Adaptive entropy-based learning with dynamic artificial neural network

Entropy models the added information associated to data uncertainty, proving that stochasticity is not purely random. This paper explores the potential improvement of machine learning methodologies through the incorporation of entropy analysis in the learning process. A multi-layer perceptron is applied to identify patterns in previous forecasting errors achieved by a machine learning methodology. The proposed learning approach is adaptive to the training data through a re-training process that includes only the most recent and relevant data, thus excluding misleading information from the training process. The learnt error patterns are then combined with the original forecasting results in order to improve forecasting accuracy, using the Rényi entropy to determine the amount in which the original forecasted value should be adapted considering the learnt error patterns. The proposed approach is combined with eleven different machine learning methodologies, and applied to the forecasting of electricity market prices using real data from the Iberian electricity market operator – OMIE. Results show that through the identification of patterns in the forecasting error, the proposed methodology is able to improve the learning algorithms’ forecasting accuracy and reduce the variability of their forecasting errors.
expected payoff, the REP can effectively protect itself against price variations. Offering time-variable retail rates also can increase the expected profit of the REPs.

Adaptive Portfolio Optimization for Multiple Electricity Markets Participation

The increase of distributed energy resources, mainly based on renewable sources, requires new solutions that are able to deal with this type of resources' particular characteristics (namely, the renewable energy sources intermittent nature). The smart grid concept is increasing its consensus as the most suitable solution to facilitate the small players' participation in electric power negotiations while improving energy efficiency. The opportunity for players' participation in multiple energy negotiation environments (smart grid negotiation in addition to the already implemented market types, such as day-ahead spot markets, balancing markets, intraday negotiations, bilateral contracts, forward and futures negotiations, and among other) requires players to take suitable decisions on whether to, and how to participate in each market type. This paper proposes a portfolio optimization methodology, which provides the best investment profile for a market player, considering different market opportunities. The amount of power that each supported player should negotiate in each available market type in order to maximize its profits, considers the prices that are expected to be achieved in each market, in different contexts. The price forecasts are performed using artificial neural networks, providing a specific database with the expected prices in the different market types, at each time. This database is then used as input by an evolutionary particle swarm optimization process, which originates the most advantage participation portfolio for the market player. The proposed approach is tested and validated with simulations performed in multiagent simulator of competitive electricity markets, using real electricity markets data from the Iberian operator-MIBEL.
Electricity Markets Ontology to Support MASCEM's Simulations

Power systems worldwide are complex and challenging environments. The increasing necessity for an adequate integration of renewable energy sources is resulting in a rising complexity in power systems operation. Multi-agent based simulation platforms have proven to be a good option to study the several issues related to these systems, including the involved players that act in this domain. To take better advantage of these systems, their integration is mandatory. The main contribution of this paper is the development of the Electricity Markets Ontology, which integrates the essential concepts necessary to interpret all the available information related to electricity markets, while enabling an easier cooperation and adequate communication between related systems. Additionally, the concepts and rules defined by this ontology can be extended and complemented according to the needs of other simulation and real systems in this area. Each system's particular ontology must import the proposed ontology, thus enabling the effective interoperability between independent systems.

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Energy Optimization for Distributed Energy Resources Scheduling with Enhancements in Voltage Stability Margin

The need for developing new methodologies in order to improve power system stability has increased due to the recent growth of distributed energy resources. In this paper, the inclusion of a voltage stability index in distributed energy resources scheduling is proposed. Two techniques were used to evaluate the resulting multiobjective optimization problem: the sum-weighted Pareto front and an adapted goal programming methodology. With this new methodology, the system operators can consider both the costs and voltage stability. Priority can be assigned to one objective function according to the operating scenario. Additionally, it is possible to evaluate the impact of the distributed generation and the electric vehicles in the management of voltage stability in the future electric networks. One detailed case study considering a distribution network with high penetration of distributed energy resources is presented to analyse the proposed methodology. Additionally, the methodology is tested in a real distribution network.

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Evaluation of different initial solution algorithms to be used in the heuristics optimization to solve the energy resource scheduling in smart grids

Over the last years, an increasing number of distributed resources have been connected to the power system due to the ambitious environmental targets, which resulted into a more complex operation of the power system. In the future, an even larger number of resources is expected to be coupled which will turn the day-ahead optimal resource scheduling problem into an even more difficult optimization problem. Under these circumstances, metaheuristics can be used to address this optimization problem. An adequate algorithm for generating a good initial solution can improve the metaheuristic’s performance of finding a final solution near to the optimal than using a random initial solution. This paper proposes two initial solution algorithms to be used by a metaheuristic technique (simulated annealing). These algorithms are tested and evaluated with other published algorithms that obtain initial solution. The proposed algorithms have been developed as modules to be more flexible their use by other metaheuristics than just simulated annealing. The simulated annealing with different initial solution algorithms has been tested in a 37-bus distribution network with distributed resources, especially electric vehicles. The proposed algorithms proved to present results very close to the optimal with a small difference between 0.1%. A deterministic technique is used as comparison and it took around 26 h to obtain the optimal one. On the other hand, the simulated annealing was able of obtaining results around 1 min.
Metalearning to support competitive electricity market players' strategic bidding

Electricity markets are becoming more competitive, to some extent due to the increasing number of players that have moved from other sectors to the power industry. This is essentially resulting from incentives provided to distributed generation. Relevant changes in this domain are still occurring, such as the extension of national and regional markets to continental scales. Decision support tools have thereby become essential to help electricity market players in their negotiation process. This paper presents a metalearner to support electricity market players in bidding definition. The proposed metalearner uses a dynamic artificial neural network to create its own output, taking advantage on several learning algorithms already implemented in ALBidS (Adaptive Learning strategic Bidding System). The proposed metalearner considers different weights for each strategy, based on their individual performance. The metalearner's performance is analysed in scenarios based on real electricity markets data using MASCEM (Multi-Agent Simulator for Competitive Electricity Markets). Results show that the proposed metalearner is able to provide higher profits to market players when compared to other current methodologies and that results improve over time, as consequence of its learning process. (C) 2016 Elsevier B.V. All rights reserved.
Multi-agent based modeling for electric vehicle integration in a distribution network operation

The purpose of this paper is to present a multi-agent based modeling technology for simulating and operating a hierarchical energy management of a power distribution system with focus on EVs integration. The proposed multi-agent system consists of four types of agents: i) Distribution system operator (DSO) technical agent and ii) DSO market agents that both belong to the top layer of the hierarchy and their roles are to manage the distribution network by avoiding grid congestions and using congestion prices to coordinate the energy scheduled; iii) Electric vehicle virtual power plant agents are in the middle level of the hierarchy and their roles are to manage the charge process of the electric vehicles; iv) Electric vehicle agents are placed at the bottom layer of the hierarchy and they represent electric vehicle owners with different users’ profiles. To demonstrate the coordination behavior of the proposed system, a multi-agent simulation platform is developed based on the co-simulation environment of JACK, Matlab and GAMS. The aim of the multi-agent system is to simulate the collaborative (all agents contribute to achieve an optimized global performance) but also competitive environment (each agent will try to increase its utilities or reduce its costs). [All rights reserved Elsevier].

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Simulated annealing to handle energy and ancillary services joint management considering electric vehicles

The massive use of distributed generation and electric vehicles will lead to a more complex management of the power system, requiring new approaches to be used in the optimal resource scheduling field. Electric vehicles with vehicle-to-grid capability can be useful for the aggregator players in the mitigation of renewable sources intermittency and in the ancillary services procurement. In this paper, an energy and ancillary services joint management model is proposed. A simulated annealing approach is used to solve the joint management for the following day, considering the minimization of the aggregator total operation costs. The case study considers a distribution network with 33-bus, 66 distributed generation and 2000 electric vehicles. The proposed simulated annealing is matched with a deterministic approach allowing an effective and efficient comparison. The simulated annealing presents a solution closer to the one obtained in the deterministic approach (1.03% error), yet representing 0.06% of the deterministic approach CPU time performance.

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Agent-Based Smart Grid Market Simulation with Connection to Real Infrastructures

The consensus behind Smart Grids (SG) as one of the most promising solutions for the massive integration of renewable energy sources in power systems has led to the practical implementation of several prototypes and pilots that aim at testing and validating SG methodologies. The urgent need to accommodate such resources of distributed and intermittent nature and the impact that a deficient management of energy sources has on the global population require that alternative solutions are experimented. This paper presents a multi-agent based SG simulation platform that is connected to physical resources, so that realistic scenarios with palpable influence on real resources can be simulated. The SG simulator is also connected to the Multi-Agent Simulator of Competitive Electricity Markets (MASCEM), which provides a solid framework for the simulation of restructured electricity markets. Taking advantage on the complementarities between the simulators, a SG market is proposed, and a realistic simulation scenario, using two real buildings acting in a simulated SG is presented.

