Flexanalytics Documentation

Release 0.1

Ricardo Fernández-Blanco

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Contents

FlexAnalytics is an ERC Starting Grant project led by Juan Miguel Morales, and developed by his research group OASYS. This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No 755705).

This project aims to provide data-driven methodologies for paradigmatic problems in power systems operations in the context of smart grids.

CHAPTER 1

Preamble

Activating the demand response, although a major challenge, may also bring tremendous benefits to society, with potential cost savings in the billions of euros. This project will exploit methods of inverse problems, multi-level programming and machine learning to develop a pioneering system that enables the active participation of a group of price-responsive consumers of electricity in the wholesale electricity markets. Through this, they will be able to make the most out of their flexible consumption.

FlexAnalytics proposes a generalized scheme for so-called inverse optimization that materializes into a novel data-driven approach to the market bidding problem that, unlike existing approaches, combines the tasks of forecasting, model formulation and estimation, and decision-making in an original unified theoretical framework. The project will also address big-data challenges, as the proposed system will leverage weather, market, and demand information to capture the many factors that can affect the price-response of a pool of flexible consumers.

On a fundamental level, *FlexAnalytics* will produce a novel mathematical framework for data-driven decision making. On a practical level, *FlexAnalytics* will show that this framework can facilitate the best use of a large amount and a wide variety of data to efficiently operate the sustainable energy systems of the future.

On this site you can find more details on *FlexAnalytics*. All work related to the project is summarised below.

CHAPTER 2

Contents

2.1 Journal papers

The project *FlexAnalytics* has produced several research papers, which have been published in high-impact journals:

1. A. Esteban-Pérez and J.M. Morales, *Distributionally Robust Stochastic Programs with Side Information Based on Trimmings*, *Mathematical Programming*, vol. 195, no. 1, pp. 1069–1105, November, 2022.
2. A. Esteban-Pérez and J.M. Morales, *Distributionally Robust Optimal Power Flow with Contextual Information*, European Journal of Operational Research‘ vol. 305, no. 1, pp.O.A, October, 2022.
3. A. Jiménez-Cordero, J.M. Morales and S. Pineda, *Warm-starting Constraint Generation for Mixed-integer Optimization: A Machine Learning Approach*, *Knowledge-Based Systems* vol. 253, pp.109570, October, 2022.
4. A. Porras, S. Pineda, J.M. Morales and A. Jimenez-Cordero, *Cost-driven Screening of Network Constraints for the Unit Commitment Problem* *IEEE Transactions on Power Systems*, (EA) pp. 1–1 March, 2022.
5. S. Pineda and J.M. Morales, *Is Learning for the Unit Commitment Problem a Low-hanging Fruit?* *Electric Power Systems Research*, (EA) vol. 207, pp. 107851, June, 2022.
6. M. A. Muñoz, S. Pineda and J.M. Morales, *A Bilevel Framework for Decision-making Under Uncertainty with Contextual Information*, *Omega*, (EA) vol. 108, pp. 102575, April, 2022.
7. R. Fernández-Blanco, J.M. Morales, S. Pineda and Á. Porras, *Inverse Optimization with Kernel Regression: Application to The Power Forecasting and Bidding Of A Fleet Of Electric Vehicles*, *Computer and Operations Research*, vol. 134, pp. 105405, October 2021.
8. A. Jiménez-Cordero, J.M. Morales and S. Pineda, *A Novel Embedded Min-Max Approach for Feature Selection in Nonlinear Support Vector Machine Classification*, *European Journal of Operations Research*, vol. 293, no. 1, pp. 24–35, August 2021.
9. A. Esteban-Pérez and J.M. Morales, *Partition-based Distributionally Robust Optimization via Optimal Transport with Order Cone Constraints*, *4OR A Quarterly Journal of Operations Research*, June 2021.
10. R. Fernández-Blanco, J.M. Morales and S. Pineda, *Forecasting the Price-response of a Pool of Buildings via Homothetic Inverse Optimization*, *Applied Energy* vol. 290, pp.116791, May 2021.

11. S. Pineda, J.M. Morales and A. Jiménez-Cordero, *Data-Driven Screening of Network Constraints for Unit Commitment*, *IEEE Transactions on Power Systems*, vol. 35, no. 5, pp. 3695–3705, September 2020.

12. M. A. Muñoz, J.M. Morales, and S. Pineda, *Feature-driven Improvement of Renewable Energy Forecasting and Trading*, *IEEE Transactions on Power Systems*, vol. 35, no. 5, pp. 3753–3763, September 2020.

13. Á. Porras, R. Fernández-Blanco, J.M. Morales and S. Pineda, *An Efficient Robust Approach to the Day-ahead Operation of an Aggregator of Electric Vehicles, IEEE Transactions on Smart Grid*, vol. 11, no. 6, pp. 4960–4970, June 2020.

14. S. Pineda, R. Fernández-Blanco and J.M. Morales, *Time-Adaptive Unit Commitment*, *IEEE Transactions on Power Systems*, vol. 34, no. 5, pp. 3869–3878, September 2019.

15. S. Pineda and J.M. Morales, *Solving Linear Bilevel Problems Using Big-Ms: Not All That Glitters Is Gold*, *IEEE Transactions on Power Systems*, vol. 34, no. 3, pp. 2469–2471, May 2019.

2.1.1 Distributionally Robust Optimal Power Flow with Contextual Information

This is a summary of the work that can be found in [1]. Open Access pdf is available at [2].

Abstract

In this paper, we develop a distributionally robust chance-constrained formulation of the Optimal Power Flow problem (OPF) whereby the system operator can leverage contextual information. For this purpose, we exploit an ambiguity set based on probability trimmings and optimal transport through which the dispatch solution is protected against the incomplete knowledge of the relationship between the OPF uncertainties and the context that is conveyed by a sample of their joint probability distribution. We provide a tractable reformulation of the proposed distributionally robust chance-constrained OPF problem under the popular conditional-value-at-risk approximation. By way of numerical experiments run on a modified IEEE-118 bus network with wind uncertainty, we show how the power system can substantially benefit from taking into account the well-known statistical dependence between the point forecast of wind power outputs and its associated prediction error. Furthermore, the experiments conducted also reveal that the distributional robustness conferred on the OPF solution by our probability-trimmings-based approach is superior to that bestowed by alternative approaches in terms of expected cost and system reliability.

Citation

If you would like to cite this work, please use the following citation:

> Adrián Esteban-Pérez, Juan M. Morales, ´Distributionally Robust Optimal Power Flow with Contextual Information‘ European Journal of Operational Research, 2022

You can use this bibtex entry:

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@article{ESTEBANPEREZ2022,
title = {Distributionally Robust Optimal Power Flow with Contextual Information},
journal = {European Journal of Operational Research},
year = {2022},
issn = {0377-2217},
doi = {https://doi.org/10.1016/j.ejor.2022.10.024},
url = {https://www.sciencedirect.com/science/article/pii/S0377221722008128},
author = {Adrián Esteban-Pérez and Juan M. Morales},}
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2.1.2 Warm-starting Constraint Generation for Mixed-integer Optimization: A Machine Learning Approach

This is a summary of the work that can be found in [1]. Open Access pdf is available at [2].

