



**DEPARTMENT OF ENERGY TECHNOLOGY**  
AALBORG UNIVERSITY

## **PhD Public Defence**

**Title:** Flexible Control for Local Heating and Transportation Units in Low Voltage Distribution System

**Location:** Pontoppidanstræde 105, room 4.127

**Time:** Monday 11 November at 13.00

**PhD defendant:** Rakesh Sinha

**Supervisor:** Professor Birgitte Bak-Jensen

**Moderator:** Associate Professor Erik Schaltz

**Opponents:** Associate Professor Erik Schaltz, Dept. of Energy Technology, Aalborg University (Chairman)  
Dr. Damian Flynn, University College Dublin, Ireland  
Professor Geert Deconinck, KU Leuven, Belgium

**All are welcome. The defence will be in English.**



## Abstract:

Global concern to reduce carbon footprints has led pursuit towards fossil fuel independent energy systems in every energy sectors. Various energy sectors such as electricity, heating/cooling, gas and transportation are operated independently. Integrated operation of thermal and electricity or transportation and electricity systems are popular among the researchers. To exploit long term benefit from renewables, the integrated operation of the multi-energy system is essential. Each energy system is capable of operating in harmony with mutual benefits from each other for its stable operation. To achieve security and efficiency in the integrated energy system, the flexible operation of the various energy system is necessary. Electricity being the most vulnerable system with fluctuating generation from renewables, flexibility is achieved from an integrated energy system. As electricity cannot be stored directly without high costs, it can take advantage of thermal, gas and transportation systems to store surplus generation from renewables. On the other hand, electricity conversion from these storages can serve as reserve capacity during deficit in electricity generation from renewables. The Danish energy model has supported technical innovation and development to enhance sustainable integration of renewables in multi-energy sectors.

Danish electricity and thermal energy infrastructure have evolved from centralised to decentralised systems in recent years. The decentralised system has improved security, efficiency and reliability in energy transmission and consumption. Thus, the concept of decentralised and integrated electrified thermal and transportation system in low voltage (LV) distribution networks is explored in this research work. The coupling of thermal, electrical and transportation system, in LV residential networks, generates unprecedented challenges in modelling, planning, operation and control of these systems. An appropriate and feasible methodology is investigated to identify and address these challenges. As a consequence, the compromise between numerical complexities and physical phenomena exhibited by the models of energy networks components are examined. A numerical model of an existing Danish LV residential network is considered as a test platform for steady-state simulation of the integrated operation of electrified thermal and transportation units. Actual data from the energy distributors and survey are diagnosed to understand and improve the flexibility of the integrated system.

Relevant modelling of the active controllable loads and storages are crucial for optimal operation and flexible control. Thermal loads (electric boiler and heat pumps) and electric vehicles are considered as active loads. The general and specific capabilities of the average and stratified models of the thermal storage tank are presented. The influence of these models in the representation of technical parameters and scope of work is discussed in brief.

The consumption patterns of electricity, thermal and transportation needs are based on users comfort. Thus, data analytics is applied to estimate flexibility from these energy sectors to activate demand response. The complexity of social and external environment components, influencing thermal consumptions, are aggregated to estimate thermal demands using the neural net and similar day method. These methods are applicable and simple to generate appropriate estimated values, which are compared with values from time-series estimations techniques. The advantages of data analysis and thermal storage tank usage for optimal scheduling of an electric boiler based on the spot price of electricity is demonstrated.



From a spatial perspective, the individual thermal units in residences are examined for its relevance to flexibility and impact in integrated LV residential network. Then the heating sector is aggregated to provide services to the local area, represented by the LV grid. The outcome of these analyses is investigated to identify possible integration options concerning technical/social complexities, hosting capability and immediate need for electric grid reinforcement.

Finally, coordinated operation of thermal and transportation sector at each residence in the LV network are further analysed with demand response to enable efficient monitoring and flexible operation. The demand response control units are local and autonomous. A rule-based method for charging of electric vehicles is discussed to avoid communication infrastructure necessary for extensive data handling and optimisation process. Comprehensive models of control architecture deal with priority based on energy requirements and location of loads in the radial feeder of LV grid. This technique helps to support the flexible operation of thermal and transportation loads within the operational limits of the electricity network while securing end-users need simultaneously.