

A photograph of two workers in safety gear (hard hats, high-visibility vests, and harnesses) installing solar panels on a roof. The panels are dark blue and arranged in rows. The background shows a clear blue sky and some greenery.

SOLAR ENERGY 101

Renewable energy solar farms

An introduction to and overview of Solar Farm
Power Generation Systems, their risk management
and insurance considerations

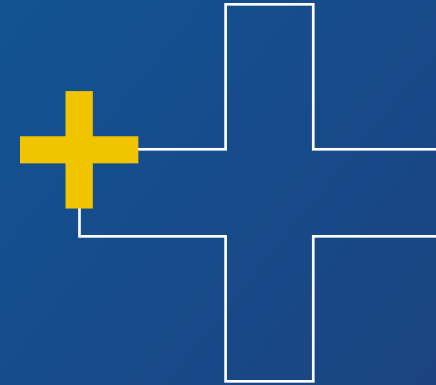


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Introduction

Solar farms, also known as solar parks or solar fields, are large areas of land containing interconnected solar panels positioned together over many acres, to harvest large amounts of solar energy at the same time. Solar farms are designed for large-scale solar energy generation that feeds directly into the grid, as opposed to individual solar panels that usually power a single home or building.

A typical solar farm will include:

- Solar Panels
- Solar Trackers / Mounting System
- Combiner Boxes
- Inverters
- Switchgear
- MV Transformer
- Export Cable or Transmission Lines

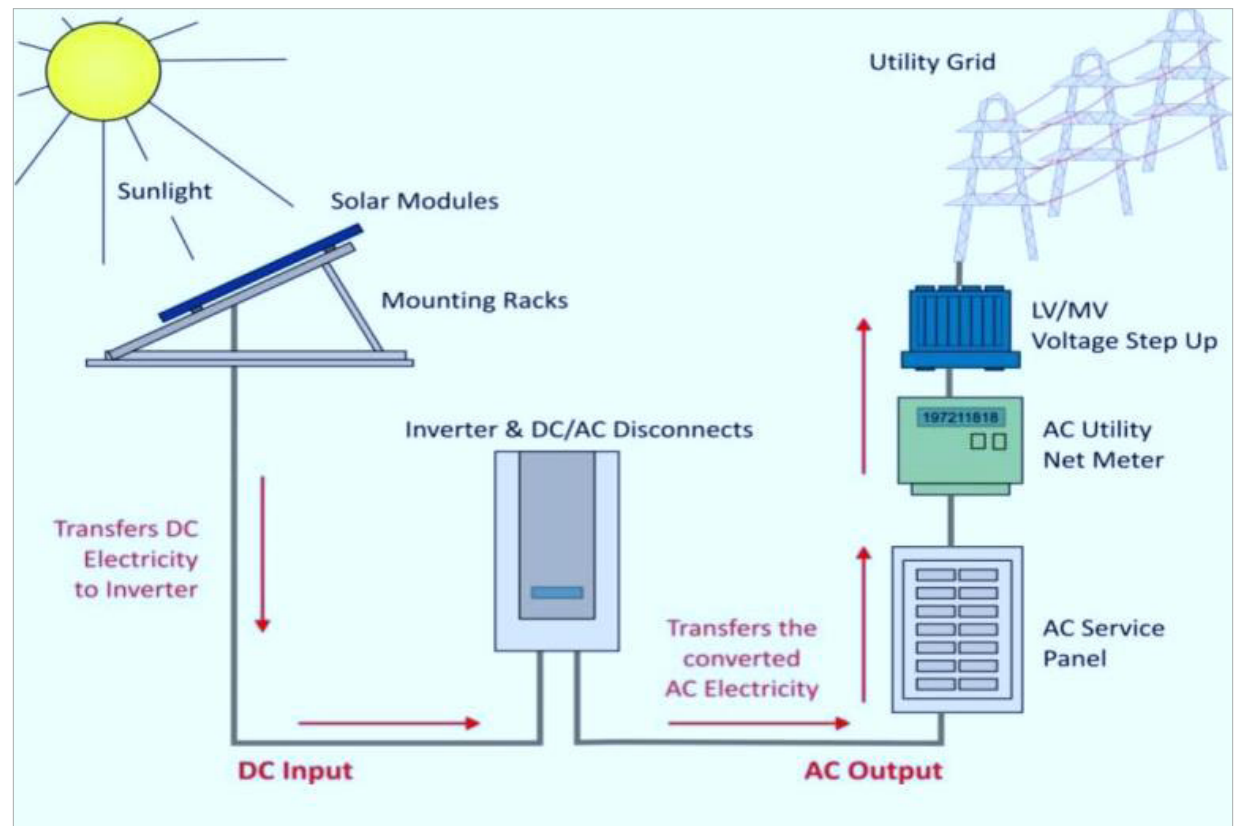


PHOTO: Typical layout of a solar project

Solar panels

A solar panel, also known as a photovoltaic (PV) panel, is a device that converts sunlight into direct current (DC) electricity. Solar panels are composed of photovoltaic cells made of silicon, which are connected in series and covered by a glass or plastic protective layer. The panels are designed to be mounted on rooftops, walls or on the ground. They are connected to an inverter that converts the DC electricity into alternating current (AC) for use in homes or businesses.

