European Research Infrastructure supporting Smart Grid Systems Technology Development, Validation and Roll Out

TRANSNATIONAL ACCESS
USER PROJECT FACT SHEET

USER PROJECT	
Acronym	**DAMS4IRMA**
Title	**Distributed Adaptive MPC agentS for Integrated energy Resources MAnagement in smart buildings**
ERIGrid Reference	
TA Call No.	

HOST RESEARCH INFRASTRUCTURE			
Name	Department of Electrical Engineering, Technical University of Denmark (DTU)		
Country	**Denmark**		
Start date	**October 30, 2018**	**Nº of Access days**	**10**
End date	**March 8, 2019**	**Nº of Stay days**	**10+18**

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1. USER PROJECT SUMMARY (objectives, set-up, methodology, approach, motivation)

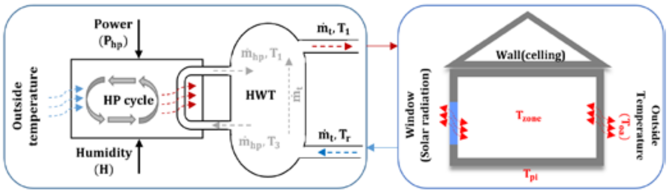
The DAMS4IRMA project deals with flexible loads in smart grids. It aims at the design and testing of an efficient strategy to optimize the real-time behavior of smart buildings, including different types of storages unit and energy sources such as PV panels, wind turbines and local generators, in order to introduce the highest possible level of flexibility, while preserving comfort, to be used in services to the smart (micro) grid. The DAMS4IRMA project investigates the possibility to clearly separate the user load profile from the desired comfort level, through the adoption of distributed optimization techniques, suitably tailored for the purpose. The DAMS4IRMA project thus provides a contribution to the renewable resources penetration in the market and to an acceptable level of flexibility of the load in the future smart grids.

More in detail, the addressed scenario is a smart building connected to a smart power grid including different Energy Storage Systems (ESS) - both electrical and thermal storages are here considered -, photovoltaic generators, wind turbines, hydro-power plants. The mentioned smart power grid is connected to the main distribution grid through a Point of Common Coupling (PCC). Any of these energy resources is endowed with an intelligent control: for example, a load will have a local flexible controller (Load Control - LCs) enforcing requirements fulfilment and also the necessary flexibility, a wind turbine will have a control system able to maximize energy production and performance and make reliable and adjustable production prediction, a battery will have its own charge control, and also a Microgrid Controller (MC) will be in place to manage the overall energy exchanges at the PCC. The load considered in the DAMS4IRMA project is the thermal load obtained with thermo-electrical machines like heat pumps.

The goal of DAMS4IRMA project proposal is twofold: (i) using different type of energy storages (thermal and electrical) for modification of consumer's purchasing patterns and behaviour by shifting the demand away from peak hours and (ii) design a suitable control and management architecture to ensure the required demand in a more economic and efficient manner. The selected methodological tool to obtain the above goals is the Model Predictive Control (MPC) technique, but in the form of distributed adaptive MPC (DaMPC), where a community of independent local predictive controllers interact in a cooperative and non-cooperative scheme to a global and local goal, and every controller is endowed with prediction capability and optimization facility over a future finite horizon. In the literature, the approach is novel.

In the given scenario, the project will propose and investigate a new configuration of using Thermal Energy Storage (TES) and an innovative distributed real-time optimization technique to exploit inertia and storages of energy to decouple load request to the electrical grid from the user comfort control problem.

2. MAIN ACHIEVEMENTS (results, conclusions, lessons learned)



In this research, the main goal was to implement an MPC-based control strategy for a smart building connected to a smart power grid, using DERs' predictive optimization potential to support the introduction of a large penetration level of energy storages. In this project, an MPC controller is implemented for load shifting in a centralized approach in the base scenario, although extensions are possible even in this project.

The original contributions of this work are:

1) Building an easy, fast to implement model for thermal energy storage and heatpump, and a continuous-time linear state-space model for the building connected to the TES by a 3-way valve

2) Developing a nonlinear model of variable circulated water-flow rate hot water tank for the prediction purposes connected to the Heat-Pump

3) Implementing a centralized MPC based control scheme which is used to realize the load shifting for the heaters' power consumption and also optimal decision for charging/discharging the thermal energy storage (TES), although satisfy the comfort conditions;

4) Integrating weather forecast information and dynamic power price into the MPC based control strategy;

5) Simulating and testing an MPC controller on a real power grid with high penetration of RESs.

Concerning demand side, another interesting contribution of this project was to investigate the impact of the presence of the more accurate nonlinear model of TES on the optimization problem. Lastly, different scenarios was considered based on different control strategies, i.e. Centralized MPC, Heuristic for the comparison purposes.

Moreover, a detailed model of a generic heat pump, so-called reference model, is developed and experimentally validated. Then, the reference model is used to formulate several control-oriented models of the heat pump, namely the formulas defining the Coefficient of Performance (COP) based on increasing levels of complexity. Finally, the project explores the impact of the simplification level of the heat pump model on the overall quality of temperature control in a building, and on electrical energy consumption. The research investigates also the impacts of different control-oriented models of the air-to-water heat pump on the COP prediction and optimal control performance. The results show up to 5% improvement in the energy saving using more accurate model of the heat pump, under a normal tuning. The proposed model can be exploited for the dynamic pricing and also application of the demand side management strategies, where it can provide an accurate prediction of the heat pump COP.

3. PLANNED DISSEMINATION OF RESULTS (journals, conferences, others)

Accepted:

Soroush Rastegarpour, Luca Ferrarini, Lorenzo Caseri “Experimental Validation of the Control-Oriented Model of Heat Pumps for MPC Applications “, IEEE 15th International Conference on Automation Science and Engineering (CASE), Vancouver, BC, Canada, August 22-26, 2019.