The island of Graciosa in the Azores could soon be powered entirely by regenerative energy.

New Energy – Wind and Sun Bring Independence

Purely regenerative energy supply for an entire island

One of the Azore Islands in mid-Atlantic: Plenty of sunshine. Constant wind. And miles away from any power grid or any filling station for diesel generators. The obvious answer? Switch to regenerative energy sources for the entire island's electricity supply. In other words, power from the sun and the wind.

Purely Regenerative Energy Supply

An autonomous, CO_2-neutral power supply based on regenerative energies for remote areas – islands or villages – that are far away from the main power grid: That's what we're planning and developing at Younicos. Our first project is for the island of Graciosa in the Azores. At the moment, diesel fuel for the island's generators is brought in regularly by sea. Wind farms and photovoltaic systems could make this a thing of the past and give the island a less expensive alternative. 70-90% of the required energy would come from the sun

and the wind, and the remaining 10-30% could be generated from locally produced biofuels. Add a 3-megawatt sodium sulfur battery as electricity storage to compensate for large supply fluctuations, and the island will be completely independent of fossil fuels.

However, before turning the whole island and its inhabitants into a test object, we reproduced their power grid at our Berlin test facility. Our power supply concept is undergoing two years of close scrutiny here. We are thoroughly testing the transition from conventional to regenerative energy, simulating extreme situations, checking and optimizing different control strategies, and verifying that our concept is both real-world-proof and economical. The test setup is the first-ever experimental plant of this kind in the megawatt range that we know of.

Test Facility

The test setup comprises a complete power supply grid. Obviously, Berlin does not have the same wind and sun conditions as the Azores. So we use simulation models for the wind and solar power to obtain data for

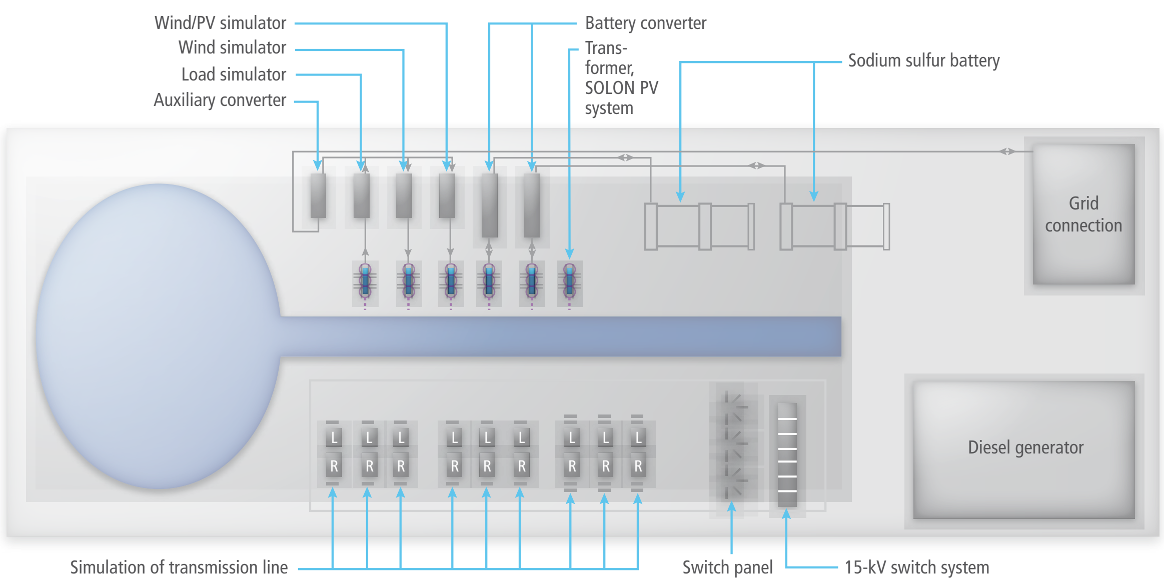


Figure 1: The wind and solar energy of Graciosa, one of the Azore Islands, is simulated at the test facility in Berlin.

power supply control. The weather data for the simulation is measured on Graciosa itself and then processed in real time in the simulation at the test facility. This ensures that our concept satisfies real-world requirements.

The facility consists of the following components (figure 1):

- 2 x 500-kW NaS batteries with a total capacity of 6 MWh
- 2 x 500-kW battery converters
- 1-MW diesel generator representing a conventional power supply
- 210-kW photovoltaic system
- 2-MW wind farm simulator consisting of a converter with an integrated wind turbine for converting wind measurements into power input
- 1-MW load simulator consisting of a converter for running through a load profile
- Transmission links at medium voltage level, assembled from transformers and power lines, and represented by concentrated elements R, L and C
- Switch panel for setting up different grid topologies
- Short circuit generator for optimizing the protection concept in future grids

dSPACE hardware for controlling the battery converters and for simulating the wind strength, solar radiation and load conditions.