Abstract

Mixed Integer Linear Programs (MILP) are well known to be NP-hard (Non-deterministic Polynomial-time hard) problems in general. Even though pure optimization-based methods, such as constraint generation, are guaranteed to provide an optimal solution if enough time is given, their use in online applications remains a great challenge due to their usual excessive time requirements. To alleviate their computational burden, some machine learning techniques (ML) have been proposed in the literature, using the information provided by previously solved MILP instances. Unfortunately, these techniques report a non-negligible percentage of infeasible or suboptimal instances. By linking mathematical optimization and machine learning, this paper proposes a novel approach that speeds up the traditional constraint generation method, preserving feasibility and optimality guarantees. In particular, we first identify offline the so-called invariant constraint set of past MILP instances. We then train (also offline) a machine learning method to learn an invariant constraint set as a function of the problem parameters of each instance. Next, we predict online an invariant constraint set of the new unseen MILP application and use it to initialize the constraint generation method. This warm-started strategy significantly reduces the number of iterations to reach optimality, and therefore, the computational burden to solve online each MILP problem is significantly reduced. Very importantly, all the feasibility and optimality theoretical guarantees of the traditional constraint generation method are inherited by our proposed methodology. The computational performance of the proposed approach is quantified through synthetic and real-life MILP applications.

Citation

If you would like to cite this work, please use the following citation:

> Asunción Jiménez-Cordero, Juan Miguel Morales, Salvador Pineda *Warm-starting Constraint Generation for Mixed-integer Optimization: A Machine Learning Approach* in Knowledge-Based Systems vol. 253 pp. 109570, 2022.

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title={Warm-starting constraint generation for mixed-integer optimization: A Machine
↪Learning Approach},
year={2022},
volume={253},
number={-},
pages={109570},
doi={10.1016/j.knosys.2022.109570}}
ISSN={0950-7051},}
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2.1.3 Cost-driven Screening of Network Constraints for the Unit Commitment Problem

This is a summary of the work that can be found in [1]. Open Access pdf is available at [2].

Abstract

In an attempt to speed up the solution of the unit commitment (UC) problem, both machine-learning and optimization-based methods have been proposed to lighten the full UC formulation by removing as many superfluous line-flow constraints as possible. While the elimination strategies based on machine learning are fast and typically delete more constraints, they may be over-optimistic and result in infeasible UC solutions. For their part, optimization-based methods seek to identify redundant constraints in the full UC formulation by exploring the feasibility region of an LP-relaxation. In doing so, these methods only get rid of line-flow constraints whose removal leaves the feasibility region of the original UC problem unchanged. In this paper, we propose a procedure to substantially increase the line-flow constraints that are filtered out by optimization-based methods without jeopardizing their appealing ability of preserving feasibility. Our approach is based on tightening the LP-relaxation that the optimization-based method uses with a valid inequality related to the objective function of the UC problem and hence, of an economic nature. The result is that the so strengthened optimization-based method identifies not only redundant line-flow constraints but also inactive ones, thus leading to more reduced UC formulations.

Citation

If you would like to cite this work, please use the following citation:

A. Porras, S. Pineda, J. M. Morales and A. Jimenez-Cordero, "Cost-driven Screening of Network Constraints for the Unit Commitment Problem," in IEEE Transactions on Power Systems, doi: 10.1109/TPWRS.2022.3160016. 2022

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year={2022},
volume={},
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pages={1-1},
doi={10.1109/TPWRS.2022.3160016}}
ISSN={1558-0679},}
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2.1.4 Is Learning for the Unit Commitment Problem a Low-hanging Fruit?

This is a summary of the work that can be found in [1]. Open Access pdf is available at [2].

Abstract

The blast wave of machine learning and artificial intelligence has also reached the power systems community, and amid the frenzy of methods and black-box tools that have been left in its wake, it is sometimes difficult to perceive a glimmer of Occam's razor principle. In this letter, we use the unit commitment problem (UCP), an NP-hard mathematical program that is fundamental to power system operations, to show that simplicity must guide any strategy to solve it, in particular those that are based on learning from past UCP instances. To this end, we apply a naive algorithm to produce candidate solutions to the UCP and show, using a variety of realistically sized power systems, that we are able to find optimal or quasi-optimal solutions with remarkable speedups. Our claim is thus that any sophistication of the learning method must be backed up with a statistically significant improvement of the results in this letter.

Citation

If you would like to cite this work, please use the following citation:

S. Pineda and J.M. Morales, *Is learning for the unit commitment problem a low-hanging fruit?* doi.org/10.1016/j.epsr.2022.107851, 2022.

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title={Is learning for the unit commitment problem a low-hanging fruit?},
year={2022},
volume={207},
number={-},
pages={107851},
doi={doi.org/10.1016/j.epsr.2022.107851}}
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2.1.5 A Bilevel Framework For Decision-making Under Uncertainty With Contextual Information

This is a summary of the work that can be found in [1]. Open Access pdf is available at [2].

Abstract

In this paper, we propose a novel approach for data-driven decision-making under uncertainty in the presence of contextual information. Given a finite collection of observations of the uncertain parameters and potential explanatory variables (i.e., the contextual information), our approach fits a parametric model to those data that is specifically tailored to maximizing the decision value, while accounting for possible feasibility constraints. From a mathematical point of view, our framework translates into a bilevel program, for which we provide both a fast regularization procedure and a big-M-based reformulation that can be solved using off-the-shelf optimization solvers. We showcase the benefits of moving from the traditional scheme for model estimation (based on statistical quality metrics) to decision-guided prediction using three different practical problems. We also compare our approach with existing ones in a realistic case study that considers a strategic power producer that participates in the Iberian electricity market. Finally, we use these numerical simulations to analyze the conditions (in terms of the firm's cost structure and production capacity) under which our approach proves to be more advantageous to the producer..

Citation

If you would like to cite this work, please use the following citation:

M.A. Muñoz, S. Pineda, J.M. Morales, *A bilevel framework for decision-making under uncertainty with contextual information*, *Omega*, vol. 108, pp. 102575, Abril, 2022.

You can use this bibtex entry:

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  pages={102575},
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}
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2.1.6 Distributionally Robust Stochastic Programs with Side Information Based on Trimmings

This is a summary of the work that can be found in [1]. Open Access pdf is available at [2].

