Design of a PV-Supplied, Grid-Connected Storage Test Bed for Flexibly Modeling Future Energy Scenarios

Rosemarie Velik[1], Klaus Kafka[2], Lukas Neumaier[1], Johannes Schmid[2], Herbert Pairitsch[3], Winfried Egger[4], Julian Silva-Martinz[4]

[1]CTR Carinthian Tech Research AG, 9524 Villach/St. Magdalen, [2]ALPINE-ENERGIE Österreich GmbH, 4030 Linz,

[3]Infineon Technologies Austria AG, 9500 Villach, [4]Fachhochschule Kärnten, 9524 Villach/St. Magdalen

Introduction and Motivation

The necessity of substituting fossil fuels and nuclear power with renewable energy (e.g., solar and wind) brings completely new challenges to the energy market including the followings:

- Shift from a centralized to a decentralized production
- Decentralized feeding into grid can negatively effect grid stability
- Time of production ≠ time of consumption
- Production variable over time and imperfectly predictable

Measures suggested to handle these challenges include:

- Load shifting of energy consumers to times when energy is produced
- Storage of produced energy
- Local consummation/storage of locally produced energy
- Variable pricing models based on current demand and supply

Within the framework of the project Vision Step I – Smart City Villach, a PV-supplied, grid-connected storage test bed was designed with the objective to offer the possibility of flexibly investigating and testing a wide range of future scenarios in the renewable energy context. In this poster, an overview of the characteristics of this test bed is presented as well as envisioned experiments to be carried out with it.

Requirements Specification

In a first phase, important requirements for the test bed were specified, which are summarized in the following:

- Test bed should mime a household
- Test bed should include
  - a renewable energy source (preferably PV)
  - a battery storage
  - controllable/switchable loads
  - a grid connection
- Test bed should be three-phase
- Test bed should in a first instance consist of standard components to provide a reference against which newly developed components can be benchmarked
- Test bed should allow high flexibility in testing and therefore
  - be modular to allow an easy exchange of components for different tests
  - allow a control of all relevant components and a monitoring/ measurement of all relevant values
  - allow energy flows in all possible directions

Test Bed Design and Implementation

Based on the requirements specification, it was decided to develop a test bed according to the overview picture of Fig. 1. As location for the test bed, the Energy & Science Labs of the Carinthian University of Applied Sciences in the Technology Park Villach was chosen (see Fig. 2).

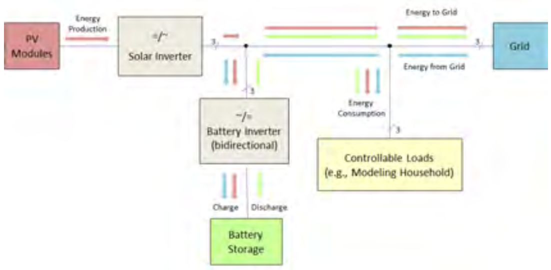

Fig. 1 Schematic overview of main building blocks of test bed and possible energy flows (sensing and control units are not depicted)

Having defined the principle structure and location of the test bed, the next step was the selection and dimensioning of the individual components (PV system, storage system, loads, and monitoring and control units) (see Fig. 4).

Photovoltaics System

Based on simulation tools considering the orientation of the building and the tilt angle of the roof on which the PV modules should be installed as well as shadow effects from neighboring buildings and trees, the PV system was dimensioned and the optimal module placement on the roof was determined (see Fig. 2 and Fig. 3).

Fig. 2 Roof characteristics of building on which PV modules are installed

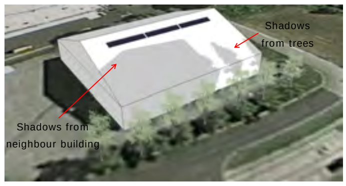

Fig. 3. Worst case shadow simulations (21st of December) for determining the optimal position of PV modules

As a result, a 5.4 kWp photovoltaic system consisting of 22 PV modules of the type E-2000|245 and a DC/AC SMA solar inverter of the type Sunny Tripower 5000TL-20 were selected and it was defined that the PV modules should be placed in the upper quarter of the roof to avoid shadowing effects.

Storage System

For electricity storage, in a first instance, 8 solar lead-acid batteries of the type 12 V SGI 300 were selected from which always four are connected in series resulting in two parallel 48 V strings with a electricity storage volume of in sum 28,8 kWh. In later stages, it is planned to additionally purchase lithium batteries. As battery inverter, three bidirectional uniphase Studer inverters of the type XTM2600-48 are used, supplemented by an ENS31NA as three-phase grid monitoring system.

Loads

To be able to mimic realistic household scenarios and to allow for the evaluation of different load shifting strategies, switchable loads are foreseen as well as a completely controllable load (realized by an asynchronous machine) that can model arbitrary load curves.

Monitoring and Control

The direction of energy flows within the test bed are controlled via a Beckhoff PLC system, which is connected to a PC for realizing more complex energy management algorithms. For monitoring purposes, a range of different sensors are used including temperature and solar radiation sensors on the PV modules, temperature sensors on the battery inverters, and power/watt meters in all DC and AC branches.

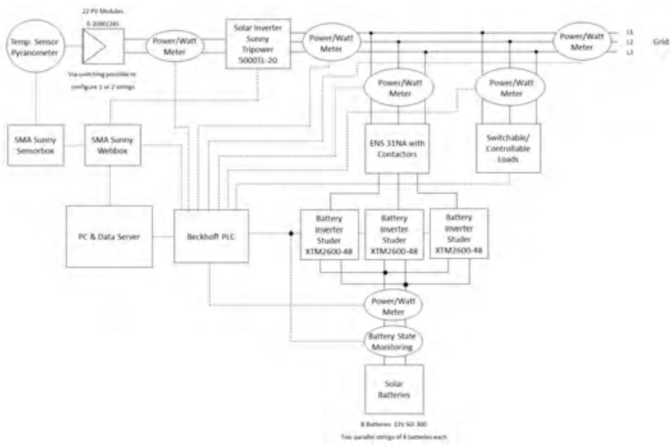

Fig. 4 Circuit diagram of test bed

Envisioned Research Questions and Experiments

The test bed is currently installed in the facilities of the Carinthian University of Applied Sciences in the Technology Park Villach. Once operational, the test bed will be used to carry out a wider range of experiments including topics like:

- Energy flow analyses
- Developing and benchmarking of a new battery inverter featuring grid support measures (e.g., power factor correction)
- Investigation of different battery types (lead, lithium)
- Second life strategies for batteries (from e-mobility)
- Novel energy management strategies (e.g., inclusion of weather data, situation awareness, load shifting, variable pricing, energy trading, optimal storage operation)
- Hardware in the loop simulations and scale up simulations (e.g., for energy neighborhood management)
- Durability, usability, efficiency, and profitability analyses

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