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District and Building Energy Systems: A Collaborative Exchange of Results on Optimal System Operation for Energy Efficiency †

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† Presented at Sustainable Places 2019 (SP 2019), Cagliari, Italy, 5–7 June 2019.

Published: 19 July 2019

Abstract: Workshop organized by INDIGO project as a collaborative activity among EU funded projects in the area of District Energy Systems. The objective of the workshop was twofold: (1) to create a cluster of European funded projects working in the area of Energy Systems; and (2) to create a networking opportunity in which to share experiences on the results and difficulties of the researches, and to identify synergies.

Keywords: district; building; energy systems; energy efficiency; optimization

1. Introduction

"District and Building Energy Systems: A collaborative exchange of results on optimal system operation for energy efficiency", was a workshop within the Conference Sustainable Places 2019 aimed at clustering EU funded projects working with district heating and cooling and with building energy systems, in order to share the results of the projects and to identify synergies among the different researches.

This has been the third clustering workshop organized by INDIGO project within Sustainable Places. In 2017, the experience was interesting to introduce the projects existent in the area and to make contacts with the researchers; in 2018 the event was focused on presenting specific results and to plan future collaborations; this year the workshop was focused on technical developments in the area of optimization.

2. Presentations

2.1. INDIGO: "A Virtual Test-Bed for Model Predictive Control Developments in District Cooling Production Systems"

INDIGO [1] aims to realise more efficient and economic planning, control and management of existing district cooling (DC) networks. This will be achieved through two specific objectives: (i) to widen the use of DC systems and motivate the competitiveness of European DC market by the development of open-source tools for planning and modelling DC systems [2]; (ii) to reduce primary energy use via improved DC system management strategies aimed at system efficiency maximisation and cost minimisation [3].

One of the developments to achieve the second objective is to propose a control strategy for the Production plant (chillers and storage) that solves the Unit Commitment and Economic Dispatch problems with a thermal approach.

The INDIGO project offers a control for the Production plant of DC based on a Model Predictive Control (MPC) that handles demand predictions, weather forecast, equipment characteristics and operation objectives. One of the greatest challenges of using an MPC for the control of the plant is that a model satisfying these requirements is necessary. However, such model must comply with certain constrains including:

- Being descriptive enough to capture the most significant dynamics of the components, considering that these systems combine both fast and slow dynamics as well as different multi-physics behavior.
- Being computationally light as the optimization problem to be solved by the MPC implies a high amount of computation.

Some advanced controllers have been tested in DC, but they use very simple models such as in [4–6] in which the dynamics of the chiller are not considered at all or the ones that use detailed models have turned out to be computationally too demanding, such as the ones mentioned in [7], which were not suitable for real-time applications. Moreover, in [8], the importance of integrating data-driven models in order to advance in the intelligent control algorithms is highlighted.

INDIGO has developed models that fulfil the two constrains. For the first one, detailed parametric models are developed with Modelica for different types of chillers. Then different Machine Learning techniques are used in order to reduce the models to achieve lighter models from the computational point of view. These reduced models are fast enough to be used in real-time controllers and still define accurately the dynamics of the systems.

Finally, the INDIGO project has developed a systematic methodology and corresponding tools to define and build the aforementioned models and MPC and has validated them.

2.2. THERMOSS: "Optimising with Heat Pumps: From Centralised Systems to District Heating Networks"

THERMOSS Project [9] is at its final stage and a lot has been done so far in terms of technological development and optimization strategies.

THERMOSS has a strong focus on demonstration of gas-based technologies and improved control at dwelling and at district level. The centralized systems in the four detached houses in Latvia have been retrofitted with mCHP, GAHP and hybrid heat pumps. A smart thermostatic valve system has been furthermore included, allowing to reach 25/33% energy savings.

The UK demo-sites of the tower building and the multi-apartment building both have decentralized heating equipment in the main boiler plant room. They have been retrofitted respectively with new generation HIUs and GAHP. The smart thermostatic valve solution will also be applied to a whole area of the multi-apartment building block, in combination with GAHP.

The largest demo site is a district heating network in Spain, consisting of 570 apartments. Here, decentralized heat pumps have been installed at substation level, providing for 26/28% energy savings. The optimization algorithms for this case are currently under investigation by research centres, aiming to select the most convenient and sustainable heating technology at any time. Meanwhile, a two-way heat exchanger prototype is being prepared, allowing to exchange thermal energy from and to buildings (prosumers).

2.3. OPTi-Sim: "Integration of Waste Heat from Data Centers in District Heating Networks: A Post-OPTi Project Case Study"

The Horizon 2020 project OPTi [10] has developed methods and tools for the automatic generation of city-scale digital twins to enable simulate, what-if analysis, and engineering on DHC systems. The feasibility of the approach was demonstrated on the dynamic simulation and engineering of the city scale district heating network of Luleå, Sweden. The simulation environment OPTi-Sim is a full scale digital twin of a district heating network aligned with the visions of Industry 4.0 and the Digital Roadmap for District Heating and Cooling.