- **Design:** Solar panels are designed to capture as much sunlight as possible and convert it into electricity. The cells in the panel are made of silicon and arranged in a grid-like pattern, with metal contacts at the top and bottom of each cell. The cells are connected in series to increase the voltage and multiple panels can be connected in parallel to increase the current. The panels are covered by a glass or plastic layer to protect the cells and to provide a weather-resistant surface.



PHOTO: Solar panel array

Solar panels (cont.)

- **Specifications:** The specifications of a solar panel can vary, but typically cover:
 - › **Power output:** This is the amount of electricity that the panel can produce and is measured in watts (W).
 - › **Efficiency:** This is the percentage of sunlight that is converted into electricity and ranges from 15-20% for standard panels to over 20% for high-efficiency panels.
 - › **Size:** The size of the panel is measured in square meters (m²) and can vary from 0.5 m² for a small panel, to over 6 m² for a large panel.
 - › **Weight:** The weight of the panel is typically between 15-30 kg, depending on the size and material used.
 - **Operation:** When sunlight hits the cells in a solar panel it creates a flow of electrons that generates a current. The current flows from the top to the bottom of each cell, through the metal contacts and into the wiring that connects the cells. The inverter then converts the DC electricity into AC electricity.
 - **Maintenance:** Solar panels require very little maintenance but it is recommended to clean them regularly to ensure they operate at maximum efficiency. Dirt and debris can accumulate on the surface of the panels and reduce the amount of sunlight that reaches the cells. To clean the panels, they can be wiped down with a soft cloth or a mild soap solution.
- Risks/What can go wrong:**
- **Breakage:** The glass or plastic layer on the panels can break if hit by a heavy object or if subjected to extreme weather conditions. This can cause the cells to be exposed to the elements and can reduce the efficiency of the panel.
 - **Wiring issues:** The wiring connecting the cells in the panel can become damaged over time which can also reduce efficiency. It is not unheard of for wiring to be damaged by animal activity.

Solar trackers

Solar trackers are devices designed to enhance the efficiency of solar panels by continuously orienting them to optimize their exposure to sunlight throughout the day. There are three main types of tracker: fixed-tilt, single-axis and dual-axis:

- **Design and Specification:** Single-axis trackers have one degree of freedom and can rotate around a single axis (typically north-south) while dual-axis trackers can rotate around both the north-south and east-west axes. The design involves a combination of mechanical and electronic control systems. Key specifications include tracking accuracy, rotation speed, payload capacity and power consumption.
- **Operation:** Solar trackers use sensors (such as light sensors or GPS) to detect the sun's position and adjust the orientation of the solar panels accordingly. This maximizes the panels' exposure to sunlight leading to increased energy generation compared

to fixed installations. The control system calculates optimal angles for the tracker movement throughout the day.

- **Maintenance:** Regular maintenance involves checking for physical wear and tear, cleaning debris from the tracking mechanism, and inspecting sensors and control systems. Monitoring software can help identify any anomalies in real-time. Maintenance schedules can vary depending on manufacturers recommendations and environmental conditions.
- **Protection Functions:** Solar trackers often include protection functions to ensure safe operation in adverse conditions. Stowage during high winds is a crucial safety feature to prevent damage to the tracker or the solar panels. When wind speeds reach a certain threshold the tracker will automatically move the panels into a horizontal stow position to minimise wind resistance and potential damage.

Advantages:

- **Increased Energy Production:** Solar trackers can significantly enhance energy output by optimising panel orientation to capture more sunlight throughout the day. This increased generation can improve the overall profitability of an energy project.
- **Time-of-Day Generation:** Solar trackers can align panels to capture the sun's rays at different angles throughout the day. This aligns well with peak energy demand periods, potentially increasing the value of the generated electricity.
- **Reduced Land Footprint:** By combining wind and solar generation on the same land a wind farm with solar trackers can maximize land usage, increasing overall energy output without the need for additional space.

Solar trackers (cont.)

Disadvantages:

- **Cost:** Solar trackers involve additional upfront costs for equipment, installation, and maintenance. This can affect the initial profitability of a wind farm especially if the cost is not justified by the added energy production.
- **Maintenance Complexity:** Solar trackers introduce a new layer of maintenance complexity compared to fixed-tilt solar installations. Mechanical components, sensors and control systems require regular upkeep, potentially increasing maintenance costs.
- **Risk of Damage:** Wind farms are exposed to high wind speeds and solar trackers can be vulnerable to damage during severe storms. The moving parts of the trackers and the panels themselves could be at risk leading to potential downtime and repair expenses.

