Energy Informatics.Academy Conference 2023

Technical program

SDU CENTER FOR ENERGY INFORMATICS
EI.A Energy Informatics.Academy
UNICAMP
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DTU
isep Instituto Superior de Engenharia do Porto

Table of Content

Preface

The Energy Informatics.Academy Conference 2023 (EI.A 2023) has collected great contributions from researchers and practitioners in various scientific, technological, engineering, and social fields to disseminate original research on the application of digital technology and information management theory and practice to facilitate the global transition towards sustainable and resilient energy systems.

With the whole technical program committee's effort, in total thirty-nine (39) high-quality papers (including full papers and short papers) and three (3) abstract papers are accepted and will be presented at the conference.

These 42 papers cover the following eight themes, elucidating the breadth and depth of research and development in the energy sector and its convergence with digital technologies:

- AI Methods in Energy
- Data-Driven Smart Buildings
- Energy and Industry 4.0
- Energy and Smart Cities
- Energy Forecasting
- Smart Electricity System
- Smart Energy Device Management
- Smart Heating and Cooling System

Each theme brings forward a wealth of knowledge and novel ideas that promise to shape the future trajectory of energy systems and their integration into digitalization. From exploring innovative technologies and methodologies to discussing practical challenges and future perspectives, the papers enrich the conference's discourse, offering attendees a comprehensive overview of the latest in the field. Consequently, the conference becomes a fertile ground for exchanging ideas, fostering collaborations, and catalyzing future advancements in the energy sector.

Furthermore, eight keynote speeches will provide deep insights and diverse perspectives into the evolving realm of energy and technology:

- "Energy transition in Brazil", by Prof. Dr. Luiz Carlos Pereira da Silva, University of Campinas, Brazil
- "Artificial Intelligence Applied in the Electricity Sector as a Strategic Investment Theme in the Research, Development and Innovation Program of ANEEL" by Mr. Lucas Dantas Xavier Ribeiro, Brazilian Electricity Regulatory Agency, Brazil
- "Explainable AI for energy and smart grids: from concepts to real-world applications", by Prof. Dr. Zita A. Vale, Polytechnic of Porto, Portugal
- "Hierarchies of Controllers for the Future Weather-Driven Smart Energy System", by Prof. Dr. Henrik Madsen, Technical University of Denmark
- "The importance of supervising energy consumption and production", by Prof. Dr. Marcelo Stehling de Castro, Federal University of Goiás, Brazil

- “Application of Data Analytics to Electrical Energy Systems”, by Prof. Dr. Walmir Freitas, University of Campinas, Brazil
- “Energy & Digital Agroindustry”, by Dr. Barbara Teruel, University of Campinas, Brazil
- “Energy Informatics Educational Design”, by Prof. Dr. Bo Nørregaard Jørgensen, University of Southern Denmark, Denmark

Each speaker, with their expertise in various facets of energy systems and technology, will enrich the dialogue, fostering a multi-dimensional discussion on the challenges, solutions, and future pathways in the energy sector. Engaging Q&A sessions will be followed the speeches, further elaborating on the pertinent themes and facilitating an exchange of ideas among the participants and speakers alike.

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Special session	Name	Affiliation	Country
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	Hamid Reza Shaker	University of Southern Denmark	Denmark
	Etienne Saloux	Natural Resources Canada	Canada
	Martin Brüssau	SAMSON Aktiengesellschaft	Germany
	Mathieu Vallee	Grenoble / National Institute for Solar Energy	France
Data-Driven Smart Buildings	Stephen White	CSIRO - Australia's National Science Agency	Australia
	Esther Borkowski	Institute of Technology in Architecture, ETH Zurich	Switzerland
	Etienne Saloux	Natural Resources Canada	Canada
	Patrick So	Electrical and Mechanical Services Department, Hong Kong	China
	Bo Nørregaard Jørgensen	University of Southern Denmark	Denmark
Digitalization, AI &related Technologies for Energy Efficiency & GHG Emissions Reduction in Industry	Mouloud Amazouz	Natural Resources Canada	Canada
	Michelle Levesque	Natural Resources Canada	Canada
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Program

Overview

The EI.A conference will be organized at the School of Electrical and Computer Engineering, University of Campinas (UNICAMP - FEEC)
The address is: Av Albert Einstein, 400, Campinas-SP, Brazil.

Date	Activity	Start time	End time
6-8 December	Registration	08:30	17:30
6 December	Opening ceremony	09:00	09:30
	Keynote speech*2	09:30	10:30
	Coffee break	10:30	10:50
	Paper session - Energy and Industry 4.0	10:50	12:30
	Lunch	12:30	13:30
	Paper session - Data-Driven Smart Buildings	13:30	14:30
	Coffee break	14:30	15:00
	Paper session - AI Methods in Energy	15:00	17:00
7 December	Keynote speech*3	09:00	10:30
	Coffee break	10:30	10:50
	Paper session - Smart Heating and cooling System	10:50	12:30
	Lunch	12:30	13:15
	Paper session - Energy Forecasting	13:15	14:35
	Coffee break	14:35	15:00
	Paper session - Smart Energy Device Management	15:00	16:30
	Formal dinner	19.00	22:00
8 December	Keynote speech*3	09:00	10:30
	Coffee break	10:30	11:00
	Paper session - Smart Electricity System	11:00	12:30
	Lunch	12:30	13:30
	Paper session - Energy and Smart Cities	13:30	14:30
	Coffee break	14:30	15:00
	Closing remark - Best paper announcement - EI.A 2024 announcement	15:00	16:00

Program Day One (6th December 2023)

Activity	Start time	End time
Opening ceremony	**09:00**	**09:30**
Keynote speeches	**09:30**	**10:30**

Energy transition in Brazil
By Prof. Dr. Luiz Carlos Pereira da Silva, University of Campinas, Brazil

Artificial Intelligence Applied in the Electricity Sector as a Strategic Investment Theme in the Research, Development and Innovation Program of ANEEL
By Mr. Paulo Luciano de Carvalho, Brazilian Electricity Regulatory Agency, Brazil

Coffee break	**10:30**	**10:50**
Paper session - Energy and Industry 4.0	**10:50**	**12:30**

Session Chair: Dr. Kristoffer Christensen

Impact of Setpoint Control on Indoor Greenhouse Climate Modeling
By Marie-Pier Trépanier, Université Laval, Canada

A Modifiable Architectural Design for Commercial Greenhouses Energy Economic Dispatch Testbed
By Christian Skafte Beck Clausen, University of Southern Denmark, Denmark

Business Models for Digitalization Enabled Energy Efficiency and Flexibility in Industry: A Survey with Nine Case Studies
By Zhipeng Ma, University of Southern Denmark, Denmark

Identifying Best Practice Melting Patterns in Induction Furnaces: A Data-Driven Approach Using Time Series K-Means Clustering and Multi-Criteria Decision Making
By Daniel Anthony Howard, University of Southern Denmark, Denmark

Machine learning applied to industrial machines for an efficient maintenance strategy: a predictive maintenance approach
By Carlos Ramos, GECAD/LASI/Polytechnic of Porto, Portugal

Lunch	**12:30**	**13:30**

Paper session - Data-Driven Smart Buildings **13:30** **14:30**

Session Chair: Dr. Etienne Saloux

A Real-Time Non-Invasive Anomaly Detection Technique for Cooling Systems
By Keshav Kaushik, BITS Pilani, India

Smart Data-driven Building Management Framework and Demonstration
By Xu Kan, The Hong Kong Polytechnic University, China; Jeremy Ho, Hong Kong Electrical and Mechanical Services Department (EMSD), China

Advances in Machine-Learning Based Disaggregation of Building Heating Loads: A Review
By Synne Krekling Lien, Norwegian University of Science and Technology, Norway

Early stage design methodology for energy efficiency in buildings using asynchronous distributed task queues framework (Video presentation)
By Vishal Garg, Plaksha University, India

A novel approach for climate classification using agglomerative hierarchical clustering (Video presentation)
By Vishal Garg, Plaksha University, India

Incorporating Resilience into the IoT-based Smart Buildings Architecture (Video presentation)
By Sera Syarmila Sameon, Universiti Tenaga Nasional, Malaysia

Coffee break **14:30** **15:00**

Paper session - AI Methods in Energy **15:00** **17:00**

Session Chair: Prof. Hildo Guillardi Júnior

Managing Anomalies in Energy Time Series for Automated Forecasting
By Oliver Neumann, Karlsruhe Institute of Technology (KIT), Germany

Illuminating Metaheuristic Performance using Vortex MAP-Elites for Risk-Based Energy Resource Management
By José Almeida, GECAD-LASI-Polytechnic of Porto, Portugal

Comparing Manual vs Automatic Tuning of Differential Evolution Strategies for Energy Resource Management Optimization
By José Almeida, GECAD-LASI-Polytechnic of Porto, Portugal

Standard energy data competition procedure: A comprehensive review with a case study of the ADRENALIN load disaggregation competition
By Balázs András Tolnai, University of Southern Denmark, Denmark

Deep HarDec: Deep Neural Network Applied to Estimate Harmonic Decomposition
By Luiz Gustavo Reis Bernardino, São Paulo State University (UNESP), Brazil

Automating Value-Oriented Forecast Model Selection by Meta-Learning: Application on a Dispatchable Feeder
By Maximilian Beichter, Karlsruhe Institute of Technology, Germany

Program Day Two (7th December 2023)

Activity	Start time	End time
Keynote speeches	**09:00**	**10:30**
Application of Data Analytics to Electrical Energy Systems *By Prof. Dr. Walmir Freitas, University of Campinas, Brazil* The importance of supervising energy consumption and production *By Prof. Dr. Marcelo Stehling de Castro, Federal University of Goiás, Brazil* Energy & Digital Agroindustry *By Dr. Barbara Teruel, University of Campinas, Brazil*		
Coffee break	**10:30**	**10:50**
Paper session - Smart Heating and cooling System *Session Chair: Dr. Dirk Vanhoudt*	**10:50**	**12:30**
Digital Twin-Based Fault Detection and Prioritisation in District Heating Systems: A Case Study in Denmark *By Henrik Alexander Nissen Søndergaard, University of Southern Denmark, Denmark* Virtual Sensor-Based Fault Detection and Diagnosis Framework for District Heating Systems: A Top-Down Approach for Quick Fault Localisation *By Lasse Kappel Mortensen, University of Southern Denmark, Denmark* Field Implementation of a Predictive Control Strategy in District Heating Systems: a Tale of Two Demonstration Sites *By Etienne Saloux, CanmetENERGY in Varennes, Natural Resources Canada* Future-Proof Substation Design for Low-Temperature Operation of Domestic Hot Water *By Michele Tunzi, DTU, Denmark* Optimal scheduling and electricity market participation of district heating under uncertainty *By Amos Schledorn, Technical University of Denmark, Denmark* Digitalization of District Heating and Cooling Systems (Video presentation) *By Dietrich Schmidt, Fraunhofer Institute for Energy Economics and Energy System Technology IEE, Germany* Assessment of residential district cooling system based on seasonal consumption data (Video presentation) *By Vishal Garg, Plaksha University, India*		
Lunch	**12:30**	**13:15**

