DEVELOPMENT, PRODUCTION AND VERIFICATION OF THE SECOND GENERATION OF AC-MODULES (PV2GO)

Increasing life time and lowering cost-price by reducing the number of components significantly

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This paper has been presented at the "19th European PV Solar Energy Conference and Exhibition", 7-11 June 2004, Paris, France

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ABSTRACT: In the PV2GO project a new AC-module inverter is developed, taking into account all relevant aspects from a European market point of view (standards, market, application, R&D goals). Project goal is to achieve turnkey system costs of 3 €/Wp for a modular plug-and-play AC-module PV system. The R&D goal is to develop an advanced DC-control system consisting of a state-of-the-art programmable digital device and an ASIC for the AC-control of the inverter. This development took place within the framework of the optimal topology concept and design, taking into account suitable production technology and packaging for large-scale production. In the PV2GO project the new AC-modules were tested in a number of test sites in various parts of Europe and the reliability was assessed through Highly Accelerated Stress Tests. Further an optimisation study of a manufacturing process for the new generation of AC-modules for high volume output was carried out. Another task was the pre-certification procedure to assure compliance with the European guidelines and standards.
Keywords: Qualification and Testing - 1: Small Grid-connected PV Systems - 2: Inverter – 3

1. PURPOSE OF THE WORK

As pointed out in the White Paper "Energy for the future" of the European Commission, the main target of photovoltaic R&D projects is a profound cost reduction for solar electricity generation down to 3 Euro/Wp on the mid term. To achieve this goal, a new generation of AC modules was developed, and production volume had to be increased to a larger scale. The inverter part of the AC module had to be designed for reliable operation during the typical PV-module lifetime of twenty years.

2. DESCRIPTION OF WORK

In the PV2GO project, a new AC module inverter was developed, taking into account all relevant aspects from a European market point of view (standards, market, application, R&D goals). For the PV-module a standard 130-Wp Eurosolare module was chosen. The R&D goal was to develop an advanced DC-control system consisting of a state-of-the-art programmable digital device and an Application Specific Integrated Circuit (ASIC) for the AC-control of the inverter. Topology concept, thermal and magnetic design were optimised with regard to production technology and packaging for large-scale production. The new AC modules were tested in a number of field-test sites in various parts of Europe and their reliability was assessed through Highly Accelerated Stress Tests. Energetic performance and power quality have been tested in the laboratory. Further in the PV2GO project an optimisation study of the manufacturing process of the new generation of AC-modules for high volume output was done. Another task was the pre-certification procedure to assure compliance with the European guidelines and standards.

3. RESULTS OF THE WORK

AC-modules are a recent type of grid-connected PV-systems. Because of the small system size the investment is well within reach of many people and the system can in principal be coupled directly to the grid without any additional requirements ("plug and play"). This has opened a new and successful market for grid-connected PV-systems.

The inventarisation of the product design requirements was carried out by means of a questionnaire and distributed to all the partners. On the basis of this questionnaire the requirements in the field of marketing, standards, functionality, mass production demands, lifetime and reliability were gathered, and a concept product specification document was set-up.

Research was carried out in the field of the inverter concept. The optimal topology was chosen, in direct relation with the control concept. The design of the power electronic circuit is robust, focussed on reliability and cost reduction. This was accomplished by the integration of control and power conversion functions and the thermal, electric and mechanical optimisation of the design for large-scale production. This involved among others, the power electronic topology, the control concept, the mechanical design and the production process.

From the beginning of the project the integration of micro-controller and the PWM-controller and other functionality were identified as the major changes to gain better performance in the field of reliability and component costs.

For isolation reasons it was decided to develop two control systems, one for the control and communication electronics on the DC side and the other for the control electronics on the AC side.

In essence the reliability of an AC-module inverter is determined by the robustness of the design. This means the thermal and electrical usage of the components in the first place. In the second place

the producibility of the design contributes strongly to the reliability and the costs of the product. The technologies and mechanical concepts used offer inherently good thermal-mechanical and easy assembly by hand properties.

Picture 1, the second prototype of the PV2GO inverter without enclosure

Two very important results were increased reliability and reduced cost, as confirmed by calculations on the second prototype of the PV2GO inverter.

The mean time between failure (MTBF) of the second prototype PV2GO inverter using Bellcore TR332 (Method 1, Parts count, Case 1, T amb. 40°C and 50% rated electrical stress) is about 25 years. The reliability improvement achieved is strongly expressed with the following comparison: the same MTBF calculations on an "off the shelf" similar PV inverter gave about 15 years.