Abstract

We consider stochastic programs conditional on some covariate information, where the only knowledge of the possible relationship between the uncertain parameters and the covariates is reduced to a finite data sample of their joint distribution. By exploiting the close link between the notion of trimmings of a probability measure and the partial mass transportation problem, we construct a data-driven Distributionally Robust Optimization (DRO) framework to hedge the decision against the intrinsic error in the process of inferring conditional information from limited joint data. We show that our approach is computationally as tractable as the standard (without side information) Wasserstein-metric-based DRO and enjoys performance guarantees. Furthermore, our DRO framework can be conveniently used to address data-driven decision-making problems under contaminated samples. Finally, the theoretical results are illustrated using a single-item newsvendor problem and a portfolio allocation problem with side information.

Citation

If you would like to cite this work, please use the following citation:

> Esteban-Pérez, A., Morales, J.M. Distributionally robust stochastic programs with side information based on trimmings. Mathematical Programming vol. 195, no. 1, pp 1069–1105 (2022). https://doi.org/10.1007/s10107-021-01724-0

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  journal={Mathematical Programming},
  volume={195},
  number={1},
  pages={1069--1105},
  year={2022},
  publisher={Springer}
}
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2.1.7 Inverse Optimization with Kernel Regression: Application to The Power Forecasting and Bidding Of A Fleet Of Electric Vehicles

This is a summary of the work that can be found in [1]. Open Access pdf is available at [2].

Abstract

This paper considers an aggregator of Electric Vehicles (EVs) who aims to learn the aggregate power of his/her fleet while also participating in the electricity market. The proposed approach is based on a data-driven inverse optimization (IO) method, which is highly nonlinear. To overcome such a caveat, we use a two-step estimation procedure which requires solving two convex programs. Both programs depend on penalty parameters that can be adjusted by using grid search. In addition, we propose the use of kernel regression to account for the nonlinear relationship between the behavior of the pool of EVs and the explanatory variables, i.e., the past electricity prices and EV fleet's driving patterns. Unlike any other forecasting method, the proposed IO framework also allows the aggregator to derive a bid/offer curve, i.e. the tuple of price-quantity to be submitted to the electricity market, according to the market rules. We show the benefits of the proposed method against the machine-learning techniques that are reported to exhibit the best forecasting performance for this application in the technical literature.

Citation

If you would like to cite this work, please use the following citation:

R. Fernández-Blanco, J. M. Morales, S. Pineda, and Á. Porras ´Inverse Optimization with Kernel Regression: Application to The Power Forecasting and Bidding Of A Fleet Of Electric Vehicles´, *Computer and Operations Research*, vol. 134, pp. 105405, Oct. 2021.

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  author={Ricardo Fernández-Blanco and Juan Miguel Morales and Salvador Pineda and␣
↪Álvaro Porras},
  journal={Computers & Operations Research},
  volume={134},
  number={},
  pages={105405},
  year={2021},
  publisher={Elsevier}
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2.1.8 A Novel Embedded Min-Max Approach for Feature Selection in Nonlinear Support Vector Machine Classification

This is a summary of the work that can be found in [1]. Open Access pdf is available at [2]

Abstract

In recent years, feature selection has become a challenging problem in several machine learning fields, such as classification problems. Support Vector Machine (SVM) is a well-known technique applied in classification tasks. Various methodologies have been proposed in the literature to select the most relevant features in SVM. Unfortunately, all of them either deal with the feature selection problem in the linear classification setting or propose ad-hoc approaches that are difficult to implement in practice. In contrast, we propose an embedded feature selection method based on a min-max optimization problem, where a trade-off between model complexity and classification accuracy is sought. By leveraging duality theory, we equivalently reformulate the min-max problem and solve it without further ado using off-the-shelf software for nonlinear optimization. The efficiency and usefulness of our approach are tested on several benchmark data sets in terms of accuracy, number of selected features and interpretability

Citation

If you would like to cite this work, please use the following citation:

> Asunción Jiménez-Cordero and Juan Miguel Morales and Salvador Pineda, "A novel embedded min-max approach for feature selection in nonlinear support vector machine classification" in European Journal of Operational Research, vol. 293, no. 1, pp. 24-35, Aug. 2021

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@ARTICLE{JIMENEZCORDERO2020,
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year={2021},
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volume={293},
number={1},
pages={24-35},}
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2.1.9 Partition-based Distributionally Robust Optimization via Optimal Transport with Order Cone Constraints

This is a summary of the work that can be found in [1]. Open Access pdf is available at [2].

Abstract

In this paper we wish to tackle stochastic programs affected by ambiguity about the probability law that governs their uncertain parameters. Using optimal transport theory, we construct an ambiguity set that exploits the knowledge about the distribution of the uncertain parameters, which is provided by: (1) sample data and (2) a-priori information on the order among the probabilities that the true data-generating distribution assigns to some regions of its support set. This type of order is enforced by means of order cone constraints and can encode a wide range of information on the shape of the probability distribution of the uncertain parameters such as information related to monotonicity or multi-modality. We seek decisions that are distributionally robust. In a number of practical cases, the resulting distributionally robust optimization (DRO) problem can be reformulated as a finite convex problem where the a-priori information translates into linear constraints. In addition, our method inherits the finite-sample performance guarantees of the Wasserstein-metric-based DRO approach proposed by Mohajerin Esfahani and Kuhn (Math Program 171(1–2):115–166. https://doi.org/10.1007/s10107-017-1172-1, 2018), while generalizing this and other popular DRO approaches. Finally, we have designed numerical experiments to analyze the performance of our approach with the newsvendor problem and the problem of a strategic firm competing à la Cournot in a market.

Citation

If you would like to cite this work, please use the following citation:

> Esteban-Pérez, A., Morales, J.M. Partition-based distributionally robust optimization via optimal transport with order cone constraints. 4OR-Q J Oper Res (2021). https://doi.org/10.1007/s10288-021-00484-z

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  author={Esteban-Pérez, Adrián and Morales, Juan M.},
  journal={4OR},
  volume={},
  number={},
  pages={},
  year={2021},
  publisher={Springer}
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2.1.10 Forecasting the Price-response of a Pool of Buildings via Homothetic Inverse Optimization

This is a summary of the work that can be found in [1]. Open Access pdf is available at [2]

Abstract

This paper focuses on the day-ahead forecasting of the aggregate power of a pool of smart buildings equipped with thermostatically-controlled loads. We first propose the modeling of the aggregate behavior of its power trajectory by using a geometric approach. Specifically, we assume that the aggregate power is a homothet of a prototype building, whose physical and technical parameters are chosen to be the mean of those in the pool. This allows us to preserve the building thermal dynamics of the pool. We then apply inverse optimization to estimate the homothetic parameters with bilevel programming. The lower level characterizes the price-response of the ensemble by a set of marginal utility curves and a homothet of the prototype building, which, in turn, are inferred in the upper-level problem. The upper level minimizes the mean absolute error over a training sample. This bilevel program is transformed into a regularized nonlinear problem that is initialized with the solution given by an efficient heuristic procedure. This heuristic consists in solving two linear programs and its solution is deemed a suitable proxy for the original bilevel problem. The results have been compared to state-of-the-art methodologies.