Paper session - Energy Forecasting *Session Chair: Dr. João Soares*	**13:15**	**14:35**

Deep Learning Models to Estimate and Predict the Solar Irradiation in Brazil
By Wesley Angelino de Souza, Federal University of Technology - Parana, Brazil

Comparison of Inputs Correlation and Explainable Artificial Intelligence Recommendations For Neural Networks Forecasting Electricity Consumption
By Daniel Ramos, GECAD/LASI/Polytechnic of Porto, Portugal

Computational Approaches for Green Computing of Energy Consumption Forecasting on non-working periods in an office building
By Daniel Ramos, GECAD/LASI/Polytechnic of Porto, Portugal

Solar Energy Forecasting: Case Study of the UNICAMP Gymnasium
By Gleyson Roberto do Nascimento, University of Campinas (UNICAMP), Brazil

Coffee break	**14:35**	**15:00**

Paper session - Smart Energy Device Management *Session Chair: Dr. Michele Tunzi*	**15:00**	**16:30**

Distribution Grid Monitoring Based on Widely Available Smart Plugs
By Simon Grafenhorst, Karlsruhe Institute of Technology, Germany

Analysis of Electrical Equipment at UNICAMP: Insights from the Inventory Database
By Hildo Guillardi Júnior, São Paulo State University, Brazil

Design of Digital Controllers for Grid-Connected Voltage Source Converter Operating as Voltage or Current Source
By Wesley Angelino de Souza, Federal University of Technology - Parana, Brazil

Results of Testing a Smart Controller for Peak Shaving in An Italian Demo Site
By Dirk Vanhoudt, VITO, Belgium

Management Strategies for an EP device in an Energy Packet Grid (Video presentation)
By Marcel Wessbecher, Karlsruhe Institute of Technology, Germany

Power Consumption Analysis as a Detection Indicator for Cyberattacks on Smart Home Devices (Video presentation)
By Thomas Bleistein, August-Wilhelm Scheer Institut gGmbH, Germany

Program Day Three (8th December 2023)

Activity	Start time	End time
Keynote speeches	**09:00**	**10:30**

Explainable AI for energy and smart grids: from concepts to real-world applications
By Prof. Dr. Zita A. Vale, Polytechnic of Porto, Portugal

Hierarchies of Controllers for the Future Weather-Driven Smart Energy System
By Prof. Dr. Henrik Madsen, Technical University of Denmark

Energy Informatics Educational Design
By Prof. Dr. Bo Nørregaard Jørgensen, University of Southern Denmark, Denmark

Coffee break	**10:30**	**11:00**
Paper session - Smart Electricity System *Session Chair: Dr. Wesley Angelino de Souza*	**11:00**	**12:30**

Gossen's First Law in the Modeling for Demand Side Management: A First Heat Pump Case Study
By Chang Li, Karlsruhe Institute of Technology (KIT), Germany

Measurement of the Wood Stove Impact on the Electric Power Consumption of a Norwegian Detached House
By Abolfazl Mohammadabadi, The Norwegian University of Science and Technology, Norway

Market Abstraction of Energy Markets and Policies – Application in an Agent-Based Modeling Toolbox
By Florian Maurer, University of Applied Sciences, Germany

Distributed Resources Remuneration on a Medium Voltage Network with Uncertainty and Seasonal Impacts
By João Soares, GECAD-LASI-Polytechnic of Porto, Portugal

New Perspectives on Clustering for Demand Response (Video presentation)
By Anupama Kowli, Indian Institute of Technology Bombay, India

Lunch	**12:30**	**13:30**

Paper session - Energy and Smart Cities *Session Chair: Prof. Carlos Ramos*	**13:30**	**14:30**

Multi-Agent Based Simulation for Investigating Electric Vehicle Adoption and Its Impacts on Electricity Distribution Grids and CO2 Emissions
By Kristoffer Christensen, University of Southern Denmark, Denmark

Brazilian utilities' invoice data understanding: extraction, data standardization and consumption overview from partner universities
By Hildo Guillardi Júnior, São Paulo State University, Brazil

Distributed energy resources and EV charging stations expansion planning for grid-connected microgrids
By João Soares, GECAD-LASI-Polytechnic of Porto, Portugal

Coffee break	**14:30**	**15:00**

Closing remark Best paper announcement EI.A 2024 announcement	**15:00**	**16:00**

Keynote speakers

Energy transition in Brazil

Luiz Carlos Pereira da Silva
Professor, University of Campinas, Brazil

Luiz Carlos Pereira Da Silva received a B.Sc. degree in electrical engineering from Universidade Federal de Goiás, Goiás, Brazil, in 1994, and the M.Sc. and Ph.D. degrees in electrical engineering from the University of Campinas (UNICAMP), Campinas, Brazil, in 1997 and 2001, respectively. In 1999, was a Visitant Researcher at the University of Alberta, Canada. In 2008, he was a Visitant Professor at the Technical University of Denmark-DTU. He is currently a Professor at the Department of Systems and Energy, UNICAMP. His research interests include energetic efficiency, optimization, planning, and control of electrical power systems, and applications of artificial intelligence in power systems.

Artificial Intelligence Applied in the Electricity Sector as a Strategic Investment Theme in the Research, Development and Innovation Program of ANEEL

Mr. Paulo Luciano de Carvalho
Secretary of Innovation and Energy Transition, Brazilian Electricity Regulatory Agency, Brazil

Paulo Luciano de Carvalho graduated in Electrical Engineering from the Universidade Estadual Paulista-Unesp (1993), Master in Electrical Engineering from the Federal University of Engineering of Itajubá-UNIFEI (1997) and postgraduate degree in Business Strategy from Fundação Getúlio Vargas -FGV (2004). He is a public servant with a career specializing in the regulation of public energy services. He began his activities at ANEEL with the Superintendency of Inspection of Electricity Services, later joining the teams of the Superintendence of Concessions, Permissions and Authorizations for Transmission and Distribution-SCT, the Superintendency of Regulation of Transmission Services–SRT and the Advisory Board from ANEEL. From March 2018 he assumed the Superintendence of Research and Development and Energy Efficiency. In May 2023, he took on the role of Secretary of Innovation and Energy Transition at ANEEL.

Application of Data Analytics to Electrical Energy Systems

Walmir Freitas
Professor, University of Campinas, Brazil

Prof. Walmir Freitas is a renowned expert in the areas of distribution systems, distributed generation, power quality, and protection. He has served as the Editor of the IEEE Transactions on Power Delivery and as

the Chair of the IEEE/PES Working Group on Power Quality Data Analytics, earning recognition for his outstanding technical report. With over 20 years of experience, Prof. Freitas has led more than 50 R&D projects for utilities and government agencies in Brazil, Canada, and India, and has published over 80 journal papers while supervising more than 50 researchers. He holds a Ph.D. in Electrical Engineering from the University of Campinas and has also worked as a Visiting Professor in Canada.

The importance of supervising energy consumption and production

Marcelo Stehling de Castro
Professor, Federal University of Goiás, Brazil

Marcelo Stehling de Castro is a highly experienced professor in the School of Electrical and Computer Engineering at the Federal University of Goiás, Brazil, where he has been teaching since 1996. He has extensive expertise in the areas of Smart Cities, Smart Grids, Sustainability, Network Engineering, and Optical Communications. His research interests include communications networks, process management, and engineering education. He has played an active role in coordinating and participating in various research and development projects funded by ANEEL (Brazil's National Electric Energy Agency). With over 25 years of experience in academia, Marcelo is a recognized authority in his field and a valuable asset to the academic community.

Energy and Digital Agroindustry

Bárbara Teruel
Associate Professor, University of Campinas, Brazil

Bárbara is an Associate Professor and communication coordinator of the Sustainable Campus Project at the School of Agricultural Engineering, UNICAMP. Her research focuses on precision and digital technologies for agroindustry, with specialization in automation and control of agroindustry processes. With a MSc degree in Mechanical Engineering from Cuba and MSc and PhD degrees from UNICAMP, she has extensive experience in nationally and internationally funded projects. Bárbara also leads partnership and agreement initiatives with universities across Europe, Central and South America, and the United States.

Explainable AI for energy and smart grids: from concepts to real-world applications

Zita A. Vale
Professor, Coordenadora Principal, Polytechnic of Porto, Portugal

Zita Vale is a Full Professor of Electrical Engineering at the Institute of Engineering – Polytechnic of Porto (ISEP). She is Co-Editor-in-Chief of Applied Energy and has been involved in over 60 funded projects focused on developing and using artificial intelligence techniques such as Knowledge-Based systems, Multi-Agent systems, Neural networks,

Particle Swarm Intelligence, and Data Mining. With more than 200 published journal papers, her research focuses on Power and Energy Systems, specifically in the application of Artificial Intelligence techniques. Zita Vale received her PhD from the University of Porto in 1993, and her Habilitation in 2003.

Hierarchies of Controllers for the Future Weather-Driven Smart Energy System

Henrik Madsen
Professor and section head in Stochastic Dynamical Systems, Technical University of Denmark

Henrik Madsen is a distinguished professor of Mathematical Statistics with a specialization in Stochastic Dynamical Systems at the Technical University of Denmark. He has over 35 years of experience in the analysis and modeling of stochastic dynamics systems, with a particular interest in energy systems, environmental systems, and finance. Henrik has authored or co-authored over 650 papers and 12 books on various topics, including Time Series Analysis, General and Generalized Linear Models, Integrating Renewables in Electricity Markets, and Statistics for Finance. He has received numerous awards and honors, including the title of Knight of the Order of Dannebrog by Her Majesty the Queen of Denmark in 2016 and Doctor HC at Lund University in 2017.

Energy Informatics Educational Design

Bo Nørregaard Jørgensen
Professor, founder and head of SDU Center for Energy Informatics, University of Southern Denmark

Professor, Dr. Bo Nørregaard Jørgensen is the founder and head of the Center for Energy Informatics at the University of Southern Denmark. Center for Energy Informatics is an interdisciplinary research center focusing on digital solutions for facilitating the transition toward a sustainable energy system. The center's research is conducted in close collaboration with industrial partners, public bodies, and government agencies. Dr. Jørgensen research focuses on digital solutions for integration of the demand-side with the supply-side in the energy sector, from the technology and business perspectives. He holds a Ph.D. in Computer Science from the University of Southern Denmark, a M.Sc. and a B.Sc. in Computer System Engineering from Odense University, Denmark.

