A TESTING AND DEMONSTRATION FACILITY FOR PV SYSTEMS AND COMPONENTS

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Abstract

A test and demonstration facility for PV and PV hybrid systems and system components has been designed and installed at Dalarna University in Sweden. The facility allows studies of complete PV systems or single components in a range of 0.1-10 kW. The facility includes two grid-connected PV systems, a PV Hybrid off-grid system, three emulators and the necessary measurement and control equipment. Tests can be done manually or automatically through programmed test procedures controlled that will be implemented in Labview. The facility shall be used by researchers, professionals of the industry and engineering students.

Background

Dalarna University (DU) is a regional University in the middle of Sweden offering a wide range of educational programmes and is active in several fields of research (www.du.se). In 1984 the Solar Energy Research Center (SERC) has been founded at DU and today hosts the leading Swedish research group for solar energy systems. Among the focus areas are solar thermal and wood pellet heating systems, seasonal heat storage and heat pump systems. In the recent years, Photovoltaic systems have become a more important part of the activities at the SERC. Several demonstration plants have been installed and the PV lab facilities have been extended. The emphasis of the work at SERC is on system studies, both theoretically by system simulations and practically, by lab experiments with grid-connected, off-grid and PV-hybrid systems. DU also offers a one year Master programme in solar energy engineering (www.eses.org), a bachelor programme in energy engineering and a two year energy technician programme. Students from those programmes are involved in the research and lab activities within PV systems. Several Master thesis projects have been done as part of the lab development [1, 2, 3, 4].

Objectives

The testing and demonstration facility presented in this article aims to serve both educational and research purposes. In detail, the system was designed and built with the following purposes.

- To run manual and automatic tests of small scale grid-connected and off-grid PV systems as well as individual system components.
- To test small scale PV hybrid systems/components with different types of generators.
- To study micro-grid solutions with DC and/or AC coupling.
- To study various losses in PV systems and the effect of ground reflection with snow cover.
- To evaluate the long term performance of PV systems.
- To demonstrate different technologies for small scale renewable electricity generation.
- To give students the opportunity to do lab exercises and project work.

An important constraint was that the test facility had to re-use as much of the previously installed demonstration plants as possible. Details of these previous installations can be found in [1, 2, 3, 4].

Somewhat similar test facilities have been built in Australia and the USA [5, 6]. However, these facilities are designed for testing only PV-Diesel and PV-Wind hybrid systems respectively.

System description

A starting point for the lab facility has been two existing demonstrations plants, a 3 kW PV grid-connected system and a 0.5/1 kW PV-Wind Hybrid off-grid system. The new facility should provide the possibility to test various types of system solutions and therefore it was important to design the complete system with a high level of flexibility. For example, the 3 kW grid connected system can now be used either for grid-connection, for testing of inverters or, after an easy to do reconfiguration, for a 24VDC connection to the PV-Hybrid off-grid system. All wiring and electrical components are designed for these options. The PV-Wind hybrid system was reused with its original setup except for the battery bank that has been replaced by new lead acid cells with a total capacity of 11kWh. Furthermore, the hybrid system was complemented with a methanol fuel cell on the DC bus and a genset on the AC bus of the system. The AC bus is primarily formed by a bi-directional SMA Sunny Island inverter. This AC bus or AC micro-grid can also be fed by the 3 kW PV system via two SMA grid inverters.

The three emulators (PV array, AC load and DC load) can be either used separately, e.g. to test an inverter or a charge controller, or can be connected at to the AC or DC bus of the Hybrid system/micro-grid to emulate PV electricity generation and/or AC and DC loads. The emulators can be controlled by Labview for running automated test programs.

All relevant system variables are permanently monitored and recorded with a data logger. A separate power quality measurement unit is installed to measure and record the AC power quality of the grid inverters and the micro-grid.

The diagram in Figure 1 shows the final principle layout of the facility. The grey marked circles and squares indicate the new components; the white ones are the previously existing components.

