A Multi-commodity Simulation Tool Based on TRIANA

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Abstract. In this paper we extended the simulator based on the TRIANA concept, with a model for the heat demand of households. The heat demand is determined based on factors such as building properties, user setpoints and weather conditions. The simulator exploits the flexibility of both the electricity and heat components to optimize the stream of both commodities, heat and electricity.

Keywords: TRIANA · Demand side management · Heating system

1 Introduction

Over the previous decade, there has been an increase in the amount of locally generated energy, e.g. by installing PV panels. As a result, a considerable part of the electricity needed in the local grids can be supported by these renewable energy production. However, the demand hours do not always match the production hours of renewable energies. Technologies such as electrical and thermal storage, and smart gird concepts steering controllable devices can help to balance the locally generated energy and the total demand.

This paper presents a multi-commodity simulation tool of a smart controlled micro-grid using the TRIANA simulator. As an example we show a simulation that aims to balance the supply and demand of heat and electricity for a group of houses in such a micro-grid. In the current tool, PV panels and a central combined heat and power system (CHP) are the local energy producers. Additionally, each house is equipped with time-shiftable devices, an electric battery and a floor heating system.The desired tool can be used to answer questions like e.g. under which conditions such a micro-grid with local production, storage and demand has the ability to operate independent of the grid.

2 The TRIANA Simulator

TRIANA is a three-step control methodology for energy management and has been developed at the University of Twente [2,3]. The three steps are: prediction, planning and real-time control. Prediction of the demand and production is done on device level. To match the demand and production locally as good

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as possible, a planning is determined for a certain time horizon based on the achieved predictions. Finally, real-time control steers the system in the direction of the planning.

TRIANA optimizes the planning toward an objective using a central controller. In this work, we use the profile steering method introduced in [4] to control the devices. This methodology attempts to steer the realized profile of the system toward a desired profile. In other words, it minimizes the deviation between the realized energy usage and a desired profile.

Modeling an energy system in TRIANA is done by using suitable component models termed devices. The following three types of device are examples of device classes supported by TRIANA:

- Uncontrollable devices: Uncontrollable devices can be divided into consumers and producers. Devices such as lighting and ventilation consume electricity and have a static consumption profile. The producers, such as PV panels, have a static production profile, which is achieved by predictions based on weather data, the size, efficiency and orientation of PV panel, etc.
- Time-shiftable devices: These kinds of device, like washing machines, offer flexibility of their starting time and they have the constraint to be finished before a specific time. Based on this time specification it can be decided what the best time is to turn a device on.
- Buffer devices: Buffer devices have more flexibility, since they can be charged and discharged. Hereby, constraints such as a certain state of charge up to a specific time may have to be taken into account. Various type of devices can be categorized as a buffer with specific characteristics. Examples of buffer-typed devices include normal buffer such as a battery, buffer-converter devices such as a thermal buffer and buffer-time-shiftable devices such as electrical vehicle.

Although TRIANA is a general concept, the developed simulation tool up to now was mainly electricity oriented and did not have any components to model the heat demand of a house. E.g. in [5] just a static input is used for describing the heating demand of houses. However, a smart grid oriented control will be more effective if a sophisticated house model is used that also describes the flexibility of the heating system of a house in relation to building properties, user setpoints and weather conditions. This leads to a dynamic heat model that reveals the flexibility of the heating system.

The main contribution of this paper is to add such a heating system component to TRIANA (see Sect. 3). In this way the heat demand is no longer just static, but can be incorporated in the control of the house to match demand and supply on grid level.

3 Extending TRIANA with Heat Components

The heating system added to the TRIANA simulation tool is a floor heating system for a single house as is described in [1]. In this heating system, thermal nodes with a thermal capacitance are defined for the floor and for a zone which is affected by separation walls, inner and outer envelope walls and the ceiling. The zone node is affected by ventilation, infiltration, appliances and the presence of people. Furthermore, the solar gain through the window area is also considered.

The controller of the floor heating system is also dependent on some other variables, i.e. max floor temperature, user setpoints (T_s), acceptable deviation from setpoint (d). The heating system is modeled such that it turns on when the zone temperature (T_z) is low and deviates more than d from T_s ($T_z < T_s - d$). It stays on until either the zone temperature passes the highest acceptable deviation ($T_z > T_s + d$) or the maximum floor temperature is reached.

Within the implemented use case, the heat demand of the houses in a neighborhood is aggregated to a heat pool which is connected to a heat buffer and a CHP plant. Figure 1 represents the neighborhood energy system using the model described in [3].

