Integration of photovoltaic technology in cafeteria building, at Indian Institute of Technology, New Delhi

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Abstract

Integration of solar photovoltaics of 25 kWp capacity has been achieved in an existing building of the cafeteria on the campus of the Indian Institute of Technology, Delhi by creating a solar roof covering an area of about 250 m². The photovoltaic array is inclined at an angle of 15° from the horizontal and faces due south.

The architectural challenge of the project lies in achieving integration of the system with the existing habitat, to be aesthetically appealing, structurally sound and enclosing a space which is proposed for commercial usage and exhibition purposes.

The interior space of the solar photovoltaic roof has to be protected from the summer heat and for the same a composite system of natural and mechanised ventilation and cooling systems is proposed.

The design of the solar photovoltaic roof has been conceived, the architectural and interior designs finalised. A model has been prepared for a perspective view and clarity of form.

1. Introduction

The ‘keyword’ in the energy sector these days is ‘tomorrow’. What is going to
happen tomorrow? Is it going to be what we go to see in the movies of the future, or is it going to be the scientific vision of today, we do not know for sure.

However, we do know that the replacement of conventional sources of energy and fuels with the renewable sources of energy is not just essential but inevitable, in order to have sustainable levels of energy supply. Solar energy, rather, solar generated energy is a critical component of the renewable energy mix. Our interest, that is interest of the architects, really arises from the fact that “the building sector takes up about 25% of the electrical energy besides energy from several other sources”.

The International Energy Agency (IEA) has taken up a joint programme with the member countries for demonstrating the use of advancing solar building technologies with the objective of reducing or rather eliminating the use of purchased energy in the building sector.

Until now, the designers had several sustainable technologies at hand, ranging from:

- premium thermal insulation
- advanced heating, ventilation and air-conditioning (HVAC) systems and equipment
- passive solar design techniques
- active solar thermal technologies, to
- energy efficient lighting and devices.

These have reduced the building energy requirements considerably.

But now it seems possible to go beyond the basics of energy-conscious buildings, to produce high value energy from a building envelope, using it and sharing it, without creating air or noise pollution, and without being visually defacing.

It is true, from a more realistic point of view, that the PV systems today are still a potential technology in terms of matching the economics of grid power generation. Yet, with technological improvements and pronounced needs for sustainable energy systems, integrated PV systems in buildings could be the answer in the coming future.

The building can be a net electricity producer. However, this does limit one to a rather ‘technical’ visual aesthetic or an aesthetic generated by superimposition of technology on the architectural form. Our endeavour at IIT Delhi was to attempt a new aesthetic giving a new dimension to the axiom ‘form follows function’.

2. Building concept

The primary objective of the project is to design a live model that generates energy for use in the building, besides creating a public space for exhibits and conferences, using PVs as multi-functional elements—for shelter, for power, for
the skin of the building and as a generator of visual form/aesthetic in the process of design.

The challenge for the designers is how to bring about the fusion between technology and architecture. The photovoltaic (PV) modules can be multi-functional building elements, yet conceiving them as a part and parcel of the design process creates a new vocabulary by itself. Traditionally, the PV modules or PV arrays were mounted on dedicated structures, typically removed from the building itself. At present, we see the integration of PV systems with architectural design being attempted in forms such as direct mounting onto building structure, serving as a part of the skin of the building, helping to create a natural link on-site between the electrical supply and demand, as well as reducing the quantity of power required from the grid.

3. Integrated design approach and methodology

We already know that the PV systems originated from a discovery that two metal plates dipped in dilute acid generated electricity when exposed to sunlight. The technological advancements on the same concept have made possible the integration of PV systems with built forms.

Firstly, the PV systems were studied from three perspectives

- architectural
- technical
- environmental

The architectural studies brought forth the following observations:

- provide dual/multiple use of material (generating electricity and acting as building envelope/skyline)
- enhance pay-back considerations wherein the building is used as a support or mounting structure, eliminating the need for land, and thereby permitting PV systems high density areas
- are available in a variety of colours and styles, with potential for architectural composition in the integrated forms
- are flexible, giving the designers a flexible medium that can be a potent tool for moulding the creativity and visualisation of the architect into reality.

From the technical study, carried out by the Centre for Energy Studies, Indian Institute of Technology, New Delhi, it was observed that PV systems in buildings:

- provide an appropriate match between electricity production and the building’s electrical requirements, especially in commercial applications
- result in reduced utility peak delivery requirements
• eliminate transmission and distribution systems required in case of grid power supply
• do not require additional infrastructure installations
• save resource and energy consumption in connections, bill payments, transmission, etc.

