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Integrating Component Failures for Performance Uncertainty in Solar Photoltatic System Cost Modeling

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Overview

The purpose of this work is to demonstrate the effects of photovoltaic (PV) system reliability on lifetime system costs. Using a modified photovoltaics performance and reliability model, several scenarios are developed to simulate faults and component failure on the overall PV system's lifetime energy production, and lifetime costs. Typically, techno-economic studies for PV quantify system performance challenges primarily due to solar resource variability and model uncertainty. However the work presented here goes one step further and utilizes a PV array performance model with stochastic realizations of component level failures, which can provide a more accurate representation how PV systems operate in the field. With this level of system detail, performance and costs are presented in a probabilistic manner which is necessary for assessing project risk in the project specification and design phases, as well as during normal lifetime operations. To demonstrate this capability, a representative 250 kilowatt (kW) fixed ground-mount system is simulated to show how different maintenance scenarios impact energy production and levelized energy costs. These costs may increase by 50 to 100% over the lifetime of a technology when relatively simple operational maintenance and new procedures may have alleviated these cost fluctuations. For context, not preparing for an outage of an inverter, modules or Direct Current (DC) combiner boxes may increase operations and maintenance (O&M) costs for a coupled PV array running in series by $0.03 per kilowatt-hour (kWh). Thus, using a prescribed maintenance schedule, PV costs could be reduced over the life of the system by a substantial amount. Gathering information from manufacturers can further refine the results of a reliability-focused PV performance model to help bracket levelized cost of energy (LCOE) estimates and plan for component repair and replacement.

Methods

Sandia National Laboratories (SNL) developed an analytical tool for evaluating reliability-centric impacts to performance that can be used to compare against different PV technologies and operational scenarios. This tool, The Photovoltaic Reliability and Performance Model (PV-RPM) improves the techno-economic analysis by calculating the effects of component faults and failures on the overall systems' Levelized Cost of Energy (LCOE) with confidence intervals included as a result of applying a probabilistic framework. A substantial amount of effort was given to its development by Miller et al. (2011, 2012) and Granata et al. (2011). Similar systems analyses combining component performance and LCOE calculations helped lay additional energy systems topology in the performance-to-cost include Kobos et al. (2006) and Roach et al. (2014).

The topology of the model builds from external user inputs, solar insolation calculations based on a weather module, Weibull failure distributions for select components that result in various scenarios of AC kWh and LCOE model calculations. With this framework, a multitude of financial, engineering and location-specific scenarios can be developed to assess the relative influence of the factors. The generally referred to 'reliability module' incorporates the Weibull failure distributions and their effects on the modules, DC combiners, the inverter, and the LCOE calculations where additional O&M costs account for recognizing, addressing and replacing the failed components.

Results

To model PV module failures and inverter failure, the analysis modeled Weibull functions and their corresponding Probability Density functions by varying the scale and shape of the Weibull functions. Figure 1 illustrates the initial results of several representative scenarios with increasingly higher failure rates across select system components. Table 1 describes the illustrative failure scenarios for the number of Inverters, DC combiner box and Module failures across the system's 20 year engineering lifetime.

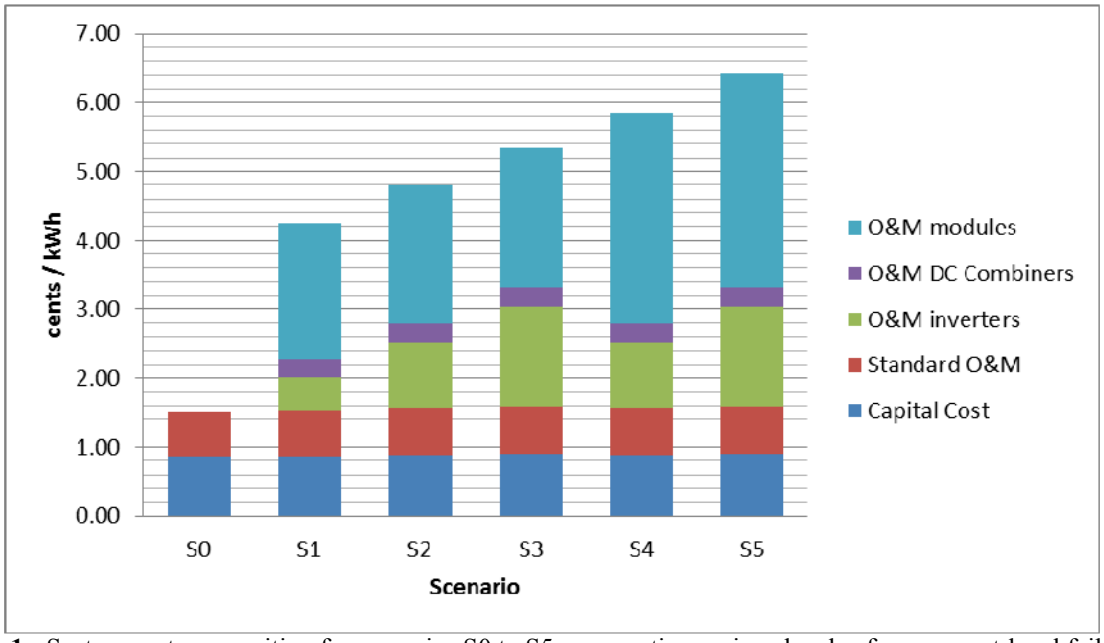

Figure 1: System cost composition for scenarios S0 to S5 representing various levels of component-level failure rates.

Table 1: PV-RPM component failure scenarios across the system's 20 year performance lifetime.

Scenario	**S0**	**S1**	**S2**	**S3**	**S4**	**S5**
Number of failures per component [Inverters, DC combiners, Modules]	[0, 0, 0]	[2, 20, 243]	[4, 20, 243]	[6, 20, 243]	[4, 20, 307]	[6, 20, 307]

Conclusions

The PV-RPM work has a well-defined core of brining performance data into the calculations for select costs across a PV system. The strength in this modeling approach is how carefully and systematically the effects of performance at the component level affect the overall system's output and subsequent LCOE. The existing PV-RPM work is well situated to incorporate and combine the latest financial aspects with the reliability and availability analyses. With these analyses comes an opportunity to provide a useful tool to the O&M service provider community and therefore other stakeholders such as financial and insurance groups. Additionally, this work can serve as the guiding basis to understand the latest needs on system performance based metrics and reporting to utilize this information when developing the system's costs including other renewables, carbon capture and storage systems and other salient energy technology performance and cost modeling.

References

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