Villa Castelli

Operazione co-finanziata dall’Unione Europea, Fondo Europeo di Sviluppo Regionale, dallo Stato Italiano, dalla Confederazione elvetica e dai Cantoni nell’ambito del Programma di Cooperazione Interreg V-A Italia-Svizzera. (Codice progetto 603882)

Introduction

Built in the second half of the nineteenth century as a noble residence, Villa Castelli is a historical set in a landscape of extraordinary beauty on the east coast of Lake Como. Originally a noble residence, it has mostly served as a holiday home over the years. The current architectural form of the villa is the result of a series of expansion works and refurbishment projects. The latest energy refurbishment works, part of a conservative restoration project, involved the integration of photovoltaic modules into the villa roof.

Design approach

The conservative restoration project originated from the need to resolve problems related to the lakeside position of the property, which has caused structural subsidence and created widespread rising damp. The plan provided for the radical refurbishment of the envelope and systems, while conserving the prestigious architectural aspect of the building. The building is protected by articles 136 and 142 of the Urban Planning Code and by urban planning restrictions that require the maintenance of the valuable internal structure. The works were the result of collaboration within a multidisciplinary team led by the client, who set the project goals and also handled the technical aspects of the project.

The architectural project was handled by the architect Valentina Carì, who coordinated the team and dealt with the supervision of works, the aspects regarding the conservative restoration and interior design. The structural part was handled by the STI technical engineering firm, which dealt with the static consolidation of the existing structure. The energy project was handled by the Bolzano-based firm Solarrum, which dealt with the energy efficiency works for the envelope, systems planning and energy calculations. Through specific workshops, the Institute for Renewable Energy at the European Academy of Bolzano (EURAC) verified the executive details through three-dimensional thermo-hygrometric simulations and implemented a “post-operam” monitoring system to provide real-time monitoring of temperature, relative humidity, carbon dioxide concentration, surface temperature and level of illumination in the building. The company Solbian handled the planning and installation of the photovoltaic system integrated into the roof. Lastly, the villa served as a pilot building for the validation of calculations and certification procedures with the CasaClimaR© protocol. The project also won the 2016 CasaClima award.

Aesthetic integration

The integration of the photovoltaic modules into the roof was based on the following criteria; coplanarity, respecting of existing lines, module grouping, respecting of the shape and proportions of the pitched roof, attention to detail and colour selection. The modules are level with the roof and respect the symmetry of its lines. They were designed specially to respect the triangular or trapezoidal shape of the roof sections, seeking as much as possible to respect the perception of an even covering of the entire surface. Furthermore, all of the modules are oriented in the same way, in line with the orientation of the building, in order to minimise their visibility from the surrounding area. With regards to colour integration, a colour was chosen for the metal surface that references typical local materials, allowing for visual integration when viewed from the lake and the surrounding area.

Energy integration

The electricity produced almost entirely covers the energy requirements of the building, represented (i) by the energy consumption of a geothermal heat pump, which provides hot water for washing and heating together with an 8-kW heating stove, and (ii) a mechanical ventilation system complete with heat exchangers and comprising three units, one for each floor.

The BIPV system is connected to a system for the monitoring of electricity production and consumption, and a series of remote-controlled sockets that allow for the direct management of energy demands on the system. The monitoring system collects data on photovoltaic production and on emission of energy to and withdrawal of energy from the grid. Furthermore, through the weather data available, it forecasts production and on the basis of this, rationalises the automatic activation of controlled charging. This process optimises the use of the system, comparing production and consumption data and allowing, above all in the event of a surplus in energy production, to dynamically increase consumption of self-produced energy through the activation of controlled charging. The BIPV project, managed by Solbain, took into consideration the expected shade over the course of the day, and over the entire year, as well as an estimate of possible future energy requirements of the building.

Technology integration

Flexible modules have been integrated into the roof, glued directly onto the aluminium surface with the use of a structural double-sided adhesive tape that has a thermal expansion coefficient in line with that of the roofing material. This technology was created in collaboration with the National Research Council and is characterised by an innovative lamination process for the monocrystalline cells that uses special selected technopolymers for encapsulation.

