Identification of Technical Risks in the PV Value Chain and Quantification of the Economic Impact on the Business Model

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Summary

Historical performance data for PV systems on which to base technical risks assessments and investment decisions are difficult to be accessed by all market players, such as investors, PV plant owners, EPC contractors, etc. Reasons for this difficulty are to be found in the short time that most PV systems have been operational (GWs cumulative installations in many countries were only reached after 2010) and a tendency among system operators and component manufacturers to keep available performance data as confidential. In addition, detailed performance data are in most cases not available for PV plants of low capacity (e.g. residential-commercial market segments up to 250 kWp) as the cost of monitoring is still perceived as an added cost. Finally, although description of failure and corrective measures is common practice in the field of operation and maintenance (at least in paper form), this is not often carried out with the sufficient level of details to derive meaningful statistical analysis due to missing cost information and lack of a common approach in the assignment of failures to a specific category. For the PV industry to reach mature market level, a better understanding of technical risks, risk management practices and the related economic impact is thus essential to ensure investor's confidence.

Purpose of the work

The Solar Bankability project is an EU-funded project under the Horizon 2020 Work Programme. The project aims to establish a common practice for professional risk assessment, which will serve to reduce the risks associated with investments in PV projects. One of the objectives of Solar Bankability is to improve the current understanding of several key aspects of risk management during the project lifecycle, from identification of technical risks and their economic impact, to the process of mitigating and allocating those risks among project parties, to transferring those risks through insurance, warranties, preventive maintenance, etc. To achieve this, in Solar Bankability we have started building upon existing studies and collecting available statistical data of failures with the aim to i) suggest a guideline for the categorisation of failure, ii) introduce a framework for the calculation of uncertainties in project planning and how this is linked to financial figures, and iii) develop a methodology for the assessment of the economic impact of failures occurring during operation but which might have originated in previous phases.

Scientific innovation and relevance

In the Solar Bankability project, the risk analysis has the aim to assess the economic impact of technical risks and how this can influence various business models and the LCOE. This paper presents a first attempt to implement cost based Failure Modes and Effects Analysis (FMEA) to the PV sector to define a methodology for the estimation of economic losses due to planning failures, system downtime and substitution/repair of components. The methodology is based on statistical analysis and can be applied to a single PV plant or to a large portfolio of PV plants in the same market segment.

Results :

The method to derive cost priority numbers (CPN) for all PV components and phases of the PV values chain has been developed and applied to the collected failure data. The aim was to prioritize the technical risks by means of CPN ranking and the associated economic impact. The quality of the analysis depends on the amount of failure data available and on the assumptions taken for the calculation of a cost priority number. The overall results can be linked to the cost of periodic and corrective maintenance and form the basis to estimate the impact of various risk scenarios in different business models.

Explanatory pages

Preliminary results and conclusions

The typical approach in risk analysis in technical projects is to apply a classic Failure Modes and Effects Analysis (FMEA) where the various risks, belonging to a certain phase and component, can be prioritized through their Risk Priority Number (RPN). In the FMEA, each identified risk is evaluated for its severity (S), occurrence (O) and detectability (D); numbers are used to score each of these evaluation parameters. The RPN is then obtained by multiplying these three factors with the following formula: RPN = S x O x D.

The classic FMEA with RPNs, although important, is incomplete and needs to be enhanced to include a method to assess the cost impact of each risk. A classic FMEA was thus deemed as not adequate as the technical risk analysis needs to provide a framework for the calculation of the economic impact. Many articles are available for cost priority FMEA applied to other fields with a special coefficient called CPN (cost priority number) corresponding to RPN (risk priority number) for the classic FMEA. Unfortunately, no analysis has been found in the literature for photovoltaic plants. The literature is mainly related to automotive or wind turbine market.

In the project we therefore aimed to implement a cost-based FMEA by introducing a Cost Priority Number (CPN) which would include cost consideration directly in the risk assessment. To do so, it is important to understand what the needs are from a Levelized Cost of Electricity (LCOE) point of view and from the business model analysis point of view. A CPNs ranking prioritizes risks which have a higher economic impact. However, it might not be applicable to each type of risk.

Technical risks identified before the operational phase (Testing / Planning / Transportation & Installation) can be defined as Year 0 risks in a business model if they have an impact on the business model since the beginning of operation. Other technical risks can be defined as root cause of failures occurring during operational phase. For these risks is important to understand how the variability and associated uncertainty is calculated and how the values are distributed in terms of probability. These aspects are essential for the calculation of exceedance probability (see Figure 1).

