EI.A-SDC Asia PhD workshop 2021

Technical program

(virtually) Beijing, 28, May 2021

Energy Informatics.Academy
The global community for energy informatics

SDC
The university partnership
Denmark – China

Table of Contents

Preface

The 1st EI.A - SDC Asia Ph.D. workshop is co-organized with Energy Informatics.Academy (EI.A) and the Sino-Danish Center (SDC) Sustainable Energy Systems, aims to support Ph.D. candidates in their research, offers them from the field a unique possibility to present and discuss, receive feedback, and exchange comments with peers and experienced researchers.

With the workshop committee's effort, in total ten (10) papers are accepted and will present their Ph.D. research works at the workshop. The Ph.D. research projects cover three important aspects of the energy informatics domain: energy systems, energy in buildings and industry, energy markets and business.

Three best papers are sponsored by SDC Sustainable Energy, will be awarded at the workshop.

Sincerely,

Workshop Chair
Birte Holst Jørgensen, Technical University of Denmark, Denmark
Bo Nørregaard Jørgensen, University of Southern Denmark, Denmark
Guangchao Chen, University of Chinese academy of sciences, China

Workshop Committee
Zheng Ma, University of Southern Denmark, Denmark
Sebastian Büttrich, IT-University of Copenhagen, Denmark
Qiuwei Wu, Technical University of Denmark
Christian T. Veje, University of Southern Demark
Hongbo Duan, University of Chinese Academy of Sciences, China
Yun Lin, Harbin Engineering University, China
Guoping Rong, Nanjing University, China

Program

Friday 28 May 2021			Central European Time		Beijing Time	
Activity	**Title**	**Presenter**	Start	End	Start	End
	Opening	Birte Holst Jørgensen Guangchao Chen	8.30	9.00	14.30	15.00
Keynote speech	Key research fields in energy Informatics	Bo Nørregaard Jørgensen	9.00	9.30	15.00	15.30
	Coffee break		9.30	9.35	15.30	15.35
PhD project Presentations **Energy system**	Analysis and Application of Model Predictive Control in Energy Systems	Tao Yang	9.35	10.35	15.35	16.35
	Data-driven proactive and predictive maintenance of power distribution systems	Lasse Kappel Mortensen				
	Flexible time aggregation for energy systems modelling	Koen van Greevenbroek				
	Coffee break		10.35	10.40	16.35	16.40
PhD project Presentations **Buildings and industry**	Optimizing Energy Consumption in Industrial Buildings	Sasanka N. Ranasinghe	10.40	12.00	16.40	18.00
	PCM-based cooling solution for ventilation applications	Viktor Ljungdahl				
	Automated demand-side flexibility identification and utilization in energy optimization	Jakob Bjørnskov				
	Digital Twin Framework for Industrial Production Processes	Daniel Anthony Howard				
	Lunch/dinner break		12.00	12.45	18.00	18.45
PhD project Presentations **Energy markets and business**	Agent-based simulation framework for evaluating energy flexibility algorithms and adoption strategies	Kristoffer Christensen	12.45	13.45	18.45	19.45
	Evaluation of Business Profitability for Planned Generation of Battery-assisted PV Considering Bidding to Wholesale Market	Ryu Ando				
	A digital twin framework for evaluating industrial consumers' demand response participation: a comparison between Denmark and China	Nicolas Fatras				
	Coffee break		13.45	13.50	19.45	19.50
Keynote speech	The origins of energy informatics	Rick Watson	13.50	14.20	19.50	20.20
Group discussion & exercises	Challenges and necessary training and education for research in energy informatics	Three groups of all PhD candidates	14.20	15.00	20.20	21.00
Group presentations	Energy system Buildings and industry Business and electricity market	All PhD candidates	15.00	15.30	21.00	21.30
	Best paper awards Closing		15.30	16.00	21.30	22.00

Keynote speakers

Key research fields in energy Informatics

Prof. Bo Nørregaard Jørgensen
Center for Energy Informatics, the University of Southern Denmark, Denmark

Professor, Dr. Bo Nørregaard Jørgensen is the founder and head of Center for Energy Informatics at the University of Southern Denmark. SDU Center for Energy Informatics is an interdisciplinary research center focusing on digital solutions for facilitating the transition towards a sustainable energy system. The center's research is conducted in close collaboration with industrial partners, public bodies, and government agencies. As head of center, Dr. Jørgensen represents the University of Denmark at national and international events, in advisory boards and government reference committees. He is an appointed member of the Danish Academy of Technical Science. 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.