Paper abstracts

Note: the order of the paper abstracts follows the paper sessions.

Energy and Industry 4.0

Impact of Setpoint Control on Indoor Greenhouse Climate Modeling

Marie-Pier Trépanier[1][0009-0002-6793-6893] and Louis Gosselin[1][0000-0002-5210-7083]

[1] Department of Mechanical Engineering, Université Laval, Québec QC, Canada

Abstract. Greenhouse agriculture is a crucial solution to global food security and sustainability challenges, as it provides a controlled environment for plant growth, resulting in higher yields and efficient resource utilization. Climate control plays a critical role in determining energy consumption and plant growth within greenhouse systems. The selection and optimization of control parameters have a significant impact on the overall performance. This study conducted simulations of a tomato greenhouse located in Montreal, Canada, with the aim of evaluating the effect of different control setpoints in the presence of high-pressure sodium (HPS) supplemental lighting and light-emitting diode (LED) supplemental lighting on greenhouse performance. To comprehensively assess the influence of each control setpoint, a sensitivity analysis (SA) was performed, systematically varying the control setpoints over a wider range than what is typically observed in tomato production. The SA utilized different control setpoints as inputs, while energy consumption and crop yield were considered as outputs. The setpoints for relative humidity and air temperature during the light period were identified as the most influential factors. This highlights the importance of accurate measurements and predictions of temperature and humidity to optimize environmental conditions in indoor greenhouses when implementing a predictive control strategy. The results obtained from this SA can contribute to the development of reduced-order models that focus on the most influential variables.

Keywords: Greenhouse, Energy consumption, Control.

A Modifiable Architectural Design for Commercial Greenhouses Energy Economic Dispatch Testbed

Christian Skafte Beck Clausen [1][0000-0003-3118-7253], Bo Nørregaard Jørgensen [1][0000-0001-5678-6602] and Zheng Grace Ma [1][0000-0002-9134-1032]

[1] SDU Center for Energy Informatics, Maersk Mc-Kinney Moeller Institute, The Faculty of Engineering, University of Southern Denmark, Odense, Denmark

Abstract. Facing economic challenges due to the diverse objectives of businesses and consumers, commercial greenhouses strive to minimize energy costs while addressing CO2 emissions. This scenario is intensified by rising energy costs and the global imperative to curtail CO2 emissions. To address these dynamic economic challenges, this paper proposes an architectural design for an energy economic dispatch testbed for commercial greenhouses. Utilizing the Attribute-Driven Design method, core architectural components of a software-in-the-loop testbed are proposed, which emphasizes modularity and careful consideration of the multi-objective optimization problem. This approach extends prior research by implementing a modular multi-objective optimization framework in Java. The results demonstrate the successful integration of the CO2 reduction objective within the modular architecture with minimal effort. The multi-objective optimization output can also be employed to examine cost and CO2 objectives, ultimately serving as a valuable decision-support tool. The novel testbed architecture and a modular approach can tackle the multi-objective optimization problem and enable commercial greenhouses to navigate the intricate landscape of energy cost and CO2 emissions management.

Keywords: Modifiability, architecture, economic dispatch, testbed, greenhouse energy systems.

Business Models for Digitalization Enabled Energy Efficiency and Flexibility in Industry: A Survey with Nine Case Studies

Zhipeng Ma[1] [0000-0002-4049-539X], Bo Nørregaard Jørgensen[1] [0000-0001-5678-6602], Michelle Levesque[2], Mouloud Amazouz[3], Zheng Grace Ma[1] [0000-0002-9134-1032]

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[2] CanmetMINING-Sudbury, Natural Resources Canada, 1079 Kelly Lake Road Sudbury, ON P3E 5P5 Canada
[3] CanmetENERGY Varennes, Natural Resources Canada, 1615 Lionel-Boulet Blvd. Varennes, QC J3X 1S6 Canada

Abstract. Digitalization is challenging in heavy industrial sectors, with many pilot projects facing difficulties to be replicated and scaled. Case studies are strong pedagogical vehicles for learning and sharing experience & knowledge, but are rarely available in the literature. Therefore, this paper conducts a survey to gather a diverse set of nine industry cases, which are subsequently subjected to analysis using the business model canvas (BMC). The cases are summarized and compared based on nine BMC components, and a Value of Business Model (VBM) evaluation index is proposed to assess the business potential of industrial digital solutions. The results show that the main partners are industry stakeholders, IT companies, and academic institutes. Their key activities for digital solutions include big-data analysis, machine learning algorithms, digital twins, and Internet of Things developments. The value propositions of most cases are improving energy efficiency and enabling energy flexibility. Moreover, the technology readiness levels of six industrial digital solutions are under level 7, indicating that they need further validation in real-world environments. Building upon these insights, this paper proposes six recommendations for future industrial digital solution development: fostering cross-sector collaboration, prioritizing comprehensive testing and validation, extending value propositions, enhancing product adaptability, providing user-friendly platforms, and adopting transparent recommendations.

Keywords: Industry 4.0, Digitalization, Energy Efficiency, Energy Flexibility, Business Model.

Identifying Best Practice Melting Patterns in Induction Furnaces: A Data-Driven Approach Using Time Series KMeans Clustering and Multi-Criteria Decision Making

Daniel Anthony Howard[1][0000-0003-4556-0602], Bo Nørregaard Jørgensen[1][0000-0001-5678-6602], and Zheng Ma[1][0000-0002-9134-1032]

[1] SDU Center for Energy Informatics, Maersk Mc-Kinney Moller Institute, University of Southern Denmark, Odense, Denmark

Abstract. Improving energy efficiency in industrial production processes is crucial for competitiveness, and compliance with climate policies. This paper introduces a data-driven approach to identify optimal melting patterns in induction furnaces. Through time-series K-means clustering, the melting patterns could be classified into distinct clusters based on temperature profiles. Using the elbow method, 12 clusters were identified, representing the range of melting patterns. Performance parameters such as melting time, energy-specific performance, and carbon cost were established for each cluster, indicating furnace efficiency and environmental impact. Multiple criteria decision-making methods including Simple Additive Weighting, Multiplicative Exponential Weighting, Technique for Order of Preference by Similarity to Ideal Solution, modified TOPSIS, and VIseKriterijumska Optimizacija I Kompromisno Resenje were utilized to determine the best-practice cluster. The study successfully identified the cluster with the best performance. Implementing the best practice operation resulted in an 8.6% reduction in electricity costs, highlighting the potential energy savings in the foundry.

Keywords: Energy Efficiency, Foundry Industry, Induction Furnace, Timeseries K-means Clustering, Multi-criteria Decision Making.

Machine learning applied to industrial machines for an efficient maintenance strategy: a predictive maintenance approach

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Abstract. Maintenance activities are crucial in manufacturing environments to reduce machine breakdowns and maintain product quality. However, traditional maintenance strategies can be expensive, as they can lead to unnecessary maintenance activities. As a result, Predictive Maintenance (PdM) can be a great way to solve these issues, as it enables the prediction of a machine's condition/lifespan allowing for maintenance-effective manufacturing. This paper aims to address these issues by proposing a novel methodology to improve the performance of PdM systems, by proposing a machine learning training methodology, an automatic hyperparameter optimizer, and a retraining strategy for real-time application. To validate the proposed methodology, a random forest and an artificial neural network model are implemented and explored using a synthetic dataset that replicates industrial machine data to show the robustness of the proposed methodology. Obtained results are promising as the implemented models can accomplish up to 0.97 recall and 93.15% accuracy.

Keywords: Data Preprocessing, Hyperparameter Optimization, Predictive Maintenance.

Data-Driven Smart Buildings

A Real-Time Non-Invasive Anomaly Detection Technique for Cooling Systems

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Abstract. The cooling systems contribute to 40% of overall building energy consumption. Out of which, 40% After identifying the anomalies, we find the cause of the anomaly. Based on the anomaly, the solution recommends a fix. If there is a technical fault, our proposed technique informs the technician regarding the faulty component, reducing the cost and mean time to repair. In the first stage, we propose a domain-inspired statistical technique to identify anomalies in cooling systems. We observe the Area Under the Curve of the Receiver Operating Characteristic (AUC − ROC) score of more than 0.93 in both simulation and experimentation. In the second stage, we propose using a rule-based technique to identify the anomaly's cause and classify it into three classes. We observe an AUC −ROC score of 1. Based on the anomaly classification, in the third stage, we identify the faulty component of the cooling system. We use the Nearest-Neighbour Density-Based Spatial Clustering of Applications with Noise (NN-DBSCAN) algorithm with transfer learning capabilities to train the model only once, where it learns the domain knowledge using simulated data. The overall accuracy of the three-stage technique is 0.82 and 0.86 in simulation and experimentation, respectively. We observe energy savings of up to 68% in simulation and 42% during experimentation.

Keywords: Cooling systems· Fault Detection· IoT.

Smart Data-driven Building Management Framework and Demonstration

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Abstract. The building sector holds a significant impact over global energy usage and carbon emissions, making effective building energy management vital for ensuring worldwide sustainability and meeting climate goals. In line with this objective, this study aims to develop and demonstrate an innovative smart data-driven framework for building energy management. The framework includes semantic multi-source data integration schema, AI-empowered data-driven optimization and predictive maintenance strategies, and digital twin for informative and interactive human-equipment-information building management platform. A case study was conducted in a typical chiller plant on a campus located in Hong Kong, China. The results show that the deployment of the proposed smart data-driven framework achieves chiller sequencing control in a more robust and energy-efficient manner. Specifically, the proposed control strategy achieves energy savings of 5.9% to 12.2% compared to the conventional strategy. This research represents an important step forward in the development of smarter and more sustainable building management practices, which will become increasingly critical as we strive to reduce our environmental impact and combat climate change.

Keywords: Building Energy Management, Data-driven models, Digital Twin.

