PHOTOVOLTAIC SYSTEMS: RISKS AND RECOMMENDATIONS

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Across Canada, renewable energy is growing exponentially, and National Resources Canada (NRC) says wind and photovoltaic (PV) solar is the forefront of that growth. As of 2019, there were 138 PV solar farms across Canada, with the majority of them developed in Ontario. With more than a decade of PV technology development, and with the continuous growth and evolution driven by global initiatives to lower greenhouse gas emissions, the potential for unique risks and the need for experts grows more pertinent.

Although PV solar technology may seem like any other system composed of mechanical and electrical parts, the equipment and configuration vary significantly. Because of this complexity, a failed PV system may not be simple to diagnose or remediate, resulting in higher project costs and lengthy periods of business interruption. In this whitepaper, we discuss the background on PV solar, the configurations that exist currently, some of the unique risks that these systems face, and highlight examples of past claims.

Highlights

- Understanding photovoltaic (PV) solar systems
- Risks associated with PV systems based on expert experience
- The difficulties in replacing failed PV system modules
- Examples of claim scenarios

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Background and History

PV modules convert sunlight into direct current (DC) electricity through the "photovoltaic effect." PV arrays can be mounted on flat roofs, sloped roofs, or ground-mounted. While an individual PV module only produces approximately 45 volts (V) at 8.5 amps (A), modules are connected in series to produce strings with voltages of up to 1000 V of direct current (VDC) at 8.5 A. A typical PV string, 1000 VDC at 8.5 A, is more than enough energy to power an electric clothes dryer.

Although the NRC data shows PV systems in Canada as early as 2005, real development did not start until about 2010. In 2009, the Ontario government passed the Ontario Green Energy Act to encourage the development of green energy projects. Subsidies under the act made photovoltaic (PV) projects viable business opportunities for those willing to build PV arrays and sell the power generated back to the

Ontario power grid. Similar government-backed subsidies, aimed at promoting a shift toward renewable energy sources, exist throughout Canada and the world.

Since 2013, PV solar capacity in Canada has gone up by 151% and generates 8x more electricity. In 2017, approximately 98% of photovoltaic (PV) arrays in Canada had been installed in Ontario, totalling 2,206 megawatts (MW), capable of powering over 500,000 homes. PV installations within the city, such as on rooftops, have the advantage of producing energy where it is used. This is a benefit that countries like Germany have used in creating a more stable electric grid.

Risks Resulting in Claims

PV system failures have the potential to supply a significant amount of uncontrolled energy to the racking, building structure, or ground, often resulting in fires. The power grid supplies alternating current (AC) power, requiring inverters on PV arrays to convert the DC output of modules into AC power. Most grid-tied PV systems do not store energy.

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Our engineers have investigated numerous claims involving PV systems arising from many different issues, including:

- The use of installers and electricians that are inexperienced with PV solar panels, resulting in electrical faults and fires
- Improper design leading to equipment failure, fire, or inefficiency leading to loss or reduced income
- Roof damage due to installation
- Overloading of the roof structure (inadequate structural design)
- Water ingress beneath PV systems
- Inappropriate maintenance intervals implemented
- Lightning
- Grid overvoltage
- Wind loads
- Snow loads
- Hail
- Heavy rain and flooding, particularly of ground-mounted systems
- Settlement and heaving of ground-mounted structural support systems
- Equipment manufacturing defects and commissioning test errors

Investigation of claims involving PV systems may appear similar to claims involving more common building structural and electrical systems. However, in many cases there are significant differences that, if the claim is investigated by an engineer unfamiliar with such systems, may lead to substantial errors or missed opportunities for cost recovery or claim defence. We will be reviewing some case examples in this paper.

PV System Cost Reductions and the Resulting Increase in Insurance Claim Costs

Due to advances in manufacturing techniques and improved materials, PV module efficiency has increased significantly in the last ten years. This efficiency increase, combined with the declining cost of balance of system components, has resulted in installation costs significantly decreasing from $7.00/watt (W) to less than $1.50/W. Gains in module efficiency reduces the number of modules, racking, wiring, and labour required to achieve the same energy output. The array design philosophy has also evolved with decreasing component costs, causing systems to favour many smaller 'string' inverters instead of a single large central inverter. Ironically, the advances in module efficiency and the reduction in installation and balance of system costs has generated more complex and expensive remediation for existing arrays, as legacy parts are frequently not available and new components are not compatible.

