Practical course
Smart Energy Systems
Report

Sandro Speth
Markus Zilch
Dominik Wagner

Wintersemester 18/19

1 Introduction

The traditional power grid is changing more and more over time. Due to increasing sensitization for the use of renewable and reliable sources of energy instead of nuclear power sources or fossil energy sources, there is an increasing accommodation of renewable energy. To fulfill our daily energy need only with such energy sources is quite difficult and needs lot of planning and simulation. In this work we build a smart energy system to simulate a smart grid.

A smart grid is an energy efficient system with information and communication technology, automation and awareness of energy consumption. There are many different actors and technologies which are connected to each other and interoperate to optimize the grid.

A smart energy system creates the bridge between a power grid and a resilient and reliable smart grid. Users can simulate reliable energy sources, as well as different kinds of energy consumers, e.g. homes or offices. Simulation of distributed energy sources and automation of processes build an energy management system. Through this microgrids we can possibly rely completely on renewable energy sources in the future. This can be checked with our smart energy system.

The report is structured as follows. In section 2 we present our system design. First, we give some basic foundations which are relevant for our smart energy system, such as the difference between kWh and kW. Afterwards we present our functional requirements for the smart energy systems as user stories. From these functional requirements we created our architecture which will be described in this section as well.

2 System Design

2.1 Difference between kW and kWh

W is a measuring scale for energy applied per time instance. There are different possibilities to describe W in common terms. A pretty graphic one is the movement of mass. $1W$ equals $1kg$ of mass moved by 1 meter in one second: $1\frac{kg*m^2}{s^3}$. Or in electrical terms: $1W$ equals 1 Ampere of electrical power with a voltage of 1 Volt. Both of those formulas are equal to a much simpler Term for Watt: $1W = 1J/s$. In simple terms, 1 Watt is the same as one Joule of energy applied over 1 second. For completeness, $1kW = 1000W$[6][1][7].

Wh are the common term for measuring energy consumption and production. $1Wh$ is $1W$ applied continuously over 1 hour. $1Wh = 1W * 1h = 1J/s * 3600s = 3600J$. For a scientific context the Wh therefore is simply not used, instead the common SI standard J is used. In comparison, Wh is the total amount of energy used. W is how much energy is used in a specified timeslot (mostly 1 second)[4][2].

2.2 Difference between consumption and demand

Electricity consumption and electricity demand are two different properties and measured with different measurement units. The following section contains a description of both and an example at the end.

2.2.1 Demand

The demand is the rate of consumption of electricity or mathematical speaking the demand is the derivation of the consumption [8]. Most of the time the demand is measured in Watt. If you turn on a 100W light bulb, it will demand 100W while it is turned on. At the same time the grid must provide electricity at a rate of 100W. In most cases it is possible to calculate the demand with the following formula [5].

$$Demand = Voltage * Current$$

Some customers also have to pay for the demand or peak demand they have because if you have a higher (peak) demand the grid has to support this [8][3].

2.2.2 Consumption

It is easier to understand electricity consumption because we are more used to this concept [8]. Many people deal with electricity consumption while paying their electricity bill because most German electricity meter measure only the consumption. The consumption is the amount of electricity used per time unit [8][3]. Most of the time the consumption is measured in kilowatt per hour. The formula to calculate the consumption is the following [8].

$$Consumption = Demand * Time$$

For example, 5 W LED bulbs turned on for 1h have the consumption of 5 Wh.

Sandro Speth
Markus Zilch
Dominik Wagner

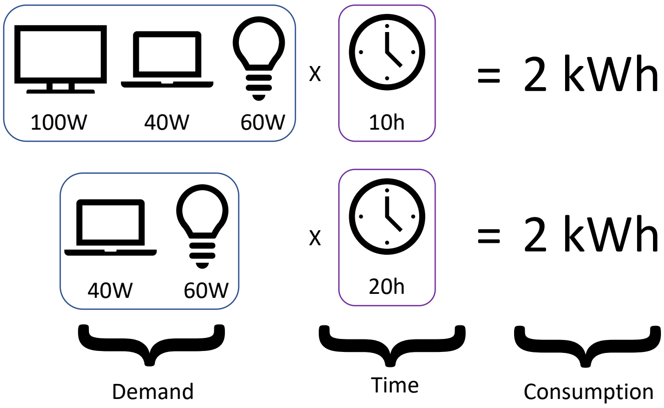

Figure 1: Example for demand and consumption

2.2.3 Difference

The demand is the rate of which we use energy and the consumption is the total energy used for a given time frame [8]. The formulas also show this relation between the consumption and the demand. The consumption is the demand multiplied with the time. If someone turns on 1 heating unit with a demand of 1kW for 2 hours than the demand during this hours is 1kW, but the consumption is 2kWh. The consumption is the same if two heating units are used for half an hour, but the demand is doubled (2kW). Figure 1 contains another but similar example. To put it in simple terms the demand is comparable with the speed of a car and the consumption is the distance you drive. The faster you drive the more distance is accumulated over time.