Citation

If you would like to cite this work, please use the following citation:

> Ricardo Fernández-Blanco and Juan Miguel Morales and Salvador Pineda, "Forecasting the price-response of a pool of buildings via homothetic inverse optimization" in Applied Energy, vol. 290, pp. 116791, May. 2021

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author={R. {Fernández-Blanco}, J. M. {Morales} and S. {Pineda}},
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↪optimization},
year={2021},
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volume={290},
pages={116791},}
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2.1.11 Data-Driven Screening of Network Constraints for Unit Commitment

This is a summary of the work that can be found in [1]. Open Access pdf is available at [2]

Abstract

The transmission-constrained unit commitment (TC-UC) problem is one of the most relevant problems solved by independent system operators for the daily operation of power systems. Given its computational complexity, this problem is usually not solved to global optimality for real-size power systems. In this paper, we propose a data-driven method that leverages historical information to screen out network constraints in the TC-UC problem. First, past data on demand and renewable generation throughout the network are used to learn the congestion status of transmission lines. Then, we infer the lines that will not become congested for upcoming operating conditions based on such learning and disregard their capacity constraints. This way, we formulate a reduced TC-UC problem that is easier to solve. Numerical results on a medium- and a large-size power system show that the proposed approach outperforms existing ones by significantly reducing the computational time while obtaining solutions that are equal or close to the one obtained with the original TC-UC problem. Furthermore, the purely data-driven method we propose can be seamlessly complemented with a constraint generation procedure to guarantee that the optimal solution to the original TC-UC problem is eventually recovered.

Citation

If you would like to cite this work, please use the following citation:

S. Pineda, J. M. Morales and A. Jiménez-Cordero, "Data-Driven Screening of Network Constraints for Unit Commitment," in IEEE Transactions on Power Systems, vol. 35, no. 5, pp. 3695-3705, Sept. 2020.

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title={Data-Driven Screening of Network Constraints for Unit Commitment},
year={2020},
volume={35},
number={5},
pages={3695-3705},}
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2.1.12 Feature-driven Improvement of Renewable Energy Forecasting and Trading

This is a summary of the work that can be found in [1]. Open Access pdf is available at [2]

Abstract

Inspired from recent insights into the common ground of machine learning, optimization and decision-making, this paper proposes an easy-to-implement, but effective procedure to enhance both the quality of renewable energy forecasts and the competitive edge of renewable energy producers in electricity markets with a dual-price settlement of imbalances. The quality and economic gains brought by the proposed procedure essentially stem from the utilization of valuable predictors (also known as features) in a data-driven newsvendor model that renders a computationally inexpensive linear program. We illustrate the proposed procedure and numerically assess its benefits on a realistic case study that considers the aggregate wind power production in the Danish DK1 bidding zone as the variable to be predicted and traded. Within this context, our procedure leverages, among others, spatial information in the form of wind power forecasts issued by transmission system operators (TSO) in surrounding bidding zones and publicly available in online platforms. We show that our method is able to improve the quality of the wind power forecast issued by the Danish TSO by several percentage points (when measured in terms of the mean absolute or the root mean square error) and to significantly reduce the balancing costs incurred by the wind power producer.

Citation

If you would like to cite this work, please use the following citation:

M. A. Muñoz, J. M. Morales, and S. Pineda, *Feature-driven Improvement of Renewable Energy Forecasting and Trading*, *IEEE Transactions on Power Systems*, vol. 35, no. 5, pp. 3753-3763, 2020.

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year={2020},
volume={35},
number={5},
pages={3753-3763},
doi={10.1109/TPWRS.2020.2975246}}
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2.1.13 An Efficient Robust Approach to the Day-ahead Operation of an Aggregator of Electric Vehicles

This is a summary of the work that can be found in [1]. Open Access pdf is available at [2].

Abstract

The growing use of electric vehicles (EVs) may hinder their integration into the electricity system as well as their efficient operation due to the intrinsic stochasticity associated with their driving patterns. In this work, we assume a profit-maximizer EV-aggregator who participates in the day-ahead electricity market. The aggregator accounts for the technical aspects of each individual EV and the uncertainty in its driving patterns. We propose a hierarchical optimization approach to represent the decision-making of this aggregator. The upper level models the profit-maximizer aggregator's decisions on the EV-fleet operation, while a series of lower-level problems computes the worst-case EV availability profiles in terms of battery draining and energy exchange with the market. Then, this problem can be equivalently transformed into a mixed-integer linear single-level equivalent given the totally unimodular character of the constraint matrices of the lower-level problems and their convexity. Finally, we thoroughly analyze the benefits of the hierarchical model compared to the results from stochastic and deterministic models.

Citation

If you would like to cite this work, please use the following citation:

> Á. Porras, R. Fernández-Blanco, J. M. Morales and S. Pineda, "An Efficient Robust Approach to the Day-ahead Operation of an Aggregator of Electric Vehicles," in IEEE Transactions on Smart Grid, doi: 10.1109/TSG.2020.3004268, 2020

You can use this bibtex entry:

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journal={IEEE Transactions on Smart Grid},
title={An Efficient Robust Approach to the Day-Ahead Operation of an Aggregator of␣
↪Electric Vehicles},
year={2020},
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volume={11},
number={6},
pages={4960-4970},
doi={10.1109/TSG.2020.3004268}}
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2.1.14 Time-Adaptive Unit Commitment

This is a summary of the work that can be found in [1]. Open Access pdf is available at [2]

Abstract

The short-term operation of a power system is usually planned by solving a day-ahead unit commitment problem. Due to historical reasons, the commitment of the power generating units is decided over a time horizon typically consisting of the 24 hourly periods of a day. In this paper, we show that, as a result of the increasing penetration of intermittent renewable generation, this somewhat arbitrary and artificial division of time may prove to be significantly suboptimal and counterproductive. Instead, we propose a time-adaptive day-ahead unit commitment formulation that better captures the net-demand variability throughout the day. The proposed formulation provides the commitment and dispatch of thermal generating units over a set of 24 time periods too, but with different duration. To do that, we use a clustering procedure to select the duration of those adaptive time periods taking into account the renewable generation and demand forecasts. Numerical results show that, without increasing the computational burden, the proposed time-adaptive unit commitment allows for a more efficient use of the system flexibility, which translates into a lower operating cost and a higher penetration of renewable production than those achieved by a conventional hourly unit commitment problem.

Citation

If you would like to cite this work, please use the following citation:

S. Pineda, R. Fernández-Blanco, and J. M. Morales, *Time-Adaptive Unit Commitment*, *IEEE Transactions on Power Systems*, vol. 34, no. 5, pp. 3869–3878, Sep. 2019.