Advances in Machine-Learning Based Disaggregation of Building Heating Loads: A Review

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Abstract. This review article investigates the methods proposed for disaggregating the space heating units' load from the aggregate electricity load of commercial and residential buildings. It explores conventional approaches together with those that employ traditional machine learning, deep supervised learning, and reinforcement learning. The review also outlines corresponding data requirements and examines the suitability of a commonly utilized toolkit for disaggregating heating loads from low-frequency aggregate power measurements. It is shown that most of the proposed approaches have been applied to high-resolution measurements and that few studies have been dedicated to low-resolution aggregate loads (e.g. provided by smart meters). Furthermore, only a few methods have taken account of special considerations for heating technologies, given the corresponding governing physical phenomena. Accordingly, the recommendations for future works include adding a rigorous preprocessing step, in which features inspired by the building physics (e.g. lagged values for the ambient conditions and values that represent the correlation between heating consumption and outdoor temperature) are added to the available input feature pool. Such a pipeline may benefit from deep supervised learning or reinforcement learning methods, as these methods are shown to offer higher performance compared to traditional machine learning algorithms for load disaggregation.

Keywords: Load disaggregation, non-intrusive load monitoring, Smart Meter Analytics, Machine learning, Space Heating, Building Energy Use

Early stage design methodology for energy efficiency in buildings using asynchronous distributed task queues framework

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Abstract. Energy consumption in the building sector is about 40% of total energy consumed globally and is trending upwards, along with its contribution to greenhouse gas (GHG) emissions. Given the adverse impacts of GHG emissions, it's crucial to integrate energy efficiency into building designs. The most significant opportunities for enhancing energy performance are present during the initial phases of building design, which are less impacted by other design constraints. Various tools exist for simulating different design options, providing feedback in terms of energy consumption and comfort parameters. These simulation outputs must then be analyzed to derive design solutions. This paper presents an innovative approach that utilizes user input parameters, processes them through cloud computing, and outputs easily understandable strategies for energy-efficient building design. The methodology employs Asynchronous Distributed Task Queues (DTQ)—a scalable and reliable alternative to conventional speedup techniques—for conducting parametric energy simulations in the cloud. The goal of this approach is to assist design teams in identifying, visualizing, and prioritizing energy-saving design strategies from a range of possible solutions for each project.

Keywords: Asynchronous Distributed Task Queues, Parallel Simulations, Building Energy Analysis.

A Novel Approach For Climate Classification Using Agglomerative Hierarchical Clustering

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Abstract. Climate classification plays a significant role in the development of building codes and standards. It guides the design of buildings' envelope and systems by considering their location's climate conditions. Various methods, such as ASHRAE Standard 169, Köppen, Trewartha utilize climate parameters such as temperature, humidity, solar radiation, precipitation, etc., to classify climates. When establishing requirements in building codes and standards, it is crucial to validate the classification based on the building's thermal loads. This paper introduces a novel methodology for classifying cities based on the number of similar days between them. It calculates similarity using daily mean temperature, relative humidity, and solar radiation by applying threshold values. A matrix of similar days is analyzed through agglomerative hierarchical clustering with different thresholds. A scoring system based on building thermal load, where lower scores signify better classification, is employed to select the best method. The method was tested using U.S. weather data, yielding a lower score of 54.5 compared to ASHRAE Standard 169's score of 63.09. This suggests that the new approach results in less variation in thermal loads across cluster zones. The study used thresholds of 7°C for daily mean temperature, 45% for daily mean relative humidity, and 35 Wh/m2 for daily mean solar radiation, which was found to yield the lowest score.

Keywords: Climate Classification, Building Energy Performance, Hierarchical Clustering.

Incorporating Resilience into the IoT-based Smart Buildings Architecture

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Abstract. The design of IoT-based smart buildings places great emphasis on network infrastructure and the integration of resilience into the overall system. The research aims to develop a methodology that comprehensively integrates resilience into the design of IoT-based smart buildings. The study reviews the existing literature on IoT-based smart buildings, emphasizing energy efficiency through the design of resilient architecture platforms. Fundamental aspects of resilience architecture in IoT-based smart buildings are explored, along with an examination of current research efforts and challenges in IoT resilience. The methodology employed for integrating resilience into the architecture design is described, revealing the utilization of the Design Science Research (DSR) methodology to enhance the architecture's fault tolerance, survivability, and adaptability. The paper concludes with a summary of key findings and suggests future research directions for further enhancing the resilience of IoT-based smart building architectures.

Keywords: Resilience Architecture, Energy Efficiency, Smart Building.

AI Methods in Energy

Managing Anomalies in Energy Time Series for Automated Forecasting

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Abstract. The increasing number of recorded energy time series enables the automated operation of smart grid applications such as load analysis, load forecasting, and load management. However, to perform well, these applications usually require clean data that well represents the typical behavior of the underlying system. Unfortunately, recorded time series often contain anomalies that do not reflect the typical behavior of the system and are, thus, problematic for automated smart grid applications such as automated forecasting. While various anomaly management strategies exist, a rigorous comparison is lacking. Therefore, in the present paper, we introduce and compare three different general strategies for managing anomalies in energy time series forecasting, namely the raw, the detection, and the compensation strategy. We compare these strategies using a representative selection of forecasting methods and real-world data with inserted synthetic anomalies. The comparison shows that applying the compensation strategy is generally beneficial for managing anomalies despite requiring additional computational costs because it mostly outperforms the detection and the raw strategy when the input data contains anomalies.

Keywords: Anomalies, Anomaly management, Forecasting, Energy time series.

Illuminating Metaheuristic Performance using Vortex MAP-Elites for Risk-Based Energy Resource Management

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Abstract. With the current state of the electrical power system, regarding the increase of renewable generation integration and electric vehicle penetration to reduce gas emissions, the energy resource management problem becomes extremely complex to optimize due to the significant dimensionality and uncertainty. Metaheuristic optimization algorithms become efficient methods since they guarantee a balance between optimal and practical solutions, but they lack explainability and are treated as black-box techniques. In this work, we introduce an improved version of the Multi-dimensional Archive of Phenotypic Elites (MAP-Elites) algorithm incorporating the Vortex Search to generate new candidate solutions in the iterative process. The VS MAP-Elites is then used to optimize the energy resource management problem for a 13-bus distribution network considering risk analysis due to the existence of extreme scenarios in the day-ahead operation. Two different behaviors of the problem were considered, namely demand response ratio and renewable ratio, and the effect that they have on metaheuristic performance was analyzed through the visualization of the elite archive. Results showed that VS MAP-Elites achieved better cost results compared to MAP-Elites, around a 25% reduction, since it was able to diversify the search space finding better solutions for the considered problem characteristics.

Keywords: Energy resource management, MAP Elites, Metaheuristic, Optimization, Visualization, Vortex search.

Comparing Manual vs Automatic Tuning of Differential Evolution Strategies for Energy Resource Management Optimization

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Abstract. The energy resource management problem in energy systems is hard to optimize, mainly due to non-linear restrictions and a large number of variables involved. This is partly because of the increased integration of distributed energy resources. Computational intelligence optimization techniques, namely evolutionary algorithms, are regarded as efficient techniques for identifying optimal and near-optimal solutions. However, these algorithms usually have in their design several parameters that need to be set and, in most cases, tuned for a given problem to find good solutions. This work proposes an automatic configuration approach of different differential evolution strategies using the irace package to solve a centralized day-ahead energy resource management problem. The problem considers an aggregator managing multiple resources, such as renewable generation, battery energy systems, electric vehicles, and loads with demand response capabilities. The aggregator aims to minimize operational costs and maximize revenues to obtain a profit. We compare the results of a “manual” tuning of parameters with the results obtained with the auto-tuned parameters using irace. Results show that the automatic configuration improves the profits of the aggregator in almost all strategies (except for DE/either-or-algorithm/1), getting the best results, an improvement of around 7%, with the automatically tuned DE/target-to-best/1 mutation strategy.

Keywords: Automatic tuning, Differential evolution, Energy resource Management, Evolutionary algorithms, Iterated racing, Optimization.

Standard energy data competition procedure: A comprehensive review with a case study of the ADRENALIN load disaggregation competition

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Abstract. Crowdsourcing data science competitions have become popular as a cost-effective alternative to solving complex energy-related challenges. However, comprehensive reviews on hosting processes remain scarce. Therefore, this paper undertakes a detailed review of 33 existing data competitions and 12 hosting platforms, complemented by an in-depth case study of the ADRENALIN load disaggregation competition. The review identifies essential elements of competition procedure, including platform selection, timeline, datasets, and submission and evaluation mechanisms. Based on proposed 16 evaluation criteria, the similarities and differences between data competition hosting platforms can be categorized into platform scoring and popularity, platform features, community engagement, open-source platforms, region-specific platforms, platform-specific purposes, and multi-purpose platforms. The case study underscores strategic planning's critical role, particularly platform selection. The case study also shows the importance of defining competition scope which influences the whole competition content and procedure, especially the datasets.

Keywords: Data science competition, Data competitions, Competition Platforms, Competition timelines

Deep HarDec: Deep Neural Network Applied to Estimate Harmonic Decomposition

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Abstract. A Deep Harmonic Decomposition (Deep HarDec) approach is proposed in this paper, being developed by means of a deep neural network, allowing to obtain estimations of the amplitude and phase quantities of a given periodic signal. Consequently, harmonic characterization of periodic signals is explored in this paper, assessing the suitability of the Deep HarDec. Such a method can be potentially applied to the real-time management of electric power systems as well as other control applications, supporting the monitoring of harmonic distortions and providing means to active filtering interventions targeting power quality improvement. In order to build the Deep HarDec model, a dataset comprising diverse combinations of the fifth, seventh, eleventh, and thirteenth harmonic orders was considered, covering a wide range of operational perspectives. A grid search technique was used to find the best configuration for the multi-layer perceptron adopted for the approach, and the deep neural network was subjected to a training procedure targeting the harmonic estimation. A study case focusing on a selective active filtering application demonstrates that the Deep HarDec can effectively decompose harmonics, supporting the synthesis of real-time compensation references to tackle harmonic distortions in an electric grid.

Keywords: artificial neural networks, active power filter, deep learning, harmonic decomposition, harmonic estimation, multi-layer perceptron, power quality.

Automating Value-Oriented Forecast Model Selection by Meta-Learning: Application on a Dispatchable Feeder

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Abstract. To successfully increase the share of renewable energy sources in the power system and for counteract their fluctuating nature in view of system stability, forecasts are required that suit downstream applications, such as demand side management or management of energy storage systems. However, whilst many forecast models to create these forecasts exist, the selection of the forecast model best suited to the respective downstream application can be challenging. The selection is commonly based on quality measures (such as mean absolute error), but these quality measures do not consider the value of the forecast in the downstream application. Thus, we introduce a meta-learning framework for forecast model selection, which automatically selects the forecast model leading to the forecast with the highest value in the downstream application. More precisely, we use a meta-learning approach that considers the selection task as a classification problem. Furthermore, we empirically evaluate the proposed framework on the downstream application of a smart building's photovoltaic-battery management problem known as dispatchable feeder on building-level with a data set containing time series from 300 buildings. The results of our evaluation demonstrate that the proposed framework reduces the cost and improves the accuracy compared to existing forecast model selection heuristics. Furthermore, compared to a manual forecast model selection, it requires noticeably less computational effort and leads to comparable results.