The production cost of the second prototype PV2GO inverter is strongly reduced with respect to a module inverter with comparable performance. This was achieved by reducing the number of components significantly. Cost calculations showed that the end-user price of the PV2GO inverter, based on 10,000 pieces annual production, can be 0.5 €/Wp.

Picture 2, the second prototype of the PV2GO inverter

After the developement and production of the second prototype AC-modules, 50 pieces were spread among the partners for a one-year test period.

For laboratory tests 12 pieces of the second prototype AC-module were used. The test results copes with the specification and are competitive with other similar inverters. For example see the static power efficiency versus the ac power in figure 1.

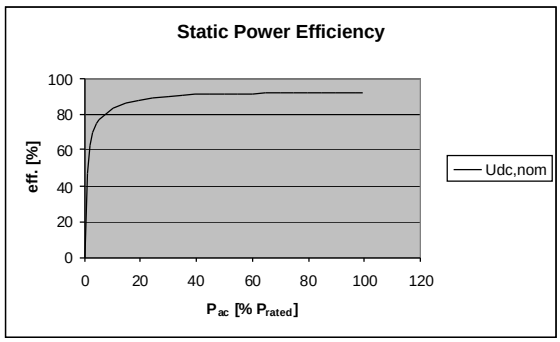

Figure 1, Static power efficiency versus ac power, measured on the second prototype

Picture 3, Large Field Test at ECN.

For the one-year field test 26 pieces of the second prototype AC-module were spread over locations in the Netherlands, Germany, Belgium and Spain. These test are finished and all modules performed well without failure. For example ten monitoring systems were located on the roof-top of an ECN building. Each system consisted of a solar module, a PV2Go inverter and an AC energy counter. The AC energy counters gave one readout per month each. The results over the period August 2002 till and including February 2003 are shown in Figure 2.

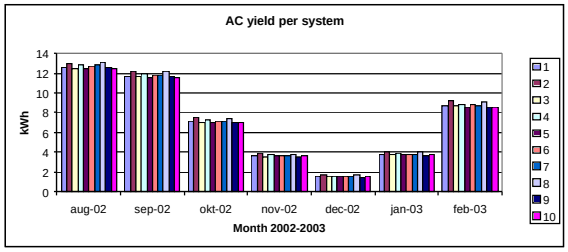

Figure 2, AC Yield per system, measured at Petten in The Netherlands

As monitoring started at August 7th, one week is missing in the results of August. Therefore the energy yield in August is about as much as the energy yield in September.

4. CONCLUSION

According to a manufacturing process study in the fourth year of the project, the goal to achieve a turnkey system cost of 3 €/Wp for a modular plug-and-play AC-module PV system can be met with the PV2GO concept. Also a very promising lifetime expectancy of the inverter part of the AC-module is achieved.

5. CONTRACTORS DESCRIPTION

All participants were principal contractors of the project. The relevant work activities they operate in, are listed underneath:

ECN
Testing of the electrical and mechanical reliability and performance in both laboratory environment and outdoor conditions of (components of) PV-systems. ECN is the Coordinator of the project.

MasterVolt
Design and large-scale production of BOS components for stand-alone and grid-connected PV-systems. Turn-key system developer.

Alpha microelectronics
Design and manufacturing of integrated power-control packages on a single-substrate: cutting-edge technology in the further reduction of price and volume of power-electronics devices.

Eurosolare
Major mc-Si PV-module manufacturer actively engaged in future developments of PV-module technology and manufacturing processes.

Iberdrola
Spanish utility company with its own R&D department in new and renewable energy technologies. Owns and operates a Test and Demonstration centre for field testing and training of technical staff.

ISET
Design and prototyping of power-electronic topologies for renewable energy systems.

NMRC
Integration of passive magnetic components and assessment of reliability of power-electronics.

IMEC
Application Specific IC designer and manufacturing of prototypes.

KU Leuven
Simulation of distributed energy production unit connected to a central distribution grid using advanced software tools. Standardisation and testing of islanding of distributed generation units.

6. AKNOWLEDGEMENT

Project funded by the European Community under the Fifth Framework Program (1998-2002)

7. INFORMATION

References: ERK5 CT1999 00014

Programme: Fifth framework

Title: Development, Production and Verification of the second Generation of AC-modules.

Duration: 42 months, from April 2000 - October 2003

Partners: ECN
Mastervolt
Alpha Microelectronics
Eurosolare
Iberdrola
ISET
NMRC
IMEC
KU-Leuven

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