Decision making

The goal of the client was to combine a conservative restoration with a significant improvement in energy performance, in order to render the entire building habitable while containing running costs. The productive close collaboration between the owners, experts and skilled labour involved formed the foundation for the decision-making processes.

Lessons learnt

The Superintendency responsible for the project assessed the following criteria as fundamental for integration; the aesthetic characteristics of the BIPV modules (colour and surface finish), their geometric positioning in relation to the shape of the roof sections and the orientation of the building (layout of the system, modularity), adherence to and coplanarity with the roof, non-reflective surfaces and visibility from the surrounding area, particularly from the road, the lake and the surrounding landscape.

The project for the roof is the result of close collaboration between the architect, the Superintendency and the company manufacturing the modules and the roof. The photovoltaic modules were already in production but had previously been used almost exclusively for sail boats and small constructions that require flexible systems.

Architectural integration took place through a long design process. Initially, the choice went to a type of module with coloured cells, in order to favour aesthetic integration with traditional local construction materials and the surrounding landscape. The roof had to be made of a material that also resolved the problems caused by the presence of a large Himalayan Cedar that loomed over the house and that, with

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the constantly falling needles, caused functional problems with the previous tiled roof. To this end, three prototypes were developed. Initially, a roof in Pietra Valmalenco, a material often used on historical buildings throughout the lake area, was chosen. The task was therefore to match the photovoltaic modules to this type of roof, for which two prototypes were made. The first required the creation of a transparent support, made by combining two sheets of glass sandwiching classic polycrystalline photovoltaic cells. Integration was based on the transparent nature of the support. The second prototype was based on chromatic matching. For this, a dedicated module was created with grey-green cells sourced from Germany, sized to adapt perfectly to the width of the Pietra Valmalenco tiles. A 1:1 scale prototype was created in collaboration with Brandoni, an Italian photovoltaic module manufacturer, in order to assess problems related to installation. The result was aesthetically pleasing, but not practical, as the modules could not be walked on and required complex maintenance. Then, a technical working group was set up involving Solbian and Prefa, to define a third prototype, which was then chosen as the definitive solution, with modules that could be walked on, were slim and efficient, and that blended in perfectly with the roof.

The design process demonstrated the importance of collaboration between technicians, artisans and manufacturers in the creation of a conservative restoration project. In designing the tailor-made photovoltaic modules, collaboration with the company supplying the roof was fundamental, as - together with the architect and the Superintendency - it was able to define a project that was integrated in terms of aesthetics, technology and energy.

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PROJECT DATA

Project type	renovation
Building use	residential
Heritage constraint	listed building
Building construction technique	pre-industrial
Building address	Bellano (LC), Italy

BIPV systems

BIPV SYSTEM DATA

Architectural system	Opaque roof
Integration year	2016
Active material	monocrystalline silicon
Module transparency	opaque
Module technology	flexible polymer layers, hidden PV, customized modules
System power [kWp]	10
System area [m²]	88.76
Modules orientation	several
Modules tilt [°]	27.5

BIPV SYSTEM COSTS

Total cost [€]	43500
€/m²	490
€/kWp	4103

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Stakeholders

Main building designer

Arch. Valentina Carì - Progetto Serr@

BIPV system designer

Solbian Energie Alternative srl

BIPV system installer

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Consultants

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Oscar Stuffer - Solarraum
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Works supervisor

Arch. Valentina Carì - Progetto Serr@

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The building before energy refurbishment © Arch. Valentina Carì

Alternative design for the roof proposed by the Superintendency © Arch. Valentina Carì

Alternative design for the roof proposed by the Superintendency © Arch. Valentina Carì

The building after energy refurbishment © Arch. Valentina Carì

A Solbian photovoltaic module integrated into the roof © Arch. Valentina Carì

Detail of a Solbian photovoltaic module © Myriam Perna, Arch. Valentina Carì

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