PROJECT INFORMATION

DOE Award Number: DE-FG36-08GO88003

Name of Recipient: San Francisco Public Utilities Commission

Project Title: MUNI Ways and Structures Building Integrated Solar Membrane Project

Name of Project: SF MUNI

Director/Principal Investigator: Lori Mitchell

Project Team:

- San Francisco Public Utilities Commission
- AEPC Group
- San Francisco Department of Public Works

EXECUTIVE SUMMARY

The initial goal of the MUNI Ways and Structures Building Integrated Solar Membrane Installation Project was for the City and County of San Francisco (CCSF) to gain experience using the integrated higher efficiency solar photovoltaic (PV) single-ply membrane product, as it differs from the conventional, low efficiency, thin-film PV products, to determine the feasibility of success of larger deployment.

As several of CCSF's municipal rooftops are constrained with respect to weight restrictions, staff of the Energy Generation Group of the San Francisco Public Utilities Commission (SFPUC) proposed to install a solar PV system using single-ply membrane

The installation of the 100 kW (DC-STC) lightweight photo voltaic (PV) system at the MUNI Ways and Structures Center (700 Pennsylvania Ave., San Francisco) is a continuation of the commitment of the City and County of San Francisco (CCSF) to increase the pace of municipal solar development, and serve its municipal facilities with clean renewable energy. The fourteen (14) solar photovoltaic systems that have already been installed at CCSF municipal facilities are assisting in the reduction of fossil-fuel use, and reduction of greenhouse gases from fossil combustion.

The MUNI Ways & Structures Center roof has a relatively low weight-bearing capacity (3.25 pounds per square foot) and use of traditional crystalline panels was therefore rejected. Consequently it was decided to use the best available highest efficiency Building-Integrated PV (BIPV) technology, with consideration for reliability and experience of the manufacturer which can meet the low weight-bearing capacity criteria. The original goal of the project was to provide an opportunity to monitor the results of

the BIPV technology and compare these results to other City and County of San Francisco installed PV systems.

The MUNI Ways and Structures Center was acquired from the Cookson Doors Company, which had run the Center for many decades. The building was renovated in 1998, but the existing roof had not been designed to carry a large load. Due to this fact, a complete roofing and structural analysis had to be performed to match the available roof loading to the existing and/or new solar PV technology, and BIPV was considered an excellent solution for this structure with the roof weight limitations. The solar BIPV system on the large roof area was estimated to provide about 25% of the total facility load with an average of 52,560 kWh per month.

In order to accomplish the goals of the project, the following steps were performed:

1. SFPUC and consultants evaluated the structural capability of the facility roof, with recommendations for improvements necessary to accommodate the solar PV system and determine the suitable size of the system in kilowatts. The electrical room and switchgear were evaluated for any improvements necessary and to identify any constraints that might impede the installation of necessary inverters, transformers or meters.

2. Development of a design-build Request for Proposal (RFP) to identify the specifications for the solar PV system, and to include SFPUC technical specifications, equipment warranties and performance warranties. Due to potential labor issues in the local solar industry, SFPUC adjusted the terms of the RFP to more clearly define scope of work between electricians, roofers and laborers.

3. Design phase of project included electrical design drawings, calculations and other construction documents to support three submittals: 50% (preliminary design), 90% (detailed design) and 100% (Department of Building Inspection permit approved).

4. Installation of solar photovoltaic panels, completion of conduit and wiring work, connection of inverters, isolation switches, meters and Data Acquisition System by Contractor (Department of Public Works).

5. Commissioning of system, including all necessary tests to make the PV system fully functional and operational at its rated capacity of 100 kW (DC-STC).

Following completion of these steps, the solar PV system was installed and fully integrated by late October 2013. The interconnection with PG&E utility grid was completed and the system began generating power on November 21, 2013. The projected annual energy generation for the system is estimated at 127,120 kWh/year.