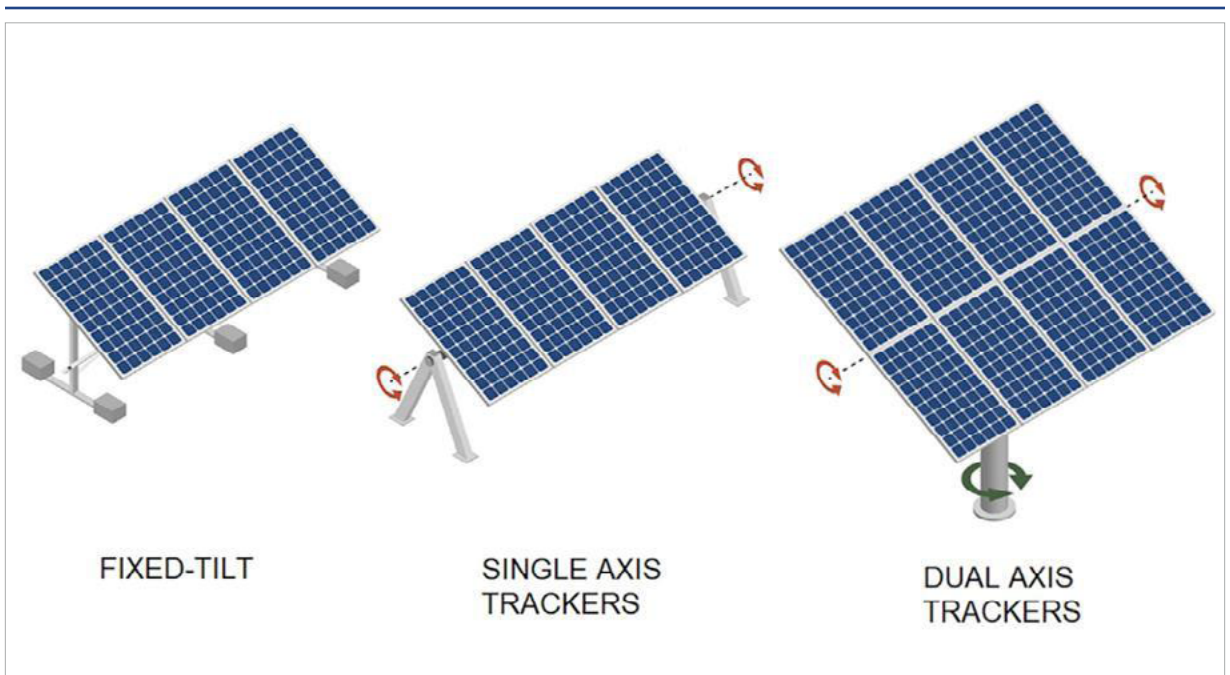


PHOTO: Solar tracker types

Solar trackers (cont.)

Risks of failures

Common risks of tracker failure include mechanical breakdowns, sensor malfunctions, control system errors and exposure to extreme weather conditions. Mechanical components may wear out over time leading to inaccurate tracking. Sensor errors can result in improper orientation. Control system failures might prevent the tracker from responding to changing solar angles.



PHOTO: Solar panel array

Solar trackers (cont.)

Risk mitigation

- **Stowage Mechanisms:** Implementing robust stowage mechanisms for the solar trackers during high winds can help mitigate potential damage risks. Properly designed stowage procedures can minimise exposure and protect the equipment.
- **Quality Components:** Using high-quality materials and reliable tracking technology can reduce the likelihood of mechanical failures and improve the overall durability of the solar trackers.

In summary, solar trackers are sophisticated systems that improve the efficiency of solar panels by optimising their orientation towards sunlight. They require regular maintenance to ensure proper functioning and include protective features like stowage during high winds. Failures can stem from mechanical, electronic, or environmental factors, emphasising the importance of maintenance and quality in their design and implementation.



