BUILDING INTEGRATION OF TOTAL 40kWp PV SYSTEMS AT CRES

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ABSTRACT: This paper reports on the installation of a total of 40kWp photovoltaic systems in the premises of CRES at Pikermi. A thorough analysis was carried out in order to identify the most appropriate places for PV integration, taking into consideration the existing infrastructures, the building layout and the available space. Six sites were selected for installation and all solar systems are grid-connected. The work is part of the "PV Enlargement" project which is co-financed by the EC.
Keywords: Building Integration – 1; Small Grid-connected PV Systems – 2; Module Integration – 3

1 INTRODUCTION

The PV installation at CRES is part of the "PV Enlargement" project network. The work is co-financed by the EC, contract No NNE5-2001-00736. Co-ordination is done by WIP – Münich and there are 29 partners involved in the project from 11 countries. One aim to be achieved in the project is to analyse and compare the performance of different technology PV systems. The state-of-the-art of PV technology performance will then be assessed by technology and by country. The evaluation of the results, in dialogue with the PV industry, shall lead to improved module efficiencies, to increased reliabilities and to an increased confidence in PV products throughout Europe.

For CRES in particular, the systems were designed and erected in a most innovative way, to be publicised as reference systems of today's PV technology. This was done by deploying optimal PV integration techniques, usage of first class equipment and materials and applying state-of-the-art engineering. The energy produced from the PV arrays will be fed into the grid, while the systems will be used by CRES for its RTD, demonstration, dissemination and educational activities as a National Centre for the promotion of RES in the country.

2 SELECTION OF SITES

The PV systems are installed in the premises of CRES at Pikermi. Investigations of the available areas, the outdoor infrastructure and the layout of the existing buildings of CRES have been conducted in order to accommodate the 40kWp total PV capacity, corresponding to approximately 360m^2 of solar module area. The morphology of the ground was also examined. A top view of the CRES premises and the 6 installations sites is presented in Fig. 1.

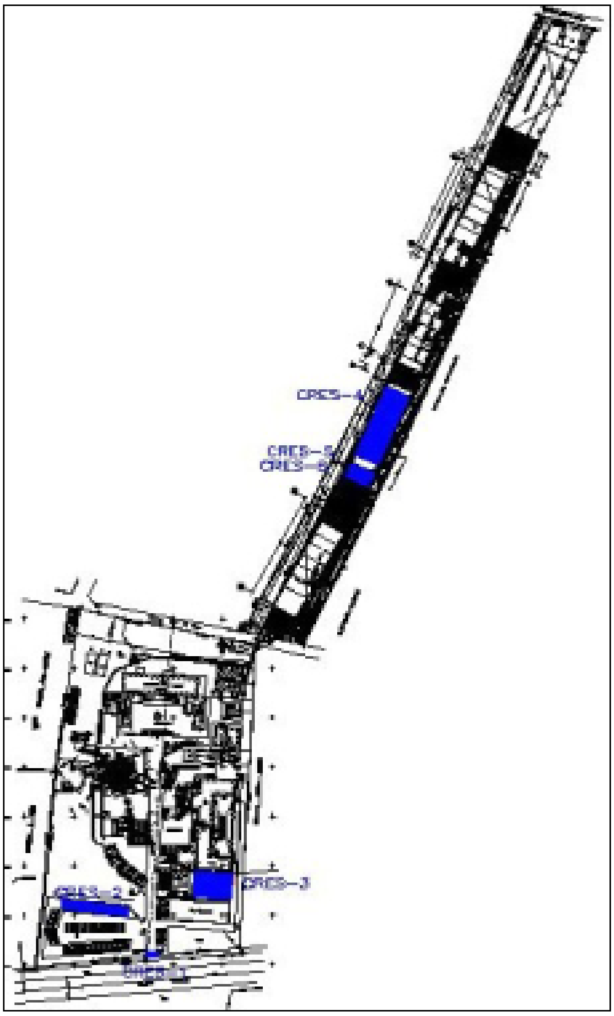

Fig. 1 Top view of CRES premises and the PV installation sites

As one of the scopes of this project is to demonstrate state-of-art PV technology, the following aspects were encountered in the integration methodologies of the systems installed at CRES:

- Minimal intervention in the existing building and site infrastructure
- No need for supportive work, such as modifications or demolishing of infrastructures, tree cutting etc.
- Major improvement in the functionality of the buildings and the outdoor installations
- Architectural advancements in several installations, providing excellent aesthetical impression e.g., integration on a building envelop, roof-top system, façade, pergola and site entrance
- Technical excellence of installations
- Almost zero shadowing from adjacent buildings, aerial cabling, flora, etc.

A number of integration techniques of PV arrays were implemented such as, main entrance, shedding of a car parking area, shedding of a veranda of the main building, and another 3 systems close to the PV Department Building (building extension, roof-top arrangement and façade integration). In every case, emphasis has been put on the architectural integration of the modules, taking into account the space availability, the design and aesthetics of the existing buildings and the surrounding space and the functionality of the systems in terms of improving the energy balance, where possible.

