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TISO
TEST OF RELIABILITY ON MODULES AND ON PV COMPONENTS

ABSTRACT

Using the infrastructure as well as the experience acquired during the photovoltaic project TISO, a facility for systematic tests under real environmental and operating conditions of commercial photovoltaic modules and components was created, in order to verify their behaviour and their reliability. The modules undergo a series of tests that have to proove their reliability in medium or high power plants.

Among the parameters which determine the use of photovoltaic modules in medium and high power plants, should be mentioned behaviour and reliability under high voltage exposure.

At the Centre, a data bank is available containing a list of the main photovoltaic modules on the market in Switzerland and their respective technical characteristics. The results of the tests carried out at the Centre have also been recorded in this data bank.

The Centre is also equipped with installations for testing medium and high-power third party plants, realized or financially supported by the Swiss Federal Office of Energy.

1. INTRODUCTION

The knowledge gained in TISO PV power plants has shown that the electrical isolation between frame and active part of the silicon, and the degradation in the a-Si modules efficiency are very often the main prejudicial weak points in the reliability of the PV plants.

On the other hand the technical data of the photovoltaic products supplied by the manufacturers are not sufficiently complete or correct to assess performance and reliability a priori.

Therefore a facility for systematic testing of commercial photovoltaic components has been created. All tests are made under real environmental conditions.

The facility started operating in May 1992 (Fig. 1).

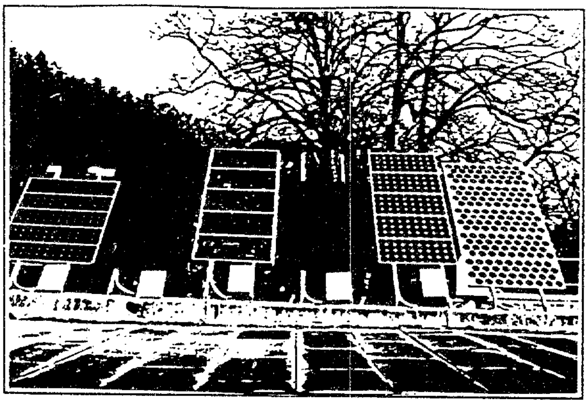

Fig. 1: View of the TISO test facility

The activities consist of measurements of different types of silicon modules (mono-, poly- and amorphous ones), tests of components related to photovoltaic technique (inverters, regulators, protections, sensors etc.), measurements on external systems realized or financially supported by the Swiss Federal Office of Energy, and the setting up of a database.

Particular attention has been placed on the reliability of the m-Si, p-Si and a-Si modules, when they are exposed to high voltages as in the case of medium to high power systems.

For a first series of tests 12 types of modules have been chosen between the ones most frequently used in the photovoltaic power grid connected plant in Switzerland.

2. TESTING PROCEDURE

The following test procedure has been adopted. First the electrical (at STC) and mechanical characteristics are measured on 6 modules of each type. These results are compared with the ones given by the manufacturer.

Then the modules are installed outside for one year, under a voltage of 1.2 kV between the frame and active part of the silicon: 1 module is exposed in short circuit conditions (Isc), 1 module is exposed with no load (Voc) and 3 modules are operated at the maximum power point (MPP) using a specially developed electronic load circuit, while the sixth module is stored in a room as reference. The aim of this test is to determine the ability of the modules to operate in a high voltage system.

For the whole period of testing the modules are periodically observed through a thermographic camera. Furthermore, a system for measuring NOCT (Nominal-Operating Cell Temperature) was elaborated. For each type of module, the measurement of NOCT is taken.

At the end of the procedure test, the electrical chacteristics (STC) of all modules are measured again.

The tests results and the data provided by manufacturers are introduced in a data bank . Figure 2 describes the testing procedure which the different modules will undergo.

REGISTRATION
Identification; mechanical and nominal electrical data

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VERIFICATION AND MEASUREMENT UNDER CONTROLLED CONDITIONS
General checks; measurement of mechanical and electrical features; electrical isolation test; NOCT

⇩

EXPOSURE UNDER REAL CONDITIONS
Exposure under real environmental conditions under highvoltage (1.2 kV) during 1 YEAR; Thermic behaviour

⇩

FINAL TESTS UNDER CONTROLLED CONDITIONS
Electrical isolation test; measurement of electrical features; general controls

⇩

DATA BANK & DATA SHEETS

Fig. 2: Testing procedure

3. RESULTS

3.1 Electrical parameters

Figure 3 sums up the given values and the average values measured (at STC) before and after the tests.