Keywords: meta-learning · forecast value · forecast model selection

Smart Heating and cooling System

Digital Twin-Based Fault Detection and Prioritisation in District Heating Systems: A Case Study in Denmark

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Abstract. Faults in district heating systems (DHS) cause sub-optimal operating conditions, which increase energy losses. As DHSs are critical infrastructure for many households in Denmark, these faults should be detected and corrected quickly. A novel model-based fault detection and diagnosis framework has been applied to detect and prioritise faults. The framework uses a bound for normal operation based on the residuals between historical sensor data and simulated properties in a digital twin of the DHS. The faults detected are prioritised based on the fault probability calculated using the Chernoff bound method. A case study on a Danish DHS has proven that the framework can produce a prioritised list of faults that maintenance crews can use to target faults with the highest probability. Furthermore, the digital twin allowed for fault location investigation, which could correlate different faults in the DHS. The framework has the potential for real-time fault detection and diagnosis. However, more precise digital twins need to be developed.

Keywords: fault detection and diagnosis, district heating systems, digital twin, Chernoff bound.

Virtual Sensor-Based Fault Detection and Diagnosis Framework for District Heating Systems: A Top-Down Approach for Quick Fault Localisation

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Abstract. For district heating systems (DHS) to operate cost-effectively, avoid disturbances of loads, and increase overall energy efficiency, faults in DHSs must be detected, located, and rectified quickly. For this purpose, a novel digital twin-based fault detection and diagnosis framework with virtual sensor employment have been developed. The framework defines virtual sensors measuring the mass flow rate in points in the DHS where sensors are absent by using the existing sensors in the system. Faults in the virtual sensors are detected when deviations occur between the calculated and digital twin-simulated mass flow rate using a bound of normal operation, allowing some degree of modelling error. To define which virtual sensors are of interest, a novel Specialised Agglomerative Hierarchical Clustering algorithm will be used. A case study on a DHS of a suburb in Odense showed how the framework was able to locate faults with a top-down approach and could indicate whether the fault was local or due to upstream faults. The framework has the potential to be implemented in real-time monitoring of a DHS.

Keywords: Fault detection and diagnosis, District heating systems, Digital twin, Virtual sensor, Machine learning

Field Implementation of a Predictive Control Strategy in District Heating Systems: a Tale of Two Demonstration Sites

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Abstract. District heating systems have become increasingly complex by integrating even more efficient technologies to help decarbonize the built environment. However, the full potential of such systems has yet to be reached due to inadequate controls. Predictive control has emerged as a promising solution to leverage operational data, modelling capabilities and various forecasts (weather conditions, price signals, carbon intensity) to optimize district energy system operation in real time. This paper discusses practical hurdles and lessons learned from the implementation of an artificial intelligence (AI)-based model predictive control (MPC) strategy in two Canadian district heating systems. These systems are equipped with natural gas boilers, which supply space and water heating through a steam network. This AI-based MPC strategy builds upon district heating demand forecasting models and data-driven boiler performance curves to optimize boiler thermal outputs that minimize greenhouse gas emissions. Practical hurdles include the usual suspects – data collection and preparation, communication with the control system, equipment maintenance – but also unexpected aspects such as weather forecast access issues and partial application of the recommendations. Lessons learned deal with the adoption of the proposed strategy, the potential for performance improvement of multiboiler district heating systems, and the scalability and generalization to more complex systems.

Keywords: Boiler Efficiency; District Heating; Field Demonstration; Load Forecasting; Model Predictive Control.

Future-Proof Substation Design for Low-Temperature Operation of Domestic Hot Water

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Abstract. The transition towards more sustainable district heating (DH) systems necessitates the operation of building heating systems at lower temperatures. However, one obstacle to achieving lower district heating return temperatures is the domestic hot water (DHW) system, specifically the circulation loop in multifamily buildings. The current systems, which utilize a single heat exchanger, often result in elevated district heating return temperatures once the circulation loop is heated. To tackle this challenge, this study investigated and tested an innovative design for future-proof DHW substations in large multifamily buildings. The proposed design decouples the heating of cold water and circulation flows through the utilization of a circulation loop booster incorporating a heat pump. The proposed configurations were tested in a Danish multifamily building connected to a DH network with a fully-instrumented substation. In comparison to a typical DHW substation equipped with a single heat exchanger, the configuration featuring the circulation loop booster demonstrated the ability to reduce the average DH return temperature from 46°C to either 34 °C or 28 °C, depending on whether the connection was parallel or serial.

Keywords: 4th generation district heating; domestic hot water; low operating temperatures; fault detection and diagnosis

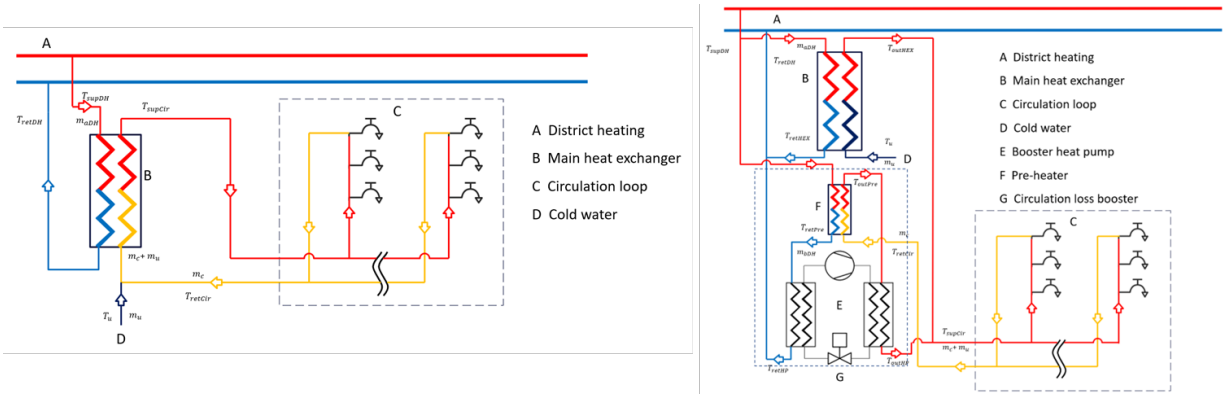

Figure 1: layout of a typical DHW substation and one with circulation booster heat pump

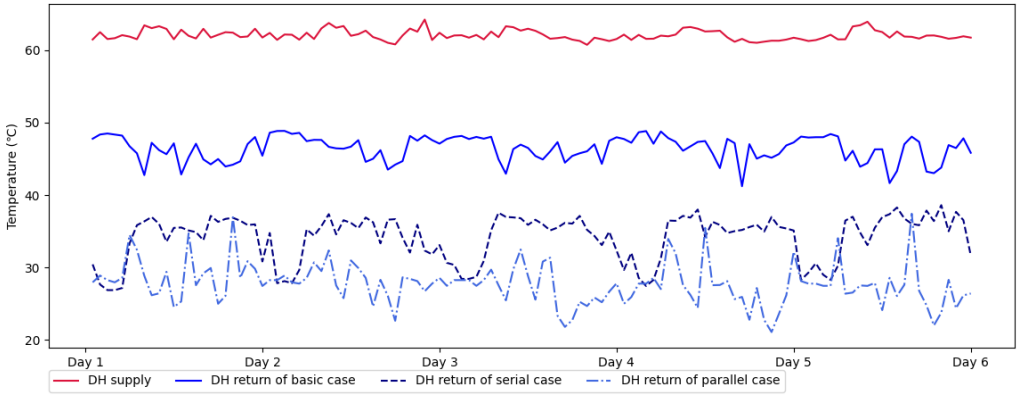

Figure 2: Field test results of the DHW substations with and without circulation loss booster

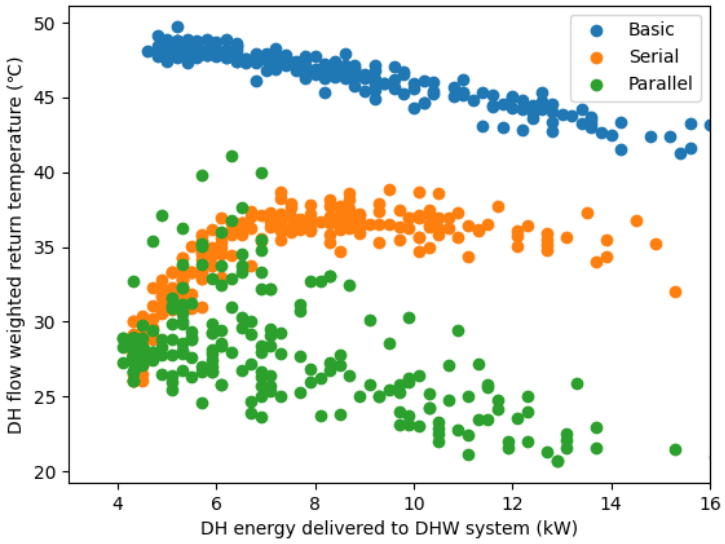

Figure 3: The correlation of the total heat delivered to the DHW system and the DH return temperature of the three configurations

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Optimal scheduling and electricity market participation of district heating under uncertainty

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Abstract. District heating takes a prominent role in decarbonising the global energy system, especially in climate zones with a significant wind energy production. This role originates not only in the sector's significant energy consumption and carbon emissions but also in its potential to provide flexibility to energy systems running on renewable energy on various time scales. This flexibility stems from the fact that storing energy in the form of heat rather than electricity yields significant cost savings. Thus, it can be beneficial to run combined heat-and-power units during periods of high electricity prices rather than high heat demand and to consume electricity for heat generation during low-price periods.
Yet, tapping this flexibility potential requires intelligent operation of district heating at the interface with the electricity sector. Such operation is not only concerned with optimally dispatching various heat generation and storage units as well as other energy conversion units but must simultaneously determine adequate electricity market bids. Related operational models need to cope with various sources of uncertainty, including electricity prices, heat demand, and variable renewable energy generation. At the same time, they need to incorporate operational details of various heat and power generators as well as sources of excess heat in order to provide useful practical decision support.
We propose a generic optimisation model for the operational scheduling and electricity market bidding in district heating systems. Various sources of uncertainty, such as electricity prices or heat demand, can be integrated in a mixed-integer linear stochastic program. The formulation is based on a network flow structure [1], which allows modelling arbitrary energy carriers and district heating systems, while electricity market bidding is tailored towards district heating operation [2]. We present the modelling approach alongside results from extensive case studies on district heating systems in Denmark. Preliminary results indicate wide applicability of the modelling approach.

