FORUM SOLAR: A LARGE PV PERGOLA FOR FORUM 2004

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ABSTRACT: In the context of the Forum Barcelona 2004, a large photovoltaic pergola, 50 meters high, has been constructed. A 443 kWp PV generator, with 2686 I-165 modules, will feed 3·125 kW ACEF inverters. This PV grid-connected plant will generate 1250 kWh/kWp. During present year a second phase will be initiated for installing an additional system of 850 kWp. Therefore this system will be the largest urban PV system in Spain.

Keywords: Large Grid Connected Systems, Supporting Structures, Inverter

1. INTRODUCTION

From May to September 2004, the FORUM Barcelona 2004 will be celebrated in Barcelona, Spain. The Forum is a festive journey designed to bring the three main themes to life: cultural diversity, sustainable development and conditions for peace. For 141 days, this will be the place where millions of visitors experience cultures and entertainment from around the world through large and small scale exhibitions, workshops, markets, performances, games and more. [1]

Several meetings, exhibitions, infrastructures and recommendations will be devoted to sustainable development as one of three axis of Forum. Among these infrastructures it should be highlighted a solar totem, a large photovoltaic pergola constructed as a monument to solar energy.

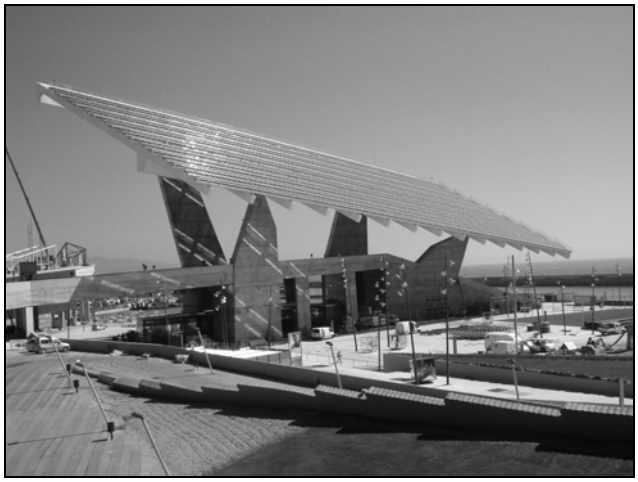

Image 1.- View of FORUM PV Pergola

The original design is due to Spanish architects Martínez Lapeña and Elias Torres. A huge structure composed by four legs of different height and slope supports a 3410 m2 photovoltaic generator. Maximum height of structure is 54 meters above sea level. Therefore, this is one of the largest urban photovoltaic systems.

2. CONSORTIUM: ORGANISATION

As a result of a public call for tender, the consortium FORUM SOLAR assumes the turnkey project. The consortium FORUM SOLAR is composed by:

- ENDESA, utility private company.
- SERIDOM, company belonging to Engineering Consortium IDOM, devoted to execution and management of turn-key projects
- INABENSA, installation company.
- ISOFOTON, manufacturer and project engineering of PV systems.

To fulfill project deadlines was the challenge from the very beginning. Organisation, planning and coordination of tasks among companies of the consortium was fundamental in the context of a huge urban operation with lots of installations being carried out simultaneously both in time and space.

Therefore: SERIDOM worked as manager and coordinator of costs and periods project; ISOFOTON as technical responsible for guarantee of energy production, assistance for design of PV system and main supplier of the project (modules); INABENSA as manager of installation; ENDESA as administrative delegate of the FORUM SOLAR consortium for grid connection.

3. PHOTOVOLTAIC GENERATOR

The 443,2 kWp PV generator is composed by 2686 modules with the following characteristics:

- Nominal Power: 165 Wp
- Power Tolerance: 5%
- Frameless, transparent Tedlar.

Modules were packed in groups of 360 units. 16 ones of each group were randomly chosen and sent to IER-CIEMAT for independent quality control and power measuring. Previously, 4 modules were calibrated and used as reference ones for the whole campaign of tests both in IER-CIEMAT and in ISOFOTON factory. IER-CIEMAT [2] is an Spanish public laboratory devoted to investigation and certification in the field of renewable energies, including PV.

