Decentralized Electrical Energy Supply and Electromobility

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***Abstract* – An increasing electric mobility leads to an increasing need for electricity. The goal is to get this increased amount from renewable resources, not from coal-fired power stations. The shown approach in the project NEEMO uses photovoltaics, co-generation and local storage. This leads to a decentralized supply with some self-sufficiency. Using simulations with advanced models we can see the amount of self-sufficiency and the involved losses in the inverters. Measurements in existing systems are used to verify the simulation results and improve the models.**

I. INTRODUCTION

In Germany we have ambitious goals concerning climate protection and CO_2 emissions. Concerning mobility there is a strong push to electric mobility. But for charging all these electric cars we need the electricity, but it is not feasible to produce this in conventional coal-fired power stations, as this would lead to increased CO_2 emissions. And this can't be the way. This laid the foundation of a concept of decentralized renewable production of electricity. The easiest way to produce green energy is by photovoltaics (PV). This has already been popular in Germany now for over 25 years with the first German Renewable Energies Act (EEG) from 1990. With this act the production of green energy is heavily subsidized and many German households and enterprises took the chance to produce green energy and make money. This configuration is shown in fig. 1. With this act these facilities can supply to the grid at a high price guaranteed for 20 years. These days the first installations reach this point and when supplying to the grid the can only get the market price, which is very low now. This leads to the idea to use this energy on the own premises and probably charge an electric car (EC).

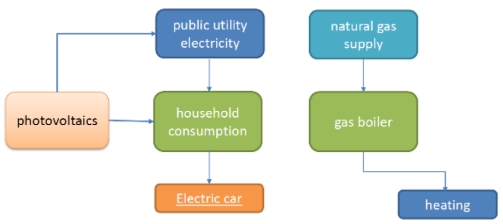

Figure 1: Home with PV and EC

II. CHARGING AN ELECTRIC CAR

But there is a substantial problem: during the day the car is typically away and parked at work and the desire is to charge it during the night. The only solution is to store the electricity locally in a home storage for electric energy device (HSEE).

While charging the battery during the summer is of no problem, in winter it becomes very difficult to obtain the necessary charge. But typically we also need energy for heating. Here comes the idea to use a combined heat and power unit (CHP). It provides the necessary heat and also produces electricity. This CHP ideally complements photovoltaics for the necessary power generation. The only drawback is, that only when heat is required, electricity is produced. Adding a storage device also for heat makes the operation of the CHP independent of the current heat required. The final setup shows fig. 2.

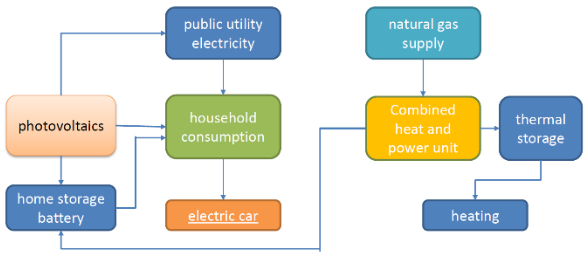

Figure 2: Home with PV, HSEE, CHP and EC

This is now the basis for simulating the energy flow and requirements. The first simulations were presented already in [1]. Further improvements of the MATLAB models enhanced the results of the simulations [2]. But to have realistic results it is absolutely necessary to validate the models. For that we equipped three houses with monitoring hardware to gather the required data. Most of the measurements reflected the simulation well, but for one home storage battery more than 8,000 kWh were stored in in and less than 7,000 kWh were taken out of that battery. This exceeded by far the calculated losses. So a closer look at this system was necessary.

III. EFFICIENCIES OF THE HOME STORAGE BATTERY SYSTEM

It revealed, that the efficiency of the rectifier for charging the batteries and the inverter for producing AC again have to be evaluated. Fig. 3 and 4 show the efficiencies over power. From measurements it was known, that the required power was most of the time between 150 and 250

W. Looking at the efficiency in fig. 4, we see that the efficiency in this region is less than 84%. Now it became clear what the reason for the losses of more than 15% of the home storage was. The consequence was to integrate the efficiency curve in the simulation model.