3 PV SYSTEM COMPONENTS AND INSTALLATION

The MPP tracking technique was identical for all PV systems in the project to allow a common base comparison of all installations. Thus, the majority of the PV Enlargement systems use inverters from one manufacturer with the same MPP tracking device.

Six in total sites were selected at CRES and the equipment was installed between August and November 2003. The systems differ from each other in the following parameters:

- Size of the array
- Combination of module type and grid inverter
- Plane angle and orientation
- Installation type (building integrated, free-standing)

Mono-crystalline silicon PV modules were used from 2 manufacturers, namely Solar Fabrik type SF 115 and Conergy type 105L. The PV systems are electrically divided into sub-arrays, each of which is connected to an individual inverter. Power electronics were supplied by Sun Power and the inverters are positioned close to the sub-arrays in order to minimise DC losses. During installation special attention was placed on the following:

- Easiness for the replacement of PV modules
- Protection of electrical connections and cabling from direct sunlight and positioning in ducts and conduits in order to minimise the visual effect
- Usage of inox parts in all supporting structures

A short description of the 6 sites and the PV system arrangement is given in the following sections.

3.1 CRES-1: Main Entrance

Laminate PV modules are used in the CRES-1 system at the main entrance in Marathonos Avenue. The array consists of 12 modules of 115Wp each, giving a total of 1380Wp. A 1.2kW inverter is used for grid connection. The inverter is positioned in a small hut built next to the entrance. The CRES-1 system is shown in Fig. 2.

Fig. 2 CRES-1 PV system at the entrance

3.2 CRES-2: Old Parking Area

Framed modules are used in the CRES-2 system at the old parking area. The PV system consists of 90 modules of 115Wp each, grouped in 6 sub-arrays of 15 modules, electrically connected in series and giving a sub-system total of 1725Wp. The overall capacity of CRES-2 system is 10350Wp. The inverter used for grid connection is rated 2.5kW and each of the 3 inverters holds two PV strings. The inverters are positioned at the back side of the parking area and they are enclosed in a robust metal box for weather protection. A view of the PV array at the parking area is shown in Fig. 3.

Fig. 3 CRES-2 PV system at the parking place

3.3 CRES-3: Solar Pergola at Main Building

A "solar pergola" is the CRES-3 system at the balcony of the 1st floor of the main building. The innovations are,

- Better aesthetical appearance and PV integration due to low tilt angle of 20^0 of the modules
- Improved shadowing effect in the veranda and thermal comfort for the visitors in the summer due to larger module area utilised for creating shadow underneath

The main building of CRES and the PV array installed at the balcony of the 1st floor are depicted in Fig. 4.

Fig. 4 CRES-3 pergola PV system at the main building

3.4 CRES-4: Building II (PV Department), Roof-top

Framed modules are installed in the CRES-4 system on the roof top of Building II which belongs to the PV Department of CRES. The PV modules are integrated with a tilt angle of 30^0 and an offset angle of 22^0 towards south-west, which is the offset angle of the whole building. This azimuth angle is not expected to affect the performance of the system on an annual basis. The existing strips of windows which provide natural lighting in the laboratories below are not be affected by the installation either. The supporting metal structure of the PV arrays is mounted on the side walls alongside the building. The supporting PV module structure was extended to the east and the west part of the building in order to provide the basis for hanging shading elements for increasing the thermal behaviour of the offices, especially during the summer period.

The system consists of 90 modules of 115Wp each, grouped in 6 sub-arrays of 15 modules each, electrically connected in series and giving a sub-system total of 1725Wp. The overall capacity of CRES-4 system is 10350Wp. Grid connection is done via 3 inverters of 2.5kW each. Each inverter holds 2 PV strings and they are positioned on the roof top of Building II, enclosed in a robust metal box for weather protection. A general view of the roof top PV array of Building II is shown in Fig. 5.

Fig. 5 CRES-4 PV system at the roof top of Building II

3.5 CRES-5: Building II (PV), Existing Structure

Laminate PV modules are integrated on the existing metal structure in the front of Building II. In this way, the PV system has a multifunctional character in terms of electricity production and shading of the south part of the building. The array consists of 64 modules of 105Wp each, grouped in 4 sub-arrays of 16 modules each, electrically connected in series and giving a sub-system total of 1680Wp. The overall capacity of CRES-5 system is 6720Wp. Two inverters of 2.0kW each are used for grid connection. Each inverter holds two PV strings. The inverters are mounted on the inner side of the wall of the south-facing balcony of Building II.