PHOTO: Solar panel installation and handling

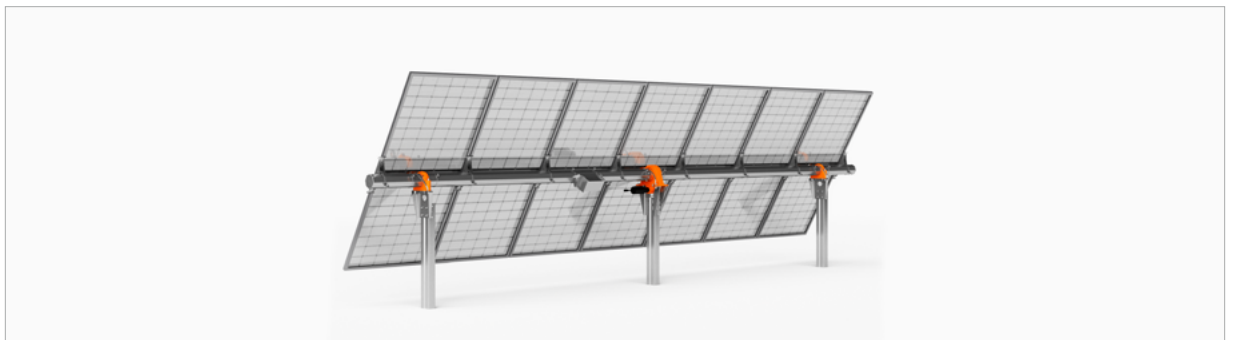


PHOTO: Solar tracker array

Combiner boxes

A solar panel combiner box is a device used in photovoltaic (PV) systems to combine the output of multiple solar panels into a single electrical circuit. It is designed to manage the electrical current generated by multiple solar panels and provide protection to the panels and the electrical system. The following is a technical description of how solar panel combiner boxes operate.

- **Design:** A solar panel combiner box typically consists of a weather-resistant enclosure, input and output terminals, fuses, and a control circuit. The enclosure is usually made of metal or plastic and is designed to protect the electrical components from the elements. The input terminals are where the output from each solar panel is connected and the output terminals provide a single combined electrical output. The fuses are designed to protect the panels and electrical system in case of an electrical overload.

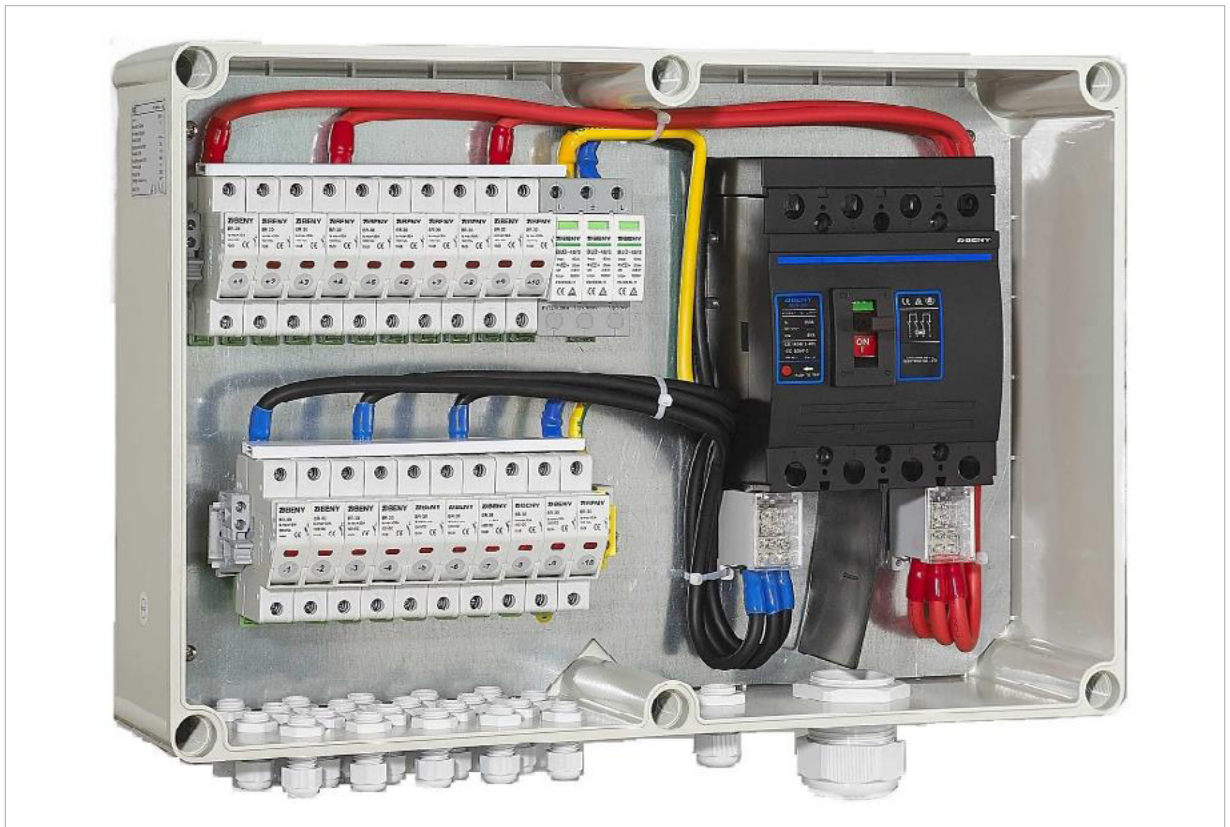


PHOTO: A typical solar combiner box (internal)

Combiner boxes (cont.)