The history of energy informatics

Prof. Rick Watson
University of Georgia

Rick Watson is a Regents Professor and the J. Rex Fuqua Distinguished Chair for Internet Strategy in the Terry College of Business at the University of Georgia. He is a former President of the Association for Information Systems. In 2011, he received the Association for Information Systems' LEO award, which is given for exceptional lifetime achievement in Information Systems. The University of Liechtenstein has established with government support a Consortium for Digital Capital Creation based on the ideas in his recent book, Capital, Systems, and Objects. For about a decade, he was Research Director for the Advanced Practices Council of the Society of Information Management and a visiting researcher at the Research Institute of Sweden (RISE) in Gothenburg.

Paper Themes

Theme	Paper title
Energy system	Analysis and Application of Model Predictive Control in Energy Systems
	Data-driven proactive and predictive maintenance of power distribution systems
	Flexible time aggregation for energy systems modelling
Buildings and industry	Optimizing Energy Consumption in Industrial Buildings
	A PCM-based cooling solution for ventilation applications
	Automated demand-side flexibility identification and utilization in energy optimization
	Digital Twin Framework for Industrial Production Processes
Business and electricity market	Agent-based simulation framework for evaluating energy flexibility solutions and adoption strategies
	Evaluation of Business Profitability for Planned Generation of Battery-assisted PV Considering Bidding to Wholesale Market
	A digital twin framework for evaluating industrial consumers' demand response participation: a comparison between Denmark and China

Paper abstracts

Analysis and Application of Model Predictive Control in Energy Systems

Authors	Tao Yang, Christian Veje
Affiliations	Center for Energy Informatics, University of Southern Denmark, Denmark

Abstract: Model predictive control (MPC) allows efficient use of energy systems and can provide considerable energy savings. However, finding a proper configuration of MPC in specific energy systems remains challenging. This doctoral project aims to develop methods of deriving the best combination of models and optimization schemes for a given energy system. The project goal will be achieved by testing different models and optimization techniques of MPC in a virtual testbed. An analysis of how to choose models and corresponding optimization techniques will be conducted based on test results. Three case studies will be carried out to evaluate the proposed methodology. It is expected to advance knowledge of setting up appropriate MPC configuration for energy systems and speed up MPC transition from academic research to wider industry implementation.

Presenter: Tao Yang is a Ph.D. student at the Center for Energy Informatics, University of Southern Denmark. His Ph.D. topic is “Analysis and Application of Model Predictive Control in Energy Systems”. Tao’s research focuses on energy system modeling, optimization, and predictive control for smart energy systems.

Data-driven proactive and predictive maintenance of power distribution systems

Authors	Lasse Kappel Mortensen, Hamid Reza Shaker and Christian T. Veje
Affiliations	Center for Energy Informatics, University of Southern Denmark, Denmark

Abstract: Motivated by the inefficient preventive and corrective maintenance strategies typically employed in nowadays power distribution systems and the advances in machine learning, this poster paper proposes research that aims to enable the application of predictive maintenance strategies in power distribution systems. Predictive maintenance relies on continuous monitoring of the power system to provide timely fault warnings, so remedial actions can be taken before permanent failures occur. Because fault data can be scarce for power distribution systems and the employment of high-fidelity sensors can be lacking, this poster paper proposes the use of data-driven models that can be developed with limited fault data or using data with a low sampling frequency.