A multi-objective optimization of the active and reactive resource scheduling at a distribution level in a smart grid context

In the traditional paradigm, the large power plants supply the reactive power required at a transmission level and the capacitors and transformer tap changer were also used at a distribution level. However, in a near future will be necessary to schedule both active and reactive power at a distribution level, due to the high number of resources connected in distribution levels. This paper proposes a new multi-objective methodology to deal with the optimal resource scheduling considering the distributed generation, electric vehicles and capacitor banks for the joint active and reactive power scheduling. The proposed methodology considers the minimization of the cost (economic perspective) of all distributed resources, and the minimization of the voltage magnitude difference (technical perspective) in all buses. The Pareto front is determined and a fuzzy-based mechanism is applied to present the best compromise solution. The proposed methodology has been tested in the 33-bus distribution network. The case study shows the results of three different scenarios for the economic, technical, and multi-objective perspectives, and the results demonstrated the importance of incorporating the reactive scheduling in the distribution network using the multi-objective perspective to obtain the best compromise solution for the economic and technical perspectives.
Analysis of Strategic Wind Power Participation in Energy Market using MASCEM simulator

In recent years the reassessment of remuneration schemes for renewable sources in several European countries has motivated the increase of wind power generation participation in electricity markets. Moreover, the continuous growth of wind power generation, as well as the evolution of wind turbines technology, suggests that wind power plants may participate in both energy and ancillary services markets with strategic behavior to improve their benefits. Thus, wind power generation with strategic behavior may have impact on market equilibrium and pricing. This paper evaluates the impact of a proportional offering strategy for wind power plants to participate in both energy and ancillary services markets. MASCEM (Multi-Agent System for Competitive Electricity Markets) is used to simulate and validate the impact of wind power plants in market equilibrium. A case study based on real and recent data for the Iberian market and its specific rules is simulated in MASCEM.

Coalition of distributed generation units to virtual power players - a game theory approach

Smart Grids (SGs) have emerged as the new paradigm for power system operation and management, being designed to include large amounts of distributed energy resources. This new paradigm requires new Energy Resource Management (ERM) methodologies considering different operation strategies and the existence of new management players such as...
several types of aggregators. This paper proposes a methodology to facilitate the coalition between distributed generation units originating Virtual Power Players (VPP) considering a game theory approach. The proposed approach consists in the analysis of the classifications that were attributed by each VPP to the distributed generation units, as well as in the analysis of the previous established contracts by each player. The proposed classification model is based in fourteen parameters including technical, economical and behavioural ones. Depending of the VPP strategies, size and goals, each parameter has different importance. VPP can also manage other type of energy resources, like storage units, electric vehicles, demand response programs or even parts of the MV and LV distribution network. A case study with twelve VPPs with different characteristics and one hundred and fifty real distributed generation units is included in the paper.

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**Cost allocation model for distribution networks considering high penetration of distributed energy resources**
The high penetration of distributed energy resources (DER) in distribution networks and the competitive environment of electricity markets impose the use of new approaches in several domains. The network cost allocation, traditionally used in transmission networks, should be adapted and used in the distribution networks considering the specifications of the connected resources. The main goal is to develop a fairer methodology trying to distribute the distribution network use costs to all players which are using the network in each period. In this paper, a model considering different type of costs (fixed, losses, and congestion costs) is proposed comprising the use of a large set of DER, namely distributed generation (DG), demand response (DR) of direct load control type, energy storage systems (ESS), and electric vehicles with capability of discharging energy to the network, which is known as vehicle-to-grid (V2G). The proposed model includes three distinct phases of operation. The first phase of the model consists in an economic dispatch based on an AC optimal power flow (AC-OPF); in the second phase Kirschen's and Bialek's tracing algorithms are used and compared to evaluate the impact of each resource in the network. Finally, the MW-mile method is used in the third phase of the proposed model. A distribution network of 33 buses with large penetration of DER is used to illustrate the application of the proposed model. [All rights reserved Elsevier].

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Day-ahead distributed energy resource scheduling using differential search algorithm

The number of dispersed energy resources is growing every day, such as the use of more distributed generators. This paper deals with energy resource scheduling model in future smart grids. The methodology can be used by virtual power players (VPPs) considering day-ahead time horizon. This method considers that energy resources are managed by a VPP which establishes contracts with their owners. The full AC power flow calculation included in the model takes into account network constraints. This paper presents an application of differential search algorithm (DSA) for solving the day-ahead scheduling. DSA method is used to minimize the operation costs for the VPP providing in satisfactory execution time. Two scenarios are presented using a 33-bus distribution network, large wind farm and several distributed energy resources to illustrate the proposed methodology. These scenarios consider a contingency on the large wind farm and different forecasts regarding load demand.

Distributed energy resources management using plug-in hybrid electric vehicles as a fuel-shifting demand response resource

In the smart grids context, distributed energy resources management plays an important role in the power systems' operation. Battery electric vehicles and plug-in hybrid electric vehicles should be important resources in the future distribution networks operation. Therefore, it is important to develop adequate methodologies to schedule the electric vehicles' charge and discharge processes, avoiding network congestions and providing ancillary services. This paper proposes the participation of plug-in hybrid electric vehicles in fuel shifting demand response programs. Two services are proposed, namely the fuel shifting and the fuel discharging. The fuel shifting program consists in replacing the electric energy by fossil fuels in plug-in hybrid electric vehicles daily trips, and the fuel discharge program consists in use of their internal combustion engine to generate electricity injecting into the network. These programs are included in an energy resources management algorithm which integrates the management of other resources. The paper presents a case study considering a 37-bus distribution network with 25 distributed generators, 1908 consumers, and 2430 plug-in vehicles. Two scenarios are tested, namely a scenario with high photovoltaic generation, and a scenario without photovoltaic generation. A sensitivity analyses is performed in order to evaluate when each energy resource is required. [All rights reserved Elsevier].
Energy resource management under the influence of the weekend transition considering an intensive use of electric vehicles

Energy resource scheduling is becoming increasingly important, as the use of distributed resources is intensified and of massive electric vehicle is envisaged. The present paper proposes a methodology for day-ahead energy resource scheduling for smart grids considering the intensive use of distributed generation and Vehicle-to-Grid (V2G). This method considers that the energy resources are managed by a Virtual Power Player (VPP) which established contracts with their owners. It takes into account these contracts, the users' requirements subjected to the VPP, and several discharge price steps. The full AC power flow calculation included in the model takes into account network constraints. The influence of the successive day requirements on the day-ahead optimal solution is discussed and considered in the proposed model. A case study with a 33-bus distribution network and V2G is used to illustrate the good performance of the proposed method.

Incentive-based demand response programs designed by asset-light retail electricity providers for the day-ahead market

Following the deregulation experience of retail electricity markets in most countries, the majority of the new entrants of the liberalized retail market were pure REP (retail electricity providers). These entities were subject to financial risks because of the unexpected price variations, price spikes, volatile loads and the potential for market power exertion by GENCO (generation companies). A REP can manage the market risks by employing the DR (demand response) programs and using its' generation and storage assets at the distribution network to serve the customers. The proposed model suggests how a REP with light physical assets, such as DG (distributed generation) units and ESS (energy storage systems), can survive in a competitive retail market. The paper discusses the effective risk management strategies for the REPs to deal...
with the uncertainties of the DAM (day-ahead market) and how to hedge the financial losses in the market. A two-stage stochastic programming problem is formulated. It aims to establish the financial incentive-based DR programs and the optimal dispatch of the DG units and ESSs. The uncertainty of the forecasted day-ahead load demand and electricity price is also taken into account with a scenario-based approach. The principal advantage of this model for REPs is reducing the risk of financial losses in DAMs, and the main benefit for the whole system is market power mitigation by virtually increasing the price elasticity of demand and reducing the peak demand.

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**MASCEM: EPEX SPOT Day-Ahead market integration and simulation**
The energy sector restructuring process in industrialized countries had the aim of reducing electricity prices by increasing competitiveness, and facilitate the integration of distributed energy resources. However, the complexity in market players' interactions has increased, and new problems have emerged. Decision support tools that facilitate the study and comprehension of these markets became extremely useful, providing players with competitive advantage. MASCEM (Multi-Agent Simulator of Competitive Electricity Markets) arises in this context, modeling and simulating real electricity markets. It is crucial to MASCEM to have the ability to simulate as many market models and player types as possible, thus enhancing the ability to recreate the electricity markets reality in its maximum possible extent. This paper presents the EPEX Spot Day-Ahead market integration in MASCEM. EPEX Spot SE's mission is to lead European markets coupling in a single unified market, thus being crucial for the study of competitive electricity markets.