The photovoltaics and architecture are a challenge for the new generation of buildings. PV systems will be integrated into designs of roofs and facades. The architects and engineers will need to integrate the PV systems over four levels during the conceptualisation, designing and construction of the buildings:

• design of building (shape, size, orientation, colour)
• mechanical integration (multi-functionality of PV modules)
• electrical integration (grid connection and/or direct use of power)
• maintenance and operation control of PV systems integrated with the typical building maintenance and control.

The environmental aspect seems equally exciting with the promise of no air pollution, no noise pollution, no need for more developed land and the use of a renewable source of energy. It seems too good to be true. Also, the requirement of no extra land, means infrastructure costs are optimised and construction energy is minimised (especially if conceived with the buildings from day one).

Secondly, it was found that the PV systems could be integrated into existing and new buildings, into roofs, into facades, skylines and different building components. This made sense because solar radiation is distributed energy source and so is energy demand. In addition, the building envelope provides sufficient area for PV arrays and additional land-use plus costs could be minimised. These also formed the main criteria for selection of the cafeteria building at IIT Delhi.

Next, case studies were made of existing systems at

• HEW, Hamburg, Germany for a facade integrated PV system
• Library in Mataro, Spain, for a facade integrated PV system, and
• Rikers Island PV roofing, New York, USA, for a roof integrated PV system.

4. Methodology

Consequently, the following set of activities were and are being taken up:

• Study of existing cafeteria building—its floor plans, internal movements, services, surroundings and urbanscape, facade and structural system
• Architectural conceptualisation and development to meet the functional, structural and technical requirements such as roof plane angle, direction of angle with relation to efficiency and orientation, natural lighting and ventilation requirements
• Architectural detailing to appropriately match and complement the existing structure
• Sizing and selection of solar PV modules for the system as a whole
• Interior designing of space
• Selection of various components
• Procurement and construction is presently going on
• Installation
• Evaluation and analysis of the generated system.

In the meantime, experiments are being made at IIT Delhi and a smaller sized model using actual panels is under preparation. Architectural innovations are being attempted through detailing and design evolution, and refinement.

5. Design parameters

<table>
<thead>
<tr>
<th>System name</th>
<th>Photovoltaic roofing system, Indian Institute of Technology, New Delhi.</th>
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<tbody>
<tr>
<td>Type</td>
<td>PV panels/shingles/crystalline</td>
</tr>
<tr>
<td>Location</td>
<td>Cafeteria Building, Indian Institute of Technology, New Delhi, India. (15 kms from Indira Gandhi International Airport, New Delhi)</td>
</tr>
<tr>
<td>Size</td>
<td>25 kW Power; 8 kW of electricity load for 10 h a day</td>
</tr>
<tr>
<td>Area</td>
<td>250.00 m² (2,900 ft²)</td>
</tr>
<tr>
<td>Standalone</td>
<td>Battery storage system, tied to an outside DG set for grid quality power</td>
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<tr>
<td>Commissioning</td>
<td>1998 (last quarter)</td>
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<tr>
<td>Principal architects</td>
<td>Suresh Goel and Associates, New Delhi, India</td>
</tr>
<tr>
<td>Associate designers</td>
<td>Srijan I &amp; P Pvt. Ltd., New Delhi, India</td>
</tr>
<tr>
<td>Project conceived by</td>
<td>Prof. N.K. Bansal, Head of Centre for Energy Studies, IIT New Delhi, India</td>
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<tr>
<td>Guided by</td>
<td>Prof. V.S. Raju, Director, IIT, New Delhi, India</td>
</tr>
<tr>
<td>Owner</td>
<td>Indian Institute of Technology, New Delhi.</td>
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A ‘form with function’ approach has been the basic and simple design concept. The parallel process has led to several adjustments, refinements and in several instances, toning down of the architectural expression. The system was found to be optimum if integrated with an angle of 15° tilt with relation to north–south axis, in Delhi’s climatic conditions, therefore giving it higher efficiency.

The compactness of the system, the height and the scale were experimented with so that the integration was within the larger panorama of the IIT campus, comprised of buildings constructed since the 1960s.
6. Our experiences

For all of us at the design office, at the Centre and for me personally, it has been an experience of learning and innovating—from the uniqueness of the project, from the technical knowledge bank of Prof. N.K. Bansal, from my father's wide experience in the architectural field and in terms of inadvertently creating a possible vocabulary of 'function (energy source), form, function (building envelope/skyline)'. This we believe is the first project of its kind in India (and possibly the first architectural attempt of such lines in the world). However, Prof. N.K. Bansal and the design team at SGA, Delhi believe it is only the beginning.

Acknowledgements

I would like to thank Mrs N. Rishbud, Prof. S. Saha, my father Architect Mr Suresh Goel and my mother Dr Malti Goel for their support.