Popular Summary of Master Thesis:

Modelling and Simulation of Smart Grids using Dymola/Modelica

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***Abstract*—Smart grid is a technological concept that in a more efficient way will integrate renewable energy sources to the power grid and at the same time give consumers opportunity to consume electricity in a smarter fashion. This popular summary summarizes the master thesis ''Modelling and Simulation of Smart Grids using Dymola/Modelica''.**

I. Introduction

Today electricity is produced mainly with fossil fuels, hydro and nuclear energy. The *non renewable energy sources* adds up to over 80% of the total electricity production[1]. The transition to more extensive use of *renewable energy sources* is necessary to reduce the emissions of greenhouse gases and to assure energy supply which otherwise will be affected by depletion of fossil fuels. Moreover, the structure of the current power grid is old and sensitive to faults and possible terrorist attacks.

By introducing locally produced electricity, or *micro generation*, end users will depend less on the ability of *large scale power stations* to produce electricity and on *transmission grids* to deliver electricity. The price of *photovoltaic solar panels* (PV) has decreased over the last years [2] and might thus be suitable for producing electricity locally. The *Vertical Axis Wind Trubine* (VAWT) might be a good way of generation electricity in an urban environment since it is not dependent on wind direction as the *Horizontal Axis Wind Turbine* (HAWT) is.

Smart grid is a concept that involves communication between different actors on the *electricity market* such as *power producers*, *transmission system operators*, *distribution system operators*, and *end users* in order to produce and consume power in a more efficient way. The communication might contain minute wise information about electricity price and power available for consumption. This will create incentives for the consumer to lower electricity consumption at times of high demand, thus high price. There are a couple of projects investigating the possibilities to implement smart grids, two of them are *Smart Grids Gotland* and *Stockholm Royal Seaport*. Both projects focus on more effective integration of renewable energy into the distribution grid and at the same time influence electricity usage by shifting consumption to periods of the day where supply of power is good and the price is low. This might include automatic systems that charge the consumers electric vehicle (EV) during the night and start electronic devices such as dishwasher or washing machine when the electricity price is low. The automatic system will both lower the overall electricity cost as well as reduce power peaks, thus the consumer will be able to reduce its contract ampere[3][4].

In figure 1 a schematic idea of a smart grid is presented. The smart house (lower right of the figure) is equipped with loads (electronic devices), a battery (EV), a connection to the external medium voltage grid and micro generation such as PV and VAWT. Each house has a *system controller* which is connected to all resources (loads, battery, external connection and generators). Its objective is to supervise and to make decisions based on current electricity price and the ability to purchase power from the external grid. If the price is low the system controller will turn on loads such as the dishwasher and charge the EV. If there is a blackout on the external grid, the system controller will disconnect the external connection, turn off low priority devices and use the battery in the EV to provide power to critical loads in the house.

The *medium voltage grid* consists of connections to houses, medium scale power generation, energy storage and a connection to high voltage grid. Its objective is to keep the voltage on the grid at a certain level and to provide power to the houses when possible. Energy is stored in the *energy storage* whenever the price is low (usually during the night) and is used during times of high price (usually during the evening).

II. Method

The modelling of smart grids was done using Dymola which is a commercial modelling and simulation program based on the Modelica modelling language. All the physical modelling, such as wind turbines and solar panels, were done using Dymola. The control program was implemented using an external program written in C++. This program ran in parallel with Dymola simulations and controlled the grid by sending signals to the resources in the smart grid. The program could for instance instruct a load to turn off to maintain the voltage level in the house.

III. Control Strategy

All houses connected to the smart grid are provided with current price information. To minimize the electricity cost for