Project Outcomes

As noted in the DOE project objectives and scope for the Muni Ways and Structures Building Integrated Solar Membrane Project, SFPUC/CCSF intended to gain experience using an integrated, high-efficiency building-integrated PV product. Unfortunately, the initially chosen membrane PV product, Open Energy, went out of business. An alternate replacement option considered was Unisolar, an amorphous PV membrane product. However, Unisolar was no longer a viable option as the company went into bankruptcy not long after Open Energy.

Subsequently, SFPUC/CCSF identified a new product option, which was considered to have the best potential to meet the project goals: a light-weight crystalline PV system from SOLON, called SOLquick. The system integrates crystalline PV with a frame constructed with Fibrex material. This system has a very low profile, has a unitary design that distributes load across the roof membrane to reduce point loads to a bare minimum – the entire system weighs just 2.7 lbs/sf, which is lower than the 4 to 4.5 lbs/sf for typical PV system assemblies. The product is about 10 watts/sf., and with its 10 degree tilt design, yields an optimized energy output while minimizing shading, and maximizing the use of roof space.

The SOLquick frame is made using Fibrex, a composite material developed by Anderson Corporation, and has been in outdoor use since 1993. This material comprised of reclaimed wood and a thermoplastic polymer is non-conductive and has good resistance to heat and moisture. The non-conductive aspect of the framing eliminates the need for electrical grounding of the racking, typically required for racking made of metal. Additionally, the aerodynamic design of the system reduces wind loading as well as point and edge loading, thereby allowing the use of less penetrations (or ballast), a key objective for SFPUC/CCSF installations.

The product is modular – it is delivered as a pre-assembled laminate and rack, and allows for quick field assembly. The product also works with various membrane options while maintaining the underlying roof membrane warranties. It also offers installation flexibility, with use of ballast and/or penetrations.

Based upon the above noted product features, SFPUC/CCSF requested and received DOE approval of the SOLON SOLquick PV system as a viable alternate for the Muni project. The SFPUC believed that this product closely matches the original project intent for a building-integrated PV system with higher PV efficiency. The above-outlined product features have the potential to allow a broader use of this system on various City buildings and SFPUC in-city water reservoirs to help SFPUC/CCSF meet its aggressive renewable energy deployment objectives.

PROJECT ACTIVITIES

Project Development

SFPUC and its' consultants (AEPC) evaluated the structural capability of the roof. The existing roof at the time was a granulated surfaced modified bitumen sheet roof that required recovering. The photovoltaic panels would then be installed over the warranted roof recover system. Weight of the PV system membrane and support equipment was required to be less than or equal to 3.25 pounds per square foot as specified in the Roof Structural Assessment Report for the site. It was determined that improvements, i.e. re-roofing, would be necessary to accommodate the solar PV system.

During the Project Development period, there were a number of delays to the project moving forward to the design and construction phases. As the initially chosen membrane PV product, Open Energy, had gone out of business, the SFPUC investigated other options for reliable building-integrated and/or light-weight PV to meet the roof restrictions, but found only a few alternatives.

There were also on-going labor disagreements in San Francisco over 2011-12 regarding the installation of solar PV systems at City facilities, which delayed other municipal solar projects, including the MUNI project. The issue involved jurisdictional disputes between electricians, roofers, and laborers over which tasks each could perform on a solar project. Ultimately, the SFPUC successfully worked with the San Francisco Department of Public Works (which had recently been installing solar PV systems on local public schools) to install the solar PV system at the MUNI facility. This allowed the use of skilled City workers who had solar installation experience and eliminated the need for the additional time required to re-issue a new RFP.

A brief summary of the activities during this period:

- RFQ was issued on December 30, 2008
- Selected eight well-qualified firms to receive RFP
- Revised RFP Contract Documents to conform to new City Requirements
- Simplified RFP & Contract Documents in order to attract additional bidders
- 1-year extension of Award granted on March 30, 2010
- Conducted survey and performed analysis of proposal responses/results
- Consulted with DOE regarding proposal acceptance
- 12-month time extension granted by DOE
- SFPUC requested prevailing wage determination from CA State Division of Labor Statistics and Research to settle division of labor disputes among solar installers.
- California Division of Labor Statistics and Research declines to issue definitive prevailing wage determinations. SFPUC adjusts the terms of the RFP to more clearly define scope of work between electricians, roofers, and laborers.

