulation and competition policy), the industrial organization and market strategy of energy companies.

Vincent Rious is senior economist at Microeconomix since 2010 (and previously an associate professor at Supélec, the Higher School of electricity, a French Grande Ecole). He is also engineering advisor at the Florence School of Regulation (at the European University Institute, Italy) in the Loyola de Palacio research programme on the European energy policy. He has a MS in engineering from Supélec (2004) and a PhD. in economics from University Paris-Sud 11 (2007). Vincent has extensive experience in economic analysis of market and regulatory mechanisms, applied to energy in particular and infrastructure networks in general. He has produced several relevant reports for utilities and regulators and widely published in professional and academic journals and conferences.

Marcelo Saguan is a senior consultant in economics and leads the Energy & Climate Practice at Microeconomix. He has extensive experience in infrastructure regulation, electricity and gas markets and environmental issues. He is also engineering advisor at the Florence School of Regulation (at the European University Institute, Italy) in the Loyola de Palacio research programme on the European energy policy. Marcelo was previously Jean Monnet Fellow at the RSCAS in the Loyola de Palacio Energy Policy Programme. He had a post-doc postdoctoral position at University of Paris 11. He holds a PhD in energy economics (2007) from the University of Paris 11 and the Ecole Supérieure d'Electricité (Supélec) and a Master degree in industrial engineering from ENIM (Metz) and from University of Cuyo, Argentina (2001).



Julián Barquín (M'94) received the Industrial Engineering degree in 1988 and the Ph.D. degree in industrial engineering in 1993 from the Comillas Pontifical University, Madrid, Spain, and a degree in physics from the Universidad Nacional de Educación a Distancia, Madrid, in 1994. Currently, he is with the research staff at the Institute for Research in Technology (IIT), Advanced Technical Engineering School (ICAI), Comillas Pontifical University. His present interests include control, operation, and planning of power systems.

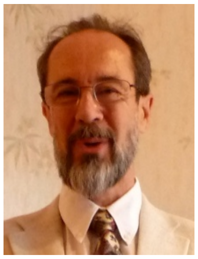
Enrique Rivero (M'10) received the B.S., Electronics and Communications Engineering degree from ITESM technological institute (Mexico) in 2004, a master degree in the Electrical Sector from Comillas Pontifical University (Spain) in 2008, and a master degree in Economics, Technology and Territory from the University of Paris-SUD XI (France) in 2009. Currently, he is pursuing a Ph.D. in Electrical Energy from Comillas Pontifical University. Since 2009, he has been working as assistant researcher at the Institute for Research in Technology for the European project OPTIMATE. His research interests include electricity markets and renewable intermittent generation promotion and integration.

Lena Kitzing was born in Braunschweig, Germany, on August 31, 1982. She graduated from the University of Flensburg as Dipl.-Wi.-Ing. in 2006. Her employment experience includes energy businesses (RWE AG and DONG Energy A/S) as well as research institutions (Fraunhofer ISE and DTU Risø National Laboratory for Sustainable Energy). Her major work focus was investments in energy projects. Lena is currently working on her Ph.D. degree at the Technical University of Denmark (DTU) in the area of energy policy instruments in an EU context.

Poul Erik Morthorst was born in Esbjerg, Denmark on November 20, 1951. He graduated from the University of Aarhus with a Master degree in Economics in 1978. He holds a position as Professor in Energy Economics at the Technical University of Denmark. His main competences include economics of renewable energy technologies, systems and market integration of these technologies and, finally, policy instruments to facilitate the uptake of renewables. He has participated in a large number of national and international panels and committees, among these the Commission for Climate Change Policy set-up by the Danish Government to give guidelines on how to make Denmark independent of fossil fuels in the long term. He is member of the board of the Danish TSO, Energinet.dk, member of the board of the Danish research programme EUDP and chairman of the Danish Research council's programme committee on sustainable energy and environment.

Sascha T. Schröder (born '83, Student Member '10) studied Industrial Engineering with a specialization in Energy and Environmental Management at the University of Flensburg, Germany and ESC Rennes, France. He has experience within economics of storage technologies, interconnector usage and network regulation as well as on micro-cogeneration. Currently, he is employed at DTU Management Engineering, Risø Campus, and pursues a PhD on market design options of offshore grids in collaboration with Energinet.dk.

Jean-Yves Bourmaud has a degree in engineering from the Paris School of Mines (Mines ParisTech / ENSMP). He began his professional experience in the field of Research and Development for Power Systems with EDF, which he joined in 1996. Since 2003, he has been Senior Engineer on cross-border management and market mechanisms in the R&D division of RTE. He has been involved in the Central Western Europe market coupling initiative, and in particular the flow-based methodology and its implementation.



Jean-Marie Coulondre graduated as power system engineer from ENSEEIHT, France, in 1975. He has worked for EDF since 1978 in System Operation and International Development, then for RTE since 2000 as R&D expert engineer. He has lead the team that has successfully proposed and promoted the European flow-based modelling. He has written and published several papers about congestion management, market coupling and other European market design issues since 2002. He has launched the OPTIMATE project in 2008 and has been its technical director up to October 2011.