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Multi-agent simulation of competitive electricity markets: Autonomous systems cooperation for European market modeling

The electricity market restructuring, and its worldwide evolution into regional and even continental scales, along with the increasing necessity for an adequate integration of renewable energy sources, is resulting in a rising complexity in power systems operation. Several power system simulators have been developed in recent years with the purpose of helping operators, regulators, and involved players to understand and deal with this complex and constantly changing environment. The main contribution of this paper is given by the integration of several electricity market and power system models, respecting to the reality of different countries. This integration is done through the development of an upper ontology which integrates the essential concepts necessary to interpret all the available information. The continuous development of Multi-Agent System for Competitive Electricity Markets platform provides the means for the exemplification of the usefulness of this ontology. A case study using the proposed multi-agent platform is presented, considering a scenario based on real data that simulates the European Electricity Market environment, and comparing its performance using different market mechanisms. The main goal is to demonstrate the advantages that the integration of various market models and simulation platforms have for the study of the electricity markets' evolution.

Support Vector Machines for decision support in electricity markets' strategic bidding

Energy systems worldwide are complex and challenging environments. Multi-agent based simulation platforms are increasing at a high rate, as they show to be a good option to study many issues related to these systems, as well as the involved players at act in this domain. In this scope the authors' research group has developed a multi-agent system: Multi-Agent System for Competitive Electricity Markets (MASCEM), which simulates the electricity markets environment. MASCEM is integrated with Adaptive Learning Strategic Bidding System (ALBidS) that works as a decision support system for market players. The ALBidS system allows MASCEM market negotiating players to take the best possible advantages from the market context. This paper presents the application of a Support Vector Machines (SVM) based approach to provide decision support to electricity market players. This strategy is tested and validated by being included in ALBidS and then compared with the application of an Artificial Neural Network (ANN), originating promising results: an effective electricity market price forecast in a fast execution time. The proposed approach is tested and validated using real electricity markets data from MIBEL – Iberian market operator.
Two-stage stochastic day-ahead optimal resource scheduling in a distribution network with intensive use of distributed energy resources

The integration of renewable sources and electric vehicles will introduce new uncertainties to the optimal resource scheduling, namely at the distribution level. These uncertainties are mainly originated by the power generated by renewables sources and by the electric vehicles charge requirements. This paper proposes a two-state stochastic programming approach to solve the day-ahead optimal resource scheduling problem. The case study considers a 33-bus distribution network with 66 distributed generation units and 1000 electric vehicles.

A Communication and Resources Management Scheme to Support the Smart Grid Integration of Multiplayers Access to Resources Information

The increasing and intensive integration of distributed energy resources into distribution systems requires adequate methodologies to ensure a secure operation according to the smart grid paradigm. In this context, SCADA (Supervisory Control and Data Acquisition) systems are an essential infrastructure. This paper presents a conceptual design of a communication and resources management scheme based on an intelligent SCADA with a decentralized, flexible, and intelligent approach, adaptive to the context (context awareness). The methodology is used to support the energy resource management considering all the involved costs, power flows, and electricity prices leading to the network reconfiguration. The methodology also addresses the definition of the information access permissions of each player to each resource. The paper includes a 33-bus network used in a case study that considers an intensive use of distributed energy resources in five distinct implemented operation contexts.
Adaptive learning in agents behaviour: A framework for electricity markets simulation

Electricity markets are complex environments, involving a large number of different entities, playing in a dynamic scene to obtain the best advantages and profits. MASCEM (Multi-Agent System for Competitive Electricity Markets) is a multi-agent electricity market simulator that models market players and simulates their operation in the market. Market players are entities with specific characteristics and objectives, making their decisions and interacting with other players. This paper presents a methodology to provide decision support to electricity market negotiating players. This model allows integrating different strategic approaches for electricity market negotiations, and choosing the most appropriate one at each time, for each different negotiation context. This methodology is integrated in ALBidS (Adaptive Learning strategic Bidding System) – a multiagent system that provides decision support to MASCEM's negotiating agents so that they can properly achieve their goals. ALBidS uses artificial intelligence methodologies and data analysis algorithms to provide effective adaptive learning capabilities to such negotiating entities. The main contribution is provided by a methodology that combines several distinct strategies to build actions proposals, so that the best can be chosen at each time, depending on the context and simulation circumstances. The choosing process includes reinforcement learning algorithms, a mechanism for negotiating contexts analysis, a mechanism for the management of the efficiency/effectiveness balance of the system, and a mechanism for competitor players' profiles definition.
optimization (ACO) techniques. The case study concerns different EVs penetration levels. Comparisons with a previous SA approach and a deterministic technique are also presented. For 2000 EVs scenario, the proposed hybrid approach found a solution better than the previous SA version, resulting in a cost reduction of 1.94%. For this scenario, the proposed approach is approximately 94 times faster than the deterministic approach.

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**Analysis of the Impact of Wind Power Participating in Both Energy and Ancillary Services Markets – The Danish Case**

The impact of a high penetration of wind power generation in power systems motivates need for an assessment of its interaction with electricity markets. With the continuous evolution of wind turbines technology, wind farms have today the ability to provide certain ancillary services with appropriate levels of security and reliability. The participation of wind farms in ancillary service markets should rely on market designs and offering strategies that satisfy power system needs, as well as their operating characteristics. Here we evaluate the system impact of different offering strategies that wind farms employ on energy and ancillary service market. We already proposed Proportional Wind Reserve Strategy (PWRS) and a Continuous Wind Reserve Strategy (CWRS) are used to determine the amount of available power for ancillary services. A case study based on real and recent data for Denmark allows evaluating impact on market prices, wind farms' revenue, as well as impact on power system reliability.

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A New Heuristic Providing an Effective Initial Solution for a Simulated Annealing approach to Energy Resource Scheduling in Smart Grids

An intensive use of dispersed energy resources is expected for future power systems, including distributed generation, especially based on renewable sources, and electric vehicles. The system operation methods and tool must be adapted to the increased complexity, especially the optimal resource scheduling problem. Therefore, the use of metaheuristics is required to obtain good solutions in a reasonable amount of time. This paper proposes two new heuristics, called naive electric vehicles charge and discharge allocation and generation tournament based on cost, developed to obtain an initial solution to be used in the energy resource scheduling methodology based on simulated annealing previously developed by the authors. The case study considers two scenarios with 1000 and 2000 electric vehicles connected in a distribution network. The proposed heuristics are compared with a deterministic approach and presenting a very small error concerning the objective function with a low execution time for the scenario with 2000 vehicles.

Automatic electricity markets data extraction for realistic multi-agent simulations

This paper presents the development of a tool that provides a database with available information from real electricity markets, ensuring the required updating mechanisms. Some important characteristics of this tool are: capability of collecting, analyzing, processing and storing real electricity markets data available on-line; capability of dealing with different file formats and types, some of them inserted by the user, resulting from information obtained not on-line but based on the possible collaboration with market entities; definition and implementation of database gathering information from different market sources, even including different market types; machine learning approach for automatic definition of downloads periodicity of new information available on-line. This is a crucial tool to go a step forward in electricity markets simulation, since the integration of this database with a scenarios generation tool, based on knowledge discovery techniques, provides a framework to study real market scenarios allowing simulators improvement and validation.

Data Extraction Tool to Analyse, Transform and Store Real Data from Electricity Markets

The study of electricity markets operation has been gaining an increasing importance in the last years, as result of the new challenges that the restructuring process produced. Currently, lots of information concerning electricity markets is available, as market operators provide, after a period of confidentiality, data regarding market proposals and transactions.
These data can be used as source of knowledge to define realistic scenarios, which are essential for understanding and forecast electricity markets behavior. The development of tools able to extract, transform, store and dynamically update data, is of great importance to go a step further into the comprehension of electricity markets and of the behaviour of the involved entities. In this paper an adaptable tool capable of downloading, parsing and storing data from market operators’ websites is presented, assuring constant updating and reliability of the stored data.