2.3 Userstories

1. As a user, I need to create one or more wind turbines in the simulation so that I can calculate the potential energy output.
2. As a user, I need to create one or more photovoltaic panels in the simulation so that I can calculate the potential energy output.
3. As a user, I need to create one or more batteries in the simulation so to save unused energy of in my simulation.
4. As a user, I need to remove one or more suppler modules like wind turbines form the simulation to get an optimal mix of all kinds of suppliers.
5. As a user, I need to remove one or more consumer modules like commercial buildings form the simulation to get an optimal mix of all kinds of consumers.
6. As a user, I need to remove one or more batteries form the simulation to remove batteries which were added by mistake.
7. As a user, I need to get the charging state of my batteries to know the impact of the energy storage on the grid.

8. As a user, I need to create one or more homes on the demand side in the simulation so that I can simulate some energy consumer.

9. As a user, I need to create one or more commercial buildings on the demand side in the simulation to simulate some high energy consumer.

10. As a user, I need to get dynamic energy prices calculated from the simulation to determine if I want to sell my produced energy or store it for later use.

11. As a user, I need to use weather data in the simulation to simulate the smart energy system more precise and realistic.

12. As a user, I need to use already saved weather data in the simulation to not be dependent on the availability of the weather service.

13. As a user, I need to generate a forecast for energy generation and demand using the simulation in order to make informed decisions.

14. As a developer, I want to add more supplier modules than just wind turbines and photovoltaic panels to the simulation to improve the smart energy system in the future with further technology due to adding more kinds of suppliers.

15. As a developer, I want to add more consumer modules to the simulation to be able to add more kinds of consumers to the simulation.

16. As a user, I want to be able to create a smart energy system which is independent to a main power grid to simulate a reliable smart grid.

17. As a user, I want to get a visual notification if the supply of energy is smaller than the demand of energy to know when more energy supplier are needed.

18. As a user, I want to model a rechargeable battery so I can store the energy for later usage, if the supply is greater than the demand.

19. As a user, I need the battery to be able to discharge energy if the supply is lower than the demand in order to make my stored energy usable and keep the demand satisfied.

20. As a user, I need the smart grid to be able to manage peaks in the demand in order to smooth the impact on the grid and reduce the likelihood of power outages.

21. As a user, I need that the demand side consumers feature different load scenarios like home users and commercial users (constant load, occasionally peak loads) in order to make the simulation accurate for real life applications.

22. As a user, I want be able to use the system with my webbrowser so that I can use different platforms to view it and have easy access to the simulated data.

23. As a user, I want to be able to see the energy supply of each individual supply component in order to be able to assess the efficiency of the supplier.

24. As a user, I want to be able to see the energy demand of individual components for efficiency assessment and informed decision making.

25. As a user, I want to see a summary of energy supply and demand for all components in order to easily assess the current situation.
26. As a user, I want to adjust the demand by postponing the use of devices during peak hours in order to prevent a complete outage of the grid or to react to one-time-only scenarios.
27. As a user, I want the simulation to adapt the demand based on the price per kWh in order to minimize costs of my energy demands and maximize profits of my energy supply.

2.4 Architecture

This section describes our system architecture. An overview over the architecture is shown in figure 2.