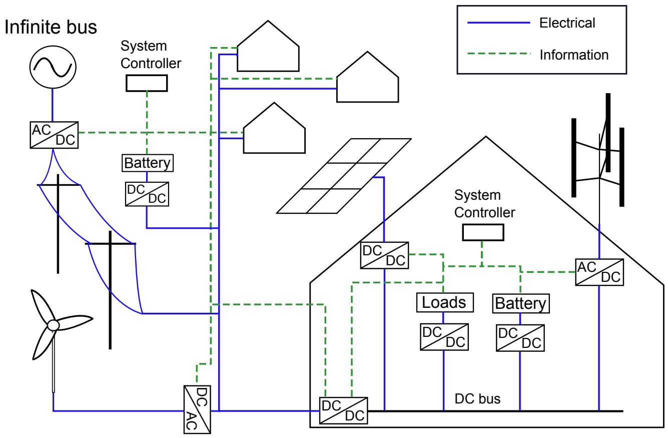


Fig. 1: Schematic figure over a smart house connected to a smart grid

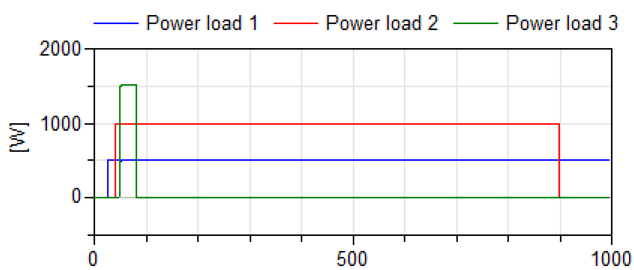


Fig. 2: House with three purely resistive loads/devices connected to a medium voltage grid.

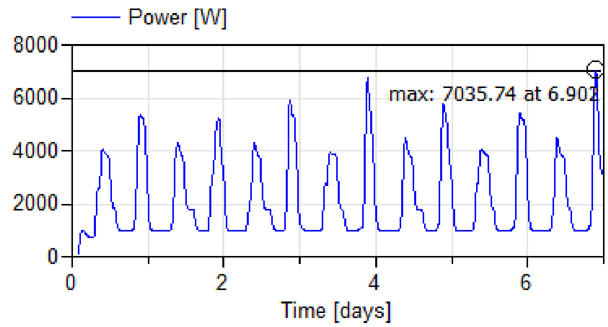
the end user the controller tries to turn on loads during times of low electricity prices. This is done by delaying certain non essential loads, such as dishwashers. In the simulations, it is assumed that the electricity price is lower during night and the controller therefore turns on these loads during night. Using this method consumption that normally is done during the day is delayed to the night. This will reduce power peaks on the grid.

Another important aspect of the smart grid is the grid robustness. By using the local energy storage at grid level or house level the controller manages to voltage control the grid during times of blackouts on the external power grid. This is done by using the local energy storage as voltage controller.

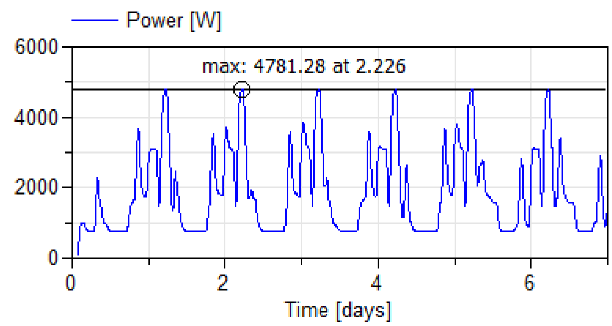
IV. Results

Year long simulations was done for a house using micro generation. The power performance achieved can be seen in figure 3. The figure shows the power consumed the first week of the year. Figure 3a shows the normal power consumption and 3b shows the power consumption using the proposed control strategy. From the year long simulation it is concluded that maximum power peak using load delay can be reduced from 7036 W to 4781 W.

Short time simulation was also done to test the robustness of the grid during external power failure. This scenario is equipped with three loads, a battery and two generators. In figure 2 the simulation results are plotted. During the first 80 seconds the house operates normally and the loads are turned on (according to their priority). At t = 80 s the high voltage grid fails and the controller is forced to turn of one load. After 440 seconds the medium voltage grid fails and the house is doing voltage control with its battery. After 900 seconds the battery can not provide enough power to the grid and the controller is forced to turn off another load.



(a) Normal power consumption, i.e. no load delay



(b) Power consumption where load delay is applied

Fig. 3: Power consumption

V. Conclusion

It is possible to reduce the total electricity cost by delaying non essential loads and charging the EV during the night. This will also reduce power peaks.

The batteries in an EV will be able to provide power to houses if there is a blackout on the medium voltage grid. Battery storage at the medium voltage grid will be able to reduce costs by charging during times of low price and discharge during times of high price.

References

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