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**Day-ahead resource scheduling including demand response for electric vehicles**
Summary form only given. The energy resource scheduling is becoming increasingly important, as the use of distributed resources is intensified and massive gridable vehicle (V2G) use is envisaged. This paper presents a methodology for day-ahead energy resource scheduling for smart grids considering the intensive use of distributed generation and V2G. The main focus is the comparison of different EV management approaches in the day-ahead energy resources management, namely uncontrolled charging, smart charging, V2G and Demand Response (DR) programs in the V2G approach. Three different DR programs are designed and tested (trip reduce, shifting reduce and reduce+shifting). Other important contribution of the paper is the comparison between deterministic and computational intelligence techniques to reduce the execution time. The proposed scheduling is solved with a modified particle swarm optimization. Mixed integer non-linear programming is also used for comparison purposes. Full ac power flow calculation is included to allow taking into account the network constraints. A case study with a 33-bus distribution network and 2000 V2G resources is used to illustrate the performance of the proposed method.

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Definition of Distribution Network Tariffs Considering Distribution Generation and Demand Response
The use of distribution networks in the current scenario of high penetration of Distributed Generation (DG) is a problem of great importance. In the competitive environment of electricity markets and smart grids, Demand Response (DR) is also gaining notable impact with several benefits for the whole system. The work presented in this paper comprises a methodology able to define the cost allocation in distribution networks considering large integration of DG and DR resources. The proposed methodology is divided into three phases and it is based on an AC Optimal Power Flow (OPF) including the determination of topological distribution factors, and consequent application of the MW-mile method. The application of the proposed tariffs definition methodology is illustrated in a distribution network with 33 buses, 66 DG units, and 32 consumers with DR capacity

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Demand Response Design and Use Based on Network Locational Marginal Prices
Power systems have been experiencing huge changes mainly due to the substantial increase of distributed generation (DG) and the operation in competitive environments. Virtual Power Players (VPP) can aggregate several players, namely a diversity of energy resources, including distributed generation (DG) based on several technologies, electric storage systems (ESS) and demand response (DR). Energy resources management gains an increasing relevance in this competitive context. This makes the DR use more interesting and flexible, giving place to a wide range of new opportunities. This paper proposes a methodology to support VPPs in the DR programs' management, considering all the existing energy resources (generation and storage units) and the distribution network. The proposed method is based on locational marginal prices (LMP) values. The evaluation of the impact of using DR specific programs in the LMP values supports the manager decision concerning the DR use. The proposed method has been computationally implemented and its application is illustrated in this paper using a 33-bus network with intensive use of DG.

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Scopus rating (2014): CiteScore 4.34 SJR 1.72 SNIP 2.391
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Research output: Contribution to journal - Journal article – Annual report year: 2014 - Research - peer-review
Distributed energy resources scheduling considering real-time resources forecast

Energy resource scheduling is becoming increasingly important, such as the use of more distributed generators and electric vehicles connected to the distribution network. This paper proposes a methodology to be used by Virtual Power Players (VPPs), regarding the energy resource scheduling in smart grids and considering day-ahead, hour-ahead and realtime time horizons. This method considers that energy resources are managed by a VPP which establishes contracts with their owners. The full AC power flow calculation included in the model takes into account network constraints. In this paper, distribution function errors are used to simulate variations between time horizons, and to measure the performance of the proposed methodology. A 33-bus distribution network with large number of distributed resources is used.

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Research » peer-review

Distributed generation and demand response dispatch for a virtual power player energy and reserve provision

Recent changes in the operation and planning of power systems have been motivated by the introduction of Distributed Generation (DG) and Demand Response (DR) in the competitive electricity markets' environment, with deep concerns at the efficiency level. In this context, grid operators, market operators, utilities and consumers must adopt strategies and methods to take full advantage of demand response and distributed generation. This requires that all the involved players consider all the market opportunities, as the case of energy and reserve components of electricity markets.

The present paper proposes a methodology which considers the joint dispatch of demand response and distributed generation in the context of a distribution network operated by a virtual power player. The resources' participation can be performed in both energy and reserve contexts. This methodology contemplates the probability of actually using the reserve and the distribution network constraints. Its application is illustrated in this paper using a 32-bus distribution network with 66 DG units and 218 consumers classified into 6 types of consumers.

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Dynamic load management in a smart home to participate in demand response events

In future power systems, in the smart grid and microgrids operation paradigms, consumers can be seen as an energy resource with decentralized and autonomous decisions in the energy management. It is expected that each consumer will manage not only the loads, but also small generation units, heating systems, storage systems, and electric vehicles. Each consumer can participate in different demand response events promoted by system operators or aggregation entities. This paper proposes an innovative method to manage the appliances on a house during a demand response event. The main contribution of this work is to include time constraints in resources management, and the context evaluation in order to ensure the required comfort levels. The dynamic resources management methodology allows a better resources management in a demand response event, mainly the ones of long duration, by changing the priorities of loads during the event. A case study with two scenarios is presented considering a demand response with 30 min duration, and another with 240 min (4 h). In both simulations, the demand response event proposes the power consumption reduction during the event. A total of 18 loads are used, including real and virtual ones, controlled by the presented house management system.

Elspot: Nord Pool Spot Integration in MASCEM Electricity Market Simulator

The energy sector in industrialized countries has been restructured in the last years, with the purpose of decreasing electricity prices through the increase in competition, and facilitating the integration of distributed energy resources. However, the restructuring process increased the complexity in market players' interactions and generated emerging problems and new issues to be addressed. In order to provide players with competitive advantage in the market, decision support tools that facilitate the study and understanding of these markets become extremely useful. In this context arises MASCEM (Multi-Agent Simulator of Competitive Electricity Markets), a multi-agent based simulator that models real electricity markets. To reinforce MASCEM with the capability of recreating the electric markets reality in the fullest possible extent, it is crucial to make it able to simulate as many market models and player types as possible. This paper presents a new negotiation model implemented in MASCEM based on the negotiation model used in day-ahead market (Elspot) of Nord Pool. This is a key module to study competitive electricity markets, as it presents well defined and distinct characteristics from the already implemented markets, and it is a reference electricity market in Europe (the one with the larger amount of traded power).
Evaluation of the Electric Vehicle Impact in the Power Demand Curve in a Smart Grid Environment

Smart grids with an intensive penetration of distributed energy resources will play an important role in future power system scenarios. The intermittent nature of renewable energy sources brings new challenges, requiring an efficient management of those sources. Additional storage resources can be beneficially used to address this problem; the massive use of electric vehicles, particularly of vehicle-to-grid (usually referred as gridable vehicles or V2G), becomes a very relevant issue. This paper addresses the impact of Electric Vehicles (EVs) in system operation costs and in power demand curve for a distribution network with large penetration of Distributed Generation (DG) units. An efficient management methodology for EVs charging and discharging is proposed, considering a multi-objective optimization problem. The main goals of the proposed methodology are: to minimize the system operation costs and to minimize the difference between the minimum and maximum system demand (leveling the power demand curve). The proposed methodology perform the day-ahead scheduling of distributed energy resources in a distribution network with high penetration of DG and a large number of electric vehicles. It is used a 32-bus distribution network in the case study section considering different scenarios of EVs penetration to analyze their impact in the network and in the other energy resources management.

Multi-agents Based Modelling for Distribution Network Operation with Electric Vehicle Integration

Electric vehicles (EV) can become integral part of a smart grid because instead of just consuming power they are capable of providing valuable services to power systems. To integrate EVs smoothly into the power systems, a multi-agents system (MAS) with hierarchical organization structure is proposed in this paper. The proposed MAS system consists of three types of agents: distribution system operator agent (DSO agent), electric vehicle fleet operator agent (EV FO agent or alternatively called virtual power plant agent) and EV agent. A DSO agent belongs to the top level of the hierarchy and its role is to manage the distribution network safely by avoiding grid congestions and using congestion prices to coordinate the energy schedule of VPPs. VPP agents belong to the middle level and their roles are to manage the charge periods of the EVs. EV agents sit in the bottom level and they represent EV owners and operate the charging behaviour of EVs.
simulate this collaborative (all agents contribute to achieving an optimized global performance) but also competitive environment (each agent will try to increase its utilities or reduce its costs), a multi-agent platform was developed to demonstrate the coordination between the interacting agents.

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DOIs: 10.1007/978-3-662-45286-8_37

**Particle Swarm Optimization of Electricity Market Negotiating Players Portfolio**
Energy systems worldwide are complex and challenging environments. Multi-agent based simulation platforms are increasing at a high rate, as they show to be a good option to study many issues related to these systems, as well as the involved players at act in this domain. In this scope the authors' research group has developed a multi-agent system: MASCEM (Multi-Agent System for Competitive Electricity Markets), which performs realistic simulations of the electricity markets. MASCEM is integrated with ALBidS (Adaptive Learning Strategic Bidding System) that works as a decision support system for market players. The ALBidS system allows MASCEM market negotiating players to take the best possible advantages from each market context. However, it is still necessary to adequately optimize the players' portfolio investment. For this purpose, this paper proposes a market portfolio optimization method, based on particle swarm optimization, which provides the best investment profile for a market player, considering different market opportunities (bilateral negotiation, market sessions, and operation in different markets) and the negotiation context such as the peak and off-peak periods of the day, the type of day (business day, weekend, holiday, etc.) and most important, the renewable based distributed generation forecast. The proposed approach is tested and validated using real electricity markets data from the Iberian operator – MIBEL.

