AN INTEGRATED PV SHADING DEVICE SYSTEM IN A UNIVERSITY BUILDING IN SESTO FIORENTINO, ITALY. A PV ENLARGEMENT PROJECT

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ABSTRACT: The PV Enlargement project, co-financed by the European Commission in the frame of the Fifth Framework Programme aims at demonstrating Europe's commitment for improved energy efficiency and cost-effectiveness of PV technology, by supporting the realisation of 29 innovative grid-connected PV systems with a total capacity of more than 1,2 MWp. The University of Florence is participating to PV Enlargement project and has recently realised a 20 kWp innovative shading PV plant on a very recent construction for the accommodation of students classrooms of the Faculties of Physics and Chemistry, in the new technological complex in Sesto Fiorentino (Florence, Italy); the realisation has been also supported by the Italian Ministry of Environment and the Tuscany Region, in the frame of the National Roof Top Programme.
The project is characterised by high architectonical integration using semi-transparent PV modules to shade the inner court space.

1 PHOTOVOLTAIC INTEGRATED PROJECT

The building is located in the new University Campus of Florence, in Sesto Fiorentino, entirely constituted of new buildings. The building has high energy consumptions and the photovoltaic system will then supply only a part of the total energy needs.

The installation should become an example for future installations of PV integrated systems. The 20 kW peak PV plant is integrated on the cover of the internal court of the classroom and library building at the "Polo Scientifico" in Sesto Fiorentino.
The PV installation is connected in parallel to the National grid and will partially cover the energy needs of the building.

The building is an isolated construction with a 4000 m^2 surface area, developed on two floors with a 560 m^2 internal garden court, generally used as an open space for students. A big library is located at the first floor. The court is centrally positioned and the PV system has been designed to create a shading effect on it.
The shading devices will be accessible for inspections thanks to the realisation of corridors trough the main and secondary structures.

1.1. Technological and scientific Innovation

The 20 kWp grid connected PV field has been realised using semi-transparent glass/tedlar PV modules. The central court of the building is rectangular (18 x 31 m), classrooms are located around the court. The shading devices realised with semitransparent PV modules, will improve the thermal performances of the building. During summer, shading element assure a good shadowing in the court, avoiding court overheating, at the first floor. At night, PV modules will shadow windows reducing temperature of the inner spaces (classrooms and library). During winter, the inner spaces will benefit from the heating produced by the solar cells, able to raise the temperature of almost 2 degrees.
The PV structure partially repairs from atmospheric agents. The distance between shading structures is about 1,80 m, calculated to avoid shadowing between modules.

View from the court

2. SYSTEM DESCRIPTION

The system is composed by 160 glass/transparent tedlar modules (PW1250), peak power 125 W, connected in series, forming 10 strings of 2 kWp; the strings are connected in parallel into five subsystem of 4 kWp each.
Every subsystem is connected to one inverter.
The photovoltaic system is composed by the following:

- **Principle structure** – 4 reticular beams of 22 m each positioned on the shortest side of the internal court cover.
- **Secondary structure** – 25 beams realised with 2 steel IPE supported by the principal beams
- **Modules structure** – modules are positioned for the longest side along beam direction, the photovoltaic modules, glass/transparent-tedlar are supported by an aluminium tripod. Modules are then sustained and screw down to the aluminium easels realised with three L steel profiles.
- **Footbridges** – to guarantee maintenance operations and security grill footbridges have been realised (made of Alugril or Orsogril) these are positioned behind the PV modules on the principal and secondary beams. The final design foresaw many handrails, but during a function check, during the realisation phase, it has been decided to keep the handrails off to improve photovoltaic efficiency in wintertime.

Photovoltaic modules are 35° tilted and south oriented. The electricity produced in DC current by PV modules is fed, after conversion into alternate 400 V and 50Hz, into the building grid connected to the Medium Voltage Distribution National Grid. The energy produced will be measured trough a dedicated meter, installed by the grid manager and accounted under the directive n° 224/00 by the National Energy Authority.

2.1. System characteristics

As anticipated, the system is composed by five subsystems for a total 20 kWp power installed.
Each string is realised by 16 modules.