- SFPUC modifies scope of work order (for MUNI as well as other CCSF solar projects) to differentiate tasks between various labor groups, i.e. electricians, roofers and laborers.
- SFPUC pursues the PV project using essentially a Design-Build approach to develop the design, but actually have the work performed using "In-house/City resources (Department of Public Works personnel), combined with the use of City purchasing contracts to secure the major project materials and components.
- SFPUC finalized the choice of Solquick (by Solon) as the best available light-weight integrated-PV technology for planned installation at the project site.
- Project construction schedule finalized.

Roof Repair (*Costs covered by SFPUC, no DOE funds used*)

Prior to installation of the solar PV system, the facility roof was repaired and recovered to maximize the roof warranty duration concurrent with the PV system installation. This work included a PVC roof covering system installed over existing insulated modified bitumen roof, replacement of metal copings, replacement of "wet" insulation, installation of protection layers below solar PV modules, and installation of membrane flashings after initial placement of rooftop solar PV modules.

Construction Phase

The following steps were performed to accomplish construction goals:

- Advertised for bids to supply solar PV modules; reviewed bids and awarded contract.
- Solar PV modules/racking system and system components purchased.
- Repair/recover facility roof in preparation for installation of solar PV system (this work was paid for solely by City of SF funds).
- 6-month extension (to December 31, 2013) granted by DOE.
- Construction phase begins Summer 2013.
- Solar PV system installed on MUNI facility roof; completed in October 2013.

Construction activities began with delivery of the Solon solar PV modules, inverters, wiring, conduits and other materials to the MUNI facilitiy. The materials were lifted to the facility roof via crane. Electrical room was cleared and prepared for the inverter pad.

Solon PV modules shipped as pre-assembled laminate and rack units, no tools or assembly required due to quick-click U-bolt interconnects. Once the system components/materials were in place, DPW crews began the layout of the solar modules and racking system. Stanchions were used to anchor the racking to the roof to meet wind and seismic requirements, and to be compliant with the new 20-year roof warranty.

DPW electricians placed conduit and wire for the solar PV system to the new PV inverter, an Advanced Energy AE100TX model (100 kW, 480v), and tied the system into the main electrical switchboard for the MUNI facility.

Solon SOLquick PV system installed at MUNI Ways & Structures facility, San Francisco

The Solon SOLquick system features included:

- 2.7 psf load, the main feature which made installation of solar PV on the limited weight roof possible;
- Wind uplift resistance of 90 miles per hour, minimizing ballast and roof penetration;
- Minimal point and edge loading, which distributes weight more evenly;
- Panel inclination of 10 degrees, which optimizes energy output.

Solon PV modules and the AE inverter were required to have Underwriter's Lab (U/L) certification and California Energy Commission (CEC) approval. The PV system has a 10 year service, repair, maintenance and replacement warranty.

The 60 HZ, 3-phase AC output voltage and configuration at the output of the System's isolation transformer was designed to be compatible with the voltage at the site's main electrical panel where the AC tie-in was made (277/480 volt 3-phase).

An Elster A3R meter was installed to measure the power and energy output for the inverter generated by the Solar PV System. The meter has a 128k Main board and 1MB extended memory.

A DAS monitoring system was installed which utilizes a datalogger that records, at a minimum, cumulative AC Energy (kWh) and AC Power (kW) generated by the Solar PV System, and Ambient Temperature (deg C), Solar Irradiance (W/sq. meter), typical PV panel temperature (deg C), and Wind Speed (m/s) and Direction as collected by the solar monitoring station. This allows the SFPUC to view current and historical data over the Internet in 5-minute intervals.

ACTUAL ACCOMPLISHMENTS VS. GOALS

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PRODUCTS DEVELOPED AND TECHNOLOGY TRANSFER ACTIVITIES

None.