Keywords: District heating; stochastic programming, electricity market bidding

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Digitalization of District Heating and Cooling Systems

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Abstract. District heating and cooling (DHC) networks are often run with a small number of sensors and actuators to provide the necessary supply and to maximize economics based on a predetermined high ecologic performance. With better knowledge of the demand and flexibility options, it is feasible to optimize heat generation and network functioning overall. Improved network management based on real-time measurement data and the incorporation of new digital business processes is made possible by a greater deployment of information and communication technology. Clarifying the role of digitalization for various components within district heating and cooling systems is necessary for ongoing growth, as is promoting opportunities for the integration of digital processes into DHC systems. Digital technologies are expected to improve the efficiency and system integration of additional renewable sources while also making the entire energy system smarter, more reliable, and more efficient. Future district energy systems could be able to completely optimize their plant and network functioning while empowering the end user thanks to digital applications. However, there are still more difficulties to be overcome, including issues with data privacy and security as well as issues with data ownership. The research findings from the IEA DHC Annex TS4 on “Digitalization of District Heating Systems – Optimized Operation and Maintenance of District Heating and Cooling Systems via Digital Process Management” are presented and discussed in this publication. https://www.iea-dhc.org/the-research/annexes/2018-2024-annex-ts4 .

Keywords: Digitalization of district heating; operation and maintenance; business processes and models.

Assessment of residential district cooling system based on seasonal consumption data

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Abstract. Residential District Cooling Systems (DCS) are crucial for maintaining thermal comfort in urban areas, making it imperative to understand occupant cooling behavior as it significantly influences DCS operation. While several studies have investigated cooling behavior within small user groups through on-site measurements or surveys, these often fall short in representing the broader population. In this study we considered 387 homes in Hyderabad, which has a DCS connection for chilled water supply. Operational data spanning three months across different seasons were meticulously selected to assess the residents' behavior for the cooling demand. In order to better facilitate the operation of the residential DCS, user load profile and system performance were analyzed using real world data for different seasons in the year. Our findings revealed notable disparities in DCS electrical consumption, with summer usage being 1.9 times higher than the monsoon period and 2.7 times higher than the winter period. Furthermore, a strong positive correlation emerged between outdoor temperature and thermal energy usage by the residents. On average, the daily thermal consumption per residence during winter, summer, and monsoon is 3.3 kWhth, 35.1 kWhth, and 10.4 kWhth respectively. Interestingly, the probability of a residence using AC during the day for the winter, summer, and monsoon seasons are 0.07, 0.41, and 0.18 respectively.

Keywords: District cooling system, Residential AC usage, seasonal data, Air conditioning, Load profile.

Energy Forecasting

Deep Learning Models to Estimate and Predict the Solar Irradiation in Brazil

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Abstract. Solar irradiation is the backbone of photovoltaic power technologies and its quantization allows to optimize energy generation. However, solar irradiation can be difficult to detect, mostly due to the design and disposition of sensors, as well as their high cost. To address this limitation, this paper proposes a deep neural network-based model to estimate global solar irradiation by only relying on weather data, focusing on applications targeting the Brazilian territory. The model uses a deep neural network trained with data from the Brazilian National Institute of Meteorology (INMET), which includes 606 nationwide weather stations and over 39 million hourly records of meteorological variables cataloged from years 2010 to 2022. Thus, in this paper i) a deep neural network is used to estimate irradiation, and ii) a long short-term memory is used to predict solar irradiation considering different time granularities: 5 minutes, 30 minutes, 6 hours, and 1 day. The results show a small error between the measured irradiation data and the calculated results with regard to the following six meteorological variables: time, temperature, relative humidity, wind speed, precipitation, and atmospheric pressure. Moreover, experimental validations conducted using a weather station set up by the authors demonstrate that the proposed models can accurately predict solar irradiation. Thus, the developed model stands as a promising approach for applications within the Brazilian perspective, improving the efficiency and reliability of solar energy generation.

Keywords: Solar irradiation, Deep learning, Weather station, Weather quantities.

Comparison of Inputs Correlation and Explainable Artificial Intelligence Recommendations for Neural Networks Forecasting Electricity Consumption

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Abstract. The energy sector explores various paths to improve the energy management of buildings. Nowadays a frequent path is to schedule load forecasting activities due to the accessibility of reliable forecasting algorithms. Data scientists usually take advantage of a large historic of consumption with weekly patterns and sensors data presenting a higher correlation with the consumption variable. However, specialists in the explainable artificial intelligence area focus on studying the positive or negative impact of each variable to the prediction accuracy. In this paper, a correlation analysis evaluates in the first stage the most reliable sensors to be used during training and forecasting tasks. In the second stage, the Local Interpretable Model-Agnostic Explanations (LIME) explainable artificial intelligence method is applied to determine which features have a stronger positive or negative influence on the prediction accuracy. The training and forecasting tasks are supported in this paper by the forecasting algorithm Artificial Neural Networks. In the case study, a historic of two years and six months is used to estimate the consumption values of a targeted week considering periods of five minutes. The results section calculates the confidence of each sensor to the prediction accuracy provided by LIME method and compares the obtained insights with the correlation analysis. The results and conclusions sections state that the two sensors more correlated with the consumption variable either contribute negatively to the prediction performance or do not contribute at all on most test targets.

Keywords: Energy Management, Energy Sector, Explainable Artificial Intelligence, Prediction Accuracy.

Computational Approaches for Green Computing of Energy Consumption Forecasting on non-working periods in an office building

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Abstract. The energy management of electrical buildings takes an active role in the energy market. Researchers tasked with the primary goal of reducing the energy costs take advantage of machine learning algorithms to predict how much energy should be bought and sold in the market ahead of time. Some researchers take account green computing approaches to reduce the energy cost spent in forecasting roles and ensure the environmental sustainability of computing devices. In this paper two forecasting algorithms known as k-nearest neighbors and artificial neural networks train an annual historic with energy consumptions and sensors devices data to predict several energy consumption values of a target week for non-working periods of either five minutes or hour schedules. The green computing area is highlighted in this paper by studying the influence that decisions intended on decreasing the energy of the CPU processing unit on forecasting activities may have in the forecasting accuracy. Such decisions include changing the training and forecasting schedule of five minutes to hour periods and excluding the retraining using updated data from the test set. The conclusions of this paper clarify that scheduling forecasts for non-working hours with the support of k-nearest neighbors algorithm contextualized for periods of five minutes results in lower errors than artificial neural networks. However scheduling forecasts for periods of five minutes instead of hour periods also results in higher energy and time dedicated for cleaning, training, and forecasting tasks.

Keywords: environmental sustainability, forecasting algorithms, green computing.

Solar Energy Forecasting: Case Study of the UNICAMP Gymnasium

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Abstract. Within the spectrum of studies conducted by the São Paulo Center for Energy Transition Studies (CPTEn), time series from the Photovoltaic Energy Plant of the UNICAMP Multidisciplinary Gymnasium (GMU-PV) were analyzed. This plant is associated with the first implementation of a photovoltaic system in the context of the Sustainable Campus Project (PCS) at UNICAMP - as a consequence, it originated the most extensive and robust time series in the project. The research, structured according to the Cross Industry Standard Process for Data Mining (CRISP-DM) methodology, aimed to identify the patterns and parameters associated with the energy production of the aforementioned photovoltaic system. Based on Machine and Deep Learning techniques, forecasting models were developed to maximize the use of available resources and promote the sustainability of this energy system at UNICAMP. In evaluating the results, it was observed that the most effective model was the Orthogonal Matching Pursuit (OMP) built from the Python low-code library, PyCaret. This regression machine learning model led to a coefficient of determination (R2) of 0.935 494 and a root mean square error (RMSE) of 8.561 679.

Keywords: Solar Energy Forecasting, Machine Learning, Deep Learning.

Smart Energy Device Management

Distribution Grid Monitoring Based on Widely Available Smart Plugs

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Abstract. The growing popularity of e-mobility, heat pumps, and renewable generation such as photovoltaics is leading to scenarios which the distribution grid was not originally designed for. Moreover, parts of the distribution grid are only sparsely instrumented, leaving the distribution system operator unaware of possible bottlenecks resulting from the introduction of such loads and renewable generation. To overcome this lack of information, we propose the use of widely available smart home devices, such as smart plugs, for grid monitoring. We detail the aggregation and storage of smart plug measurements for distribution grid monitoring and examine the accuracy of the measurements. A case study shows how the average monitoring error in a distribution grid area decreases the more measurement devices are installed. Hence, simple smart plugs can help with distribution grid monitoring and provide valuable information to the DSO.

Keywords: Smart Grid, Distribution Grid Monitoring, Smart Home Measurement Device

Analysis of Electrical Equipment at UNICAMP: Insights from the Inventory Database

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Abstract. Data plays a crucial role in understanding several problems, including those related to electrical micro, smart grids and power consumption. In addition to electrical meters, data can be sourced from different channels such as environmental conditions, user expertise, maintenance history, and inventory registries. This paper introduces a Python-based analysis tool designed to search for equipment categories that exhibit constant power consumption within the asset inventory database of the University of Campinas. The software effectively identifies and categorizes items as air conditioners, refrigerators, computers, uninterrupted power supplies and internet routers, providing detailed insights into their specific characteristics. The tool generates a comprehensive PDF report featuring item discrimination through values, charts, organized and university units. Additionally, the software incorporates identification item lists and logs, aiding in the identification of missing or mismatched data throughout the process. These reports has been utilized to establish internal guidelines for optimizing in power consumption and already help the university to improve its GreenMetric index.

Keywords: Big data · Data analysis · Python language.

Design of Digital Controllers for Grid-Connected Voltage Source Converter Operating as Voltage or Current Source

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Abstract. Digital controllers for grid-connected voltage source converters (GC-VSC) offer a noteworthy alternative to traditional continuous-time control systems. A power grid often comprises inverters, grid-forming and grid-following converters, renewable energy source units, and various local loads. Currently, the design of GC-VSC controllers is subject to restrictions and additional considerations following standards and technical recommendations for their control when operating connected or disconnected from a power grid, mainly to maintain the stability of the control system. In this context, this paper presents the design of the GC-VSC digital controllers, using mainly the concepts of dead-beat control. Thus, the main result of this project is to improve the modeling and control of the single-phase GC-VSC using the digital control method. The relative RMS errors of the GC-VSC current and load voltage are ϵif = 3.67 % and ϵvo = 0.01 %, respectively, i.e., the controller showed tracking accuracy. Simulation results using MATLAB/SIMULINK are presented to validate the proposed controllers.

