CASE STUDIES FOR BUILDING INTEGRATED PHOTOVOLTAIC (BIPV) FACADES IN THE UNITED STATES

Anthony O. Pereira

altPOWER Inc., 160 5th Avenue, Suite 807, New York, 10100-7028, USA
Ph +1 (212) 206-0547, Fx +1 (212) 206-0893, e-mail anthony@altpower.com

Jörn Jürgens

AstroPower Inc., Berger Str. 338, 60385 Frankfurt a.M., GERMANY
Ph + 1 (49) 69 94 59 7116, Fx +1 (49) 69 94 59 7118, e-mail jjurgens@astropower.com

Abstract – The US-American photovoltaic market has been increasingly shifted from stand-alone applications towards grid-tied photovoltaic (PV) systems through the past decade. Regional incentive grants are encouraging more and more homeowners to install solar modules onto their roofs in order to supplement their energy needs. However, applications for photovoltaic systems, which are aesthetically integrated into the building envelope, have been rarely shown compared to the European PV market [1].

During the past year, we have been increasingly active in designing building integrated photovoltaic (BIPV) facades into American commercial and high-rise structures. State of the art techniques for BIPV have been adapted to fulfill the requirements of American building standards. This paper presents two case studies of BIPV facades, which have been built along the East Coast within 2002.

1. INTRODUCTION

Throughout the United States there are various subsidies and incentive grants available for installing a photovoltaic power system. These financial supports not only vary from state to state, they also distinguish between different kinds of PV applications.

Along with being one of the sunniest states, California is featuring the highest utility rates for power, which brings the break even cost for turnkey PV systems into a very attractive dimension [2]. Additionally, California is offering very attractive incentives for solar companies and customers. There is buy-down money offered for modules, manufactured in California. Especially local municipal utilities are very active in supporting solar efforts.

In San Francisco, the 'Solar Bond Act' was approved allowing for the financing of PV systems on government buildings and encouraging BIPV applications.

SMUD or the Sacramento Municipal Utility District, is not only offering buy-down money for photovoltaic applications. They also strongly support BIPV efforts, where photovoltaic power plants are nicely integrated into building envelopes.

In Los Angeles, LADWP (Los Angeles Department of Water and Power) is offering very attractive support for BIPV approaches on buildings in the city. Starting at an early stage, architects are motivated to integrate PV plants into their projects.

Although not as sunny as LA, there are a good number of initiatives supporting photovoltaic applications in New York which make it the highest ranking state in a recent survey of feasibility for PV installations [3]. Funding opportunities through the New York State Energy Research and Development Authority (NYSERDA) and various laws that encourage the use of PV systems, including a net-metering law and a green building tax credit are just some of the incentives available. In particular the Battery Park City Authority (BPCA) has developed strict green building guidelines for new construction projects within their jurisdiction and developers and architects are encouraged to include BIPV systems in their designs. The BPCA administers reclaimed a portion of land in lower Manhattan along the Hudson River. Finally high energy prices help make the economic model more attractive as well.

Fig. 1: Solair – Solaire, New York BIPV façade

Not only are environmental motivations are convincing American cities to promote photovoltaics. Today cities like New York City represent a 'load pocket' a term used to identify areas where far more peak power is demanded than can be generated locally and delivery of power to the region is limited New York City in particular faces the threat of rolling blackouts each hot sunny summer afternoon, when air conditioning units dominate the power consumption [4]. A recent study by the State University of New York at Albany has shown that distributed PV systems can help shave peak demand since there is a direct correlation between hot weather, air conditioner use and solar irradiance levels. Basically the hottest periods of each day are generally sunny when PV is most efficient and it is at these times that peak demand is highest. Cities can achieve peak shaving by distributing solar power onto their building envelopes.

2. SOLAIRE – 20 RIVER TERRACE, NEW YORK

New York City has seen a considerable amount of new construction in the last 5 to 7 years and as the City continues to grow and reinvent itself, a strong interest in green constructions methods and products has arisen. Spurred by state incentives and strong legislation as well as outright mandates to encourage the use of PV systems in buildings, building integration of PV systems has been a natural progression.