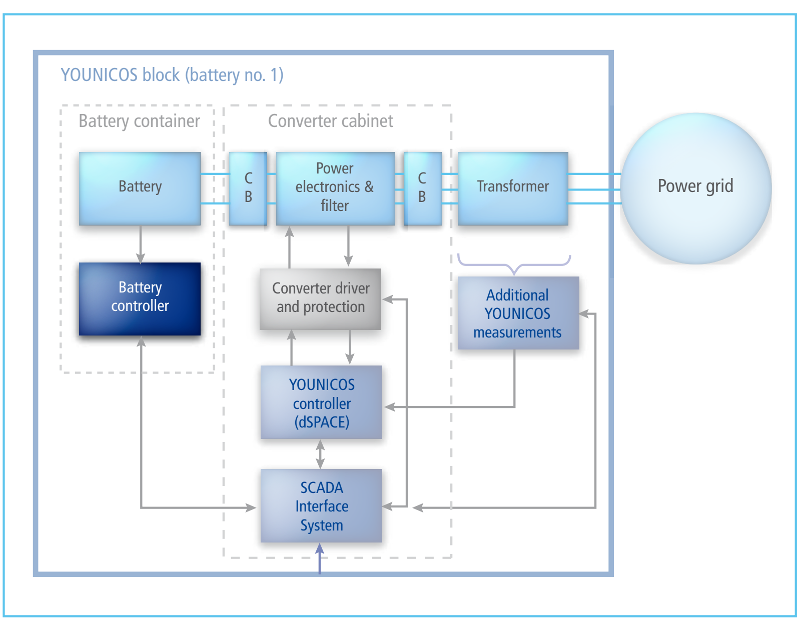
> "The tests on the world's first autonomous regenerative energy supply in the megawatt range run smoothly with dSPACE rapid prototyping hardware."
>
> *Mohamed Mostafa, Younicos*

We took great care to achieve a redundant design that would make the system robust and less error-prone. At the same time, the system had to be modular and extendable. The system's internal communication structure between the converters and the battery management system had to be as small and efficient as possible to keep it flexible, reliable, and easy to maintain.
The overall hardware structure of the test setup and the functions of the individual components are shown in figure 2.

Battery and Converter for Stability

The energy obtainable from the wind and the sun fluctuates, and long-term predictions are impossible, so the NaS batteries and the converters are vital for stabilizing the power grid. Controlling and coordinating these components, i.e., arbitrating between the available power and the power demand, are the core tasks of the battery management system and the converter control.
The batteries (figure 3) charge when the photovoltaic and wind generators are producing more electricity than is being consumed. They dis-

Figure 2: The detailed hardware structure with its functions in the test setup.



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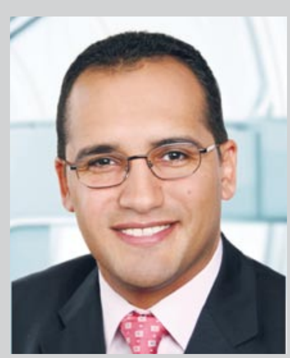

Figure 3: The sodium sulfur battery evens out power fluctuations and serves as storage for "lean" times.

charge when the generators are providing less electricity than the island requires. The fast control in the converters keeps the frequency and voltage in the grid stable. With its high cycle stability, the NaS battery is ideal for combining with renewable energy sources, where times of increased power generation and times of low power generation alternate irregularly.

Developing the Converter Control

The battery converter control has two main components: a real-time controller and a communication system.

To find the optimum control for the converter, we use rapid prototyping to test different voltage and frequency control algorithms that we designed in MATLAB®/Simulink®. For the actual tests, we use the AC Motor Control Solution from dSPACE. This consists of a DS1005 Processor Board and DS5202 FPGA Base Board with a piggyback module. The algorithms are implemented on the DS1005 by means of the dSPACE Real-Time Interface (RTI), and then executed on the board. The DS5202 provides the necessary I/O connection between the processor board and the converter. If any changes are made to an algorithm, they can quickly be transferred from MATLAB/Simulink to the DS1005 by using RTI.

The communication system monitors the interfaces between the battery, the converter, and the control, and also coordinates the battery and the converter. The system can be accessed from anywhere via a web terminal to query its status or make changes. This makes it easy to per-

Features of the NaS battery

High energy density	3 times higher than that of lead acid batteries
High capacity/duration	Discharging 6 hours at 100% or 8 hours at 75%
Lifetime	15 years, or approx. 4,500 charge cycles
Charge properties	No self-discharge No memory effect
Easy maintenance	Inspection once every 3 years
Fast response time	2 ms
Operating temperature	300 °C

Figure 4: Another Younicos project also uses energy from the sun: This solar power system feeds an autonomous charging station for electric vehicles.

Glossary

Cycle stability – An indicator of whether battery charging and discharging causes deterioration with associated performance loss.

Sodium sulfur battery – Rechargeable battery with anodes made of molten sodium and cathodes made of granite tissue soaked in liquid sulfur.

Self discharge, memory effect – Important factors in rechargeable battery use. In self-discharge, the battery loses energy even when not connected to a consumer. The result is a loss in capacity.

form remote control and remote maintenance. This is absolutely essential for a system used in remote areas or on islands, as there is not always an engineer close at hand.

Simulating Consumption, Wind, and Sun

We use our own models for simulating wind turbines and solar power plants. They are implemented and executed on several dSPACE DS1005 PPC Boards. Real wind and sun data measured on the island of Graciosa provides the input parameters for ascertaining the currently available power. This available power is then compared with a consumption profile that represents the island population's energy requirements throughout the day. Converters then perform energy distribution. Each battery is coupled to the simulated supply grid via a converter. At the test facility, the input of wind and solar energy into the electricity supply grid is simulated with the aid of two converters. The load on the grid is represented by another converter that runs through a scaled load profile of the island. In addition, a real 210-kWp (kilowatt peak) solar plant feeds into the island grid. The solar panels are installed on the roof of the Solon SE building.

The Test Objectives

During the test phase, we aim to demonstrate that a stable energy supply based on renewable energies is technically feasible and economically attractive. The amount of renewable energy fed into power grids has so far been limited because it fluctuates and impairs grid stability. We intend to show that the battery and the intelligent converter control together stabilize the island's grid, making it no problem to obtain an increasingly large part of the power supply from renewable energy sources.
When the two-year test phase has been completed, the results obtained from it will be used to change Graciosa's power supply completely to wind and solar energy. ■

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