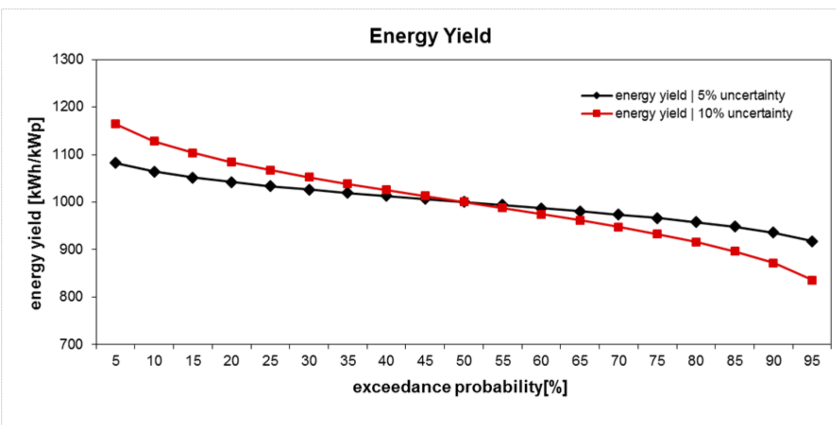

Figure 1: Exceedance probability for energy yield assuming different uncertainties calculated with a normal probability distribution function

For the calculation of the economic impact of risks, which are likely to occur during the implementation phase, namely during operation and maintenance, the Occurrence and Severity were calculated following a well-defined procedure. The methodology is designed to allow for generalization and flexibility in order to maximise the use of the methodology and to not constrain the results to the analysis carried out in the project. The severity, S, is calculated as the total plant(s) production over one year in absence of failures, the occurrence, O, is calculated based on the downtime of a specific failure normalised over the number of components and the productive hours, and the calculation of downtime costs as missing production / savings $C_{down}=L\times(FIT+PPA+RCE)$, whereas

L	Production losses due to down time	PPA	Power Purchasing Agreement
FIT	Feed-In Tariff	RCE	Retail Cost of Electricity

For the calculation of the costs due to downtime, it is in fact important to consider the missing income of feed in tariffs, the missing income from PPA, and/or the missing savings generated by PV plants installed on roofs/facades.

The costs related to fixing the failure results from the sum of the costs of repair/substitution, costs of detection, costs of staff, costs of transport and cost of labour.

$C_{fix}=(C_{det}+C_{rep/sub}+C_{transp})\cdot n_{fail}+C_{lab}\cdot t_{fix}\cdot n_{fail}$

C_{down}	Downtime costs as missing production	C_{transp}	Costs of transport
C_{fix}	Costs related to fixing the failure	C_{lab}	Cost of labour
C_{det}	Costs of detection	t_{fix}	Time to fix the failure
$C_{rep/sub}$	Costs of repair/substitution	n_{fail}	Number of failures

The sum of C_{fix} for various components is then equal to the cost of monitoring/detection and corrective maintenance. Preventive maintenance is not included in this cost as it is carried out periodically, but its impact can be assessed using the methodology as it reduces the detection time.

The calculation of the Cost Priority Number is then given by $CPN=C_{down}+C_{fix}$.

The division into various categories allows for the calculation of CPNs for very generic cases or to plant specific figures depending on the type of input data available (specific plant related figures or statistical analysis of failures).

The analysis is based on the described CPN method, the collected failure data and the defined downtime costs and fixing costs for each failure. Thus all developed results are strongly depending on the database and the defined conditions.

The first look is into the total quantity of module failures (see Figure 2). The ranking of the risks is based on the CPN, which describes the frequency and the economic impact of the specific failure. The dominant factor here is the cost of substitution, since the repairing of a defect module is only possible in particular cases, e.g. cleaning the modules, correcting potential induced degradation or replacing defect bypass diodes. And even then the claim of warranty might expire and the substitution is preferable.