Presenter: Lasse Kappel Mortensen got his bachelor’s degree in Energy Technology engineering at the University of Southern Denmark in 2019. He is currently pursuing a Ph.D. at the University of Southern Denmark. His research focuses on the use of data-driven statistical and machine learning method for proactive and predictive maintenance in energy systems.

Flexible time aggregation for energy systems modelling

Authors: Koen van Greevenbroek[1], Chiara Bordin[1], Sambeet Mishra[2]
Affiliations: [1]Department of Computer Science, UiT The Arctic University of Norway, Norway
[2]Department of Electrical Power Engineering and Mechatronics, Tallinn University of Technology, Estonia

Abstract: With high shares of renewable generation and a reliance on storage, modelling large scale energy systems is computationally challenging. One factor driving the complexity of these models is the need for a high temporal resolution over a long period; a typical baseline is modelling all 8760 hours in a year. While simple methods such as down-sampling and segmentation are effective at reducing the number of time-steps in a model, there is potential for more sophisticated simplifications. In this work, we propose a flexible time aggregation framework where individual components in the systems (e.g. generators, storage units) may be modelled at a lower time resolution. We base the method on the theory of aggregation in linear programming, giving the possibility for provable bounds on the resulting objective value. These ideas have only been explored in a limited fashion in the context of energy systems modelling, and we highlight their potential for large scale energy system models and the next steps for research.

Presenter: Koen is a PhD student in energy informatics at UiT The Arctic University of Norway, studying modelling and optimisation of energy systems. His main research interest is the mathematical formulation and simplification of complex energy system models. The current focus is the role of temporal resolution in capacity expansion models for continent-wide systems. Other interests include dealing with uncertainty (both on input and output) and formal bounds. He has a background in discrete mathematics and optimisation.

Optimizing Energy Consumption in Industrial Buildings

Authors: Sasanka N. Ranasinghe, Antorweep Chakravorty
Affiliations: Department of Computer and Electrical Engineering, University of Stavanger, Norway

Abstract: The electricity consumption of industrial buildings with many office spaces is significantly affected by the behavioral patterns and activities of the building users. Furthermore, external factors such as temperature changes, humidity and grid data are some of the common parameters that could have an effect on the energy consumption. Hence, there is a need for developing sophisticated energy consumption optimization strategies while considering all the possible factors that might affect the energy consumption to help minimizing the running cost of the buildings. The goal of this paper is to propose an intelligent framework for the optimization of the energy consumption of an industrial building while maintaining the thermal comfort inside the building.

Presenter: Sasanka Niromi Ranasinghe is a Ph.D. Research Fellow at the Department of Computer and Electrical Engineering at Faculty of Science and Technology in University of Stavanger, Norway. She completed her M.Sc. in Renewable energy at the University of Agder, Grimstad, Norway. Her current research interests cover various aspects in the field of energy informatics, including building energy management and peer-to-peer energy transactions as well as machine learning and Blockchain technology.

A PCM-based cooling solution for ventilation applications

Authors Viktor Ljungdahl, Muhyiddine Jradi and Christian Veje
Affiliations Center for Energy Informatics, University of Southern Denmark, Denmark

Abstract: In order to meet increasingly ambitious energy goals, buildings being one of the major consumers in the sector needs alternative technologies and solutions to meet heating, ventilation and air conditioning demands. Phase Change Material (PCM)-based cooling technologies in ventilation have shown potential in the recent years. In this work, a PCM-driven air heat exchanger cooling module for comfort cooling in office buildings is investigated. A numerical model of the PCM module utilizing the apparent heat capacity method with hysteresis is developed. The integration of the PCM module with a room model and a ventilation unit model is performed in order to test the system in different conditions. Simulations of the system operation under standard climatic conditions in Denmark and a short period of extreme ambient temperatures are conducted. The results demonstrated that the module performance is highly sensitive to the ambient conditions. Thermal comfort violations of 16.6°Ch for a year and 94°Ch for a five-day period of extreme temperatures are reported. Additionally, a large reduction in energy consumption was observed with the PCM module scenario compared to a conventional Direct Expansion (DX) cooling technology. A yearly electricity consumption of 109 kWh was reported for the PCM module compared to 220 kWh for the DX technology.