- **Specifications:** The specifications of a solar panel combiner box vary depending on the manufacturer but common specifications include:
 - › **Number of input circuits:** This determines the number of solar panels that can be connected to the combiner box.
 - › **Rated current:** This is the maximum electrical current that the combiner box can manage.
 - › **Rated voltage:** This is the maximum electrical voltage that the combiner box can handle.
 - › **Fuse rating:** This is the maximum current that each fuse can manage before breaking the circuit.
 - › **Enclosure rating:** This is the level of protection provided by the enclosure against environmental factors such as water, dust, and heat (see IP ratings).
 - **Operation:** The operation of a solar panel combiner box is relatively straightforward. Each solar panel is connected to an input terminal and the combined electrical output from all the panels is connected to the output terminals. When the solar panels generate electrical current the combiner box combines the current from each panel into a single electrical circuit.
 - **Maintenance:** Solar panel combiner boxes require minimal maintenance. Regular inspections of the box and its components should be performed to ensure proper functioning and to check for any signs of damage or wear. The fuses should be checked periodically to ensure that they are functioning properly and that they have not tripped.
- Risks/What can go wrong:**
- **Electrical overload:** If the combiner box is not properly sized for the electrical load, it can cause an electrical overload which can damage the panels and electrical system.
 - **Fuse failure:** Fuses can fail due to aging, environmental factors or electrical overloads. This can result in interruption of the electrical circuit and loss of power.
 - **Water damage:** If the enclosure of the combiner box is damaged or not properly sealed water can enter and cause damage to the electrical components.
 - **Corrosion:** Corrosion can occur on the electrical components if the combiner box is not properly sealed or if it is exposed to moisture.
 - **Animal Activity:** Rodents and reptiles can find themselves at home in combiner boxes and inverter cabinets on solar farms.

Inverters

A solar farm inverter is a device that converts direct current (DC) electricity generated by solar panels into alternating current (AC) electricity that is usable by the electrical grid. The inverter plays a crucial role in the operation of a solar farm as it regulates the voltage and frequency of the electricity generated to meet the requirements of the electrical grid.

Design and specifications:

- Solar farm inverters come in various sizes with capacities ranging from a few kilowatts (KW) to several megawatts (MW).
- The design of the inverter depends on the size and complexity of the solar farm as well as the required efficiency and reliability.
- Modern solar farm inverters are usually designed to be compact and efficient. They are made of durable materials to withstand harsh environmental conditions.

- Inbuilt safety features usually include over-voltage and over-current protection as well as thermal protection to prevent overheating.

Operation:

- Solar panels generate DC electricity which is then passed through a Maximum Power Point Tracker (MPPT) to optimise the voltage for maximum power output.
- The DC electricity is then fed into the inverter where it is converted into AC electricity.
- The inverter regulates the voltage and frequency of the AC electricity to meet the requirements of the electrical grid.
- The AC electricity is then fed into the electrical grid and distributed to homes and businesses.



PHOTO: A typical field inverter station

Inverters (cont.)

Maintenance:

- Regular maintenance is necessary to ensure proper operation of a solar inverter.
- This includes inspection for physical damage to the inverter, cleaning the air vents to prevent overheating and checking the firmware and software to ensure they are up to date.
- The inverter should also be checked for any performance issues such as reduced efficiency or output.

Risks/What can go wrong:

- Improper installation or maintenance can lead to issues with the inverter and the solar farm.
- Overheating, which can reduce an inverter's efficiency and lifespan.
- Inverters can malfunction or fail due to hardware or software issues, which can cause a loss of power output and potentially harm the electrical grid.
- Cybersecurity - a hacked inverter could potentially compromise the electrical grid.

MV transformer

A solar farm medium voltage (MV) step-up transformer is a key component in a photovoltaic (PV) system that converts the low voltage power generated by the solar panels to a higher voltage AC power suitable for feeding into the utility grid. The main functions of the MV step-up transformer include boosting the voltage, isolating the PV system from the grid, and providing a safe and reliable connection between the two.

Design and specifications:

- The MV step-up transformer is usually designed to operate at voltages between 6 kV and 36 kV and its rating is determined by the size of the PV system and the local electrical grid requirements.
- It is usually an oil-immersed, three-phase unit that consists of a laminated core, wound coils, oil-cooled bushings, and a tank that provides insulation and protects the transformer from external factors such as weather and moisture.

- The MV step-up transformer is typically rated by its voltage and power output and must comply with international standards such as IEC 60076-1 and IEC 61646.

Operation:

- The low voltage DC power generated by the solar panels is fed into the MV step-up transformer where it is transformed into a higher voltage AC power.
- The transformer operates by electromagnetic induction where the low voltage DC power creates a magnetic field that induces a higher voltage in the secondary coil.
- The higher voltage AC power is then fed into the grid where it is distributed to homes and businesses.



PHOTO: Electrical transformer

MV transformer (cont.)

Maintenance:

- Regular maintenance is essential to ensure the reliable operation of the MV step-up transformer and to extend its lifespan.
- The main tasks involved in maintaining the MV step-up transformer include checking the oil level and quality, tightening the connections and checking the temperature rise of the windings.
- Regular inspections and tests should be conducted to monitor the performance of the transformer and to detect any potential issues before they cause a failure.