You can use this bibtex entry:

```
@article{pineda2019_tauc,
  title={Time-adaptive unit commitment},
  author={Pineda, Salvador and Fern{\'a}ndez-Blanco, Ricardo and Morales, Juan Miguel}
↪,
  journal={IEEE Transactions on Power Systems},
  volume={34},
  number={5},
  pages={3869--3878},
  year={2019},
  publisher={IEEE}
}
```

2.1.15 Solving Linear Bilevel Problems Using Big-Ms: Not All That Glitters Is Gold

This is a summary of the work that can be found in [1]. Open Access pdf is available at [2].

Abstract

The most common procedure to solve a linear bilevel problem in the PES community is, by far, to transform it into an equivalent single-level problem by replacing the lower level with its KKT optimality conditions. Then, the complementarity conditions are reformulated using additional binary variables and large enough constants (big-Ms) to cast the single-level problemas a mixed-integer linear program that can be solved using optimization software. In most cases, such large constants are tuned by trial and error. We show, through a counterexample, that this widely used trial-and-error approach may lead to highly suboptimal solutions. Then, further research is required to properly select big-M values to solve linear bilevel problems.

Citation

If you would like to cite this work, please use the following citation:

S. Pineda and J. M. Morales, *Solving Linear Bilevel Problems Using Big-Ms: Not All That Glitters Is Gold*, *IEEE Transactions on Power Systems*, vol. 34, no. 3, pp. 2469–2471, May 2019.

You can use this bibtex entry:

```
@article{pineda2019solving,
  title={Solving linear bilevel problems using big-Ms: not all that glitters is gold},
  author={Pineda, Salvador and Morales, Juan Miguel},
  journal={IEEE Transactions on Power Systems},
  volume={34},
  number={3},
  pages={2469--2471},
  year={2019},
  publisher={IEEE}
}
```

2.2 Working papers

We never rest! *FlexAnalytics* continues its research with the following working papers and preprints:

1. Á. Porras, C. Domínguez, J. M. Morales, S. Pineda, Tight and compact sample average approximation for joint chance constrained optimal power flow, submitted May 2022
2. J. M. Morales, Miguel Á. Muñoz and S. Pineda, Value-oriented forecasting of net demand for electricity market clearing, latest version Mar. 2022.
3. A. Elías, J. M. Morales and S. Pineda, A functional data analysis approach to evolution outlier mining for grouped smart meters, also see code, latest version Oct. 2022.

2.3 Contributions to Conferences

The work developed by *Flexanalytics* has been presented in renowned national and international conferences:

1. **A. Esteban-Pérez**, Y. Rychener, **J.M. Morales** and D. Kuhn, *Data-driven distributionally robust optimization with multiple datasets:Applications to the OPF problem*, INFORMS 22, Indianapolis, USA,16-19th October, 2022. presentation
2. Á. Porras, C. Domínguez, J.M. Morales and S. Pineda, *Tight and compact sample average approximation for joint chance constrained optimal power flow*, INFORMS 22, Indianapolis, USA, 16-19th October, 2022. presentation

3. A. Jiménez-Cordero, *Solving mixed-integer programs with warm-starting constraint generation methods via machine learning tools*, 3rd Spanish Young Statisticians and Operational Researchers Meeting (SYSORM) Elche, Spain, 21st-23rd September, 2022. presentation
4. **J.M. Morales**, **S. Pineda** and Y. Dvorkin, *Learning the price response of active distribution networks for TSO-DSO coordination*, PESGM 22, Denver, USA, 17th-21st July, 2022. presentation
5. S. Pineda, J. M. Morales, A. Jiménez-Cordero, *Data-driven screening of network constraints for Unit Commitment*, PESGM 22, Denver, USA, 17th-21st July, 2022. presentation
6. J.M. Morales invited speaker at Roundtable with Forums *Opportunities and challenges of conducting OR research*, XXXII European Conference on Operational Research (EURO 22) Espoo, Finland, 4-7th July, 2022.
7. A. Jiménez-Cordero *Feature selection in (functional) SVM via bilevel optimization* YW4OR session XXXII European Conference on Operational Research (EURO 22) Espoo, Finland, 4-7th July, 2022. presentation
8. A. Jiménez-Cordero, J.M. Morales and S. Pineda *A novel machine-learning-aided approach for warm-starting constraint generation methods in MILPs*, XXXII European Conference on Operational Research (EURO 22) Espoo, Finland, 4-7th July, 2022. presentation
9. J.M. Morales, M.Á. Muñoz and S. Pineda *Value-oriented forecasting of net demand for electricity market clearing*, XXXII European Conference on Operational Research (EURO 22), Espoo, Finland, 4-7th July, 2022. presentation
10. S. Pineda and J.M. Morales, *Is learning for the Unit Commitment problem a low-hanging fruit?*, XXXII European Conference on Operational Research (EURO 22), Espoo, Finland, 4-7th July, 2022. presentation
11. M.Á Muñoz, J.M. Morales and S. Pineda, *A bilevel framework for decision-making under uncertainty with contextual information*, European Conference on Stochastic Optimization and Computational Management Science (ECSO-CMS 22), Venice, Italy, 29-30th June 1st July, 2022. presentation
12. Á. Porras, C. Domínguez, J.M. Morales and S. Pineda, *An MIP approach to tackle the Optimal Power Flow problem with probabilistic constraints*, European Conference on Stochastic Optimization and Computational Management Science (ECSO-CMS 22), Venice, Italy, 29-30th June 1st July, 2022. presentation
13. J.M. Morales and A. Esteban-Pérez, *Distributionally robust chance-constrained optimal power flow with contextual information*, European Conference on Stochastic Optimization and Computational Management Science (ECSO-CMS 22), Venice, Italy, 29-30th June 1st July, 2022. presentation
14. A. Esteban-Pérez and J.M. Morales, *Distributionally robust stochastic programs with side information based on trimmings*, Finalist for Best Paper Award. European Conference on Stochastic Optimization and Computational Management Science (ECSO-CMS 22), Venice, Italy, 29-30th June 1st July, 2022. presentation
15. Á. Porras, C. Domínguez, J. M. Morales and S. Pineda, *Chance-Constrained Optimization applied to the Optimal Power Flow problem: An MIP approach*, XXXIX National Congress of Statistics and Operational Research and the XIII Conference on Public Statistics (SEIO 2022) Granada, Spain, 7 - 10 June, 2022. presentation
16. S. Pineda, M. Á. Muñoz and J.M. Morales, *A bilevel framework for decision-making under uncertainty with contextual information*, XXXIX National Congress of Statistics and Operational Research and the XIII Conference on Public Statistics (SEIO 2022) Granada, Spain, 7 - 10 June, 2022. presentation
17. J.M. Morales and A. Esteban-Pérez, *Distributionally robust optimization with side information based on probability trimmings and optimal transport*, XXXIX National Congress of Statistics and Operational Research and the XIII Conference on Public Statistics (SEIO 2022) Granada, Spain, 7 - 10 June, 2022. presentation
18. A. Jiménez-Cordero, J.M. Morales and S. Pineda, *On warm-starting constraint generation methods via machine learning tools for solving mixed-integer programs*, XXXIX National Congress of Statistics and Operational Research and the XIII Conference on Public Statistics (SEIO 2022) Granada, Spain, 7 - 10 June, 2022. presentation

