Hungarian University of Agriculture and Life Sciences Szent István Campus

Abstract

Title of thesis: Examination of The Impact of Environmental Factors on Photovoltaic Power.

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As global energy needs rise alongside concerns over environmental sustainability, photovoltaic (PV) technology emerges as a key solution to reduce reliance on fossil fuels. Solar energy is a renewable and clean energy source, it is harnessed by PV systems to generate electricity, with the flexibility to be used for a wide range of applications, from small residential rooftops to huge utility-scale farms.PV performance is influenced heavily by several environmental factors such as particulate matter, wind, shading, and temperature, all of which can limit energy generation efficiency. This thesis investigates these environmental impacts using field experiments to simulate real-world conditions including dust accumulation, smoke exposure, shading effects, and wind interaction.

The study was conducted at the MATE Environmental Engineering Laboratory, employing PV panels connected to sensors for global radiation, temperature, particulate matter, wind speed, and wind direction. Particle matter impact was simulated using smoke bombs released under controlled conditions to simulate particulate deposition on PV panels. It is demonstrated that airborne particulate, including PM10 due to smoke experiments, reduces PV

panel efficiency both during particle release and after particle deposition as dust. Both the sedimented dust itself and the barrier it forms to light obstruct sunlight and reduce energy production until the panel surfaces upon which this dust has settled are cleaned. This reminds us of the inertial importance of overhauling regularly particularly where there is a lot of dust or pollution or even dust storms to maintain the PV efficiency.

To understand the key parameters that will make the original design feasible, shading experiments were conducted to assess the sensitivity of PV panels to partial obstructions. Results indicated that even minimal shading using liners covering varying portions of the panel surface from half coverage to small patches significantly lowers efficiency. Significantly, small obstructions have the same effect on total performance as large coverage, highlighting the importance of avoiding shaded areas for PV installations. Serial connection of PV cells exacerbates this phenomenon that a single shaded cell will cause the current flow of the entire panel, and the necessity for careful placement and possibly using microinverters or optimizers, enabling panels to work independently.

The effect of wind on PV systems comes with a dual face. Although the airflow keeps the panels relatively cool and more effective, it also brings airborne dust that might fall onto the panels, decreasing light penetration. In experiments, it was discovered that wind direction had effects on particulate deposition on the PV panels and that particular wind directions drove more dust onto those PV panels resulting in lower PV voltage. Consistent with the need for strategic positioning to balance cooling benefits with potential dust accumulation, this finding corroborates the need for strategic positioning to balance cooling benefits with potential dust accumulation.

Results from this research show that environmental factors can have dramatic impact on PV system performance decreased by shading and particulate matter. To achieve maximum PV energy yield, PV systems need to be cleaned periodically, have protection through innovative coatings, and be installed in locations that ensure modest shading and limited dust exposure. These findings provide useful insight for PV system design and operation in regions with difficult environmental conditions to enable the more ubiquitous adoption of solar energy as a dependable and sustainable source of power.