**Real-time Energy Resource Scheduling considering a Real Portuguese Scenario**
The development in power systems and the introduction of decentralized generation and Electric Vehicles (EVs), both connected to distribution networks, represents a major challenge in the planning and operation issues. This new paradigm
requires a new energy resources management approach which considers not only the generation, but also the management of loads through demand response programs, energy storage units, EVs and other players in a liberalized electricity markets environment. This paper proposes a methodology to be used by Virtual Power Players (VPPs), considering the energy resource scheduling in smart grids, considering day-ahead, hour-ahead and real-time scheduling. The case study considers a 33-bus distribution network with high penetration of distributed energy resources. The wind generation profile is based on a real Portuguese wind farm. Four scenarios are presented taking into account 0, 1, 2 and 5 periods (hours or minutes) ahead of the scheduling period in the hour-ahead and real-time scheduling.

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Reinforcement Learning Based on the Bayesian Theorem for Electricity Markets Decision Support
This paper presents the applicability of a reinforcement learning algorithm based on the application of the Bayesian theorem of probability. The proposed reinforcement learning algorithm is an advantageous and indispensable tool for ALBidS (Adaptive Learning Strategic Bidding System), a multi-agent system that has the purpose of providing decision support to electricity market negotiating players. ALBidS uses a set of different strategies for providing decision support to market players. These strategies are used accordingly to their probability of success for each different context. The approach proposed in this paper uses a Bayesian network for deciding the most probably successful action at each time, depending on past events. The performance of the proposed methodology is tested using electricity market simulations in MASCEM (Multi-Agent Simulator of Competitive Electricity Markets). MASCEM provides the means for simulating a real electricity market environment, based on real data from real electricity market operators.

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New challenges are arising in managing power systems as these systems become more complex due to the use of high levels of distributed generation, mainly based on renewable energy sources, and due to the competitive environment within the power sector. At the same time, the use of Phasor Measurement Units (PMUs) provides more information and enables wide-area monitoring with accurate timing. One of the challenges in the near future is converting the high quantity and quality of information provided by PMUs into useful knowledge about operational state of a global system. The use of real-time simulation in closed-loop is essential to develop and validate new real-time applications of wide-area PMU data. This paper presents a simulation platform developed within the research project Secure Operation of Sustainable Power Systems (SOSPO). The SOSPO simulation platform (SOSPO-SP) functions in a closed-loop, integrating new real-time assessment methods to provide useful information to operators in power system control centers and to develop new control methodologies that handle emergency situations and avoid power system blackouts.
Strategic Bidding for Electricity Markets Negotiation Using Support Vector Machines

Energy systems worldwide are complex and challenging environments. Multi-agent based simulation platforms are increasing at a high rate, as they show to be a good option to study many issues related to these systems, as well as the involved players at act in this domain. In this scope the authors' research group has developed a multi-agent system: MASCEM (Multi-Agent System for Competitive Electricity Markets), which simulates the electricity markets environment. MASCEM is integrated with ALBidS (Adaptive Learning Strategic Bidding System) that works as a decision support system for market players. The ALBidS system allows MASCEM market negotiating players to take the best possible advantages from the market context. This paper presents the application of a Support Vector Machines (SVM) based approach to provide decision support to electricity market players. This strategy is tested and validated by being included in ALBidS and then compared with the application of an Artificial Neural Network, originating promising results. The proposed approach is tested and validated using real electricity markets data from MIBEL - Iberian market operator.

SW-platform for R&D in Applications of Synchrophasor Measurements for Wide-Area Assessment, Control and Visualization in Real-Time

The Danish research project "Secure Operation of Sustainable Power Systems (SOSPO)" is currently being conducted in a collaboration by a group of partners from academia and industry. The focus of the project is on how to achieve secure operation of the power grid as large scale thermal power plants, supplied by fossil fuel, are phased out in favor of non-controllable renewable energy sources like wind and solar energy. In particular, the SOSPO project aims to develop real-time stability and security assessment methods as well as wide-area control methods to re-establish stable and secure operation when a critical operation has been identified. An important part of the SOSPO project is the development of a SW-platform that enables testing and demonstrations of the various methods for wide-area assessment, control and visualization the project delivers. In order to test the methods under realistic conditions, the future system scenarios are
represented in a real time grid simulator that is an integrated part of the platform. The SW - platform provides structured access to any model parameter as well as access to real - time phasor measurement unit (PMU) and remote terminal unit (RTU) snapshots. Having such structured access to relevant data greatly eases the implementation process of new methods. The SW - platform is facilitated by PowerLabDK at the Technical University of Denmark, which is a new state - of - the - art experimental laboratory for technology development, testing, training and demonstration of technologies within electric power and energy. More specifically, the SW - platform exploits the Intelligent Control Lab facilities in PowerLabDK, which provides access to a powerful Real - Time Digital Simulator, a SCAD A system, a full scale experimental power system control room with a video wall and an IBM Blade center for the implementation of the SW - platform and the wide - area methods developed in SOSPO. This paper provides insights into the details of the SOSPO SW - platform including the technical infrastructure and the platform architecture

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Towards a unified European electricity market: The contribution of data-mining to support realistic simulation studies
Worldwide electricity markets have been evolving into regional and even continental scales. The aim at an efficient use of renewable based generation in places where it exceeds the local needs is one of the main reasons. A reference case of this evolution is the European Electricity Market, where countries are connected, and several regional markets were created, each one grouping several countries, and supporting transactions of huge amounts of electrical energy. The continuous transformations electricity markets have been experiencing over the years create the need to use simulation platforms to support operators, regulators, and involved players for understanding and dealing with this complex environment. This paper focuses on demonstrating the advantage that real electricity markets data has for the creation of realistic simulation scenarios, which allow the study of the impacts and implications that electricity markets transformations will bring to the participant countries. A case study using MASCEM (Multi-Agent System for Competitive Electricity Markets) is presented, with a scenario based on real data, simulating the European Electricity Market environment, and comparing its performance when using several different market mechanisms.

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Application-Specific Modified Particle Swarm Optimization for energy resource scheduling considering vehicle-to-grid

This paper presents a modified Particle Swarm Optimization (PSO) methodology to solve the problem of energy resources management with high penetration of distributed generation and Electric Vehicles (EVs) with gridable capability (V2G). The objective of the day-ahead scheduling problem in this work is to minimize operation costs, namely energy costs, regarding the management of these resources in the smart grid context. The modifications applied to the PSO aimed to improve its adequacy to solve the mentioned problem. The proposed Application Specific Modified Particle Swarm Optimization (ASMPSO) includes an intelligent mechanism to adjust velocity limits during the search process, as well as self-parameterization of PSO parameters making it more user-independent. It presents better robustness and convergence characteristics compared with the tested PSO variants as well as better constraint handling. This enables its use for addressing real-world large-scale problems in much shorter times than the deterministic methods, providing system operators with adequate decision support and achieving efficient resource scheduling, even when a significant number of alternative scenarios should be considered. The paper includes two realistic case studies with different penetration of gridable vehicles (1000 and 2000). The proposed methodology is about 2600 times faster than Mixed-Integer Non-Linear Programming (MINLP) reference technique, reducing the time required from 25h to 36s for the scenario with 2000 vehicles, with about one percent of difference in the objective function cost value.

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Source-ID: n:oai:DTIC-ART:elsevier/391342750::33224
Research output: Contribution to journal › Journal article – Annual report year: 2013 › Research › peer-review

Contextual Intelligent Load Management Considering Real Time Pricing in a Smart Grid Environment

The use of demand response programs enables the adequate use of resources of small and medium players, bringing high benefits to the smart grid, and increasing its efficiency. One of the difficulties to proceed with this paradigm is the lack of intelligence in the management of small and medium size players. In order to make demand response programs a feasible solution, it is essential that small and medium players have an efficient energy management and a fair optimization mechanism to decrease the consumption without heavy loss of comfort, making it acceptable for the users. This paper addresses the application of real-time pricing in a house that uses an intelligent optimization module involving artificial neural networks.

