Storage sizing and validation of an off-grid house: a case in the US and in the Netherlands

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***Abstract*—This work uses experimental data collected from an Austin-Texas-the US and a Nunspeet-the Netherlands house to calculate the size of storage needed for an islanded off-grid house. In our study an off-grid house is considered to be supplied with 100% use of renewable energy during the summer period where cooling demand is neglected. In this case, solar photovoltaic (PV) and batteries are the main electrical energy providers. Both scenarios showed that a battery of 48V with 2000Ah could provide the necessary electricity for one day stand-alone operation. In order to validate the storage sizing, the energy requirements were scaled down and simulated by the DEMkit simulation software** [1]**. Furthermore, a battery was constructed and used in the scaled size to observe the battery behavior during the loads. Electrochemical impedance spectroscopy was used for characterizing the battery state of charge. The results show that the PV-battery system is capable of providing the energy needed for the house in an off-grid scenario for the studied period without showing black-out.**

Keywords—microgrid; storage;sizing;islanded;off-grid house

I. INTRODUCTION

Power generated from sustainable energy, such as solar photovoltaic (PV) cells are a good option for generating renewable power for households. However, the technology is constrained due to weather conditions which influences its energy output. Due to this variation, energy-storage technologies e.g batteries are a relevant option for providing energy when it is needed and not supplied by PV [2].

A 100% off-grid house is becoming an important asset in electrical grids [3]. It can support two main aspects: to bring flexibility to the grid and to bring electricity to remote places. For the first aspect, the house can be disconnected from the grid and work in stand-alone mode during black-out or maintenance. Second, it could bring access to electricity to remote places that are still not connected to the grid. However, the viability of a 100% off-grid house depends on the reliability of the system and the right storage sizing.

The goal of this paper is to evaluate two scenarios: First, a comparison between the solar PV and storage sizing needed for an off-grid house in Austin Texas and a house in Nunspeet- the Netherlands excluding the cooling demand. Second, a realistic sizing validation is performed. The validation uses a simulation of loads that are directed to a scaled battery based on the DEMkit concept presented by Hoogsteen [1]. The analysis is performed using simulations with a holistic view on smart grids for loads controlled and a sea-salt battery for which the charge is predicted by electrochemical impedance spectroscopy (EIS), which gives a more precise value for the battery state of charge than voltage or current control methods.

II. THE OFF-GRID HOUSE

To characterize the load that would occur to an off-grid house in Texas, data provided by Pecan Street Inc in Austin, Texas was used. The data is part of its ongoing study for smart grids and demonstration studies [4]. The study utilizes a test bed of 300 modern, green-built homes built after 2007, and 160 homes ranging from 10 to 92 years of age. The homes are equipped with electricity, gas, and water metering equipment. Of the 300 homes in the study, 185 are equipped with rooftop solar PV panels, which are metered separately from electric demand. This database has been used in previous studies for battery analyzes and modeling [5].

In the case of Nunspeet-the Netherlands, data was taken from one single house with similar load characteristic than the house in Austin-Texas. The houses were characterized based on the following available information:

- Capacity of installed solar PV
- Energy consumption baseline available
- Use of electric vehicles
- Electric heating/cooling equipment

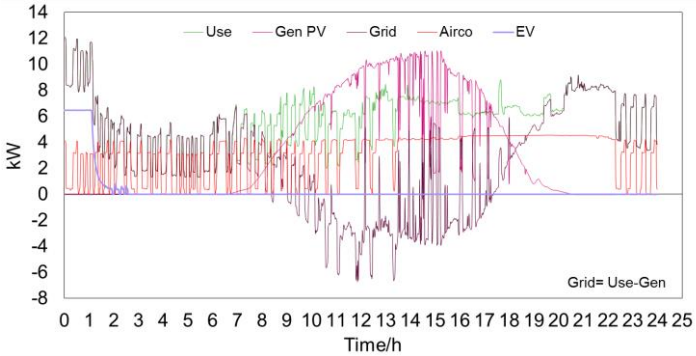

Figure 1 Electricity behavior in one house in Austin-Texas on a summer day without storage