Before and during the tests:

In general in the silicon-crystalline modules a slight decrease in power has been observed during the reliability tests (min -0.7%; max -5.6%, cf. fig. 3 P2 and P3). However, the main differences found are those between the real parameters of the modules and those indicated by the suppliers. In fact already before the tests, the nominal electrical values given by the manufacturers are not the same as the values measured under standard conditions, which are usually lower (cf. fig 3, P1 and P2, m-Si and p-Si modules). The differences range between -15.2% and +6.3% and the average is -3.9%.

On the other hand the a-Si tandem module at our disposal, before the tests resulted in higher measurements, i.e. +16.4%. However, during the tests, degradation is much greater (-30.1%).

Type of module	Pmax @ STC [Wp] GIVEN by manuf (P1)	MEASURED TISO Before (P2)	MEASURED TISO After (P3)	Δ P [%] (P2-P1)/P1	Δ P [%] (P3-P2)/P2	Δ P [%] (P3-P1)/P1
UPM880 (USSC)	22	25.6	17.9	+16.4	-30.1	-18.6
BP460 (BP Solar)	60	53.6	52.3	-10.7	-2.4	-12.8
M55 (Siemens)	53	52.3	49.4	-1.3	-5.5	-6.8
NT907S (Sharp)	70	69.4	65.5	-0.9	-5.6	-6.4
BPX47500 (Photowatt)	48	40.7	40.4	-15.2	-0.7	-15.8
MSX60 (Solarex)	60	57.3	55.0	-4.5	-4.0	-8.3
H60 (Helios)	60	53.6	51.4	-10.7	-4.3	-14.3
PWX500 (Photowatt)	46	48.9	47.1	+6.3	-3.6	-2.4
LA361K51S (Kyocera)	51	51.1	-	+0.2	-	-
GPV110M (GPV)	110	106.6	-	-3.1	-	-
MSX120 (Solarex)	120	115.2	-	-2.5	-	-
BP585 (BP Solar)	85	84.6	-	-0.4	-	-

Fig. 3: Nominal power given and measured before and after the exposure. The module UPM880 is a a-Si tandem module.

After the tests:

The power at STC at the end of tests were in 4 cases out of 8 outside the limit of ± 10% with respect to the values supplied by the manufacturer (cf fig. 3, P3-P1/P1).

3.2 Mechanical parameters

The measured mechanical dimensions differ a little from the ones given by the manufacturer; the weight, however differs by up to 9.5% (average of the absolute value: 3.8%).

3.3 Reliability of electrical insolation

The test is successfully completed if there isn't any breakdown of the dielectric or on the module surface, if the final electrical isolation resistance is not less than 50 MOhm and if the I-V characteristic is degraded not more than 5% @ STC.

Up to now, no modules undergoing the test of reliability under high voltage suffered from damage that could be seen or measured. This shows the high level of reliability which the modules have achieved and reveals the improvement in the lamination process of modules.

3.4 Thermal behaviour

The two main aspects of thermal behaviour of the modules is analysed: variations in electrical parameters versus temperature (coeff. of temperature) and special types of overheating (e.g. terminal box). For this purpose a thermographic camera is used: differences of temperature of 10°C have been observed between cells of the same module. This was observed in every type of silicon crystalline module connected at MPP or in short-circuit. No hot-spots were found in the open-circuit modules nor were they found in a-Si tandem modules.

Through thermographic analysis it has been possible to observe some hot areas in the electronics of the 10 kW plant's inverter. It has been also possible to find and repair a breakdown of the 4 kW plant inverter.

The measurements of the NOCT are reported in fig. 4. Analysis of these results shows a difference in absolute value in the order of between 1% to 13% with respect to the data supplied by the manufacturer.