Notable risks and potential failures:

- Like any electrical equipment the MV step-up transformer is subject to a range of risks and potential failures including overloading, overheating and insulation failure.
- Overloading can occur when the transformer is subjected to excessive currents which can cause damage to the windings and result in a failure.
- Overheating can be caused by poor ventilation, high ambient temperatures and faulty cooling systems, and can result in a reduced lifespan and potential failure.
- Insulation failure can be caused by a range of factors including age, moisture ingress and electrical stress, and can result in a short circuit or a complete failure of the transformer.

Export cable

A solar farm export cable is a specialised electrical cable designed to transmit the power generated by a photovoltaic (PV) array to the grid. The design of these cables considers several factors including the voltage and current capacity of the PV system, distance from the array to the grid connection point and the environmental conditions in which it will operate.

The specification of a solar farm export cable typically includes its maximum operating voltage, current rating and insulation resistance. The cable must be capable of safely transmitting the maximum power output of the PV system without overheating or suffering from electrical losses. The cable must also meet relevant electrical and safety standards such as International Electrotechnical Commission (IEC) standards, to ensure it is suitable for use in the electrical grid.

The operation of a solar farm export cable is

relatively straightforward. When the PV system is generating electricity the current flows through the cable to the electrical grid. In order to ensure that the cable operates efficiently and safely it must be properly installed and maintained. This may include regular inspections and testing of the cable and its connection points as well as cleaning and replacing damaged or worn components as needed.

Notable risks

There are several notable risks associated with the construction and operation of solar farm export cables. One of the biggest risks to the export cable arises during the construction / laying process. This often involves multiple cable joints which need to be designed and installed by specialists to ensure the long-term viability of the

cable joint over years of operation and cycling. It is possible that cables damaged during shipping/ construction are buried and the damage is not known until the solar farm becomes operational.

Another pertinent risk is the potential for electrical faults, such as short circuits, which can result in damage to the cable or surrounding equipment. Another risk is the potential for physical damage to the cable, such as damage from heavy machinery, rodents or exposure to harsh weather conditions.

These risks can be mitigated through proper installation and maintenance practices such as using protective conduit, regular inspections and monitoring for signs of wear and damage.

Transmission lines

Grid transmission lines are electrical power transmission systems that transmit high voltage electricity from power plants to substations and distribution systems which then distribute the electricity to homes and businesses. These transmission lines are designed to transmit electricity over long distances with minimum power loss.

- **Design:** Grid transmission lines typically consist of towers, conductors, insulators, and grounding systems. The towers are made of steel or concrete and are designed to support the weight of the conductors and withstand wind and ice loads. The conductors are made of aluminium or copper and carry the electrical current. The insulators are used to separate the conductors from the towers and prevent electrical discharge. The grounding system is used to protect against electrical fault conditions and lightning strikes.
- **Specification:** Grid transmission lines are designed with specific voltage levels, typically in the range of 115 kilovolts (kV) to 765 kV. The conductors are chosen based on their current-carrying capacity which is a function of the cross-sectional area, material and temperature. The insulators must be able to withstand high voltage stress and environmental conditions such as rain, snow and wind. The towers must be strong enough to support the weight of the conductors and insulators and be able to withstand wind and ice loads.
- **Operation:** Grid transmission lines operate by transmitting electrical energy from the power plants to substations through the transmission lines. The electrical energy is transformed to high voltage at the power plants and then stepped down to lower voltage levels at the substations. The lower voltage is then distributed to homes and businesses through the distribution system. During normal operation the transmission lines must maintain a constant voltage level to ensure a reliable power supply.
- **Maintenance:** Grid transmission lines require regular maintenance to ensure their reliability and safety. This includes periodic inspections, cleaning, and tightening of the conductors and insulators, as well as the replacement of damaged components. Grounding systems must also be checked and maintained to ensure their effectiveness in protecting against electrical fault conditions and lightning strikes.

Transmission lines (cont.)

Notable risks

There are several potential risks associated with grid transmission lines including electrical faults, lightning strikes and equipment failure. Electrical faults can occur due to insulation failure, conductor damage or other issues. Lightning strikes can cause damage to the conductors, insulators and grounding systems. Equipment failure can result from a variety of causes including corrosion, aging and mechanical failure. To mitigate these risks grid transmission lines are equipped with protection systems that detect and isolate faults, and automatic voltage regulation systems that maintain a constant voltage level.