Keywords: Grid-Following, Grid-Forming, Dead-beat controller, Digital control, Voltage source converter.

Results of Testing a Smart Controller for Peak Shaving in An Italian Demo Site

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Abstract. Digitalisation will become increasingly important in district heating (DH) networks, since it will make the networks more sustainable, reliable and profitable [3]. One family of the digital tools which is currently being research and developed, consists of smart controllers to optimize the operation of those networks. We have developed and tested such a smart controller for reducing the peak heat load in DH systems. This smart controller builds further upon the results of the Horizon 2020 STORM [4] and TEMPO [5] projects. In STORM, a building heat demand response system was developed to manage and optimize the heat supply power profile. The TEMPO project continued on this path, introducing two novelties. On the one hand, the use of additional energy flexibility through supply temperature control was enabled. On the other hand, the modelling of district heating assets was extended with increased physical detail, i.e. transitioning from thermal power-flow modelling to thermal-hydraulic modelling.

This controller has been tested in an isolated branch of the district heating network of Brescia, Italy. A cloud-based platform is used to collect real-time data from various sources and to communicate control signals calculated by the smart control algorithms. Previously, tests have already taken place in the heating season 2021-2022 [6]. Development has since then further progressed, and a new series of tests was performed in 2022-2023. The test results will be presented and discussed.

Figure 1 shows an overview of the demonstration site [7]. The site consists of a DH network delivering heat to 43 flats in an apartment building, and 30 single-family houses. The heat network is connected to the main DH network in the city of Brescia, operating at 130°C (supply) / 60°C (return) during the coldest days. Nonetheless, a mixing station was installed between the main DH network and the network in the demonstration site, enabling dynamical adaptation of the supply temperature to the demo site network branch by mixing hot supply water of the main network with cooled-down return water of the demo site network branch.

The objective of the tests was to reduce the power consumption peaks in the demo site network branch. Therefore, two approaches were tested. First, the heat demand of the buildings was modified by automated demand response. In this approach, the heat consumption of the buildings was temporary and automatically modified compared to regular operation (building mass activation). Second, the supply temperature of the network branch was automatically increased in anticipation of the moment of peak heat consumption, so that the eventual peak consumption became lower than in baseline operation. As such, the network pipes itself were used as a thermal energy storage buffer (network activation).

To assess the performance of the controller actions, the peak heat load was measured and compared for test periods of 1-2 weeks without control actions to gather benchmark data, and with control actions.

The analysis of the results show that the controller calculates sensible control actions. In case of the building activation, the controller is trying to enforce the buildings to reduce their heat consumption when a consumption peak is predicted. For the network activation case, the controller tries to increase the supply temperature in the network before the predicted heat consumption peak.
Nevertheless, the impact of the control signals on the peak heat load delivered mixed results, and less good than hoped for. Deeper analysis showed that this could be attributed to the limited capacity of the substation heat exchanger in the apartment building, making it very difficult to influence the heat demand of the building. Furthermore, the limited network length in the demo site resulted in a very limited pre-charging capacity of the branch.
Despite the unfulfilled results of the test campaign, a lot of knowledge was gathered about the system, and improvements were identified and implemented. These improvements will be tested in the next heating season (winter 2023-2024).

Keywords: digitalization, smart control, demand response, energy flexibility, supply temperature reduction, peak shaving

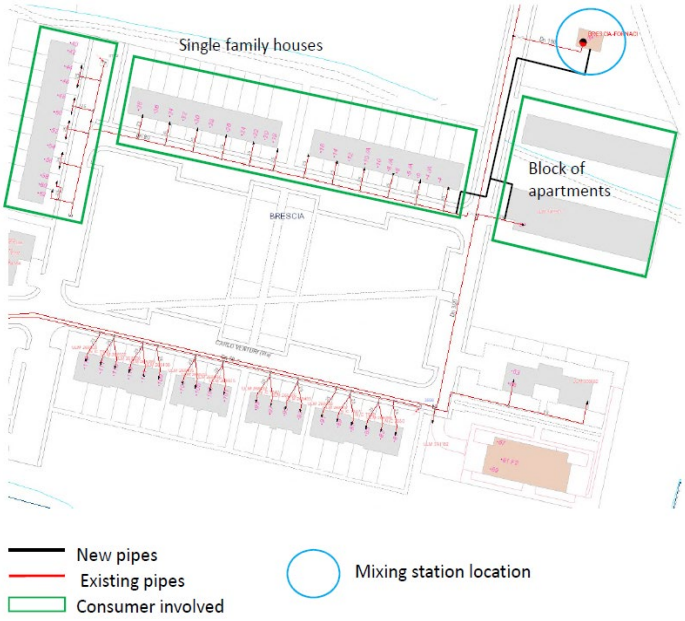

Figure 1: Overview of the demo site

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Management Strategies for an EP device in an Energy Packet Grid

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Abstract. The increasing use of renewable energy sources, which are predominantly based on power electronics, and the increasing demand for electricity due to the electrification of the transportation and heating sectors have brought new challenges to traditional power grids. In order to address these challenges, the so-called Energy Packet Grid (EP Grid) proposes a novel operating scheme for the power grid that focuses on the control of the power electronic components of the grid and considers the limitations of the grid equipment and power lines. The present article specifically deals with the management of a single Energy Packet Device (EP device) as an active participant within this grid structure. It outlines the challenges associated with managing an EP device and presents three employable control strategies: Three-Step Switching Controller, Probabilistic Range Control, Packetized Energy Management. A simulation environment is created to evaluate the effectiveness of these control strategies. The results of the simulations compare the impact of the different strategies on the operation of EP devices. The primary contribution of this article is the proposal of management strategies for EP devices, highlighting the challenges involved and suggesting solutions to mitigate uncertainty in EP device management.

Keywords: Energy Packet Grid, EP Device Management Strategies, Smart grid, Simulations and Modeling.

Power Consumption Analysis as a Detection Indicator for Cyberattacks on Smart Home Devices

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Abstract. The increasing prevalence of smart home devices has created new opportunities for cyberthreats and -attacks, necessitating effective security measures for their protection. This study investigates the potential of using power consumption analysis as an indicator for detecting cyberattacks on smart home devices. Through the examination of power data from a hardware testbed of 10 different devices over a one-month period, distinct groups of devices with varying power consumption patterns during simulated cyberattacks were identified. The findings reveal noticeable changes in power consumption during attacks across all devices, suggesting that monitoring power data could help detect threats and initiate appropriate countermeasures. Moreover, this study provides insights into the limitations and challenges associated with the stated approach and suggests avenues for future research. This study contributes to smart home security by demonstrating the feasibility of using power consumption analysis as an additional layer of protection for IoT devices and their users.

Keywords: Smart home security, cyberattacks, anomaly detection, IoT devices, power consumption patterns, data analysis.

Smart Electricity System

Gossen's First Law in the Modeling for Demand Side Management: A First Heat Pump Case Study

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Abstract. Gossen's First Law, also known as the law of diminishing marginal utility, describes the decreasing marginal utility gained from an increased consumption of a good or service and this is observed in various areas. This paper proposes the hypothesis that Gossen's First Law also holds in the modeling for Demand Side Management. It motivates the exploration of how the utility of a model depends on its complexity in this context, in order to provide a guideline that helps developing more simple and efficient models. We then propose a methodology for this investigation and apply it to a ground source heat pump in a standalone house. For this purpose, four mathematical models are developed with different degrees of simplification based on a detailed mathematical model. The model complexity is then quantified, and the simulation results are compared with actual measurement data to explore the utility of each model. The first results are in line with our hypothesis. Finally, we outline the next steps to provide more results and thoroughly verify the hypothesis.

Keywords: Demand Side Management (DSM), Distributed Energy Resources (DER), Ground Source Heat Pump (GSHP), Modeling

Measurement of the Wood Stove Impact on the Electric Power Consumption of a Norwegian Detached House

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Abstract. Wood stoves are commonly used as space heating systems in Norwegian houses. However, the specific impact of wood stoves on electric power remains relatively unexplored and is investigated in our study. We also aim to reveal the coincidence between the wood stove operation and the use of electric appliances during the different hours of the day, as it directly impacts the total electric power of the dwelling. Detailed field measurements have been performed in a detached house equipped with a wood stove and electric radiators in the cold climate of Trondheim, Norway. As expected, the use of the wood stove leads to a significant reduction of the space-heating power. However, as wood stoves are operated manually, there are still periods when the electric radiators are operated at maximum power. Nevertheless, we discovered a positive correlation between the usage of the wood stove and electric appliances. It means that when occupants are active, they extensively use their electric appliances and are more likely to use the wood stove simultaneously. Consequently, the peak power of electric appliances does not coincide with the peak power of the electric radiators so that the total electric power of the dwelling is reduced by using the stove.

Keywords: Wood Stove, Space Heating, Electricity Consumption.

Market Abstraction of Energy Markets and Policies - Application in an Agent-Based Modeling Toolbox

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Abstract. In light of emerging challenges in energy systems, markets are prone to changing dynamics and market design. Simulation models are commonly used to understand the changing dynamics of future electricity markets. However, existing market models were often created with specific use cases in mind, which limits their flexibility and usability. This can impose challenges for using a single model to compare different market designs. This paper introduces a new method of defining market designs for energy market simulations. The proposed concept makes it easy to incorporate different market designs into electricity market models by using relevant parameters derived from analyzing existing simulation tools, morphological categorization and ontologies. These parameters are then used to derive a market abstraction and integrate it into an agent-based simulation framework, allowing for a unified analysis of diverse market designs. Furthermore, we showcase the usability of integrating new types of long-term contracts and over-the-counter trading. To validate this approach, two case studies are demonstrated: a pay-as-clear market and a pay-as-bid long-term market. These examples demonstrate the capabilities of the proposed framework.

Keywords: energy market design, agent-based simulation, market modeling

Distributed Resources Remuneration on a Medium Voltage Network with Uncertainty and Seasonal Impacts

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Abstract. The current landscape of the electric world is shifting toward a cleaner and more sustainable pattern. While this is a known fact, there is still very little consideration for how distributed generators (DG) should be compensated when studying the network, whether through planning or operation/reconfiguration. The DG remuneration needs to be considered in modern network studies, especially when there is a high percentage of renewable energy penetration. Another major factor that should be given an adequate amount of importance is the introduction of uncertainty to the data used along the process. Thus, this study applies uncertainty to wind and solar generation and load, with its degree varying according to the season and daily periods. This study is applied to a 180-bus network in the Leiria district, Portugal, with 42 Wind farms, 33 Photovoltaic (PV) parks, as well as three biomass generators, and a substation belonging to the Distribution System Operator (DSO). The network also has two Energy Storage Systems (ESS) already in place owned by an outside party, but the model allows for the installation of more from the DSO. This study is done from the point of view of the DSO, aiming to minimize the investments and expenditures on their part while fairly remunerating the participants using a two-stage stochastic model. There are 16 main scenarios in this model, the combinations of the four seasons and daily periods. The results are promising with a Payback of 3.02 years.