19. A. Elías, J.M. Morales and S. Pineda, *Functional depths in the context of functional time series*, XXXIX National Congress of Statistics and Operational Research and the XIII Conference on Public Statistics (SEIO 2022) Granada, Spain, 7 - 10 June, 2022. presentation

20. J. Huete, A. Elías, J.M. Morales and S. Pineda, *Forecasting the energy consumption of multiple buildings*, XXXIX National Congress of Statistics and Operational Research and the XIII Conference on Public Statistics (SEIO 2022) Granada, Spain, 7 - 10 June, 2022. presentation

21. A. Elías, J.M. Morales and S. Pineda, *Depth-based outlier detection for grouped smart meters: a functional data analysis toolbox*, 14th International Conference of the ERCIM WG on Computational and Methodological Studies (CMStatistics 2021), London, UK 18 - 20 December, 2021. presentation

22. A. Jiménez-Cordero, J.M. Morales and S. Pineda, *An offline-online strategy to improve MILP performance via machine learning tools*, New Bridges between Mathematics and Data Science. The Mathematical Strategic Network (Red Estratégica de Matemáticas (REM)), Valladolid, Spain, 8 - 11 November, 2021. presentation and video

23. J.M. Morales, M. Á. Muñoz and S. Pineda *Contextual merit-order dispatch under uncertain supply*, The Institute for Operations Research and the Management Sciences Annual Meeting (INFORMS 2021) Anaheim, USA, 24-27 October, 2021. presentation

24. S. Pineda, J.M. Morales and Y. Dvorkin *Learning-based coordination of transmission and distribution operations*, The Institute for Operations Research and the Management Sciences Annual Meeting (INFORMS 2021) Anaheim, USA, 24-27 October, 2021. presentation

25. A. Porras, J. M. Morales, S. Pineda, A. Jiménez-Cordero *Cost-driven screening of network constraints for the unit commitment problem*, The Institute for Operations Research and the Management Sciences Annual Meeting (INFORMS 2021) Anaheim, USA, 24-27 October, 2021. presentation

26. A. Elias, J. M. Morales, S. Pineda *Depth-based outlier detection for grouped smart meters: A functional data analysis toolbox*, The Institute for Operations Research and the Management Sciences Annual Meeting (INFORMS 2021) Anaheim, USA, 24-27 October, 2021. presentation

27. J.M. Morales, *Data-driven power systems (operations)*, Plenary Speaker Session, 31st European Conference on Operational Research (EURO 2021) Athens, Greece, 11 - 14 July, 2021. presentation

28. A. Esteban-Pérez and J.M Morales, *Distributionally robust optimization with side information based on probability trimmings and optimal transport*, 31st European Conference on Operational Research (EURO 2021) Athens, Greece, 11 - 14 July, 2021. presentation

29. S. Pineda, J. M. Morales and Y. Dvorkin, *Learning-based coordination of transmission and distribution operations*, 31st European Conference on Operational Research (EURO 2021) Athens, Greece, 11 - 14 July, 2021. presentation

30. M.Á. Muñoz, J.M.Morales and S.Pineda, *A bilevel framework for decision-making under uncertainty with contextual information*, 31st European Conference on Operational Research (EURO 2021) Athens, Greece, 11 - 14 July, 2021. presentation

31. Á. Porras, J.M. Morales, S.Pineda and A. Jiménez-Cordero, *Cost-aware constraint screening for the unit commitment problem*, 31st European Conference on Operational Research (EURO 2021) Athens, Greece, 11 - 14 July, 2021. presentation

32. A. Jiménez-Cordero, J. M. Morales and S. Pineda, *On improving MILP performance via machine learning tools*, 31st European Conference on Operational Research (EURO 2021)Athens, Greece, 11 - 14 July, 2021. presentation

33. S. Pineda, J.M. Morales and A. Jiménez-Cordero, *Data-driven screening of network constraints for unit commitment*, IEEE Power & Energy Society PowerTech Conference, Madrid, Spain, June 28 - July 2, 2021. presentation

34. S. Pineda, R. Fernandez-Blanco and J.M. Morales, *Time-adaptive unit commitment*, IEEE Power & Energy Society PowerTech Conference, Madrid, Spain, June 28 - July 2, 2021. presentation

35. Á.Porras, R.Fernández-Blanco, J.M.Morales and S.Pineda, *An efficient robust approach to the day-ahead operation of an aggregator of electric vehicles*, IEEE Power & Energy Society PowerTech Conference, Madrid, Spain, June 28 - July 2, 2021. presentation

36. M.A. Muñoz, J.M.Morales and S.Pineda, *Data-driven strategies for trading renewable energy production*, IEEE Power & Energy Society PowerTech Conference, Madrid, Spain, June 28 - July 2, 2021. presentation

37. M.Á. Muñoz, S. Pineda and J. M. Morales, *Optimal strategy of a Cournot firm through profit-driven learning*, The Institute for Operations Research and the Management Sciences Annual Meeting (INFORMS 2020) (online), 7-11 November 2020. presentation and video

38. A. Jiménez Cordero, S. Pineda and J.M. Morales, *Interpretable learning in power system operations*, The Institute for Operations Research and the Management Sciences Annual Meeting (INFORMS 2020) (online), 7-11 November 2020. presentation and video

39. Á. Porras, R. Fernández-Blanco, J.M. Morales and S. Pineda, *An efficient robust approach to the day-ahead operation of an aggregator of electric vehicles*, The Institute for Operations Research and the Management Sciences Annual Meeting (INFORMS 2020) (online), 7-11 November 2020. presentation

40. S. Pineda, J.M. Morales and A. Jiménez Cordero, *Data-driven screening of network constraints for unit commitment*, The Institute for Operations Research and the Management Sciences Annual Meeting (INFORMS 2020) (online), 7-11 November 2020. presentation and video

41. J.M. Morales, R. Fernández-Blanco and S. Pineda, *A homothetic inverse optimization approach to forecast the price-response of a pool of buildings*, The Institute for Operations Research and the Management Sciences Annual Meeting (INFORMS 2020) (online), 7-11 November 2020. presentation and video

42. A. Esteban-Pérez and J.M. Morales, *Distributionally robust prescriptive analytics based on optimal transport*, The Institute for Operations Research and the Management Sciences Annual Meeting (INFORMS 2020) (online), 7-11 November 2020. presentation and video

43. A. Jiménez-Cordero, J.M. Morales and S. Pineda, *A novel min-max approach to select features in nonlinear SVM classification*, elevator pitch – Autumn School on Bilevel Optimization, Trier University, Germany - virtual conference, 12-14 October 2020. presentation