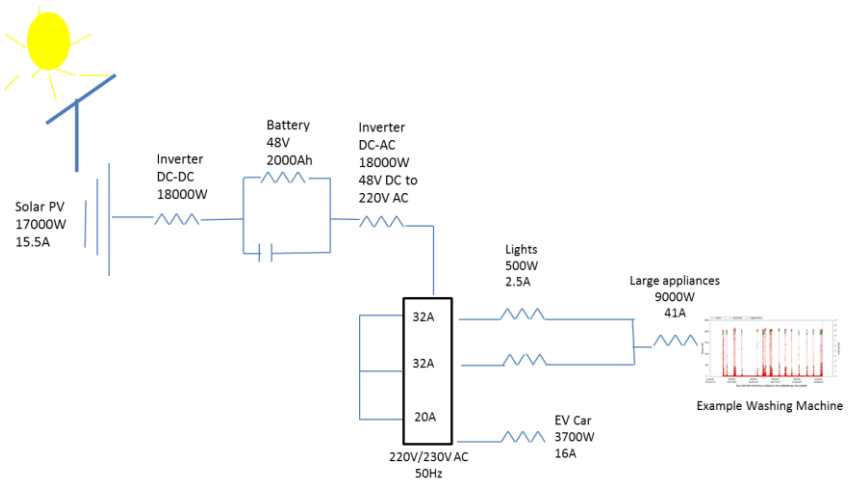

Figure 2 Off-grid circuit description for a house in Nunspeet-the Netherlands, using a battery as principal power.

III. Sizing Characterisation

Figure 1 shows the energy consumption during one day in a house in Austin-Texas. It also shows the load coming from an electric vehicle, air conditioned systems and energy generated by solar PV panel (gen PV). The data was recorded every five minutes during a day in the summer. The grid is the delta between the load (use) and the generation (gen PV). The load between 9:00-18:00 hours has the same volume as the solar PV energy generated. This suggests that the house can be off-grid during a sunny day for a period of 9 hours. However, during the night the load is mostly higher than the generation due to the air conditioning and the electric vehicle (EV). During this time, the electricity is provided by the grid. The largest peak load observed was 12kW between 0:00 to 2:00 hours due to the EV charging and air conditioning. The results indicate that there is a shortage during the night for creating a house 100% off-grid.

A similar case was studied in a house in Nunspeet-the Netherlands. After analyzing the energy demands and the electrical energy consumption, a model of a house connected to a battery as the main power source was created. Figure 2 shows a model of the off-grid circuit to provide electricity to a house in the Netherlands. The circuit is based on the assumption that all solar PV energy is stored in a battery with enough size to provide electricity for one stand-alone operation. The off-grid system has the following characteristics:

- Load 30 kWh/day
- A solar PV system of 17kWp
- DC to DC inverter of 18kW
- Battery of 48V and 2000Ah
- DC to AC inverter of 18kW
- A frequency regulator for 50Hz-60Hz

To create the 100% off-grid scenario a large battery of 48V battery and 2000Ah is needed. The voltage is chosen acoording to the current regulation for battery systems. Note that the fire department and authorities in the US have declared that in the ideal case 48V may be the best voltage for battery installation [6].

IV. The Model House

The model house has been tested using scaled data from the Pecan Street database. A scaled battery has been constructed and sized to provide the electricity demand for the scaled load. The house loads are controlled by the DEMKit algorithm presented by Hoogsteen [1]. This algorithm simulates loads of appliances close to reality. In the full paper, the details of the storage sizing will be provided and the results for the model house with the data of battery discharge-charge and EIS behavior will be presented.

V. Conclusion

A battery of 48V and 2000Ah charged by a solar PV system of 17kWp can create an off-grid house if we do not take the demand for heating/cooling into account in Austin Texas and in Nunspeet-the Netherlands. Nevertheless, more test needs to be done in order to assure the reliability of the system especially during winter periods.

VI. References

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