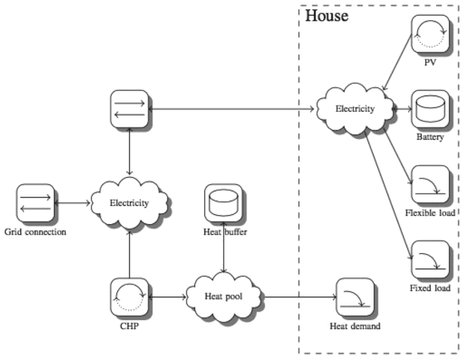


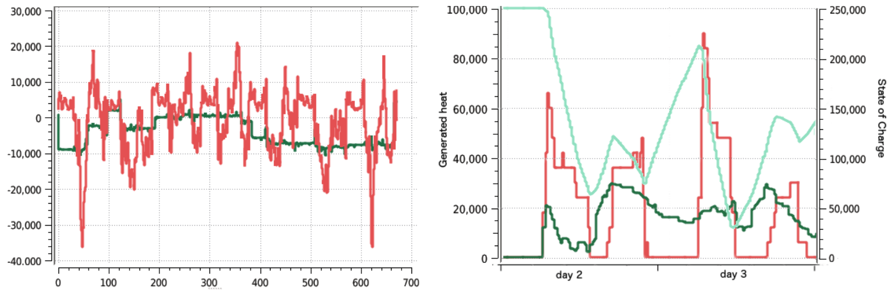
Fig. 1. The neighborhood energy system schematic [5]

For scheduling all flexible appliances in the house, as well as the CHP plant and the heat buffer, we use the profile steering method introduced in [4]. Hereby, the heat buffer gives the CHP plant flexibility to carry out some pre-heating by filling the buffer already before the time the heat is required, when electricity is needed. The only constraints now is that the state of charge of the buffer always must be enough to provide the predicted heat consumption for the next periods.

4 Results

In this section, a case study that consists of both heat and electricity demand is presented as an example of a multi-commodity simulation in TRIANA.This case study has already been described in [5]. The model includes 16 well-insulated terraced houses, with controllable devices, namely a washing and dish washing machine, and an electric battery. The houses heated with floor heating, are equipped with solar-PV panels, and located in a typical Dutch area. Moreover, there is a central CHP plant in the neighborhood, incorporating a heat buffer (see Fig. 1). Furthermore, inflexible loads are given for each house. The aim of this case is to investigate to what extent the CHP plant can meet the electricity demand of the houses.

Two cases are compared. The first case uses the static heat demand as a direct input for the CHP (Base), and the CHP has to meet the heat demand directly. In the second case, the heating model is used, and all flexible devices in the house are controlled to adopt their energy profile to the generation of the CHP (Control). Hereby, the CHP is also controlled and uses the thermal storage to supply the heat demand.



(a) Total grid power demand (kw) per Time interval (for 1 week)

(b) Generating heat demand using the CHP and heat buffer

Fig. 2. – Base – Control – State of Charge (Color figure online)

For the evaluation, a week with high heat demand and low PV generation is chosen, in which the total amount of generated electricity by the CHP is always higher than the total electricity consumption of all houses. Thus, in principle the CHP could meet all electricity demand. Such a week is ideal to investigate the effectiveness of using a control methodology for flexible devices such as CHP.

In Fig. 2a, the resulting total power profiles of the complete neighborhood are given for both cases. In the Base case, electricity generated by the CHP is often not enough to meet all the electricity demand. However, in the Control case, the profile of the CHP can meet the demand using only a minimal amount of energy from the grid. In contrast to the Base case with a large swing, the Control case has a flat profile due to the balancing.

Figure 2b shows the CHP heat production for both cases and the state of charge for the heat buffer in the Control case for 2 days. The generated heat in Control case is less spiky than the Base case, since it is using the heat buffer to meet the heat demand.

5 Conclusion and Future Work

In this paper, a first approach to extend the TRIANA simulator to networks which include both heat and electricity is presented. The resulting tool is evaluated on data obtained from a model described in [5], where the heating system is based on floor heating system of a Dutch low energy house. The control method aims to flatten the electricity profile and to minimize the import of electricity from the grid. Hereby, the flexibility of the devices is used.

Future work will aim to investigate different control methods to control the heating system. This is expected to give more flexibility to the CHP heat generation.

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