Due to voltage input of inverter, a configuration of 79 rows with 34 modules in series has been used. Since dispersion losses are directly related to number of modules in series, it is recommended to classify them by current values when that number is high. [3]

In order to carry out classification previously to manufacturing, an internal production database was used as reference. Therefore three categories were established so modules were classified as soon as power was measured. It should be noted that both values from database and power measuring were corrected to include reference from CIEMAT.

PV generator is electrically DC floating. Due to high voltages used (>600 Vdc), a permanent insulation monitoring device is installed inside DC protection and control box. Several mechanisms of protection can be activated when an insulation fault is detected: for example, disconnection of PV generator and inverter, short-circuit of PV generator and direct connection to earth [4]. This action can be programmed and selected through remote control.

Image 2.- Installation of set of 12 modules

4. SUPPORT STRUCTURE

Stability against wind forces, height of 50 meters opposite to the sea without obstacles, "sail effect" due to the large surface, frameless modules, forced an structural design which achieves elastic exhaustion of materials. Besides, polymeric adhesives were used so as to prevent galvanic corrosion in a marine ambient.

These facts motivated a test of a prototype according to standard E 1830-01 "Standard Test Methods for Determining Mechanical Integrity of Photovoltaic Modules", chapter 5.5 "Cyclic Load Test Apparatus" and chapter 5.5.1 "Air Bag Scheme". The aim of this test was to check if the set of structure and frameless module could deal with:

A static load test of 2400 Pa to simulate wind loads on both module surfaces corresponding to a wind speed of 58 m/s (209 km/h). This test, repeated 100 times, was satisfactorily fulfilled.

A dynamic load test of 10 000 cycles duration and peak loading to 1440 Pa, 0,34 Hz frequency to simulate dynamic wind. This test was satisfactorily fulfilled.

Final result of the test can be observed in next photograph. After 87 cycles of 3200 Pa static load (278 km/h), part of the secondary structure was broken and then the module too. Before these 87 cycles, three sets of 100 cycles with 2400, 2800 and 3000 Pa were applied successfully.

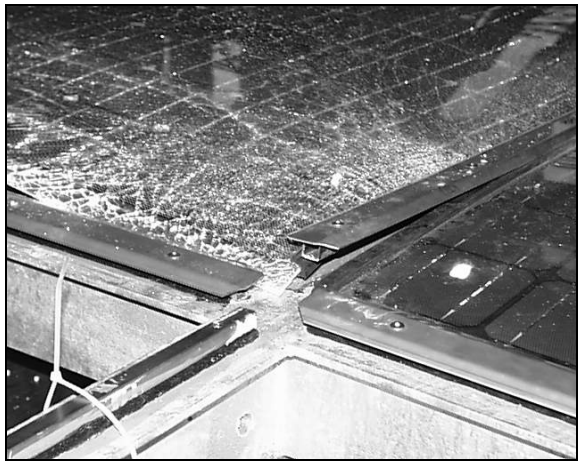

Image 3.- Result of the test after 87 cycles with 3200 Pa static load

5. INVERTER

The consortium decided to choose the inverter equipment through a call for tender. Three important European manufacturers were invited to participate. Finally the ACEF model from Enertron was selected. This model has next characteristics:

- Self commuted with IGBT
- AC Current by hysteresis bands.
- Nominal Power: 125 kW (three units)
- Input: 450 - 756 Vdc (MPP: 450 - 620 Vdc)
- THD (Current, 100% load) < 5%
- Power Factor: >98% for output above 25%
- Maximum Efficiency (including LF transformer): 96%
- European Efficiency (including LF transformer): 94%
- Noise level: <65 dB.

Three main features must be highlighted:

- A Master-Slave-Slave control technology is used. Global efficiency will be improved, especially during morning and afternoon and with low irradiance levels. Control equipment is independent from inverters, so any of them can be selected as Master or Slave.
- An additional inverter will be installed in parallel as stand-by. This way availability of energy can be improved providing a fast response when an inverter is damaged.
- As a condition included in the contract, values of efficiency and availability of equipments are guaranteed by the manufacturer. Penalty can be applied in case of deviation.

6. ENERGY PRODUCTION

Energy production has been calculated with the software PVSYST 3.2 [5] with corrections obtained from experience of E. Caamaño [6] and E. Lorenzo [7] from IES-UPM and grid-connected plants of ISOFOTON.