Changes in module efficiency have prompted changes in module voltage and current characteristics. Replacing a ten-year-old 220 W module with a new 320 W module is not always feasible and manufacturers do not have an inventory of older modules. Where there is a module loss, the configuration determines whether one module, a row of modules, or a whole array needs replacement to ensure matching current and voltage characteristics for all modules in a given string or zone. Remediation costs for a loss where a single module was damaged could vary significantly from system to system. Inverter technology has also advanced with several inverter manufacturers ceasing operation in the past ten years. Getting parts from a defunct inverter manufacturer is difficult or impossible and greatly increases the remediation timeline, increasing the business interruption losses. In the case of a system with a central inverter, a single component as simple as a fuse can result in loss of production of the entire system.

Case Studies

Excess Claim for Lost Revenue

In this Ontario case, familiarity with PV system design and the Ontario feed-in tariff (FIT) was critical to determine the loss of system revenue accurately. The claimed cause for the loss was mechanical damage due to excessive snow and ice buildup on the modules. Our investigation confirmed the mechanical damage but found that the lost revenue was overstated. The overstatement likely wouldn't have been detected by an electrical engineer unfamiliar with PV system design.

PV system production is limited by the output of the inverter that converts the DC power from the modules to AC power suitable for use by the grid. Typical system design dictates that the nameplate capacity of the modules (DC) should exceed the nameplate capacity of the inverters (AC output) by at least 20%, and often as much as 40%. The array is constructed larger on the DC side to compensate for times when irradiance (available sun energy) is reduced due to poor weather or time of year. In other words, rather than designing the system so that it reaches the desired AC output on clear, sunny days at the height of summer, which does not represent the typical weather conditions in Ontario year-round, the system is designed with enough panels that the desired total panel DC energy output is reached on days with less than optimal irradiance. On sunny days, where the module DC output exceeds the inverter AC output capacity, the output is capped by the inverter.

In the case we investigated, the FIT contract between the solar farm owner (the Insured) and the Ontario government was only for the AC output of the inverter. Calculating loss of revenue based on the DC capacity of the array, as the Insured did, would significantly overstate the loss. The Insured made a lost revenue claim to its insurer based on the energy output that the panels were capable of under perfect conditions, which was over what the FIT contract provided. The results of our recognition were more accurate revenue calculations, reducing the claim for lost revenue by more than $300,000 CAD.

Improperly Specified Transformer

In this scenario occurring in Ontario, a transformer was installed that was not compatible with the existing building transformer. Rooftop mounted PV arrays are normally installed in parallel with the existing building electrical system. This means the neutral of both transformers will be common. The internal impedance of the PV system transformer differed from the building transformer significantly, causing high circulating currents on the neutral transformer and resulted in an electrical fire, damaging the transformer, inverter, and associated switchgear and conductors. The fire damaged more than $150,000 of equipment and resulted in business interruption losses of more than $350,000. Our engineers were able to correctly identify the cause of the failure and get the system safely back online.

Most of the time, we, as forensic engineers, only have an impact post-loss. In this case, quick and accurate determination of the cause of the loss allowed our engineers to identify systems at other locations with similar design deficiencies, thus reducing the risk of additional fires and losses.

Summary

Since PV systems within Canada are either reaching or have exceeded ten years since their installation, maintenance issues are becoming more prevalent, creating claims with significant business operation costs. While a PV system may seem like a collection of electrical parts that are common to other facilities, there are substantial differences in how the PV systems are designed, constructed, and operated. A thorough understanding of how PV systems are designed, built, and how they interact with the electrical grid and function is important when dealing with insurance losses with solar farms. Such understanding can adequately assess the cause, identify potential excess claims for business losses, and reduce remediation costs without loss of system quality or post-remediated production, saving time and money.