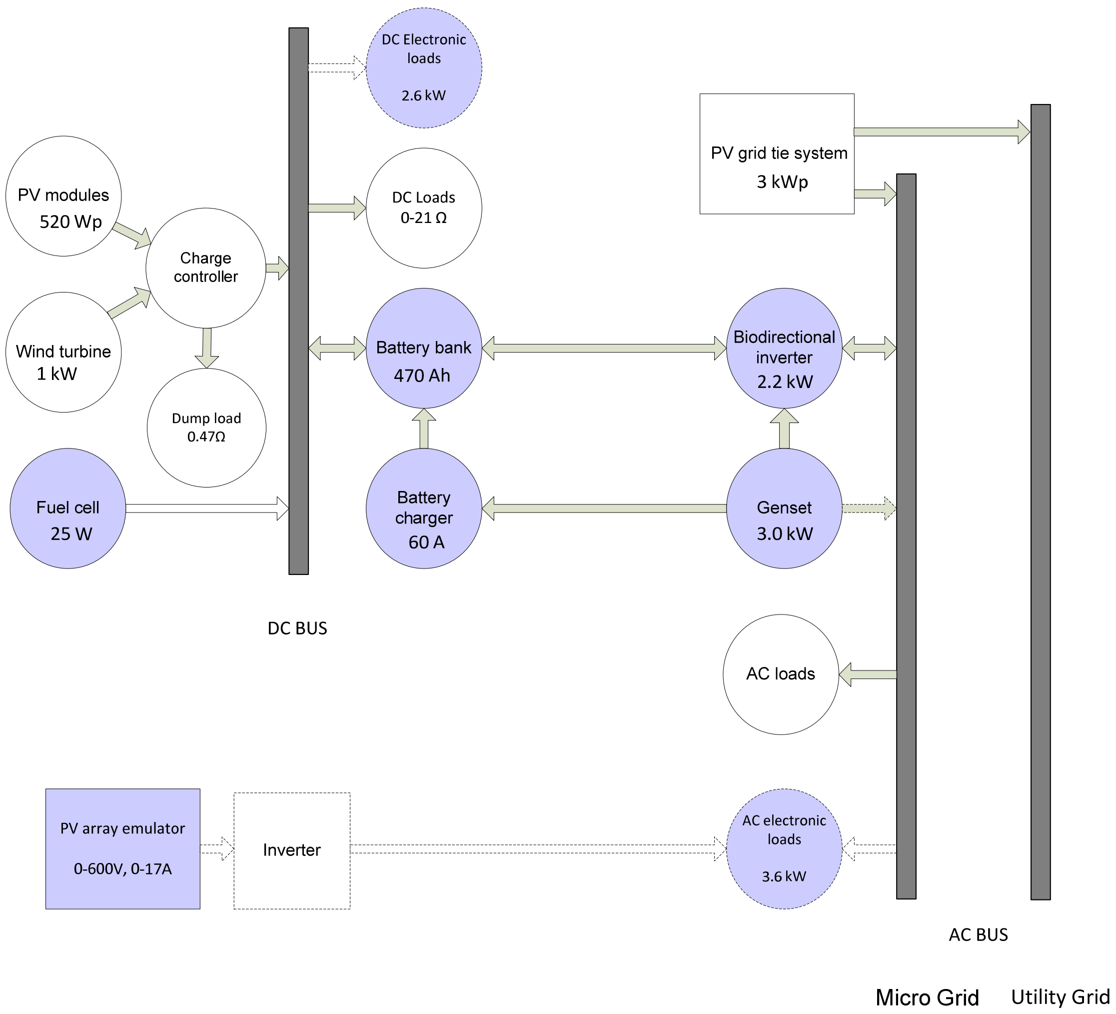

Figure 1: System layout of the PV testing facility.

A detailed technical description of the test facility can be found also in [4].

Grid connected system

The original 3 kW PV system consisting of 72 GPV 12V mono-crystalline modules was divided in two identical 1.5kW systems and grid-connected via two SMA sunny boys SB 1200 inverters. The arrays have the same azimuth (0°) and tilt (60°) which allows for side-by-side tests or more specifically for studies of shading effects, soiling and ground reflection. The interconnections of the modules in the combiner boxes can easily be reconfigured to create different output voltages (24V, 48V and 400V and by that allowing the use of the arrays in different system types and testing schemes. The modules were originally manufactured and installed in 1993, thus have been in use for 20 years. The installed monitoring equipment will make it possible to continue the long term performance study of the modules.

Hybrid system and micro-grid

Another important aspect for the design of the lab facility was the possibility to test hybrid system configurations for off-grid systems, especially for use in rural electrification. For AC coupling of the generators a SMA Sunny Island bi-directional inverter has been used, providing the base for a mini AC grid and allowing the charge of the batteries from different AC sources. A 3 kW Honda AC genset (EU 3Ois) for AC coupling and an Efoy direct methanol fuel cell (Efoy 600) for DC coupling were integrated. The AC bus is connected to AC loads and can be connected to the AC load emulator. The battery bank consisting of 12 Exide 2V cells type OPZs solar 660 can be charged via the Sunny Island and the Bergey PV-Wind Hybrid charge controller. As a backup also a Victron Centaur 24-60 grid charger has been installed.

Emulators

The advanced testing of systems, system configurations and components required the implementation of emulators to emulate the input sources and/or the loads. The installed Chroma emulators for the PV array (62100H-600S), the AC/DC Load (63201) and DC load (63803), can be controlled and programmed manually for dynamic test sequences. With the help of the emulators it will be possible to do system and component testing throughout the year independently from weather conditions and available PV generators and loads. The operating ranges are as follows:

- PV array emulator: 10 kW with a current range of 0-17A and a voltage range of 24-600VDC.
- AC/DC load emulator: 3.6 kW with a current range of 0-36A and a voltage range of 50-350VDC.
- DC load emulator: 2.6 kW, a voltage range of 16-80V and with a supply of 30-300A.