PHOTO: Overhead transmission lines

Solar farm - notable risks

In recent years there have been numerous major losses and significant incidents affecting large solar farms. Some notable cases are detailed below:

- **Fire incidents:** Solar farms are prone to fires due to the use of high-voltage electrical equipment and the high temperatures generated by the panels. For example in 2014 a fire at the San Luis Obispo solar farm in California caused an estimated \$7 million in damages.
- **NATCAT / weather-related damage:** Severe weather conditions such as hurricanes, storms and hail can cause significant damage to solar panels and related equipment. For example Hurricane Michael (2018) caused significant damage to solar farms in Florida.
- **Theft and vandalism:** Solar farms are often located in remote areas making them vulnerable to theft and vandalism. In some cases thieves have stolen valuable components such as inverters, wiring and even entire panels.
- **Technical failures:** Technical failures can also lead to significant losses. For example the failure of a transformer or a component within the inverter can result in a complete shutdown of the system leading to a loss of power generation and revenue.
- **Grid connection issues:** Solar farms need a reliable connection to the grid in order to supply electricity to consumers. Any issues with the grid connection, such as outages or equipment failures, can lead to a loss of power generation and revenue.

These are just a few examples of the types of losses and incidents that can affect large solar farms. It is important for operators to complete regular maintenance, implement proper grounding and lightning protection, and to place appropriate insurance coverage to minimise their risks and safeguard their ongoing operation.

Solar farm project phases

1. **Feasibility:** This involves evaluating the potential site, considering factors such as location, solar resource, topography, access to transmission and distribution lines, environmental impact and local regulations. This stage also involves conducting a preliminary economic analysis to determine the viability of the project including expected costs and revenues.
2. **Design:** This stage involves creating detailed plans and designs for the solar farm including the number and type of solar panels, the orientation and tilt of the panels, the type of mounting system and the layout of the site. The design must also include the electrical systems that will connect the solar panels to the grid and the inverters that will convert the DC power generated by the panels into AC power that can be used by the grid.
3. **Permitting:** The permitting process involves obtaining the necessary approvals and permits from local, state and federal authorities, including environmental and land-use permits as well as those for electrical connections to the grid.
4. **Construction:** This stage involves the actual physical construction of the solar farm including the preparation of the site, the installation of the solar panels and electrical systems, and the commissioning of the site. Construction can take several months to complete depending on the size of the project.
5. **Commissioning:** This involves testing and verifying that the solar farm is operating correctly including checking the electrical connections, monitoring system performance and ensuring that the site meets safety and environmental standards.
6. **Operation:** The solar farm is now operational and producing electricity which will be sold to the grid or directly to customers. Ongoing maintenance is required to ensure that the solar farm continues to function at optimal levels. This includes cleaning the panels, replacing faulty components and monitoring the performance of the electrical systems.

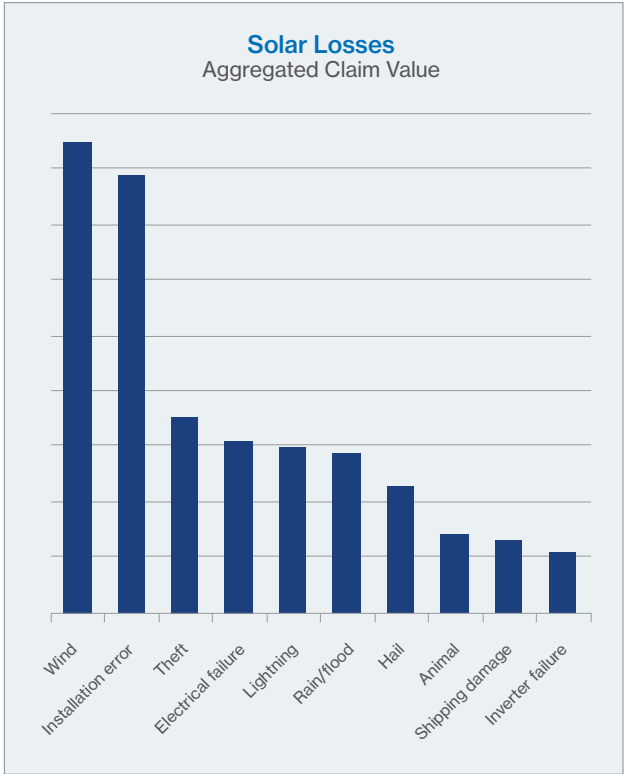
Crawford renewable energy loss database

The Crawford renewable energy loss database captures over 3,000 major losses on renewable energy projects. This database provides valuable insights into the causes and factors contributing to losses in the renewable energy sector, allowing insurers, risk managers and renewable energy project owners to improve their risk management practices.