3.6 CRES-6: Building II (PV), Parking Solar Curtain

The PV modules of the CRES-6, so-called "solar curtain" system, are integrated with a tilt angle of 90^0 and an offset angle of 22^0 towards south-west, which is actually the offset angle of the whole Building II. This system was installed for two reasons,

- Provides adequate shading to the car parking area
- Gives good basis for the operation of a façade PV system, which has a high scientific value and contributes to the R&D nature of the project

PV laminates are used in the CRES-6 system and array consists of 48 modules of 105Wp each, grouped in 2 sub-arrays of 30 and 18 PV modules respectively. The overall capacity of CRES-6 system is 5040Wp. Partial shading of the array may occur by the adjacent Building I in the months December and January due to the low elevation of the sun in the horizon. Two inverter types are used for grid connection. One is rated 2.5kW and holds two PV strings of 15 modules each, while a 2.0kW is used for the rest 18 modules. The inverters are mounted on the inner side of the wall of the south-facing balcony of Building II. The inverters used in this configuration are slightly undersized due to the vertical positioning of the array. This technique provides better system performance as the inverter operates closer to its nominal full load level where the highest efficiencies are obtained. Systems CRES-5 and CRES-6 are shown in Fig. 6 below.

Fig. 6 CRES-5 and CRES-6 PV systems at Building II

A summary of the systems installed at CRES with the main technical characteristics are shown in Table 1.

Table 1 Technical characteristics of the 6 PV systems installed at CRES

System ID and Site	PV capacity, [Wp]	Array Plane and Orientation	Module type	No of modules	DC/AC Power Conditioning
CRES-1 Main entrance	1380	inclination = 33° azimuth = 0° S	SF 115, laminate	12	1 × SP 1200 / 400 1 string / 12 PVs
CRES-2 Old Parking	10350	inclination = 28° azimuth = 0° S	SF 115 A, framed	90	3 × SP 2500 / 450 2 strings / 15 PVs each
CRES-3 PV Pergola	6210	inclination = 20° azimuth = 0° S	SF 115, laminate	54	3 × SP 2000 / 450 1 string / 18 PVs each
CRES-4 PV Building II, Rooftop	10350	inclination = 30° azimuth = 22° SW	SF 115 A, framed	90	3 × SP 2500 / 450 2 strings / 15 PVs each
CRES-5 PV Building II, Structure	6720	inclination = 45° azimuth = 0° S	Conergy 105L, laminate	64	2 × SP 2500 / 450 2 strings / 16 PVs each
CRES-6 PV Building II, Solar Curtain	5040	inclination = 90° azimuth = 22° SW	Conergy 105L, laminate	48	1 × SP 2500 / 450 2 strings / 15 PVs each, 1 × SP 2000 / 450 1 string / 18 PVs
Totals	**40050**			**358**	**14 inverters**

4 DATA ACQUISITION SYSTEM

A comparison of technologies, which is not limited to only one installation site, requires the application of a standardised data acquisition system. Monitoring requirements are classified into three categories, depending on the relevance of the individual PV sub-system for the PV system network. These are the classes A, B and C, corresponding to detailed monitoring on the system and sub-system level, monitoring on the sub-system level and analogue reading of energy fed into the grid, respectively. The CRES DAS comprises one PC based data logger, a pyranometer for global horizontal irradiance measurements, a calibrated reference PV module for plane of the PV array irradiance measurements, an ambient air temperature sensor, a sensor to measure the PV module temperature and sensors to measure the voltage, current, power and energy of the PV array on the DC and on the AC level, depending on the classification of the individual sub-system

A digital visual display will be positioned next to the CRES-3 solar pergola PV system, at the balcony of the 1st floor of the main building of CRES. The display would be serving as an information board of the operation of the PV system to the people participating in meetings in the conference room.

As soon as the DAS is fully integrated, the systems will be continuously monitored and the technical data gathered, such as kWh/kWp annual yield, PR per system type etc. will be published to the scientific community.

5 FIRST RESULTS

A number of students from elementary and high schools visit CRES on a regular basis and the new PV systems attract their interest. Soon, the installation of the DAS will give an opportunity for high quality measurements and CRES will be able to support a number of thesis and university level projects.

Another interesting issue refers to the CRES-1 system, at the entrance of CRES, which is just along the Marathonos Avenue, meaning that this PV array is highly visible by hundreds of people on a daily basis. As a matter of fact, the classical Marathon race which will take part next August during the 2004 Olympic Games runs just outside CRES premises and the CRES-1 system will be seen by all attendees during this important event.

Due to its research content of the project, an exemption from the procedure to obtain an energy production licence was approved by RAE (Regulatory Authority for Energy) in October 2003. The procedure to connect the PV arrays to the low-voltage grid of PPC is currently under way.

6 CONCLUSIONS

A total of 40kWp photovoltaic systems were installed at the premises of CRES at Pikermi, with emphasis put on integration excellence and minimum intervention on existing infrastructures. Six sites were selected for the installations and almost all integration techniques were applied, such as shedding of a car parking area, shedding of a large veranda with contribution to the thermal comfort of part of a building, improvement of building aesthetics using modern power supply systems, roof-top arrangement and façade integration. The systems serve the RTD, demonstration and educational purposes of CRES and will be also used as state-of-art integration techniques of PV technology from affiliated public and private bodies.