Data of each subsystem:
-Nominal power 4000 Wp
-Open circuit tension Voc 516,8 V
-Short circuit current Isc 10 A
-Maximum power tension Vm 414,4 V
-Maximum power current Im 9,6 A

The choice to divide the system into subsystems with an inverter dedicated for each subsystem is intended to guarantee system functionality also in case of partial malfunctioning, maintaining most of the efficiency and functionality of the system.

2.2. System production

On the base of sun values on floor and on the modules plane tilted 35°, the expected productivity of the plant is around 32,000 kWh/year.

This value is referred to the energy produced by the photovoltaic generator, in reality the energy fed into the grid will be reduced for losses due to: dust on the PV modules, chemical erosion of the junctions and connections, losses due to diode cutting off, modules mismatching, inverter efficiency (generally 90%), eventual stops of the system. The value of these losses has been estimate around 25% of the energy produced, thus resulting in an estimated plant productivity of around 22,400 kWh/year.

The photovoltaic system

3. PHOTOVOLTAIC MODULES, STRINGS, GRID CONNECTION

3.1 Photovoltaic modules

The PW1250 - Photowatt module is a high efficiency module designed for large scale applications. It is made of 6 x 9 high efficiency (up to 15%) polycrystalline silicon solar cells.
The PW1250 is using a new reinforced transparent anodised aluminium frame, designed to meet Photowatt's High Quality Standards for corrosion resistance (lifetime tested 3 times longer than requested by CEI 61215) A UL version is available on request
- each module is protected by 3 bypass diodes (1 bypass diode per 18 cells)

Module weight : 12.5 kg

Module Size : 1237 x 822 x 38 mm.

Electrical ratings:
Typical power (W) 125
Operating voltage (V) 25,7
Current operating voltage (A) 4,8
Short circuit current (A) 5
Open circuit voltage (V) 32
Minimum power (W) 118,8
Temperature coefficients B = - 118 mV/°C
Power specifications at 1000W/m² : 25°C : AM 1,5
Maximum system voltage : 600V DC

3.2. String

Each string is composed of 16 modules connected in series with the following characteristics.

Number of PV modules	16
String power	2,000 W_p
Open circuit voltage	516,8 V
Short circuit current	5 A
Maximum system voltage	414,4 V
Maximum operating current	4,8 A

The interface section between the strings and each control panel is sectional on each polarity and provided by block diode, suitable for string nominal current. Over tension loader should has been installed at inverter entrance, between each polarity and earth.

3.3. String connection boards

5 string connection boards will be realised in order to parallel the strings in groups of 2.

Parallel Boards
Power 4,000 W_p
Open circuit voltage (V) 516,8 V
Short circuit current 9,6 A
Maximum system voltage 414,4 V
Maximum operating voltage 10 A

Every string connection box is characterised by:

a) The parallel of the 2 strings is realised by means of switches able to operate at full load
b) The output of the board is protected from over voltage by means of dischargers

The string connection board is subjected to the following regulations:

- Electric parts: CEI - IEC
- Structure: ASTM - D635

The parallel switch-boards are suitable for outdoor operation, waterproof and with a security protection IP65, realised with a resistant resin, having the following specifications:

–tested up to 5000 V voltage

– normal operation between -20 °C and 60 °C

Footbridges

3.4 Inverters

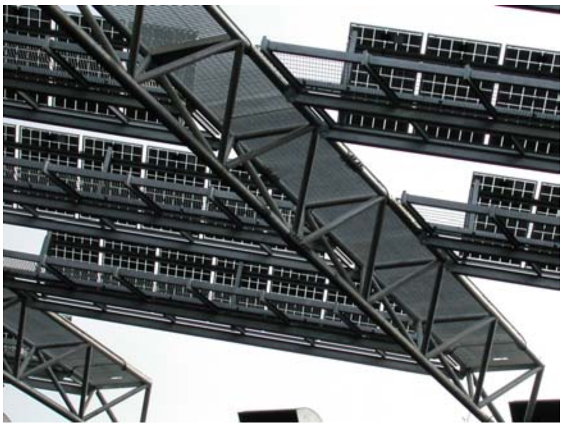
The inverter is MOSFET forced commutation type, and it uses electronic signals to operate protection devices and self diagnosis . Inverter are able to share data with a remote user.
Each inverter provides galvanic insulation between the PV field and the grid, 230 V AC, and it is protected against islanding. It is able to separate automatically from the grid and it is able to automatically recover normal parallel operation once normal grid parameters are restored.
The inverters are provided with an MPPT, Maximum Point Power Tracker to maximize system power output to present environmental conditions. Connection box is adapted for the string connection from one side and to the inverter connection to the other.
In the conbox are located 2 switches to break the DC circuit even during operation they allow to separate the inverter from the PV generator and from the grid 230 V AC; two varying impedances provide the protection against over-voltages.
The inverters have been placed in the technical room near the roof where the PV generator is installed.

