Mechanical Engineering Master's Defense

Degradation Linearity Determination And Temperature of Photovoltaic Modules in the Field

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abstract

Photovoltaic modules degrade in the field due to many factors which include environmental factors such as irradiance, temperature and soil. This thesis aims to answer two questions: 1. Do photovoltaic modules degrade linearly or not? 2. Do soiled modules operate at lower temperatures than clean modules? Answers to these questions are provided in part 1 and part 2 of this thesis respectively.

Part 1: Analysis of power degradation of PV plants: The electricity output from PV power plants degrades every year. A system is said to be working till its 80% of maximum output. Generally, a system's life is considered to last for 20-25 years and rate of degradation is commonly assumed as 1% per year. However, PV systems perform differently in different climates. In this thesis, PV systems from hot and dry climate are evaluated. PV degradation can be found out using Performance Ratio (PR), Performance Index (PI) and raw kWh output. The rate of degradation is important to calculate LCOE (Levelized cost of electricity) which is an important factor in financial calculations of a PV system. The rate of degradation is considered linear for simplicity of calculations. However, it is crucial to find a proof of that. In this thesis, statistical methods are used to check whether systems in Arizona are degrading linearly or not. Time series modeling such as Winters' method and ARIMA are used to model the data. Winters' method and Seasonal ARIMA consider the seasonality component and perform very well for small data sets of about 10 years. Output from both methods is almost equal. The difference in results between the two methods is due to difference between assigned smoothing weights of moving averages and auto-regression. Rate of degradation is found out as linear for all the evaluated systems.

Part 2: Temperature analysis of clean and soiled modules: Soiling has been an issue for PV power plants located in hot and dry climatic deserts such as Arizona. A publication from IIT Bombay stated that a soiled cell is hotter than a clean cell. The paper was based on observations in a polluted city Mumbai. In this paper, an analysis is carried out on a soiling station located in Mesa, Arizona. The soiling station consists of 10 different c-Si coupons with tilt angles varying from 0° to 45° with the difference of 5°. These coupons are cut in half, one is cleaned periodically and the other is remained soiled naturally. The analysis involves data worth for 19 months. A prolonged period of dry weather called dry spell causes more soiling density. 6 dry spells in different seasons within 19 months were analyzed. The temperature difference between a clean module and a soiled module (ΔT) is compared with the soiling loss factor (SLF). On continuous deposition of soil, the SLF decreases but the ΔT varies with seasons. An overall conclusion is made that a clean cell is hotter in winter and fall; and it is cooler in summer and spring. This effect could be due to influence of angle of incidence and ambient temperature.

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