44. Á. Porras, R. Fernández-Blanco, J.M. Morales and S. Pineda, *An efficient robust approach to the day-ahead operation of electric vehicles*, elevator pitch – Autumn School on Bilevel Optimization, Trier University, Germany - virtual conference, 12-14 October 2020. presentation

45. M.Á. Muñoz , J.M. Morales and S. Pineda, *A bilevel framework for decision-making under uncertainty with contextual information*, elevator pitch – Autumn School on Bilevel Optimization, Trier University, Germany - virtual conference, 12-14 October 2020. presentation

46. A. Jiménez-Cordero, J. M. Morales, and S. Pineda, *A min-max approach to feature selection for nonlinear SVM classification*, V Congreso de Jóvenes Investigadores La Real Sociedad Matemática Española (RSME) Castellón, Spain, 27th-31st January 2020. presentation

47. A. Esteban-Pérez and J. M. Morales, *Data-driven distributionally robust optimization via optimal transport with order cone constraints*, Jornada científica IMUS-UMA, Sevilla, Spain, 29th November 2019.

48. R. Fernández-Blanco, Á. Porras, S. Pineda, and J. M. Morales, *A data-driven forecasting model for an aggregator of electric vehicles via inverse optimization*, The Institute for Operations Research and the Management Sciences Annual Meeting (INFORMS 2019) Seattle, USA, 20th-23rd October 2019.

49. S. Pineda, R. Fernández-Blanco, and J. M. Morales, *Time-adaptive unit commitment*, The Institute for Operations Research and the Management Sciences Annual Meeting (INFORMS 2019) Seattle, USA, 20-23rd October 2019.

50. S. Wogrin, D. Tejada-Arango, S. Pineda, and J. M. Morales, *Analyzing time period aggregation methods for power system investment and operation models with renewables and storage*, The Institute for Operations Research and the Management Sciences Annual Meeting (INFORMS 2019) Seattle, USA, 20th-23rd October 2019.

51. J. M. Morales, M. Á. Muñoz, and S. Pineda, *A mathematical optimization approach to enhanced renewable energy forecasting and trading*, The Institute for Operations Research and the Management Sciences Annual Meeting (INFORMS 2019) Seattle, USA, 20th-23rd October 2019.

52. Á. Porras, R. Fernández-Blanco, J. M. Morales, and S. Pineda, Day-ahead operation of an aggregator of electric vehicles via optimization under uncertainty, 2nd International Conference on Smart Energy Systems and Technologies (SEST), Porto, Portugal, 9th-11th September 2019.

53. A. Esteban-Pérez and J. M. Morales, *Data-driven distributionally robust optimization via optimal transport with order cone constraints*, The XV International Conference on Stochastic Programming (ICSP XV), Trondheim, Norway, 29th July-2nd August 2019.

54. R. Fernández-Blanco, J. M. Morales, and S. Pineda, How can smart buildings be price-responsive?, 13th IEEE PowerTech 2019, Milano, Italy, 23rd-27th June 2019. *Best paper award*.

55. S. Pineda and J. M. Morales, *Efficiently solving linear bilevel programming problems using off-the-shelf optimization software*, 30th European Conference on Operational Research (EURO 2019) Dublin, Ireland, 23th-26th June 2019.

56. J. M. Morales, R. Fernández-Blanco, and S. Pineda, *A fast algorithm to estimate the cost and the right-hand side parameter vectors in inverse linear optimization*, 30th European Conference on Operational Research (EURO 2019) Dublin, Ireland, 23th-26th June 2019.

57. Á. Porras, R. Fernández-Blanco, S. Pineda, and J. M. Morales, *Day-ahead operation of an aggregator of electric vehicles via optimization under uncertainty*, 30th European Conference on Operational Research (EURO 2019) Dublin, Ireland, 23th-26th June 2019.

58. G. De Zotti, S. A. P. Kani, J. M. Morales and Henrik Madsen, *Control-based provision of ancillary services by flexible end-users*, 30th European Conference on Operational Research (EURO 2019) Dublin, Ireland, 23th-26th June 2019.

59. M. Á. Muñoz, J. M. Morales, and S. Pineda, *Data-driven strategies for trading renewable energy production*, The Institute for Operations Research and the Management Sciences Annual Meeting (INFORMS 2018) Phoenix, USA, 4th-7th November 2018.

60. A. Esteban-Pérez and J. M. Morales, *Data-driven distributionally robust optimization with Wasserstein metric, moment conditions and robust constraints*, 29th European Conference on Operational Research (EURO 2018) Valencia, Spain, 8th-11th July 2018.

2.4 Research Seminars

Sharing knowledge is cool! This is why *FlexAnalytics* has funded or the group have taken part in the following seminars:

1. *S. Pineda* and *J.M. Morales*, *Machine-learning Aided Operation and Planning of Power Systems*, Seminar as part of the PhD course *Optimization under uncertainty in power systems*, Institute of Electricity Economics and Energy Innovation, Graz University of Technology, Styria, Austria 26 May, 2022. The slides of the presentation can be found here.

2. *P. Kergus*, *Data-driven strategies for modeling and control - Application to building thermal modeling*, Invited speaker from LAPLACE, seminar, Ada Byron Research Centre, Málaga, Spain, 18th May 2022.

3. *J.M. Morales*, *Context-driven power system operations*, Invited speaker in the seminar series enOPTIMAL Massachusetts Institute of Technology (MIT), Cambridge, MA, EEUU, 1st April 2022. The presentation can be seen on the enOPTIMAL YouTube channel.
4. *A. Esteban-Pérez* and J.M. Morales, *Distributionally robust optimal power flow with contextual information*, College of Management of Technology (CMD) Seminar, Ecole Polythechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland, 30 November, 2021. The slides of the presentation can be found here.
5. *C. Domínguez Sánchez*, Invited guest speaker, *The Rank Pricing Problem: a mixed-integer linear optimization approach*, seminar, Ada Byron Research Centre, July 2021. The slides of the presentation can be found here.
6. *A. Jiménez-Cordero*, J. M. Morales and S. Pineda, *A novel embedded min-max approach for feature selection in nonlinear support vector machine classification*, Session candidates for the Ramiro Melendreras prize. Jornadas SEIO 2021, 9 -11 June, 2021. The slides of the presentation can be found here.
7. *A. Elías*, R. Jiménez, A.M. Paganoni and L.M. Sangalli, *Integrated depths for partially observed functional data*, Session candidates for the Ramiro Melendreras prize. Jornadas SEIO 2021, 9 -11 June, 2021. The slides of the presentation can be found here.
8. *J.M. Morales*, *S. Pineda*, M.A. Muñoz, and A. Esteban-Pérez, *Contextual decision-making under uncertainty*, NeEDS Machine Learning NeEDS Mathematical Optimization online seminars, March 2021. Watch the seminar here.
9. *S. Pineda*, M. A. Muñoz and J.M. Morales *A bilevel framework for decision-making under uncertainty with contextual information*, IUMA Day on Mathematical Optimization for Data Science, University of Zaragoza, 19 March, 2021. The slides of the presentation can be found here.
10. *A. Jiménez-Cordero*, J. M. Morales, and S. Pineda, *Feature selection in nonlinear SVM using a novel min-max approach*, NeEDS Machine Learning NeEDS Mathematical Optimization online seminars, February 2021. Watch the seminar here.
11. *S. Pineda*, *Machine-learning aided operation and planning of power systems*, New York University (Online) , April 2020. The slides of the presentation can be downloaded here and video.
12. V. Bucarey and *A. Jiménez-Cordero*, *Bilevel optimization for Stackelberg security games modeling*, *Statistical Classification*, Ada Byron Research Building , January 2020. The slides of both presentations can be downloaded here and here.