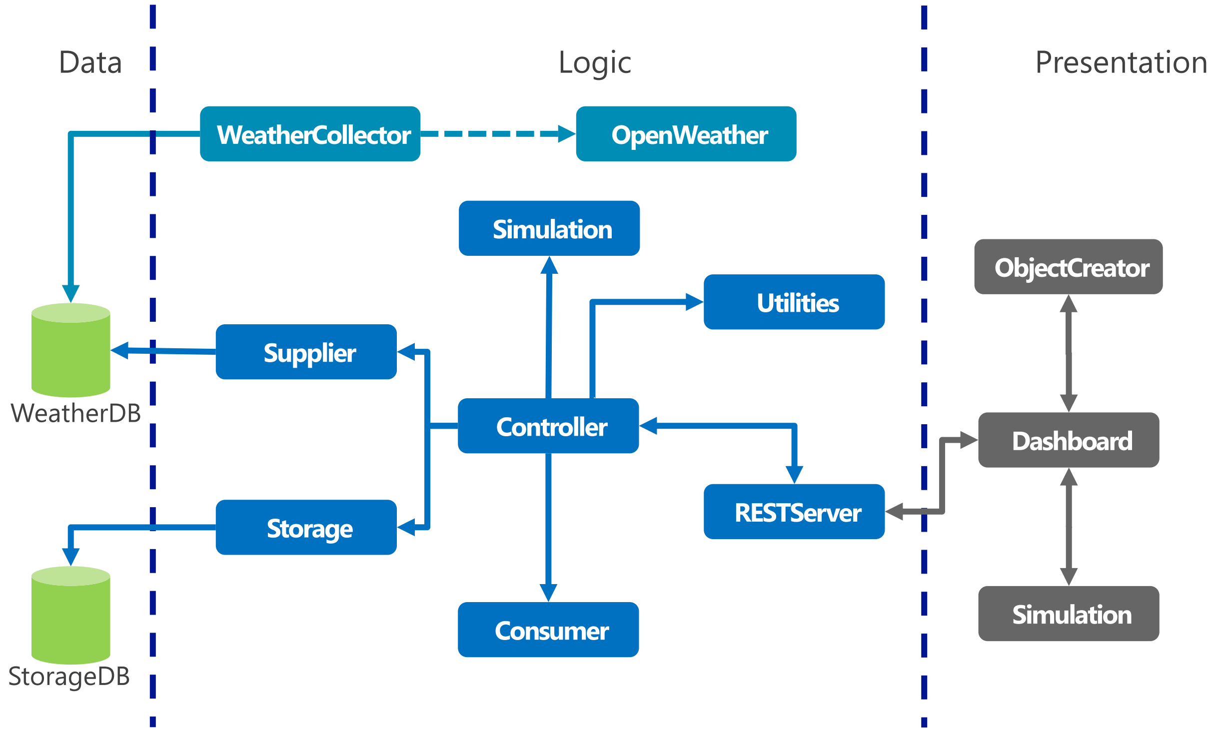

Figure 2: Smart energy system architecture

The `WeatherCollector` component is responsible for gathering actual weather data from *OpenWeather* API. This weather data is stored into a database for further use of the supply and demand components of the system.

In order for the whole system to be reliable and responsive we separated the `WeatherCollector` component from the rest of the system. It speaks only to the weather database where it get the locations for which it should collect weather data. The collected data gets written into the database and stored. Even in the case of a failure of the weather component or OpenWeather the already collected data is still accessible and therefore the system can work with it, making the system independent of the weather component. In the case of a new registration of a supplier component during a weather component failure, the database may return default values for the new component in a way the running system is not being halted by missing data. These measures should make the system reliable and and responsive in that context.

The three-layered architecture was already planned for in the first conceptions of the project, therefore no extra steps had to be taken. We divided the project in subcomponents and put them in the respective part of the architecture.
The first layer is the data layer which only consists of data-providing hardware and databases. Since the current project does not include data-providing hardware (as far as the current conception goes) only databases are left in this layer.
The second layer consists of the functional components of the project. All suppliers, storages, consumers and utility components are part of this layer, since they mostly take data from the databases and compute their respective power in- and output based on those values and give them to the simulation component. The simulation component is part of this layer, and takes the data the other component in order to model the different interactions of the smart grid. The workflow is controlled by the controller component and connects all components together. The last component in this layer is the REST component which makes the computed data from the simulation component available to the frontend layer.
The frontend layer is the third and last layer in our project. It handles the interaction with the user and makes it possible for the user to add and remove components to the smart grid simulation as he sees fit.

2.5 Conclusions

The power girds of the future will be different from the existing ones. More information will be used to make better decisions, more renewable energy sources will be integrated and more automation will happen. Also, microgrids will be a part of the energy concepts of the future. The simulation system presented in this report could help to gain a better understanding about different aspects of microgirds. The first section provided a motivation and introduction to microgirds. The next section contains basic information which are necessary to understand the problem, the functional requirements and an architecture description. The architecture is split in three layers. The webforntend, the logic layer which contains the simulation and the database layer. It also features a reliable approach to integrate an external weather component.

In the future more custom modules could be developed, to integrate even more suppliers and consumers.

References

[1] Gerard Borvon. History of the electrical units, 2011.

[2] Schweizerische Eidgenossenschaft. Bundesgesetz "uber das messwesen, 2018.

[3] enertiv. What is peak demand?, 2018.

[4] EU-Richtlinie. Eu-richtlinie 80/181/ewg in den staaten der eu bzw. dem bundesgesetz "uber das messwesen in der schweiz, 2018.

[5] Universit"at Stuttgart Otto Eggenberger. Leistung des elektrischen stroms, 2018.

[6] Applied Technology Institute Robert A. Nelson. The international system of units, 2018.

[7] Das Internationale Einheitensystem (SI). Deutsche Übersetzung der bipm-broschüre "le système international d'unités/the international system of units (8e édition", 2006). 117, 2006.

[8] Stony Brook University. Consumption vs. demand, 2018.