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Day-Ahead Resource Scheduling Including Demand Response for Electric Vehicles

The energy resource scheduling is becoming increasingly important, as the use of distributed resources is intensified and massive gridable vehicle (V2G) use is envisaged. This paper presents a methodology for day-ahead energy resource scheduling for smart grids considering the intensive use of distributed generation and V2G. The main focus is the comparison of different EV management approaches in the day-ahead energy resources management, namely uncontrolled charging, smart charging, V2G and Demand Response (DR) programs in the V2G approach. Three different DR programs are designed and tested (trip reduce, shifting reduce and reduce+shifting). Other important contribution of the paper is the comparison between deterministic and computational intelligence techniques to reduce the execution time. The proposed scheduling is solved with a modified particle swarm optimization. Mixed integer non-linear programming is also used for comparison purposes. Full ac power flow calculation is included to allow taking into account the network constraints. A case study with a 33-bus distribution network and 2000 V2G resources is used to illustrate the performance of the proposed method.

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Decision support tool for Virtual Power Players: Hybrid Particle Swarm Optimization applied to Day-ahead Vehicle-To-Grid Scheduling

This paper presents a decision support Tool methodology to help virtual power players (VPPs) in the Smart Grid (SGs) context to solve the day-ahead energy resource scheduling considering the intensive use of Distributed Generation (DG) and Vehicle-To-Grid (V2G). The main focus is the application of a new hybrid method combining a particle swarm approach and a deterministic technique based on mixedinteger linear programming (MILP) to solve the day-ahead scheduling minimizing total operation costs from the aggregator point of view. A realistic mathematical formulation, considering the electric network constraints and V2G charging and discharging efficiencies is presented. Full AC power flow calculation is included in the hybrid method to allow taking into account the network constraints. A case study with a 33-bus distribution network and 1800 V2G resources is used to illustrate the performance of the proposed method.

General information
Publication status: Published
Organisations: Department of Electrical Engineering, Automation and Control, Instituto Politécnico do Porto
Defining electricity tariffs using the knowledge about the consumers profiles in ELECON project

The increasing importance of the integration of distributed generation and demand response in the power systems operation and planning, namely at lower voltage levels of distribution networks and in the competitive environment of electricity markets, leads us to the concept of smart grids. In both traditional and smart grid operation, non-technical losses are a great economic concern, which can be addressed. In this context, the ELECON project addresses the use of demand response contributions to the identification of non-technical losses. The present paper proposes a methodology to be used by Virtual Power Players (VPPs), which are entities able to aggregate distributed small-size resources, aiming to define the best electricity tariffs for several, clusters of consumers. A case study based on real consumption data demonstrates the application of the proposed methodology. © 2013 IEEE.

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Contributors: Morais, H., Vale, Z., Faria, P., Ramos, S.
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Dispatch of distributed energy resources to provide energy and reserve in smart grids using a particle swarm optimization approach

The smart grid concept is a key issue in the future power systems, namely at the distribution level, with deep concerns in the operation and planning of these systems. Several advantages and benefits for both technical and economic operation of the power system and of the electricity markets are recognized. The increasing integration of demand response and distributed generation resources, all of them mostly with small scale distributed characteristics, leads to the need of aggregating entities such as Virtual Power Players. The operation business models become more complex in the context of smart grid operation. Computational intelligence methods can be used to give a suitable solution for the resources scheduling problem considering the time constraints. This paper proposes a methodology for a joint dispatch of demand response and distributed generation to provide energy and reserve by a virtual power player that operates a distribution network. The optimal schedule minimizes the operation costs and it is obtained using a particle swarm optimization approach, which is compared with a deterministic approach used as reference methodology. The proposed method is applied to a 33-bus distribution network with 32 medium voltage consumers and 66 distributed generation units.

General information
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Organisations: Department of Electrical Engineering, Automation and Control, Instituto Politécnico do Porto, Instituto Superior de Engenharia do Porto
Distributed Agent-based Intelligent System for Demand Response Program Simulation in the Scope of Smart Grids

Demand response programs are an important resource which can significantly increase the efficiency of future smart grids. However, preliminary experiences evidence some difficulties in making the use of these programs successful, and also increased difficulties in extending them to include relevant participation of small consumers. This paper proposes a distributed agent-based intelligent system to model and simulate a smart grid with a diversity of players, each one with its own specific configuration and goals. This system accommodates the use of physical players, e.g., real electrical installations, as well as computationally simulated agents. This paper presents the capacities of the proposed system to simulate the use of demand response programs. The system allows assessing the impact of these programs to the involved consumers, to the other players and to the whole system. In this way, the alternative demand response program structure and parameterization can be simulated and evaluated.

Distribution Networks Management with High Penetration of Photovoltaic Panels

The photovoltaic solar panels penetration increases significantly in recent years in several European countries, mainly in the low voltage and medium voltage networks supported by governmental policies and incentives. Consequently, the acquisition and installation costs of PV panels decrease and the know–how increase significantly. Presently is important the use of new management methodologies in distribution networks to support the growing penetration of PV panels. In some countries, like in Germany and in Italy, the solar generation based in photovoltaic panels supply 40% of the demand in some periods of sunny days, mainly in the weekends. In the present work are technically analysed three different approaches to improve the number of PV systems in a distribution network, namely the use of inductors/capacitors, the use of storage systems and the control of reactive power injected by inverters of PV systems.
Distribution system operation supported by contextual energy resource management based on intelligent SCADA

Future distribution systems will have to deal with an intensive penetration of distributed energy resources ensuring reliable and secure operation according to the smart grid paradigm. SCADA (Supervisory Control and Data Acquisition) is an essential infrastructure for this evolution. This paper proposes a new conceptual design of an intelligent SCADA with a decentralized, flexible, and intelligent approach, adaptive to the context (context awareness). This SCADA model is used to support the energy resource management undertaken by a distribution network operator (DNO). Resource management considers all the involved costs, power flows, and electricity prices, allowing the use of network reconfiguration and load curtailment. Locational Marginal Prices (LMP) are evaluated and used in specific situations to apply Demand Response (DR) programs on a global or a local basis. The paper includes a case study using a 114 bus distribution network and load demand based on real data.
Energy resources management in three distinct time horizons considering a large variation in wind power

The intensive use of distributed generation based on renewable resources increases the complexity of power systems management, particularly the short-term scheduling. Demand response, storage units and electric and plug-in hybrid vehicles also pose new challenges to the short-term scheduling. However, these distributed energy resources can contribute significantly to turn the short-term scheduling more efficient and effective improving the power system reliability. This paper proposes a short-term scheduling methodology based on two distinct time horizons: hour-ahead scheduling, and real-time scheduling considering the point of view of one aggregator agent. In each scheduling process, it is necessary to update the generation and consumption operation, and the storage and electric vehicles status. Besides the new operation condition, more accurate forecast values of wind generation and consumption are available, for the resulting of short-term and very short-term methods. In this paper, the aggregator has the main goal of maximizing his profits while, fulfilling the established contracts with the aggregated and external players.

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Integration in MASCEM of the Joint Dispatch of Energy and Reserves Provided by Generation and Demand Resources

The provision of reserves in power systems is of great importance in what concerns keeping an adequate and acceptable level of security and reliability. This need for reserves and the way they are defined and dispatched gain increasing importance in the present and future context of smart grids and electricity markets due to their inherent competitive environment. This paper concerns a methodology proposed by the authors, which aims to jointly and optimally dispatch both generation and demand response resources to provide the amounts of reserve required for the system operation. Virtual Power Players are especially important for the aggregation of small size demand response and generation resources. The proposed methodology has been implemented in MASCEM, a multi agent system also developed at the authors’ research center for the simulation of electricity markets

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Intelligent micro grid management using a multi-agent approach

Recent changes in electricity markets (EMs) have been potentiating the globalization of distributed generation. With distributed generation the number of players acting in the EMs and connected to the main grid has grown, increasing the market complexity. Multi-agent simulation arises as an interesting way of analysing players’ behaviour and interactions, namely coalitions of players, as well as their effects on the market. MASCEM was developed to allow studying the market operation of several different players and MASGriP is being developed to allow the simulation of the micro and smart grid concepts in very different scenarios This paper presents a methodology based on artificial intelligence techniques (AI) for the management of a micro grid. The use of fuzzy logic is proposed for the analysis of the agent consumption elasticity, while a case based reasoning, used to predict agents’ reaction to price changes, is an interesting tool for the micro grid
Intelligent remuneration and tariffs for virtual power players

Power systems have been through deep changes in recent years, namely due to the operation of competitive electricity markets in the scope of the increasingly intensive use of renewable energy sources and distributed generation. This requires new business models able to cope with the new opportunities that have emerged. Virtual Power Players (VPPs) are a new type of player that allows aggregating a diversity of players (Distributed Generation (DG), Storage Agents (SA), Electrical Vehicles (V2G) and consumers) to facilitate their participation in the electricity markets and to provide a set of new services promoting generation and consumption efficiency, while improving players’ benefits. A major task of VPPs is the remuneration of generation and services (maintenance, market operation costs and energy reserves), as well as charging energy consumption. This paper proposes a model to implement fair and strategic remuneration and tariff methodologies, able to allow efficient VPP operation and VPP goals accomplishment in the scope of electricity markets.