3.5. Grid connection

The inverters are connected to the three phase building electric system. In particular, to minimise the imbalance of the 3 phases, the 5 inverters are connected as follow: two in parallel to phase 1, two to phase 2 and one on phase 3.

The single inverter connection are realised on the least loaded phase of the system; all negative polarities of the inverters are connected together to the neuter conductor.

	2 inverter parallel	**1 inverter**
String Number	4	2
Power	6,200 W AC	3,100 W AC



Details of the PV system

4. MONITORING SYSTEM

The high costs of energy production systems from renewable sources, put in strong prominence the demand to optimise system operation, systems output and reliability.

As results, is therefore essential to be able to analyse the data and information finalised to the elaboration of prudent and punctual energetic budgets. Today everything is possible for the use of integration with "intelligent" systems of supervision, with the Remote control that allows an easy man-machine essential interaction. The integration of new electronic technologies, (Internet Embedded, Internet Automation), M2M (Communication) represents today the ideal solution to satisfy in functional way monitoring need, containing the costs. Different systems are composed of apparatuses devoted to the management as well as to the acquisition, elaboration, transmission and visualisation of information of relative trial to the different states of operation.

For operation control of the Sesto Fiorentino PV plant and its diagnostic a monitoring system has been realised, able to be connected to a PC from which it will be possible to have indication of:

- operation of inverters with indication on possible system malfunction;
- Energy input and output indications: voltage, DC and alternate current provided
- historical file of the electric performances in the last months.

The software developed on purpose for these applications has an easy to understand graphic interface. The elaboration of the data of the historical file is realised with the development of graphs and charts, and it will allow to have a report every six months. Through the constant internet connection data will be visible to the PV Enlargement group of research.

The inverters are predisposed for the assemblage of the data acquisition system. The acquisition system essentially constituted of sensors and converters, and by a Data acquisition system.

Will be measured:

1) Radiance on the modules plan.
2) Global radiation
3) Photovoltaic module Temperature
4) String DC current
5) String DC tension
6) Ambient Temperature
7) String Power and energy
8) Inverter output power and energy
9) Global output Power and energy

The PV field is predisposed for the monitoring system lodging (probes Pt100 for the temperature and pyranometer for the measurement of the total and diffused radiation).

5 DIDACTIC ACTIVITY

During the work phases of the PV system, the strong educational character, is emerged with many visits for some bachelor and Master courses of the Technological Area.

The students have been given information on the photovoltaic technology and the technical characteristics of the photovoltaic system.

Other visits will be programmed in function of the system monitoring. A computer dedicated positioned near the system, in the technical room, is equipped with a new monitoring program purposely realized for the acquisition of the data.

Data are transmitted in internet, in a dedicated portal, with the aim to diffuse energy production of the system trough the partner of the European research and to the University students.

The elaboration of the data of the historical file is realised with the development of graphs and charts, and it will allow to have a report every six months.

The web site portal of the PV system is in Italian and in English and the address is:
http://web.taed.unifi.it/abitaweb/sesto/FVsesto_ingl.htm

6 CONCLUSIONS

The plant has maximum visibility either for the configuration of the building in which has been installed, either for the urban morphology of the context in which is inserted, it can be visible also from the nearby areas.

It is anticipated that the plant after a Workshop on the occasion of the initial inauguration will be object of driven visits by students and participants to specialisation courses, but it will also be subject for surveys, experimentation and studies to widen the relative cognitive baggage to the architectural integration of photovoltaic in the urban context.

Didactic visits for Master University courses

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