2.1 Green Building Design

The newly built residential building at 20 River Terrace in Battery Park City, New York, has been developed by the Albanese Development Corporation and designed by Cesar Pelli & Ass. to be the 'Nations First Green Residential High-Rise Building' (Fig. 1). All elements of the building were equipped using the latest environmental friendly technologies. Besides clean air and a waste water treatment system, the designers of the building have used advanced insulating technologies, passive solar heating, landscaped flat roof, and of course a building integrated photovoltaic façade, which is supplying 5% of the buildings base electricity consumption.

Fig 2: Solair – BIPV façade during construction

2.2 BIPV facade

Facing the Hudson River, the front façade of the building is equipped with a 11 kW_p BIPV solar system (Fig. 2). All PV-laminates were custom shaped to adapt the building dimensions in standard glass/TEDLAR encapsulation technology. Afterwards they were integrated into a cassette façade system, which allowed an easy and fast construction of the building. The modules were wired inside the building, using flexible metal conduit and UL listed combiner boxes. A composite trade crew of union ironworkers and electricians installed the façade PV system.

2.3 Bulkhead PV installation

As a crown of the building, 11 rows of standard solar modules are horizontally mounted in front of the brick façade building a weather screen. Tilted towards the sun, these 20 kW_p of solar modules comprise the largest part of the green power supply for the building. The specially designed mounting system was fabricated by UniRac Inc., using ornamental sheet metal material.

2.4 BIPV canopy

A beautiful semitransparent canopy is covering the entrance of the building to welcome all visitors. The canopy PV modules were produced in glass/glass technology to ensure the long term stability of the weather exposed modules.

3. ASTROPOWER HEADQUARTER BIPV FAÇADE AND ROOFTOP SYSTEM

When building a new headquarters in Newark, Delaware, solar cell manufacturer AstroPower decided to implement as much solar power as possible into the building design. A 30 kW_p integrate BIPV façade is covering the front face of the building and another 310 kW_p PowerGuard system is covering the roof of the manufacturing area of the building. Altogether, the large PV installation is designed to cover the total electricity consumption of the entire administrative offices of the AstroPower headquarters.

3.1 AstroPower BIPV facade

When initially creating the concept of the building, AstroPower asked the architect to design a south oriented BIPV façade that covers the front of the office complex. The façade was constructed using a standard YKK aluminium façade system where custom sized glass/TEDLAR PV laminates were mounted into the supporting structure in lieu of traditional façade material. Newly designed 8-inch multi-crystalline APx solar cells are integrated into these modules to create a uniform blue appearance of the building (Fig. 3).

Fig. 3: AstroPower, Inc. headquarters BIPV façade in Newark, Delaware, USA

On two levels, blue tinted insulation glass windows ensure plenty of daylight for a healthy working climate of the employees. In the upper part of each window, a row of semitransparent PV modules was integrated for additional sun protection. These modules were manufactured using glass/glass technology in combination with low-E and insulated glass. It is the first time in the US, that this kind of very advanced glazing technology was used in such an application.

3.2 BIPV skylight above entrance lobby

The same insulated glass PV technology, that has been uses as sunshades in the façade, was integrated into a large skylight above the entrance lobby (Pic 4). This type of skylight application allows light to penetrate deep within the building while diffusing the light with the appropriate amount of shading to resist overheating the space below and protecting surfaces from harsh UV radiation. This slightly tilted skylight is the best-oriented part of the total BIPV installation and produces a significant percentage of power per square meter compared to the other BIPV systems.

