1. Hello everyone, my name is Bekir Caner Yagci. I have started working on my thesis in IEPG right after this Christmas. My project is about modelling and co-simulation of an industrial multi-energy system. In this presentation,…

2. I will start with what is Multi-energy system, MES and why is it important to model those systems. Secondly, I will go little deeper in the topic with my research questions and their brief explanations. Then, we will move on to “how?” part, here I will explain the overall methodology and the characteristics of my system. Finally, I will close this presentation with my modelling and control approach, my very first results and conclusion. So what is a multi-energy system?

3. Traditionally, energy systems are de-coupled from each other, which means, even though tight interactions between them exist they do not consider what is happening inside the other. In a multi energy system, different energy sources optimally interact with each other at lower system levels with the help of coupling technologies. Arguably, all energy systems are considered as multi-energy from demand to generation; however, multi-energy refers to have a whole system approach to operation and optimization of a specific case. Multi-energy systems, especially with RESs, are considered to have better technical, economical, environmental and operational advantages than those conventional de-coupled ones. However, with the stochastic variability of RES, this operation is a challenge to overcome for multi-energy systems. It is essential to model and analyze such systems to understand the operational and cost related benefits of MES. Moving to my research questions…

4. Power-to-X converters, specifically Heat pumps and electrolysers, have the potential to be an integral part of an efficient, renewable and interconnected multi energy system. However, due to the approximations made in traditional model formulations, flexibilities provided by those devices to the grid can be concealed in the simulation results. Therefore, modelling of the heat pump and electrolyser system should be investigated with respect to be optimally adapted to the requirements of the electrical system. This brings up my first question…

Moving to my next question, Planning and operation of a multi-energy system needs to be coordinated to make optimal use of the available resources. Due to the interdependencies and connectivity between previously distinct energy vectors, a more holistic energy management and modelling approach must be provided. As a result my second research question is… Lastly, if I have to summarize my project with only one sentence, this project investigates the impact of MES flexibility service providers on balancing the stochastic variability of renewable energy sources (load levelling) by using co-simulation in OpenModelica environment.

5. This figure is from a literature review paper and it summarizes how this kind of a study is carried out in the previous projects. I did not change the methodology you see in this figure but just modified it according to my objectives. As a first step, I have defined the scope of this project but I still need to fit it into a real case scenario to decide the size of each element in the system. Secondly, I moved to modelling where I characterize each element in the system. Here, I create two different models for heat pump and electrolyser for the comparison of the flexibility. Nowadays, I am at the modelling phase in parallel with the concept development. Then I will move on to control and decide the inputs outputs objectives of the control system. Hopefully after that, or in parallel with that, I will create the FMUs and carry out the Co-simulation and analysis.

6. This figure is the single line diagram of my MES. It starts with the grid at HV level. Then renewable energy sources wind and PV are connected at MV level. Finally, electrolyser, heat pump sub-systems and industrial loads are connected at LV level. What separates this model from the previous ones is that it has three different energy carriers and all three voltage levels. Usually this number is two in the previous projects this means only two energy carries and two voltage levels were considered.

Therefore, the multi-disciplinary model, developed in this study, is a step towards the simulation of complex systems in which thermal, gas and electric components are combined in order to study the effects on grid support. Now I would like to show you my modelling approach and some of my results.

7. Here you see the operational steps of the electrolyser model and the figure shows my first results for the comparison of the simple and detailed models. Electrolyser model first takes hydrogen production rate as an input from the controller considering load profiles and storage level. In the second step, using this value and mass flow equations, cell current is calculated. The difference between the simple and the detailed model is the third step. Mainly, there are three different overpotentials in the electrolyser cell, these are activation, ohmic and mass overpotentials. Activation is effective at low current densities. It is non-linear but can be linearized mathematically. Ohmic overpotential is effective at medium current densities and it is linear. Mass (bubble) overpotential is effective at high current densities and it is highly non-linear. In the previous studies and my simple model, it is assumed that the current density has maximum and minimum limits therefore it is only modelled as a linear device at constant temperature as you can see in the figure on the left. However, electrolysers have non-linear behavior at the start-up and they are highly temperature dependent. Therefore, while simple model uses linearized equations for the overpotential calculations, detailed model uses hyperbolic functions to show the behavior at start-up as you can see in the figure on the right side.

Due to high non-linearity of the mass overpotential, I am planning to ignore that one and limit the maximum current. The final step is the calculation of efficiency, input power etc. for the analysis. It is very straightforward after the first three steps. I just need to put the values into equations. Moving to heat pump…

8. Here you see the operational steps of the heat pump model and the figure shows that my result matches with the result on the paper I used for the detailed model. Heat pump model first takes input, output temperature and output heat power as an input from the controller considering load profiles and storage level. For this model, the simple and detailed versions are separated in the second step where coefficient of performance is calculated. Most of the previous studies and my simple model consider COP as constant assuming input and output temperature does not change. However, constant temperature is far from reality. Therefore, more realistic models must be developed to allow true optimal control of heat pumps within a multi-vector district energy system. For this purpose, using curve fitting and heat capacity table of a commercial heat pump I have created a polynomial equation of COP depending on Tsource and Tsink. On the left side you see the result of the paper and on the right side you see my results. As you can see, I was able to obtain the characteristics of a heat pump using curve fitting. And, on the third step, dividing the heat power output by the calculated or constant COP, I obtain the necessary input power.

9. Finally I would like to talk about the control very briefly, because I haven’t started to work on this part yet but I think I can give you the feeling of it. In this project, multi-agent based hierarchical energy management system is proposed. What this means, each subsystem, those are PV farm, wind farm, heat pump, electrolyser and grid, will be considered as an autonomous agent that can communicate with other agents of the system with the information about the adjustable power level or any other additional information. This information will result in a variety of options for the Central EMS to fulfill the load demands of its network. I am planning to include voltage and frequency support in each subsystem as and internal control and maybe I can combine the grid and the central EMS together but those are still not sure to me.

10. To conclude, today I have talked about the context of my project and showed you the very first results. At the end of this project, I am expecting to have some recommendations for the modelling of Multi-energy systems especially heat pumps and electrolysers. I want to show the impact of Power-to-X converter modelling on grid support and show the flexibility provided by multi-agent based control strategy.