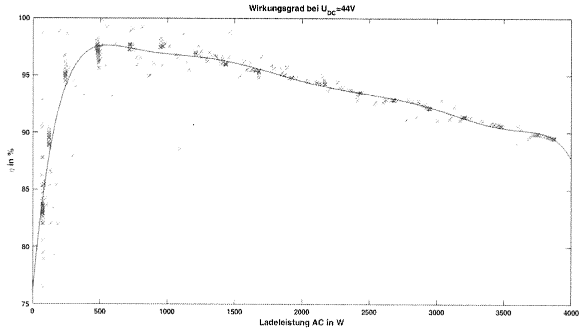

Figure 3: Efficiency of the rectifier for charging over power

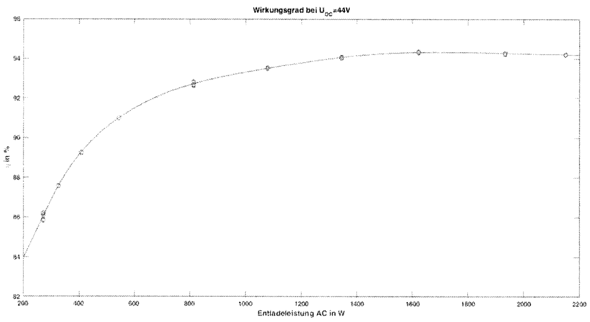

Figure 4: Efficiency of the inverter over power

From above figures we see that the efficiency heavily depends on the power. This is especially true at lower power levels. In the measured setup a charging power of 700 W to 800 W would be best and a load of 1300 W to 2100 W. In this case the efficiency is $\eta_{HSEE} = \eta_{rectifier} * \eta_{battery} * \eta_{inverter} = 0.98 * 0.90 * 0.94 = 83\ \%$

Whereas at low power levels charging at 100 W and a consumption of 200 W the total efficiency becomes $\eta_{HSEE} = \eta_{rectifier} * \eta_{battery} * \eta_{inverter} = 0.85 * 0.90 * 0.72 = 65\ \%$.

The charge-discharge efficiency for the 48 V lead-acid battery here has been previously measured at 90%, Li-ion batteries would be better.

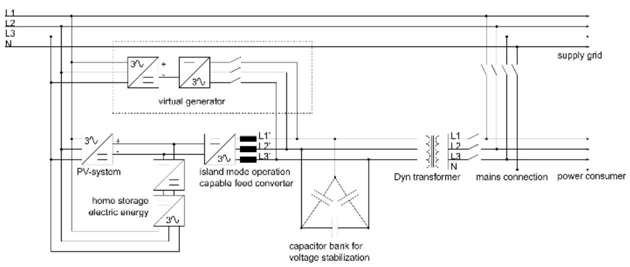

Figure 5: Setup for measuring the charge and discharge efficiency of the home storage system

IV. Structure of the new MATLAB-Simulink model for the home storage and results

In the new model for the simulations the efficiency curve was the integrated. Fig. 6 shows the enhanced model. With this model interesting aspects could be investigated. These were especially the dependence of the total losses on the capacity and the power capability of the home storage battery. Fig. 7 shows a sample. The smaller the inverter power the less the losses are and you can also see, that increasing the capacity only slightly increases the losses. Analyzing the results an interesting fact became the self-sufficiency of this energy system when using a large home storage HSEE.

