Solar Photovoltaic Plants:
Construction and Maintenance Issues

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Introduction

I am a UK-based electrical engineer and electrician by trade, based in the UK for the last 14 years. I joined the solar market in 2012 and worked for a London-based contractor. During my time there, I was both a construction and an Operation and Maintenance (O&M) manager. I joined RINA (then OST) in June of 2015 as a Technical Inspection Engineer, mainly inspecting solar PV plants. I have over 10 years of experience in electrical installations and 8 years in PV solar energy projects as a project, maintenance manager and inspection engineer. As of April of 2020, I have visited more than 400 Solar Photovoltaic (PV) plants in the UK and other countries.

Their combined capacity surpassed 3.5GW. Some were as small as 300kW (in Cornwall), a few half megawatt rooftops (in Singapore), others were 100MW (Kazakhstan), and a 1650MW complex in BenBan, Egypt. There are likely few people who have seen more UK solar farms than myself. This article provides an overview of the issues I come across regularly during the plant inspections - why they occur, and how to avoid them.

It is mostly aimed at owners, developers and contractors looking to improve the quality of their solar installations.

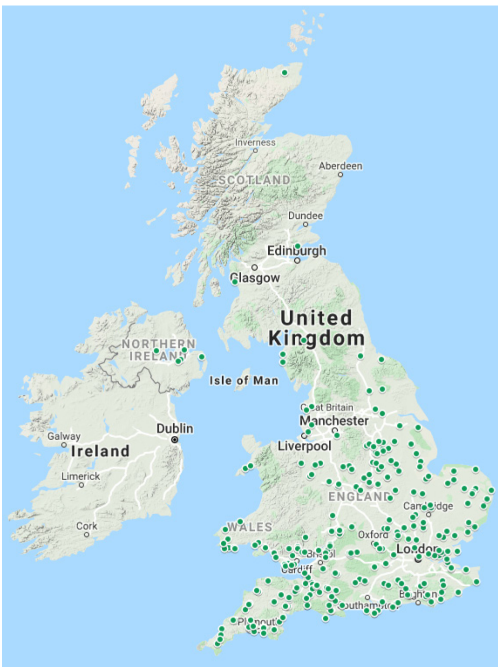

Figure 1: UK Solar PV Plants I have visited

Why issues occur

The basic principle of how a PV plant operates has remained the same: several solar modules are connected in series to form a string, all of which can produce 700V to 1500V DC. Numerous strings are then connected to a combiner cabinet, and from there, cables carry the DC voltage to a substation. In the substation, an inverter outputs DC to AC voltage, which then passes through a step-up transformer. At the end, it goes through a network of high voltage switchgear to the national grid.

The technology used in PV plants has significantly improved over the years: solar module peak power has increased substantially, inverter stations have become more efficient and resilient to external influences, communication systems allow us to monitor the plants remotely and detect issues faster. All these improvements can contribute to the reduction of maintenance time and costs however this is not always the case. As the solar energy market grows, and particularly during boom periods, contractors build plants to tight schedules and may be tempted to take shortcuts to meet schedules and minimize costs.

This may result in technical issues and risks. If problems are not detected early during the construction of the plant, or at least within the two-year acceptance period, they can affect future performance and long-term operation. A project owner/developer will need the professional view of a technical advisor to check the overall quality of the plant. This will include a detailed review of components used on site, future yield estimations and site visits during and after construction. From the owner's perspective, it is crucial for the technical advisor to identify any major issues prior to the acceptance period commencing, or at the latest, before the acceptance period is complete.

Common problems

Pyranometers

Pyranometers measure the irradiance at a solar farm, and their data is crucial to measuring the performance of a project and enforcing its performance warranties. I have witnessed hundreds of pyranometers which have been neglected. Some had not been calibrated in years, while others had their domes covered in algae or soiling. These are delicate devices that require monthly maintenance checks and should typically be calibrated every two years to maintain their accuracy. Another common issue is the inclination of the pyranometers - hundreds of them had been installed out of their contractual inclination. Owners and contractors should be careful not to overlook these important devices as Performance Ratio (PR) calculations may be compromised due to inaccurate pyranometer measurements.

Figure 2: Pyranometer out of inclination

Monitoring equipment

A very common issue is the amount of inadequately terminated and non-isolated communication cables in cabinets. Unlabelled and excessively long communication cables, all tangled together and squeezed in a small cabinet box make it impossible for an engineer to diagnose and resolve a communications issue. All cabling should be adequately labelled, and equipment should be installed in cabinets large enough to accommodate them.