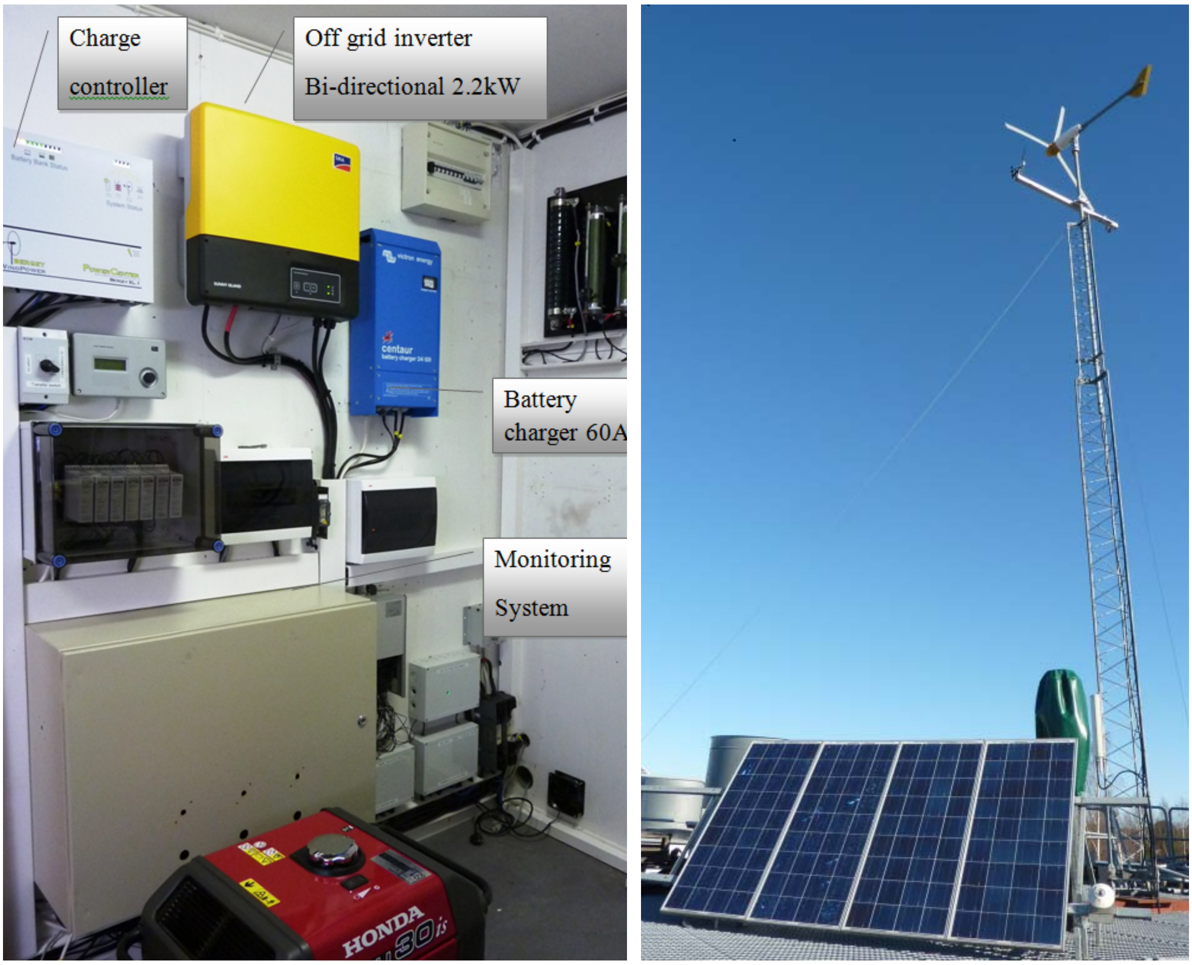

Figure 2: Indoor (left) and outdoor (right) equipment of the testing and demonstration facility.

Monitoring

The various parts of the lab facility are monitored with an Agilent data logger (34980A). All important climate data, currents, voltages and energy flow patterns are recorded. The grid connected systems are monitored in parallel with monitoring equipment provided by SMA. These data are also used for online monitoring and visualization of the system data for visitors and students.

In addition to the two mentioned logging systems, an Unipower UP2210 power quality measure unit with four measurement channels has been installed. Two of the channels monitor the AC quality of the two grid-connected inverters and one monitors the AC power of the micro-grid. The UP22100 measures the power quality with accuracy according to the standard IEC 61000-4-30, Class A. It monitors and records steady state disturbances (harmonics, flicker) and rapid voltage changes such as voltage dips, voltage swells and fast transients as well as frequency deviations.

References

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