Keywords: Distributed Resources, Remuneration, Renewable Generation, Optimal Planning, Seasonal Impacts, Uncertainty

New Perspectives on Clustering for Demand Response

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Abstract. Demand response (DR) programs have received significant attention with the proliferation of smart meters and the increasing need for demand-side flexibility to complement the growing share of renewable generation. A critical element in DR programs is the consumer selection; adhoc selection of consumers may not yield any tangible results in actual deployment. Clustering on features derived from smart meter data has shown potential for facilitating the consumer selection for DR. This paper furthers the understanding of this approach by looking at issues associated with the clustering process. Specifically, the paper identifies the problem of defining characteristic profiles for consumers exhibiting multiple consumption patterns. The characteristic profile is a key element for clustering as well as for evaluating behavior consistency. A new method for extracting characteristic profile is presented and metrics for consistency in consumption patterns are redefined. We also propose several useful attributes to quantify the peak load contributions associated with a consumer cluster. We apply the proposed techniques to Dataport smart meter data to bring fresh insights on clustering techniques that segregate consumers based on their consumption and behavioral patterns. We demonstrate how clusters formed using our proposed definition of characteristic profile show better clustering consistency. Our results also show how the proposed consistency metrics and peak attributes are useful for capturing the consumer predictability and peak contribution for a more meaningful DR program design.

Keywords: Clustering, Consumer consistency, DR consumer selection, Peak contribution

Energy and Smart Cities

Multi-Agent Based Simulation for Investigating Electric Vehicle Adoption and Its Impacts on Electricity Distribution Grids and CO2 Emissions

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Abstract. Electric vehicles are expected to significantly contribute to CO2-eq. emissions reduction, but the increasing number of EVs also introduces challenges to the energy system, and to what extent it contributes to achieving climate goals remains unknown. Static modeling and assumption-based simulations have been used for such investigation, but they cannot capture the realistic ecosystem dynamics. To fill the gap, this paper investigates the impacts of two adoption curves of private EVs on the electricity distribution grids and national climate goals. This paper develops a multi-agent based simulation with two adoption curves, the Traditional EV charging strategy, various EV models, driving patterns, and CO2-eq. emission data to capture the full ecosystem dynamics during a long-term period from 2020 to 2032. The Danish 2030 climate goal and a Danish distribution network with 126 residential consumers are chosen as the case study. The results show that both EV adoption curves of 1 million and 775k EVs by 2030 will not satisfy the Danish climate goal of reducing transport sector emissions by 30% by 2030. The results also show that the current residential electricity distribution grids cannot handle the load from increasing EVs. The first grid overload will occur in 2031 (around 16 and 24 months later for the 1 million and 775k EVs adopted by 2030) with a 67% share of EVs in the grid.

Keywords: electric vehicle, adoption curve, distribution grid, agent-based modeling, multi-agent systems, CO2 emissions

Brazilian utilities' invoice data understanding: extraction, data standardization and consumption overview from partner universities

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Abstract. Data plays a crucial role in understanding scientific problems, including those related to electrical microgrids, smart grids, and power consumption. In this scenario, one aspect that requires analysis is the consumption data that can be retrieved from monthly utility invoices. However, the analysis of utility invoices in Brazil poses a unique challenge due to variations in invoice document formats across different services, utilities, and contract types. This article addresses this challenge by developing software based on Regular Expression to extract and standardize data from diverse invoice models. Through the establishment of a database and the use of a Business Intelligence platform, the retrieval and analysis of pertinent information have been significantly improved. The focus of this article is on understanding and extracting utility invoice data, including electricity, water, piped gas, and telephony services, which have direct or indirect impacts on natural resources and human well-being. The analysis is carried out on public buildings in Brazil, specifically those associated with the São Paulo Center for Energy Transition Studies (CPTEn). The data presented in this paper encompasses consumption invoices from three universities: the State University of Campinas (Unicamp), São Paulo State University campus of São João da Boa Vista (Unesp-SJBV), and the Federal University of Goiás (UFG). It is important to note that all the analyzed information is publicly available under Brazilian law number 12,527 from November 18, 2011.

Keywords: Data understanding, Brazilian utility companies, Brazilian energy market.

Distributed energy resources and EV charging stations expansion planning for grid-connected microgrids

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Abstract. The intensification of environmental impacts and the increased economic risks are triggering a technological race towards a low-carbon economy. In this socioeconomic scenario of increasing changes and environmental concerns, microgrids (MGs) play an important role in integrating distributed energy resources. Thus, a planning strategy for grid-connected MGs with distributed energy resources and electric vehicle (EV) charging stations is proposed in this paper. The developed mathematical model aims to define MG expansion decisions that satisfy the growing electricity demand (including EV charging demand) at the lowest possible cost; such decisions include investments in PV units, wind turbines, energy storage systems, and EV charging stations. The objective function is based on the interests of the MG owner, considering constraints associated with the main distribution grid. A mixed-integer linear programming model is used to formulate the problem, ensuring the solution's optimality. The applicability of the proposed model is evaluated in the 69-bus distribution grid. Promising results concerning grid-connected MGs were obtained, including the enhancement of energy exchange with the grid according to their needs.

Keywords: Energy storage systems, EV charging stations, microgrids planning, renewable generation.

Practical information

Conference location

The School of Electrical and Computer Engineering, University of Campinas (UNICAMP - FEEC)

- The address is: Av Albert Einstein, 400, Campinas-SP, Brazil.
- Weblink: https://www.fee.unicamp.br/como-chegar/ (in Portuguese)

The location of the conference room: the main building of FEEC

- Room name and number: Sala da Congregação, LE48

Banquet location

Restaurant: Estância Grill Churrascaria

- Address: Av. Albino José Barbosa de Oliveira, 271, Jardim Santa Genebra II - Campinas
- Weblink: https://www.estanciacampinas.com.br/

Map of the main campus in Campinas city

- The FEEC building is shown in the circle on the map below
- Download the map via the link below:

https://www.unicamp.br/unicamp/sites/default/files/2019-10/Mapa_Unicamp_13042018.pdf

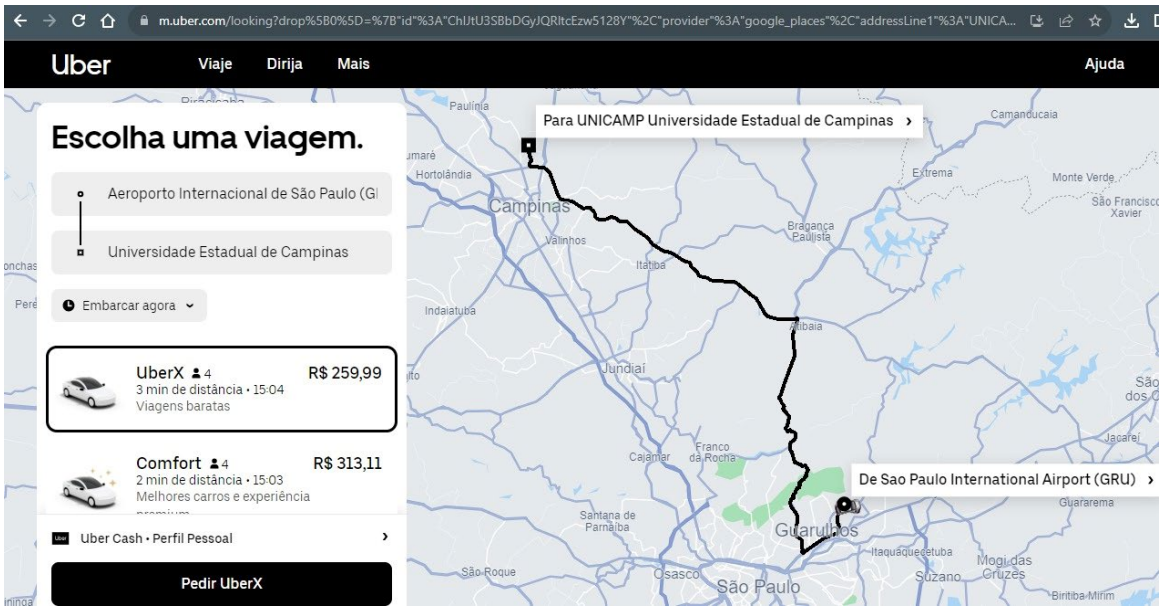
Travel tips

Did you plan the transportation?

Most foreigners visiting UNICAMP prefer to use Uber. Uber Services tend to be cheaper and easier to use than taxis. Get a price estimate - Sao Paulo https://www.uber.com/global/en/cities/sao-paulo/ From GRU (Guarulhos Airport) to UNICAMP: 300 reais (12:59 27/nov/2023)

In case you decide to rent a car at the airport, notice the following, please: "Brazil's 'Dry Law' stipulates that drivers must have a blood-alcohol content of zero. It empowers police to administer breathalyzer tests if drivers behave erratically." https://www.who.int/news/item/01-08-2022-after-lengthy-debate--brazil-s-drink-driving-law-is-fully-ratified

It's a bit complicated to use public transportation in Brazil.



Brazil Security Tips

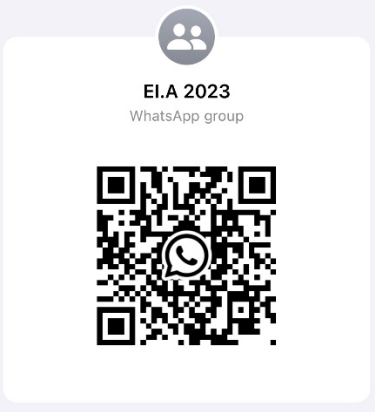
Latin America is quite different from Europe in terms of security, as you know. Just in case:

"If you want to carry a smart phone, do not put it in a tight pocket where it is visible. Never pull the phone out on the street, no matter how busy it is. If you want to call someone, look something up on google, or check your email, do it indoors. Go into a restaurant, go into a shop, go into a mall." From http://www.braziltravelbuddy.com/brazil-security-tips

Contact Information

For any enquiry, please contact us by email: contact@energyinformatics.academy

For any emergency, please contact us by mobile phone: 004531530017; or WhatsApp group "**EI.A 2023**":



(invitation link: https://chat.whatsapp.com/K8NkgnYjz8hEGqBFyonLjm)