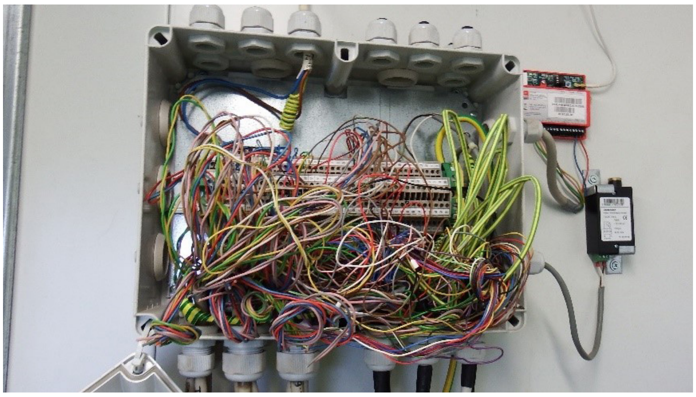

Figure 3: Inadequately terminated and non-isolated communication cables in a cabinet

Damaged modules

I often identify damaged modules when visiting sites. This module damage can be caused by mounting structure damage, from poor handling during construction, or lax maintenance practises. Module damage can be challenging to diagnose purely from monitoring a project's control system remotely, so issues can affect solar farms for longer than would be preferable. Often module damage can be identified through visual inspection, however some damage cannot be identified visually. I often perform DC string and I-V curve testing or thermography for clients to identify damage to modules or other parts of a solar farm, and would recommend string, I-V curve testing and aerial thermography is performed annually.

Figure 4: Damaged module

Mounting structure

Another issue is the condition of the mounting structure - the backbone of a PV plant. Metal frames are installed in the ground, to support most of the equipment: solar panels, cabling, combiner cabinets and other auxiliary components.

The structure is predominately made from galvanized steel and can last for more than 20 years. But often I see rust build-up and corrosion on these structures, particularly in PV plants close to the sea. On other occasions, the same problem appears in fixings (bolts and nuts) - these usually arise because of bad practices during installation (i.e. the usage of powerful power tools might strip away the protective layer of zinc and expose the bare steel to oxygen and moisture.). Farming equipment such as tractors can also damage lower sections of the structure and solar modules while grass cutting. Unfortunately, these problems are rarely identified by O&M teams or asset managers, leaving the damaged sections vulnerable to rust and corrosion.

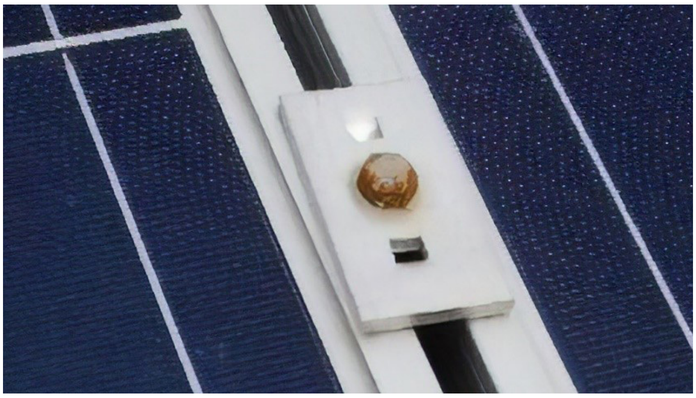

Figure 5: Module clamp corrosion on fixing

Labelling

A common issue on PV plants is the lack of labelling and signage on components and equipment. These issues can be split into two main areas:

- Lack of health and safety signage, either on access gates or perimeter fencing, to ensure risks to the public and staff are effectively communicated
- Poor labelling of components and equipment across site, making it challenging to identifying a location on site or finding the culprit causing an issue

It is a legal requirement that signage should be selected and installed in accordance with the Electricity Safety, Quality and Continuity Regulations 2002 and relevant Health and Safety site assessment to all fencing and buildings of a plant generating energy, and we recommend this issue is not overlooked when finalising the construction of projects.

Figure 6: Inadequate identification of mounting structure row

Figure 7: Missing identification on PV plant access gate

Cabling management

A PV plant can have kilometres of cables running underground and through the mounting structure. These carry the energy produced on site, and it is imperative that their integrity is maintained to the highest standards, to ensure that there is no downtime or health and safety risk to staff. Regulations in the UK state that cables that run underground should be enclosed in ducting to protect the cables from external mechanical forces. Ducting can be avoided if armoured cables are used. As the cost of armour cabling is high, contractors choose instead cabling with double insulation, as this is largely acceptable in Europe. As technical advisors, we highly recommend that contractors follow the regulations and guidelines of the country that the PV plant is build, and make the appropriate selections when it comes to cabling. One more typical issue we observe on a PV plant is unsealed cabling ducting above ground. Exposed ducting can allow easy access to vermin underground and usually vermin such as rats can damage cabling and cause extensive problems to a site. An adequate material for the environment should always be used to seal all exposed ducting across the site. It is recommended that the chosen material is cement based and it should take into consideration the impact of fire, UV radiation, wildlife and atmospheric conditions and be designed to last the lifetime of the project.

Figure 8: Unsealed cable ducting

Inadequate cable management includes missing cable protection against livestock, cabling between tables exposed to external influences such as wind, ice formation, temperature and solar radiation or not mechanically supported and protected.

Another common issue is having cables exposed to sharp edges, under compression or not adhering to minimum bend radius.