	NOCT [°C]		
Type of module	Given by the manuf.	Measured values	ΔT [%]
UPM880 (USSC)	50.00	46.27	-7.4
BP460 (BP Solar)	43.00	43.50	+1.2
M55 (Siemens)	47.00	43.68	-7.1
NT907S (Sharp)	40.00	45.22	+13.1
BPX47500 (Photowatt)	45.00	39.70	-11.7
MSX60 (Solarex)	49.00	45.07	-8.0
H60 (Helios)	40.00	43.15	+7.9
PWX500 (Photowatt)	45.00	46.72	+3.8
LA361K51S (Kyocera)	43.00	44.74	+4.0
GPV110M (GPV)	42.00	46.46	+10.6
MSX120 (Solarex)	45.00	46.88	+4.2
BP585 (BP Solar)	--	46.62	--

Fig. 4: Given and measured NOCT

4. OTHER ACTIVITIES OF TISO

Management of the TISO plants: during this project, the analyses of the behaviour of the 10 kW m-Si plant, which began to operate in '82, have been continued as well as the analyses of the 4 kW a-Si plant, in use since '88. This long term research shows that m-Si PV components are reliable and durable. There hasn't been till now any detectable loss of efficiency. The a-Si seasonal degradation and regeneration cycle is still continuing. In particular the oscillations of the cycles are less wide but seem to have stabilized at a lower level.

Measurement of third party plants: the Centre is also equipped with installations for testsing medium and high-power plants in other locations. During the project, the Centre undertook measurements of three plants. These tests were conducted in co-operation with the JRC of Ispra. An agreement for data exchange and evaluation of plants of mutual interest was concluded with this centre.

Organisation of courses and consulting: in the field of the Pacer impulse programmes, a course was organised. A further course for technical constructors is planned. The TISO Centre functions also as an intermediary between the Swiss researchers and the researchers of the JRC of Ispra.

5. CONCLUSIONS

A centre for systematic tests, under real environmental and operating conditions, of components and photovoltaic systems was created. The first measuring cycle with the modules was concluded. Besides providing the first results, these measurements confirmed the validity of the chosen procedures and the proper functioning of all the equipment. The Centre is thus ready to carry out regular tests. In short:

- Up to now 12 types of modules were chosen for the tests. 8 types of modules finished a series of tests which lasted 1 year. For 4 types of modules the exposure is still in progress. All the modules passed the electrical isolation reliability test. At the end of the test no module had any defects either in the electrical isolation or in any other parts (terminal box, frame, etc.). This shows the high level of reliability which the modules have achieved and reveals the improvement in the lamination process of modules

- It is necessary that the manufacturers make a further effort to define the nominal power of the modules in a more accurate manner. In fact the main differences found are those between the nominal parameters indicated by the suppliers and those measured before the tests, which are usually lower. **Before the tests**, the difference between the nominal power and the actually measured power was:
  from -15.2% to +6.3% for the p-Si modules
  from -10.7% to -0.4% for the m-Si modules
  +16.4% for the a-Si module

- **During the tests**, in the c-Si modules a slight decrease in power has been observed. For the a-Si module, however, degradation after exposure has been much greater.

- **After the tests**, the difference between the nominal power and the actually measured power was
  from -15.8% to -2.4% for the p-Si modules
  from -14.3% to -6.4% for the m-Si modules
  -18.6% for the a-Si module
  After the tests, half of the modules were outside the guaranteed limits of ±10%.

- Differences in size of up to 4.5 mm were found in the the lengths of the modules. Dimensions need to be even more precise for large-scale equipment.
  The excess weight amounts to 5.6%, while the weight shortages amount to up to 9.5%.

- The labels are generally insufficiently complete or non-existent. The label should at least contain the main features of the module (type, power). The documentation enclosed with the modules is often insufficient. In particular, basic information regarding mounting problems (shadows, diodes, danger from current, etc.).

- The temperature of the modules is not homogeneous and the actual power of the modules is diminished by the number of existing hot-spots. Differences of temperature of 10°C have been observed between cells of the same module. This was observed in every type of silicon crystalline module connected at MPP or in short-circuit. Thermal analysis shows how difficult it is to evaluate the working temperature correctly and therefore the electrical features of the modules. The homogeneity of the temperature must be a parameter considered by the buyers for the value and the comparaison of modules.

- The differences of NOCT amount to 13%. To a great extent this is due to the differring conditions of predefined measurement. The NOCT of the different manufacturers cannot be compared; however NOCT depends on the final application use.

- The measuring of the plants of the third parties has been started. At present, thermographic analyses and observation of the dynamic behaviour of the inverters are being made. The data of the third-party plants is being collected and processed in co-operation with the JRC of Ispra with whom an agreement regarding scentific co-operation exists.

- The collected data is entered in a data bank for modules. Besides the measured results, the data bank for modules contains the characteristics and the specifications of approx. 500 types of modules on the market, as well as addresses of manufacturers and distributors (resp. approx. 90 and 170).

6. ACKNOWLEDGEMENTS

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