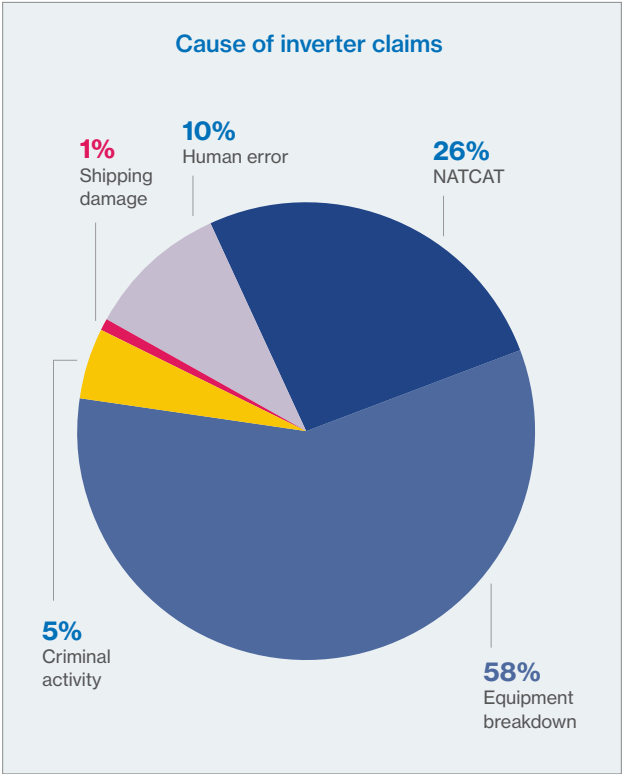
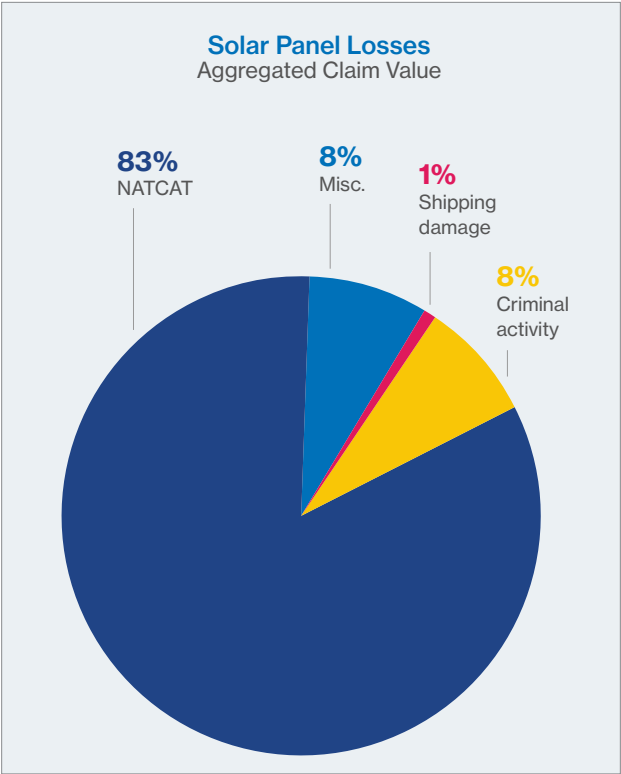
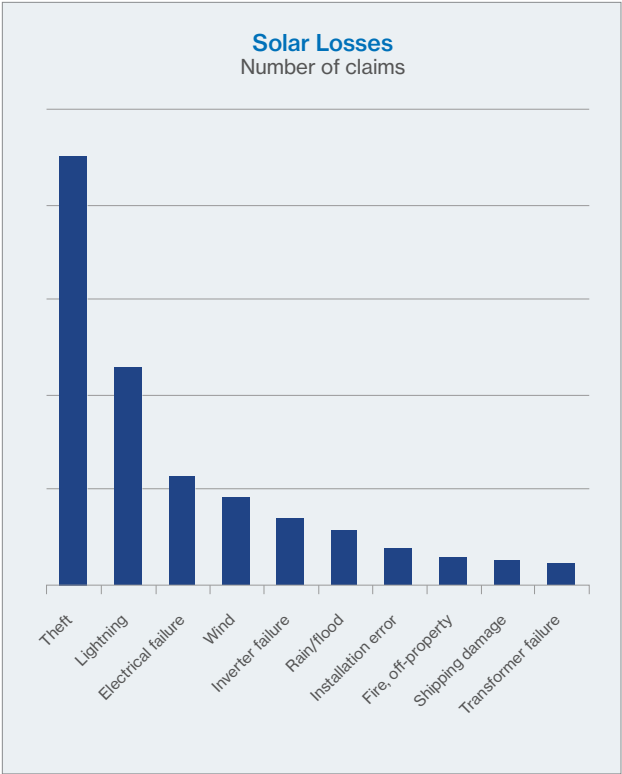
By leveraging the insights from this loss database you can gain a better understanding of the risks associated with renewable energy projects, identify potential sources of risk and implement effective risk mitigation strategies. This can ultimately lead to more accurate pricing, better claims management and improved industry performance.

Our database provides detailed information on the causes and factors contributing to losses including equipment failures, weather-related events and operational errors. By analysing this data it is possible to identify common patterns and trends and to develop strategies to mitigate these risks and reduce the likelihood of future losses.

Whether you are an insurer looking to improve your underwriting discipline, a risk manager seeking to enhance your risk assessment processes or a renewable energy project owner looking to improve the performance and sustainability of your project, the Crawford renewable energy loss database is a valuable resource.



Crawford renewable energy loss database (cont.)



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