Figure 9: Inadequate cable management

Low quality cable management can lead to small amounts of current leaking via the cabling (Riso faults). Cable insulation can be damaged if cables are mishandled during construction or it might perish if left exposed to direct sunlight and other external conditions.

Riso faults might cause inverters to trip, communication issues, or worst, electrical arcing and subsequently, fires.

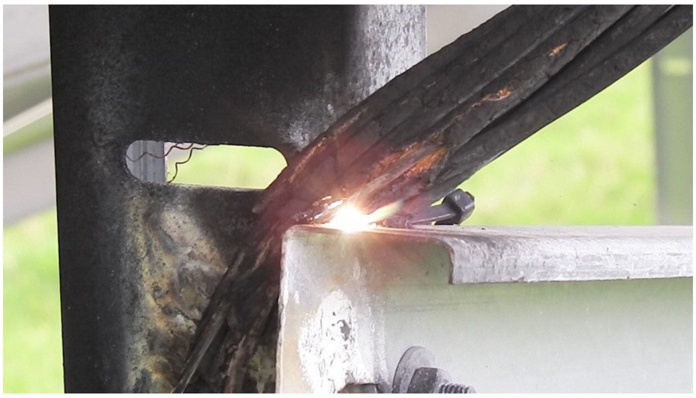

Figure 10: DC string cables on fire

Access keys

It is very common for PV plant access keys to be inadequately stored. In particular, regulations in the UK state that keys which allow access to high voltage rooms and stations should be kept stored in a safe manner, segregated from any other keys. In numerous occasions, low voltage (LV) and high voltage (HV) access keys have been found stored in the same key safe.

Any untrained and unauthorised person working on the site could easily access these rooms, potentially endangering themselves and causing problems to the plant.

It is recommended that HV keys should be segregated from LV keys and safely stored in accordance with the applicable Health and Safety site assessment and site risk assessment. Access to HV keys should only be accessible by HV accredited personnel.

Figure 11: LV and HC access keys stored in the same key safe

Substations

Substations are mainly built on concrete foundation pits, which allow easy cable entry from underneath. However, cable entries are rarely sealed, allowing water to enter the pits and accumulate in the foundations of the substation.

This can potentially compromise the lifetime of the components - such as switchgears - inside the cabin, and/or invalidate their warranties. If such issues are identified it is recommended that water is pumped out and cable entries adequately sealed in order to ensure water tightness and prevent high levels of humidity.

Figure 12: Water in substation foundations

As mentioned above, access to HV substations should be restricted to authorised personnel. Furthermore, the individual switchgear cubicles and switchgear protection devices should be padlocked to further minimize the possibility of an error by an unauthorized person. Over the years, I frequently observed missing locking mechanisms (padlocks) in switchgear cubicles.

Figure 13: Missing locking mechanisms (padlocks) in switchgear cubicles

Weather and ground conditions

Another issue is the weather. The average annual rainfall in the UK is around 1150 mm. Over the past 30 years it has rained around 156 days a year. Most UK PV plants are built on existing farm fields. Even though there is a requirement for the plants to be reseeded and planted, and for drainage to be implemented, it can take more than five years for hedgerows and grass to grow. This leaves the ground wet and waterlogged after the completion of construction. Even where drainage works have been completed according to design studies, I have often found required drainage levels insufficient such that standing water accumulates on the plant's ground. This can lead to many challenges including access, corrosion and other damage.

Figure 14: Waterlogged area in a PV plant

Access tracks can also be affected by bad weather and poor construction, making the entrance to the site challenging for vehicles and personnel. This can affect the response times of an O&M team and potentially represent a hazard. Levelling and compacting works should always be undertaken to restore access tracks, ensuring uninterrupted access to the plant.

Figure 15: Damaged access tracks

Grown vegetation, weeds and grass present underneath the solar modules can cause problems on a site: Weeds can potentially interfere with electrical connections and cabling while grown vegetation can cast shadows on modules. Vegetation management should be carried out as frequently as needed to ensure that the O&M teams can perform their tasks uninterrupted.

Figure 16: Grown vegetation around a substation

Conclusions

The list of problems I have observed over the years is long. Over the past 5 years I composed a list with more than 170 key issues which are used in the punch list reports we provide to our clients. These problems can often be traced backed to the construction phase of a PV plant, often demonstrating use of cheap components, bad practises and poor workmanship.

O&M contractors and asset managers are rarely on-site, and when they are, they are typically attending to deal with specific issues and perform corrective maintenance. Hence, small issues can build up over time. Experience shows that remote monitoring is insufficient. We would suggest that owners attend their plants on a more regular basis or pass this responsibility to their O&M teams and asset managers more formally, such that plants are regularly inspected, and small issues do not build up - a regular program of visual inspection, combined with other tests such as I-V curve testing and thermography is recommended, along with comprehensive end of warranty inspections.

If you would like to discuss any of the findings highlighted in this paper, or would like assistance at any stage of your project, from construction and acceptance period site visits, detailed End of Warranty inspections, thermography, string and IV curve testing, please get in touch.