Load Control Timescales Simulation in a Multi-Agent Smart Grid Platform

Environmental concerns and the shortage in the fossil fuel reserves have been potentiating the growth and globalization of distributed generation. Another resource that has been increasing its importance is the demand response, which is used to change consumers’ consumption profile, helping to reduce peak demand. Aiming to support small players’ participation in demand response events, the Curtailment Service Provider emerged. This player works as an aggregator for demand response events. The control of small and medium players which act in smart grid and micro grid environments is enhanced with a multi-agent system with artificial intelligence techniques – the MASGiP (Multi-Agent Smart Grid Platform). Using strategic behaviours in each player, this system simulates the profile of real players by using software agents. This paper shows the importance of modeling these behaviours for studying this type of scenarios. A case study with three examples shows the differences between each player and the best behaviour in order to achieve the higher profit in each situation.
MASCEM Restructuring: Ontologies For Scenarios Generation in Power Systems Simulators

The electricity market restructuring, along with the increasing necessity for an adequate integration of renewable energy sources, is resulting in an rising complexity in power systems operation. Various power system simulators have been introduced in recent years with the purpose of helping operators, regulators, and involved players to understand and deal with this complex environment. This paper focuses on the development of an upper ontology which integrates the essential concepts necessary to interpret all the available information. The restructuring of MASCEM (Multi-Agent System for Competitive Electricity Markets), and this system’s integration with MASGriP (Multi-Agent Smart Grid Platform), and ALBidS (Adaptive Learning Strategic Bidding System) provide the means for the exemplification of the usefulness of this ontology. A practical example is presented, showing how common simulation scenarios for different simulators, directed to very distinct environments, can be created departing from the proposed ontology.

Maximizing the Social Welfare of Virtual Power Players Operation in Case of Excessive Wind Power

The integration of growing amounts of distributed generation in power systems, namely at distribution networks level, has been fostered by energy policies in several countries around the world, including in Europe. This intensive integration of distributed, non-dispatchable, and natural sources based generation (including wind power) has caused several changes in the operation and planning of power systems and of electricity markets. Sometimes the available non-dispatchable generation is higher than the demand. This generation must be used; otherwise it is wasted if not stored or used to supply additional demand. New policies and market rules, as well as new players, are needed in order to competitively integrate all the resources.

The methodology proposed in this paper aims at the maximization of the social welfare in a distribution network operated by a virtual power player that aggregates and manages the available energy resources. When facing a situation of excessive non-dispatchable generation, including wind power, real time pricing is applied in order to induce the increase of consumption so that wind curtailment is minimized. This method is especially useful when actual and day-ahead resources forecast differ significantly. The distribution network characteristics and concerns are addressed by including the network constraints in the optimization model. The proposed methodology has been implemented in GAMS optimization tool and its application is illustrated in this paper using a real 937-bus distribution network with 20,310 consumers and 548...
distributed generators, some of them non-dispatchable and with must take contracts. The implemented scenario corresponds to a real day in Portuguese power system.

Modified discrete PSO to increase the delivered energy probability in distribution energy systems

This paper proposes a PSO based approach to increase the probability of delivering power to any load point by identifying new investments in distribution energy systems. The statistical failure and repair data of distribution components is the main basis of the proposed methodology that uses a fuzzy-probabilistic modeling for the components outage parameters. The fuzzy membership functions of the outage parameters of each component are based on statistical records. A Modified Discrete PSO optimization model is developed in order to identify the adequate investments in distribution energy system components which allow increasing the probability of delivering power to any customer in the distribution system at the minimum possible cost for the system operator. To illustrate the application of the proposed methodology, the paper includes a case study that considers a 180 bus distribution network.

Modified Particle Swarm Optimization Applied to Integrated Demand Response and DG Resources Scheduling

The elastic behavior of the demand consumption jointly used with other available resources such as distributed generation (DG) can play a crucial role for the success of smart grids. The intensive use of Distributed Energy Resources (DER) and the technical and contractual constraints result in large-scale non linear optimization problems that require computational intelligence methods to be solved. This paper proposes a Particle Swarm Optimization (PSO) based methodology to support the minimization of the operation costs of a virtual power player that manages the resources in a distribution network and the network itself. Resources include the DER available in the considered time period and the energy that can be bought from external energy suppliers. Network constraints are considered. The proposed approach uses Gaussian mutation of the strategic parameters and contextual self-parameterization of the maximum and minimum particle velocities. The case study considers a real 937 bus distribution network, with 20310 consumers and 548 distributed generators. The obtained solutions are compared with a deterministic approach and with PSO without mutation and Evolutionary PSO, both using self-parameterization.

General information
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Multi-agent approach for power system in a smart grid protection context

With increasing penetration of electricity application in society and the need of majority of appliance to electricity, high level of reliability becomes more essential; in one hand with deregulation of electricity market in production, transmission and distribution and emerge of competitive electricity markets and in the other hand with increasing penetration of Distributed Generation (DG) because of environment issues and diminishing in fossil fuel reserves and its price growth, made microgrid more attractive. Micro grids are considers as partial of SmartGrid system to accommodate DGs as well as control, protection and operation systems for electrical equipment to connect generation to consumption in better and more reliable way to maintain adequate operation system in distribution level. A highly challenging issue in Microgrid is protection scheme, which needs to develop and modify. This paper proposes a new approach for protection in a Microgrid environment as a part of SmartGrid: Multi-agent system to Protections Coordination (MAS-ProteC) which integrated in MASGriP (Multi-Agent Smart Grid Platform), providing protection services within network operation in SmartGrid in electricity market context.

Multi-Agent Based Smart Grid Management and Simulation: Situation Awareness and Learning in a Test Bed with Simulated and Real Installations and Players

The rising usage of distributed energy resources has been creating several problems in power systems operation. Virtual Power Players arise as a solution for the management of such resources. Additionally, approaching the main network as a series of subsystems gives birth to the concepts of smart grid and micro grid. Simulation, particularly based on multi-agent
technology is suitable to model all these new and evolving concepts. MASGrIP (Multi-Agent Smart Grid simulation Platform) is a system that was developed to allow deep studies of the mentioned concepts. This paper focuses on a laboratorial test bed which represents a house managed by a MASGrIP player. This player is able to control a real installation, responding to requests sent by the system operators and reacting to observed events depending on the context.

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Research: peer-review

**Multi-objective parallel particle swarm optimization for day-ahead Vehicle-to-Grid scheduling**
This paper presents a methodology for multi-objective day-ahead energy resource scheduling for smart grids considering intensive use of distributed generation and Vehicle-To-Grid (V2G). The main focus is the application of weighted Pareto to a multi-objective parallel particle swarm approach aiming to solve the dual-objective V2G scheduling: minimizing total operation costs and maximizing V2G income. A realistic mathematical formulation, considering the network constraints and V2G charging and discharging efficiencies is presented and parallel computing is applied to the Pareto weights. AC power flow calculation is included in the metaheuristics approach to allow taking into account the network constraints. A case study with a 33-bus distribution network and 1800 V2G resources is used to illustrate the performance of the proposed method.

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Research: peer-review

**Reactive Power Management Strategies in Future Smart Grids**
The reactive power management in distribution network with large penetration of distributed energy resources is an important task in future power systems. The control of reactive power allows the inclusion of more distributed recourses and a more efficient operation of distributed network. Currently, the reactive power is only controlled in large power plants and in high and very high voltage substations. In this paper, several reactive power control strategies considering a smart grids paradigm are proposed. In this context, the management of distributed energy resources and of the distribution network by an aggregator, namely Virtual Power Player (VPP), is proposed and implemented in a MAS simulation tool. The proposed methods have been computationally implemented and tested using a 32-bus distribution network with intensive use of distributed resources, mainly the distributed generation based on renewable resources. Results concerning the evaluation of the reactive power management algorithms are also presented and compared.

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Organisations: Technical University of Denmark, Instituto Politécnico do Porto, Instituto Superior de Engenharia do Porto
Real-time simulation of energy management in a domestic consumer

Recent and future changes in power systems, mainly in the smart grid operation context, are related to a high complexity of power networks operation. This leads to more complex communications and to higher network elements monitoring and control levels, both from network’s and consumers’ standpoint. The present work focuses on a real scenario of the LASIE laboratory, located at the Polytechnic of Porto. Laboratory systems are managed by the SCADA House Intelligent Management (SHIM), already developed by the authors based on a SCADA system. The SHIM capacities have been recently improved by including real-time simulation from Opal RT. This makes possible the integration of Matlab®/Simulink® real-time simulation models. The main goal of the present paper is to compare the advantages of the resulting improved system, while managing the energy consumption of a domestic consumer.

