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Photovoltaics in Roofing

As a result of the desire to achieve energy self-sufficiency with “clean energy”, solar energy production has increased an average of more than 20 percent each year since 2002, making it the world’s fastest-growing energy technology. Government subsidies and the possibility of selling excess production back to the power grid have led to building owners either installing their own power systems, or leasing their roofs to companies marketing and operating solar-electric photovoltaic (PV) systems. Low slope roofs, which represent a significant portion of the urban footprint, are often viewed as an ideal platform for solar installations. Usually free of obstructions, with good exposure to the sun, roof-top solar installations represent an efficient use of space. However, many factors must be considered before deciding whether a roof is a suitable candidate. If not carefully planned, not only can the hoped for return on investment in solar quickly evaporate, it can result instead in significant financial loss, and jeopardize the performance of the roof on which it was installed.

There are two common types of PV systems designed for roof top installations: rigid rack-mounted arrays and integrated PV systems adhered directly to the roof surfaces. This bulletin discusses the rack-mounted systems as current technology and climatic conditions has limited the use of the adhered systems in Canada.

How it works

Photovoltaic power is derived from cells that contain a solar photovoltaic material that converts solar radiation into direct current (DC) electricity. Solar cells use sunlight to produce DC electricity, which can be used to power equipment or be stored in a battery to provide power when the PV’s are not generating electricity. By using an inverter to convert the direct current (DC) to Alternating Current (AC), these systems may be used for grid-connected power generation. This allows the building owner to generate and use solar power during the day and deliver excess power directly to the utility grid. Although PV works best when there is direct sunlight, some PV technologies generate power whenever any light is available to the panel.

Mounting Techniques

There are three basic ways by which rack-mounted solar panels can be secured to the roof. The first relies on penetrations and connections to structural framing. This method allows for reduced dead loads to the structure and the ability for the designer to specify live loads. It provides the greatest number of options for the tilt of the array resulting in the greatest energy yield. This method also assures a level platform for the solar panels. The second method relies on ballasting to secure the panels. The weights of the array, racking system and additional ballast material are used to prevent wind uplift and dislocation from other loads. The advantage of this method is that fewer roof penetrations have to be made watertight. The disadvantages include an increased dead load; the tilt of the arrays may be limited depending on wind uplift loads and it may be difficult to obtain a flat platform for the arrays depending on the roof’s drainage patterns. The third option is a hybrid, which consists of a limited number of connections through the roof to the structural framing combined with ballasting material. Where this method is used, the general rule of thumb is that the fewer the number of connections, the more ballast required and vice-versa.

Risks and Hazards

FM Global has identified several important risk factors in the evaluation of roof top solar installations. These include:

- combustibility,
- wind uplift and securement,
- roof loading,
- drainage, and
- natural hazards resistance.

Combustibility

All PV cells should be tested and listed by a recognized testing laboratory. Their fire resistance should be at least as robust as the roof they are being mounted upon to comply with most building and fire codes. The most widely recognized standard for PV panels is UL 1703, Standard for Flat-Plate Photovoltaic Modules and Panels. Referenced within this standard is UL 790, Standard Test Methods for Fire Tests of Roof Coverings, which is used to determine the fire resistance performance of roof coverings exposed to simulated fire sources originating from outside a building on which the coverings are installed. The test is similar to CAN/ULC-S107-10, Standard Methods of Fire Tests of Roof Coverings, referenced in the National Building Code of Canada.

A PV array roof installation may change the way the roof reacts under fire conditions. This is due to the proximity of the panels to the roof, resulting in thermal feedback, and the wind tunnel effect between the panel and the roof that may occur under certain conditions.

Roof Loading

For new systems, the additional load of solar panels should be considered when developing the structural design for the building. For retrofit applications, it is critical to assure the roof system has the carrying capacity for the panels and will withstand any additional loads. Loads to be considered include dead loads from the PV array and associated equipment, as well as live loads such as wind, snow, rain and seismic events.

Wind loading is another significant consideration. Edges and corners of roof structures have greater wind loads than the center of the roof, requiring additional structural considerations closer to the roof edge. Wind loading can have a major impact on the PV array characteristics including the tilt angle, array location and securement method. The test protocol in CSA Standard A123.2, *Standard test method for the dynamic wind uplift resistance of membrane-roofing systems*, has been used successfully to determine the wind resistance of PV systems under dynamic loading conditions.