Among these plants special attention has been paid to the "Photocampa" system [8]. The "Photocampa" is a PV

generator, 350 kWp, integrated in a car canopy located in Tarragona (100 km from Barcelona). Since DC voltage is very similar, inverter manufacturer is the same and both installations are connected through a Medium Voltage Transformer, performance data of "Photocampa" helped to predict energy production of FORUM pergola. Besides, two quality control tests were performed by IES-UPM in Photocampa:

- Dirt in modules. 2-4% losses were obtained.
- Dispersion losses. 2% losses were obtained when classification was performed.

Using the meteorological station of the Physics Science School as a reference for annual irradiation (Ga(0)=1537 kWh/m2) the FORUM PV pergola should work with a performance of 1250 kWh/kWp.

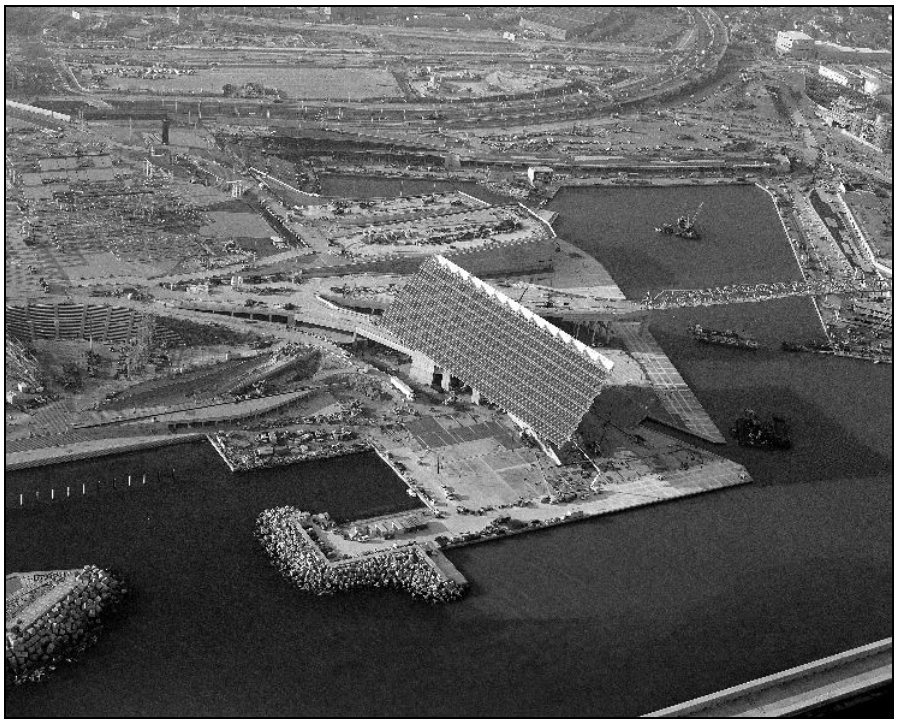

Image 4.- Aerial View of FORUM PV Pergola

7. CONCLUSION

In the context of the Forum Barcelona 2004, a large photovoltaic pergola, 50 meters high, has been constructed. A 443 kWp PV generator, with 2686 I-165 modules, will feed 3·125 kW ACEF inverters. This PV grid-connected plant will generate 1250 kWh/kWp.

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REFERENCES

[1] www.barcelona2004.org

[2] http://www.ciemat.es/eng/departamentos/dep_energen.html

[3] "Modelado de generadores fotovoltaicos: efectos de la dispersión de parámetros", R. Zilles, PhD Thesis, UPM, Madrid, 1993.

[4] "Contribución al desarrollo tecnológico de la seguridad y protección a personas en aplicaciones fotovoltaicas conectadas a la red", PhD Thesis, P. Gómez Vidal, U. Jaen, 2000

[5] www.pvsyst.org

[6] "Edificios Fotovoltaicos conectados a la red: caracterización y análisis", E. Caamaño, PhD. Thesis, UPM, Madrid, 1998.

[7] "La energía que producen los sistemas fotovoltaicos conectados a la red", E. Lorenzo, Era Solar, nº 107, 2002.

[8] "PHOTOCAMPA: PV System Integrated into a Large Car Park", O. Perpiñan et al., 17th European Photovoltaic Solar Energy Conference, Munich, 2001.