Presenter: Viktor Ljungdahl is a third year Ph.d. student at the Center for Energy Informatics at The University of Southern Denmark. His Ph.D. project is titled: "'Modelling, design and assessment of innovative phase change material-based HVAC systems". He contributes to the field of active PCM-based HVAC solutions through the extensive evaluation of the Next Generation Ventilation (NeGeV) prototype.

Automated demand-side flexibility identification and utilization in energy optimization

Authors Jakob Bjørnskov, Muhyiddine Jradi, Christian Veje
Affiliations Center for Energy Informatics, University of Southern Denmark, Denmark

Abstract: The utilization of demand-side flexibility is vital in future energy systems where the supply-side relies on renewable energy sources. In this transition, it is widely recognized that the building sector will hold a key role in providing demand-side flexibility, being currently responsible for 40% of total energy consumption in the EU. To provide this flexibility, advanced building control must be made more accessible considering that most buildings today still use inflexible rule-based control. Currently, implementation of advanced building control is associated with cumbersome and time-consuming manual work which requires expert knowledge. In this work, a data-driven and autonomous approach is therefore proposed, in the form of three general project objectives, to overcome these barriers. Namely, building energy modelling and performance data monitoring and evaluation algorithms will be identified to support energy flexibility identification and quantification. Subsequently, an automated building flexibility methodology will be developed to form the basis for energy operational optimization. Finally, this methodology will be implemented and tested in case studies to assess the impact on the energy system operation.

Presenter: Jakob Bjørnskov is a Ph.d.-student at Center for Energy Informatics, University of Southern Denmark. His research focuses on data-driven energy modeling of buildings to identify and utilize demand-side flexibility.

Digital Twin Framework for Industrial Production Processes

Authors Daniel Anthony Howard, Zheng Ma, Bo Nørregaard Jørgensen
Affiliations The Maersk Mc-Kinney Moller Institute, University of Southern Denmark, Denmark

Abstract: Due to the continuous integration of fluctuating renewable energy sources in the energy system, the security of supply is challenged. For stability and security of supply in the future energy system, it is necessary to integrate consumers through demand response. Industrial consumers have been identified as a group of consumers with significant energy flexibility potentials. However, industries hesitate to adopt energy flexibility measures due to uncertainties concerning product quality and the overall impact on production flow. This paper presents the ongoing research in developing a digital twin framework for risk mitigation in the production flow by bridging the gap between risk mitigation and demand response participation. As a result, the research provides a novel approach for production flow risk assessment and energy-aware production strategies. Using agent-based modeling as a foundation, a digital twin framework provides a robust industrial production solution. The digital twin components have been identified using agent-based modeling abstractions that govern production flow, including process, environment, product, batch, planning, conveyor, & transportation. The framework has successfully been applied across several industries for evaluating energy flexibility potentials focusing on production constraints.

Presenter: Daniel Anthony Howard is a Ph.D. fellow from the SDU Center for Energy Informatics. His research is centered around energy flexibility potentials established through a Multi-Agent-based System framework for Digital Twin solutions in the production flow process. He has collaborated with multiple industrial facilities through his research combining detailed knowledge of production processes with modeling and simulation to evaluate the impact of energy flexibility on the process flow. He holds an M.Sc in Energy Technology from the University of Southern Denmark.