Snow loads are another variable load consideration. PV arrays mounted at an angle to the roof surface distribute snow in a variety of ways. Snow will tend to drift along the roof and collect along the backside of the modules, increasing the load on the roof. It is also possible for the array to collect snow during a storm and then shed that snow once the sun comes out. This will increase the point loading on the front side of the array.

Seismic loads must also be factored into the structural calculations.

Drainage

Roof drainage must also be considered in the design of a rooftop solar installation. The PV system must not interfere with the roof's drainage. Conduits, rack penetrations, and other PV components can impede drainage and compromise the roof's performance.

Natural Hazards Resistance

The impact resistance of solar panels should also be considered. Hail, or wind borne debris may damage panels that are not sufficiently robust, necessitating expensive shut downs and replacement.

ROOF CONSIDERATIONS

Roof Condition

PV systems should be installed only on roofs that are in good condition. It makes no sense to install a thirty-year life PV system on a roof with five or ten years of serviceable life remaining. When it comes time to re-roof, the entire PV system may have to be removed to facilitate the reroofing process, and then be reinstalled. On existing buildings, this means verifying the age of the roof and the remaining length of any warranties. It also means surveying the roof for stress, damage or other existing problems. Areas of ponding water, or roof edge and flashing details have to be rectified before a PV system can be installed. Many reputable roofing system manufacturers are partnering with solar integrators and now offer PV ready assemblies that meet the rigid performance requirements of a roof suitable for a PV installation.

Wherever possible, when roof mounting solar panels, the original roofing contractor, or another manufacturer approved roofing contractor should be contacted to verify that the roof is in good condition before the work begins. The roofing contractor and roofing systems manufacturer should be present during the entire installation to ensure there is no damage to the roof and that all roofing work has been carried out in accordance with the manufacturers' instructions and good roofing practice. Upon completion of the PV installation, a thorough inspection of the roof should be carried out. Building owners should be aware that any additions or alterations to the roof, including adding roof-top equipment, without the prior consent of the roofing contractor and/or roofing system manufacturer may result in increased warranty costs, or void the roof warranty entirely.

Another important consideration is the roof wear and tear resulting from the actual PV installation and post installation maintenance. Any roof considered as a platform for PV must be designed to withstand an increased level of construction and maintenance traffic. The surfacing, membrane system, and insulation must have adequate mechanical strength to withstand the traffic they will be subjected to. There should always be walkways designed into the PV array. This is helpful for both the installation crew as well as future maintenance technicians. These personnel will likely have tool belts and tool boxes in tow, so there should be some walkways wide enough for this level of activity. People should be able to pass one another without damaging the array. Regardless of the space between rows, it is good practice to provide paths so that people are not tempted to make shortcuts through the array.

PV rack mounted systems should be designed to facilitate roof maintenance, repair, and even reroofing. This means providing sufficient clearance of the PV components from the roof, walls, roof penetrations and other PV components to allow for the repair, and removal and replacement of the roofing components as may be required.

It must be recognized that the installation of a solar array on a roof will substantially impact the cost of future roof maintenance due to the increased number of penetrations and roof top equipment components. If roof repairs are required, it may necessitate a qualified PV technician, or electrician, oversee the repair to ensure the integrity of the PV system. Conversely, a roofing technician should always be present when the PV system is serviced, or repaired to ensure the roof is not damaged.

Conclusion

The good news is that many reputable roofing system manufacturers are partnering with solar integrators and now offer PV ready assemblies that meet the rigid performance requirements of a roof suitable for a PV installation. The roofing industry is actively dialoguing with the PV industry and the architectural community to develop standards and best practices for solar roof top installations. Through roofing associations and organizations such as the Center for Environmental Innovation in Roofing our industry is heavily involved in disseminating information regarding study, design and installation of rooftop PV systems. All personnel installing roof top PV's should be trained in the proper care and functioning of the roof. Some roofing organizations and roofing contractors are now providing training to their personnel in how to properly waterproof connections and penetrations, and how to work under and around roof mounted PV systems.

Roof top PV's should only be installed on roof assemblies that are suitable platforms for the solar system and the mounting method being used. The roof assembly under a PV system should have a service life equal to, or longer than the expected service life of the PV system. This should help to minimize service disruptions during the life of the PV system.