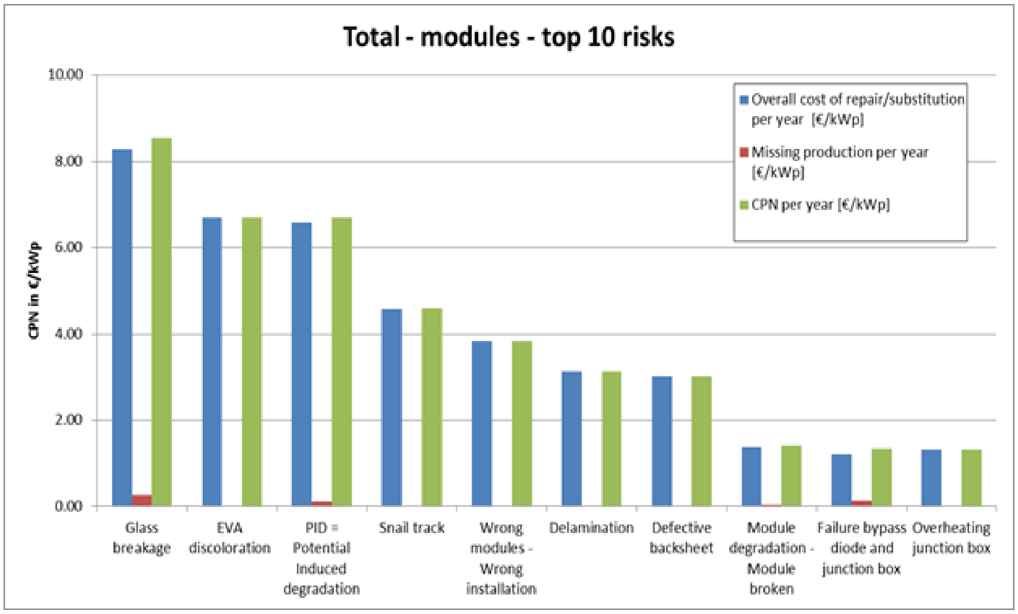

Figure 2: Overall, the common failures like glass breakage, EVA discoloration or defective backsheets bear a higher level of economic risk.

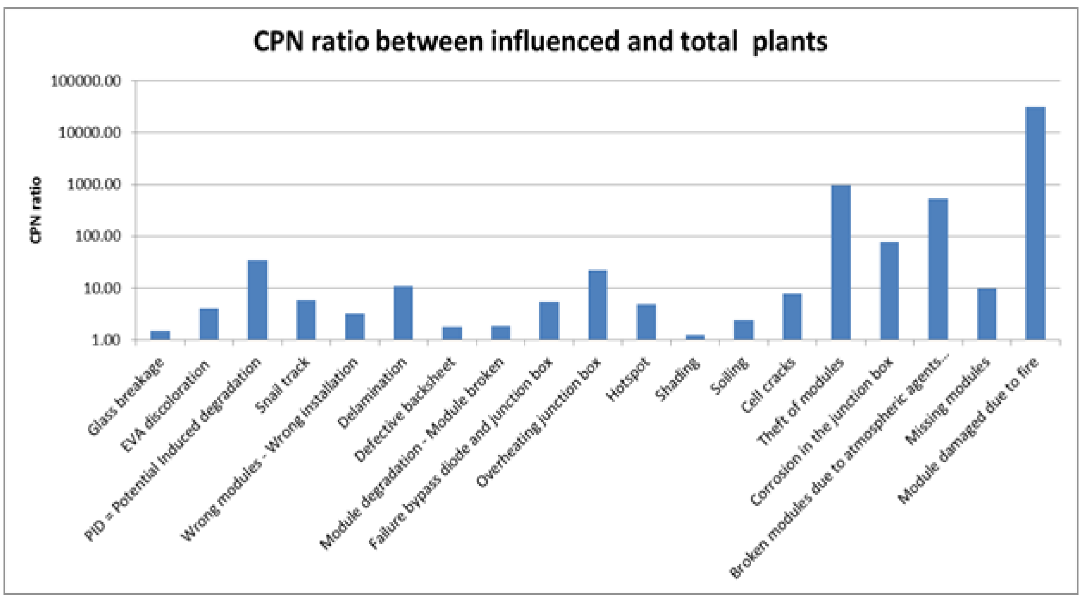

Figure 3: CPN ratio between influenced and total plants

Looking at the CPN ratio between the influenced and total plants (see Figure 3), it can be stated that if one of the failures is detected on a specific plant, the risk for more affected components by the same failure increases by a significant multiplier. That can be observed for product failures, e.g. potential induced degradation, delamination and failures with the junction box, or external influences and the plant, e. g. theft, fire or hail.