Agent-based simulation framework for evaluating energy flexibility solutions and adoption strategies

Authors Kristoffer Christensen[1], Zheng Ma[1], Yves Demazeau[2], Bo Nørregaard Jørgensen[1]
Affiliations The Maersk Mc-Kinney Moller Institute, University of Southern Denmark, Denmark
[2]Centre National de la Recherche Scientifique, France

Abstract: To achieve national and international climate goals, huge investments are expected in the transition to a low carbon society. Due to large investments and high failure rates, avoiding risks (especially the value chain risk) evaluating the energy flexibility solutions and their impact on the energy ecosystem is essential. This PhD research project aims to develop an agent-based simulation framework for evaluating energy flexibility solutions and adoption strategies in a given energy ecosystem. The simulation framework consists of two sub-frameworks. One identifying and implementing energy flexibility solutions to the agent-based simulation. Another for identifying and implementing adoption strategies to the agent-based simulation. To show proof-of-concept of the developed framework, agent-based simulations of a case study are developed based on the model framework. The case study is an investigation of electric vehicle charging in a Danish electricity distribution grid. The research project's outcomes of evaluations and recommendations of energy flexibility solutions will contribute to the climate goals.

Presenter: Kristoffer Christensen is a Danish Ph.D. fellow in the Center for Energy Informatics at the University of Southern Denmark. He has a background in energy technology engineering giving him fundamental insight into the energy system, its green transition, and its challenges. This knowledge is applied to his Ph.D. research, developing frameworks for evaluating energy flexibility solutions and adoption strategies in the energy ecosystem using agent-based simulation.

Evaluation of Business Profitability for Planned Generation of Battery-assisted PV Considering Bidding to Wholesale Market

Authors Ryu Ando, Hideo Ishii, Yasuhiro Hayashi
Affiliations Department of Advanced Science and Engineering, Waseda University, Japan

Abstract: In this study, the business revenue of bidding to Japanese intraday-wholesale-market by a battery-assisted photovoltaic (PV) power generation system was evaluated. Long short-term memory (LSTM) method, one of the advanced methodologies of deep learning, was employed for a forecast of PV generation while the persistence method, using the previous values for prediction, was adopted for electricity prices in the intraday-wholesale-market. There are two different factors for the battery operation strategy; assistance to PV planned generation to minimize the imbalance and charge / discharge according to the market price prediction to enlarge the sales. We propose a dispatch control method of the battery-assisted PV system and compare the five different scenarios by annual numerical simulations evaluating the net sales in the market per unit capacity of battery.

Presenter: Ryu Ando received his B.E. degree in Electrical Engineering from Waseda University, Tokyo, Japan, in 2017. He is currently pursuing a Ph.D. in electrical engineering. His research interests include frequency control, battery control, and renewable energy forecasting. He is a student member of the Institute of Electrical Engineers in Japan (IEEJ) and the Institute of Electrical and Electronics Engineers (IEEE).

A digital twin framework for evaluating industrial consumers' demand response participation: a comparison between Denmark and China

Authors Nicolas Fatras[1,2], Zheng Ma[1], Bo Nørregaard Jørgensen[1]
Affiliations [1]The Maersk Mc-Kinney Moller Institute, University of Southern Denmark, Denmark
[2]Sino-Danish Center for Education and Research, University of Chinese Academy of Sciences, China

Abstract: This PhD research project aims to develop a digital twin framework to simulate and evaluate industrial consumers' demand response participation in the Danish and Chinese electricity markets. The research mainly focuses on industrial consumers with a large diversity in processes and consumption profiles allowing for different flexibility implementations. The project develops a digital twin framework based on agent-based modelling to understand and simulate the industrial consumers' market participation. The framework is developed and tested using case studies from the Danish and Chinese electricity markets. This framework includes demand response strategies based on market properties, consumer flexibility properties and consumer preferences. The simulation results from the case studies allow to establish general recommendations for demand response strategies within different market contexts. Therefore, the framework can facilitate industrial consumers' evaluation of their strategies for demand response participation.

Presenter: Nicolas Fatras is a PhD student at the SDU Center for Energy Informatics and the Sino-Danish Center for Education and Research at the University of Chinese Academy of Sciences, through the SDC PhD scholarship program. His thesis focuses on the development of a digital twin framework for energy markets, applied to industrial consumers providing demand response in the Danish and Chinese electricity markets. He holds an MEng in Civil Engineering (University of Bristol) and an MPhil in Energy Technologies (University of Cambridge).