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Organisations: Department of Electrical Engineering, Automation and Control, Instituto Politécnico do Porto
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Publication date: 2013
SCADA house intelligent management for energy efficiency analysis in domestic consumers

The implementation of smart homes allows the domestic consumer to be an active player in the context of the Smart Grid (SG). This paper presents an intelligent house management system that is being developed by the authors to manage, in real time, the power consumption, the micro generation system, the charge and discharge of the electric or plug-in hybrid vehicles, and the participation in Demand Response (DR) programs. The paper proposes a method for the energy efficiency analysis of a domestic consumer using the SCADA House Intelligent Management (SHIM) system. The main goal of the present paper is to demonstrate the economic benefits of the implemented method. The case study considers the consumption data of some real cases of Portuguese house consumption over 30 days of June of 2012, the Portuguese real energy price, the implementation of the power limits at different times of the day and the economic benefits analysis. © 2013 IEEE.


The aggregation and management of Distributed Energy Resources (DERs) by an Virtual Power Players (VPP) is an important task in a smart grid context. The Energy Resource Management (ERM) of these DERs can become a hard and complex optimization problem. The large integration of several DERs, including Electric Vehicles (EVs), may lead to a scenario in which the VPP needs several hours to have a solution for the ERM problem. This is the reason why it is necessary to use metaheuristic methodologies to come up with a good solution with a reasonable amount of time. The present paper proposes a Simulated Annealing (SA) approach to determine the ERM considering an intensive use of DERs, mainly EVs. In this paper, the possibility to apply Demand Response (DR) programs to the EVs is considered. Moreover, a trip reduce DR program is implemented. The SA methodology is tested on a 32-bus distribution network with 2000 EVs, and the SA results are compared with a deterministic technique and particle swarm optimization results.
**Smart grid market using joint energy and ancillary services bids**

The power systems operation in the smart grid context increases significantly the complexity of their management. New approaches for ancillary services procurement are essential to ensure the operation of electric power systems with appropriate levels of stability, safety, quality, equity and competitiveness. These approaches should include market mechanisms which allow the participation of small and medium distributed energy resources players in a competitive market environment. In this paper, an energy and ancillary services joint market model used by an aggregator is proposed, considering bids of several types of distributed energy resources. In order to improve economic efficiency in the market, ancillary services cascading market mechanism is also considered in the model. The proposed model is included in MASCEM — a multi-agent system electricity market simulator. A case study considering a distribution network with high penetration of distributed energy resources is presented.

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**Stochastic framework for strategic decision-making of load-serving entities for day-ahead market**

The deregulation of electricity markets has diversified the range of financial transaction modes between independent system operator (ISO), generation companies (GENCO) and load-serving entities (LSE) as the main interacting players of a day-ahead market (DAM). LSEs sell electricity to end-users and retail customers. The LSE that owns distributed generation (DG) or energy storage units can supply part of its serving loads when the nodal price of electricity rises. This opportunity stimulates them to have storage or generation facilities at the buses with higher locational marginal prices (LMP). The short-term advantage of this model is reducing the risk of financial losses for LSEs in DAMs and its long-term benefit for the LSEs and the whole system is market power mitigation by virtually increasing the price elasticity of demand. This model also enables the LSEs to manage the financial risks with a stochastic programming framework.

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Stochastic Short-term Incentive-based Demand Response Scheduling of Load-serving Entities

In competitive electricity markets it is necessary for a profit-seeking load-serving entity (LSE) to optimally adjust the financial incentives offering the end users that buy electricity at regulated rates to reduce the consumption during high market prices. The LSE in this model manages the demand response (DR) by offering financial incentives to retail customers, in order to maximize its expected profit and reduce the risk of market power experience. The stochastic formulation is implemented into a test system where a number of loads are supplied through LSEs.

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Stochastic short-term maintenance scheduling of GENCOs in an oligopolistic electricity market

In the proposed model, the independent system operator (ISO) provides the opportunity for maintenance outage rescheduling of generating units before each short-term (ST) time interval. Long-term (LT) scheduling for 1 or 2 years in advance is essential for the ISO and the generation companies (GENCOs) to decide their LT strategies; however, it is not possible to be exactly followed and requires slight adjustments. The Cournot-Nash equilibrium is used to characterize the decision-making procedure of an individual GENCO for ST intervals considering the effective coordination with LT plans. Random inputs, such as parameters of the demand function of loads, hourly demand during the following ST time interval and the expected generation pattern of the rivals, are included as scenarios in the stochastic mixed integer program defined to model the payoff-maximizing objective of a GENCO. Scenario reduction algorithms are used to deal with the computational burden. Two reliability test systems were chosen to illustrate the effectiveness of the proposed model for the ST decision-making process for future planned outages from the point of view of a GENCO.

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Strategic bidding in electricity markets: An agent-based simulator with game theory for scenario analysis

Electricity markets are complex environments, involving a large number of different entities, with specific characteristics and objectives, making their decisions and interacting in a dynamic scene. Game-theory has been widely used to support decisions in competitive environments; therefore its application in electricity markets can prove to be a high potential tool. This paper proposes a new scenario analysis algorithm, which includes the application of game-theory, to evaluate and preview different scenarios and provide players with the ability to strategically react in order to exhibit the behavior that better fits their objectives. This model includes forecasts of competitor players’ actions, to build models of their behavior, in order to define the most probable expected scenarios. Once the scenarios are defined, game theory is applied to support the choice of the action to be performed. MASCEM (Multi-Agent System for Competitive Electricity Markets) is a multi-agent electricity market simulator that models market players and simulates their operation in the market. The scenario analysis algorithm has been tested within MASCEM and our experimental findings with a case study based on real data from the Iberian Market are presented and discussed.

Supervision functions - Secure operation of sustainable power systems

The globalization of use of Distributed Generation (DG) and other distributed energy resources in recent years have strongly influenced the power systems operation changes. The growing use of new technologies such as Phasor Measurements Units (PMUs) increases the possibilities and the efficiency of power systems operation control. The use of PMUs allows more penetration of DG mainly, with technologies based on renewable resources with intermittent and unpredictable operation such as wind power. This paper introduces the Secure Operation of Sustainable Power Systems (SOSPO) project. The SOSPO project tries to respond to the question “How to ensure a secure operation of the future power system where the operating point is heavily fluctuating?” focusing in the Supervision module architecture and in the power system operation states. The main goal of Supervision module is to determine the power system operation state based on new stability and security parameters derived from PMUs measurement and coordinate the use of automatic and manual control actions. The coordination of the control action is based not only in the static indicators but also in the performance evaluation of control actions. Based in the performance evaluation, the control allocation uses an adaptive mechanism to give more or less importance to the actions considering the existent operation context.

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Upper Ontology for Multi-Agent Energy Systems’ Applications

Energy systems worldwide are complex and challenging environments. Multi-agent based simulation platforms are increasing at a high rate, as they show to be a good option to study many issues related to these systems, as well as the involved players at act in this domain. In this scope the authors research group has developed three multi-agent systems: MASCEM, which simulates the electricity markets; ALBidS that works as a decision support system for market players; and MASGrIP, which simulates the internal operations of smart grids. To take better advantage of these systems, their integration is mandatory. For this reason, is proposed the development of an upper-ontology which allows an easier cooperation and adequate communication between them. Additionally, the concepts and rules defined by this ontology can be expanded and complemented by the needs of other simulation and real systems in the same areas as the mentioned systems. Each system's particular ontology must be extended from this top-level ontology.

Virtual Power Players Internal Negotiation and Management in MASCEM

Electricity Markets are not only a new reality but an evolving one as the involved players and rules change at a relatively high rate. Multi-agent simulation combined with Artificial Intelligence techniques may result in very helpful sophisticated tools. This paper presents a new methodology for the management of coalitions in electricity markets. This approach is tested using the multi-agent market simulator MASCEM (Multi-Agent Simulator of Competitive Electricity Markets), taking advantage of its ability to provide the means to model and simulate Virtual Power Players (VPP). VPPs are represented as coalitions of agents, with the capability of negotiating both in the market and internally, with their members in order to combine and manage their individual specific characteristics and goals, with the strategy and objectives of the VPP itself. A case study using real data from the Iberian Electricity Market is performed to validate and illustrate the proposed approach.