Fig. 4: BIPV skylight above entrance lobby

3.3 PowerGuard rooftop system

In addition to the BIPV façade installation, AstroPower installed a 310 kW_p PowerGuard^{TM} system on the flat roof that covers the manufacturing area. The PowerGuard system is a patented product from the PowerLight Corp and can be used in new construction or for retrofits. The innovative design allows for a less labor-intensive installation without roof penetrations. The system also has thermal insulating properties allowing for a high insulating value of R-10 and greater. The system lies flat on a non-sloped roof and helps protect the roofing membrane from harsh UV radiation thus actually protecting the roof. Since the system is ballasted, it does not require penetrations for mechanical attachment to the structure therefore allowing for roof warranties to remain valid.

4. CERTIFICATION OF BIPV MODULES

To realize both BIPV façade projects, it has been the biggest challenge was to ensure that all elements of the PV system fulfil American standards set by the NEC (National Electric Code) and UL (Underwriters Laboratories). As BIPV technologies are fairly new in the United

States and inspectors are not familiar with these types of non-standardised applications, one must work closely with national and local authorities to get approval for the installation.

In Europe, BIPV applications are fairly common and many PV companies are offering a variety of technologies in manufacturing custom designed PV modules. It is possible to get the entire module manufacturing process certified according to IEC61215 (International Electrotechnical Commission) which enables BIPV companies to manufacture modules in multiple sizes and still maintain the appropriate certification.

In the United States, UL standards do not allow certification of complete manufacturing processes. Only standard modules, which are manufactured always in the same way, with the same materials and of the same size, can be certified according to UL standards. UL listings for BIPV modules can be attained, however only on a one time/one run basis; this is an expensive and time consuming process hardly worth the investment since these unique module designs are currently not interchangeable with other building applications.

Fig. 6: 310kW$_p$ BIPV façade and rooftop system

5. LESSONS LEARNED ON BIPV FACADES IN THE UNITED STATES

Although photovoltaic power systems have been installed all over the world, this technology still is something new for many local electrical authorities and inspectors. Especially when it comes to custom designed electrical installations that are producing high currents and voltages that back-feed energy into the public utility grid. To ensure a smooth acceptance of the power system it is therefor advisable to use as many UL approved components as possible. However this is not currently possible for the custom fabricated PV modules.

5.1 Electrical approval for BIPV installations

Since both projects used custom designed photovoltaic modules and laminates that were not UL listed, it has been necessary to obtain the approval from the local authorities. In New York City, we filed an application for a special variance with the Bureau of Electrical Control's (BEC) Advisory Board. The BEC Advisory Board's approval is trend- setting and the experience has allowed them to become more familiar with PV technologies. These kinds of path-breaking decisions by local authorities will hopefully help others to realise BIPV power plants are safe and reliable.

For the Delaware project we assigned an independent testing laboratory to do a field inspection on the BIPV façade. Thorough tests were performed on site before the installation was approved for operation. These types of field inspections are probably the most effective way to receive approvals for BIPV installations.

5.2 Junction boxes in BIPV facades

For custom designed modules, mounted into façade constructions, the junction boxes do have to be accessible according to the NEC. This is a challenge when designing the interior of a building. For the Delaware façade we solved the problem with additional small access hatches in the wall that cover the particular spot behind each module where the junction boxes were located. For the New York façade, it was decided to bypass the problem by using potted junction boxes.

Additionally, all wire runs have to be installed in conduit inside buildings in the United States. This makes it difficult to use standardised and UL approved junction boxes like the Multi-Contact box. Special solutions were developed in order to ensure that the installations conformed to the national and local electrical code.

6. CONCLUSIONS

With many states having plenty of sunlight and local utilities offering very attractive incentives, the United States is experiencing growth in the grid connected PV market. An increasing portion of the growth in the grid-tied PV systems market belongs to BIPV installations. Local utilities and governments are encouraging builders to utilize these custom designed and integrated systems.

In contrast to regulations in Europe, it is more difficult to implement BIPV technologies into American buildings while meeting all the standards and building codes. Much creativity and educational work is required to get approval for BIPV installations. There is much work to do before building integrated photovoltaic applications become a common part of each and every building.

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