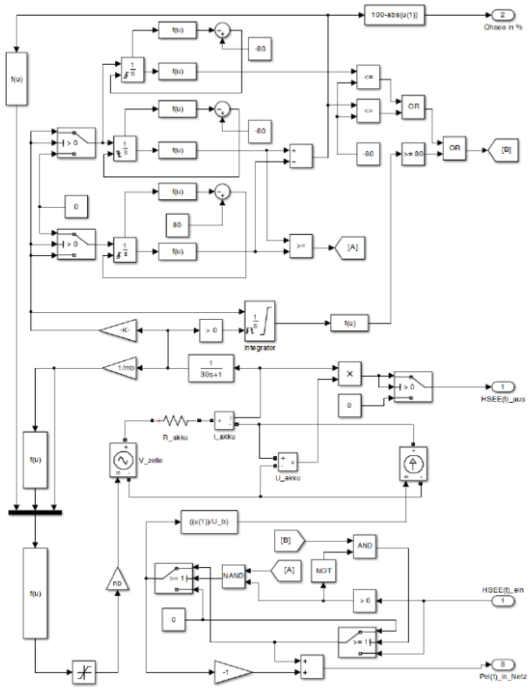

Figure 6: MATLAB-Simulink model of the home storage for electric energy

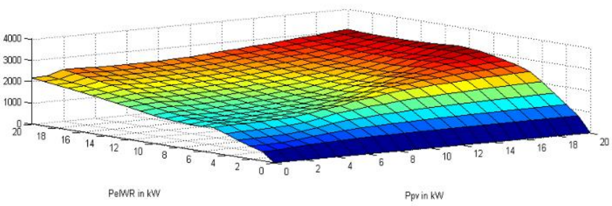

Figure 7: Power losses of the HSEE in kWh over power (left) and home storage capacity (right)

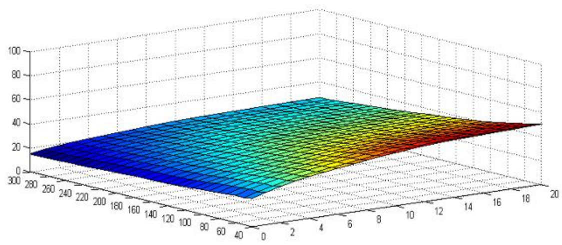

Figure 8: Self-sufficiency in percent over heat demand per m² and year (left) and home storage capacity in kWh (right)

V. FURTHER EXPANSIONS

To further enhance the availability of power during the night and in cloudy weather the idea is to include a small wind turbine [3].

VI. WEB-BASED SIMULATION

To facilitate the simulation and to bring it to public attention the software is now being ported with a web-based frontend Fig. 9 shows the input screen.

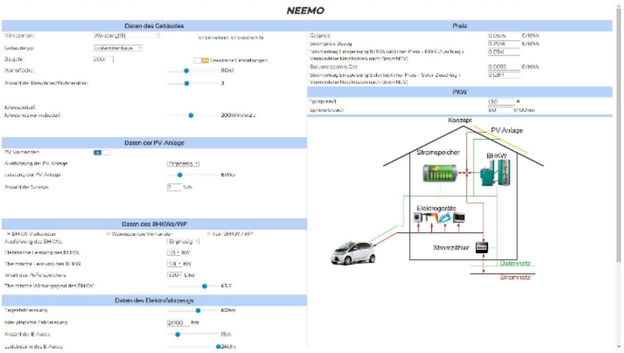

Figure 9: Input screen of the web-based simulation tool

The simulation results are then presented in figures and pie-charts, see fig. 10. There also an estimate of all costs and assets.

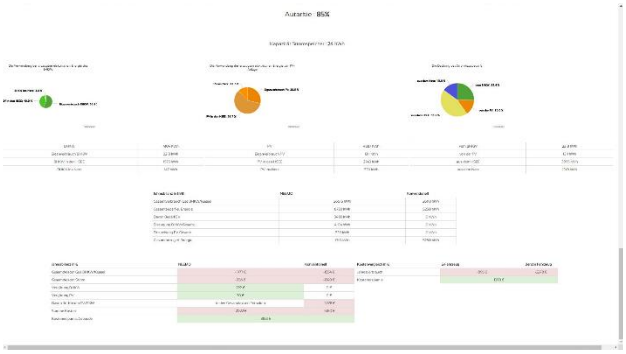

Figure 10: Presentation of the results of the simulation using the web-based tools.

VII. CONCLUSION

The developed simulation tool has now after the intense validation the capabilities to model a complex energy system for a home with PV, an electric car, a battery powered home storage and a CHP or a heat pump with a thermal storage. All systems can be parametrized and thus are capable of covering a wide range of possible installations. Also aspects from an industrial management point of view (aka costs) are calculated. Admittedly at current prices for a HSEE and CHP such a system is not yet profitable. But the prices for Li-ion batteries and power semiconductors are falling rapidly on one hand and production quantities are rising on the other hand thus making such a system feasible.

REFERENCES

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[2] Korotchenko, Ievgen: Energiesimulation für einen energieautarken Betrieb von Elektromobilen in Verbindung mit der Energieversorgung im Wohnbereich durch Nutzung regenerativer Quellen und Speicherung. Master-Thesis at FHWS, 2016

[3] Turbina TE 20 data sheet, TURBINA ENERGY AG, 2015