OPTi-Sim replicates many real-life standard components. In this case study, an air-cooled data center model is integrated into the OPTi-Sim district heating simulator and the effects on the operation are studied for the Luleå district heating case. It is shown that the utilization of the waste heat from data centers can replace the use of an electrical boiler. While waste heat recovery is beneficial, there remain challenges on how to connect the data center and also how to manage the raised level of the return temperature affecting the operation of the main CHP plant. Implementing a real-time optimization scheme with predictive capabilities is a promising approach for the latter challenge.

2.4. REACT: "Energy Dispatching Optimization for Self-Sustainable Island Communities"

REACT [11] will deliver a scalable and adaptable cloud-based ICT platform for planning and management of RES and storage enabled infrastructures supporting a holistic cooperative energy management strategy at the community level in geographical islands. The main objectives are increased RES hosting capacity coupled to large-scale energy storage deployment and unlock DR potential and optimize distribution grid flexibility. In particular, REACT will maximize the use of intermittent RES unlocking the low/medium voltage flexibility though a holistic DR strategy, considering energy demand of island residents in an aggregated way (community level) to enhance the grid security and reliability. The presentation focused on potential risks at the pilot side of Aran Island, considering the concept of "optimization of energy systems" in this case buildings. Looking at the current housing age stock, 50% of it was constructed pre-1970, there is total absence of building data in terms of drawing, walls stratigraphy specifications, and 85 % of the island households use oil for their central heating, or coal and peat.

Considering that, a methodology for community buildings selection for pre-optimization has been developed and presented. The methodology will take into account criteria as community, economical, technical and practical in order to select the most suitable buildings within the Island to be involved in the project, host the new technologies provided by the project and be ready to unlock DR potential and optimize distribution grid flexibility.

2.5. RESPOND: "Integrated Demand Response Solution for Residential Buildings: An Adaptive Performance Measurement and Verification Methodology"

RESPOND [12] aims to deploy and demonstrate an interoperable, cost effective, user centred solution, entailing energy automation, control and monitoring tools, for a seamless integration of cooperative DR programs into the legacy energy management systems. In this endeavour, RESPOND is based upon an integrated approach for real-time optimal energy dispatching, taking into account both supply and demand side, while exploiting all energy assets available at the site.

Owing to its flexibility and scalability, RESPOND solution is capable of delivering a cooperative demand response at both building and district level. To provide a seamless integration of all DR enabling elements and ensure a high replication potential, RESPOND is leveraging open standards for interoperability with smart home devices and automation systems, connectivity and extendibility towards smart grid and third party services such as for provision of energy prices, weather forecasts, etc.

Underpinned by the smart energy monitoring infrastructure, RESPOND will be able to perform reliable energy data analytics and forecasting in order to detect potential energy conservation opportunities, and to adapt, in real time, to the operational environment considering indoor and outdoor conditions, while retaining the requested comfort levels.

Through the interaction with the end users, RESPOND aims to raise their awareness by delivering measurement driven suggestions for energy demand reduction and influence their behaviour making them an active indispensable part of DR loop. In order to demonstrate the high replication potential, RESPOND targets different types of residential buildings, situated in different climate zones, having different forms of ownership (both rental as well as home-owners), population densities and underlying energy systems.

2.6 E2District: "Evaluation and Experience from DHC Demonstration Sites"

Intelligent Energy Europe expects district heating to double its share of the European heat market by 2020 while district cooling will grow to 25%. While this expansion will translate into 2.6% reduction in the European primary energy need and 9.3% of all carbon emissions, it will not be achieved through modernization and expansion alone but requires fundamental technological innovation to make the next generation of district heating and cooling (DHC) systems highly efficient and cost effective to design, operate and maintain.

The outcomes of E2District project [13] have developed and demonstrated a novel cloud enabled management framework for DHC systems, delivering compound energy cost savings of 30% through development of a District Simulation Platform to optimise DHC asset configuration targeting >5% energy reduction, development of intelligent adaptive DHC control and optimisation methods targeting an energy cost reduction between 10 and 20%, including flexible production, storage and demand assets, and system-level fault detection and diagnostics, development of behaviour analytics and prosumer engagement tools to keep the end user in the loop, targeting overall energy savings of 5%.

Author Contributions: Writing-Original Draft Preparation, Review & Editing, T.L.; 2.1 INDIGO, J.F.; 2.2 THERMOSS, F.F.; 2.3 OPTi, K.A. and W.B.; 2.4 REACT, F.S.; 2.5 RESPOND, N.T.; 2.6 E2District, M.K.

Funding: These researches were funded by European Union's Horizon 2020 research and innovation programme under Grant Agreements: INDIGO GA #696098; THERMOSS GA #723562; OPTi GA #649796; REACT GA # 824395; RESPOND GA #768619; E2District GA #696009.

Conflict of Interest: The authors declare no conflicts of interest.

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