2.5 OASYS Seminar Series

As a vital forum for brainstorming, collaboration and sharing results, the *OASYS Seminar Series* was born. A monthly seminar/research platform where, not only members of OASYS working on the *FlexAnalytics* project, but also international researchers in the field, present their ideas, and get a fresh take on the ongoing work of *FlexAnalytics*. A number of new working relationships across Europe have been forged, and even new members of the team found, thanks to this initiative.

This recently culminated in a hugely successful symposium, with a number of experts, from distinct research groups and universities around Europe, invited to speak and share their knowledge. For more details on this symposium visit our group's website.

1. Alfredo Marín (University of Murcia) *Soft-margin Support Vector Machine: Ordered weighted average and some criticism*, Ada Byron Research Centre 3rd of October, 2022.
2. Akylas Stratigakos (Center PERSEE, Mines Paris, PSL University) *Towards the prescriptive analytics paradigm for energy forecasting and optimization in power systems.*, Ada Byron Research Centre 21st of September, 2022. presentation
3. Yadira Hernández Solano (Dpt. Applied Mathematics - UMA) *Métodos de integración geométrica para sistemas con función de Lyapunov*, Ada Byron Research Centre, 23rd of June, 2022. presentation

4. Pauline Kergus (CNRS researcher at LAPLACE (Laboratory on plasma and conversion of energy, Toulouse, France)) *Data-driven strategies for modeling and control: Application to building thermal modeling*, Ada Byron Research Centre, 18th of May, 2022. presentation
5. Alejandro Fernández Gil (University of Twente Enschede, Netherlands) *The composition of mathematical alogrithms for green vehicles routing considering emissions*, Ada Byron Research Centre, 5th of May, 2022.
6. Ricardo Gazquez Torres (University of Granada) *Continuous maximal covering location problems and related problems*, Ada Byron Research Centre, 7th of April, 2022. presentation
7. **Concepción Domínguez Sánchez** "Finding valid inequalities in MILPs: techniques and examples', Ada Byron Research Centre, 24th of February, 2022. presenation
8. **Adrián Esteban Pérez** *Distributionally Robust Optimization under consensual ambiguity*, Ada Byron Research Centre, 26th of January, 2022. presentation
9. **Miguel Ángel Muñoz Díaz** *Online wind energy bidding*, Ada Byron Research Centre, 15th December 2021. presentation
10. **José Gómez de la Varga** *State estimation*, Ada Byron Research Centre, 24th of November 2021. presentation
11. **Antonio Elías Fernández** - **Asunción Jiménez-Cordero** *Machine learning-aided optimization applied to mixed integer linear programming*, Ada Byron Research Centre, 20th October 2021. presentation
12. Concepción Domínguez Sánchez (Université Libre de Bruxelles, and the S. and Operations Research Department of the University of Murcia), *The Rank Pricing Problem: a mixed-integer linear optimization approach*, Ada Byron Research Centre, 16th July, 2021. presentation

2.6 Collaboration with Other Groups

The project *Flexanalytics* has also produced the following research results in collaboration with other international research groups:

1. **J.M. Morales** and **S.Pineda**, co-editors for special edition Essays on Operations Research in Energy, *TOP* vol. 30, no. 3 pp. 427–429 October, 2022.
2. V. Bucarey, M. Labbé **J. M. Morales** and **S. Pineda**, An Exact Dynamic Programming Approach to Segmented Isotonic Regression, *Omega*, vol. 105, pp. 102516, July 2021.
3. **J. M. Morales**, **S. Pineda** and Yury Dvorkin, Learning the Price Response of Active Distribution Networks for TSO-DSO Coordination, *IEEE Transactions on Power Systems*, vol. 37, no. 4, pp. 2858-2868, July 2022.
4. M. Gržanić, **J. M. Morales**, **S. Pineda** and T. Capuder, Electricity Cost-sharing in Energy Communities Under Dynamic Pricing and Uncertainty, *IEEE Access*, vol. 9, pp. 30225–30241, February 2021.
5. D. Guericke, I. Blanco, **J. M. Morales** and H. Madsen , A Two-phase Stochastic Programming Approach to Biomass Supply Planning for Combined Heat and Power Plants, *OR Spectrum*, vol. 42, no. 4, pp. 863–900, December 2020.
6. G. De Zotti, S. A. Pourmousavi, **J. M. Morales**, H. Madsen and N. K. Poulsen, A Control-based Method to Meet TSO and DSO Ancillary Services Needs by Flexible End-users, *IEEE Transactions on Power Systems* vol. 35, no. 3, pp. 1868–1880, May 2020.
7. N. Mazzi, A. Trivella, and **J. M. Morales**, Enabling Active/Passive Electricity Trading in Dual-Price Balancing Markets, *IEEE Transactions on Power Systems*, vol. 34, no. 3, pp. 1980–1990, May 2019.
8. G. De Zotti, S. A. Pourmousavi, **J. M. Morales**, H. Madsen, and N. K. Poulsen, Consumers' Flexibility Estimation at the TSO Level for Balancing Services, *IEEE Transactions on Power Systems*, vol. 34, no. 3, pp. 1918–1930, May 2019.

9. V. Dvorkin, S. Delikaraoglou and **J. M. Morales**, Setting Reserve Requirements to Approximate the Efficiency of the Stochastic Dispatch, *IEEE Transactions on Power Systems*, vol. 34, no. 2, pp. 1524–1536, March 2019.

10. C. Ordoudis, P. Pinson, and **J. M. Morales**, An Integrated Market for Electricity and Natural Gas Systems with Stochastic Power Producers, *European Journal of Operational Research*, vol. 272, no. 2, pp. 642–654, January 2019.

CHAPTER 3

Contact

If you want to know more about this project or about the OASYS group, do not hesitate to contact us here:

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CHAPTER 4

Website Contributors

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Website originally designed and created by Ricardo Fernández-Blanco Carramolino