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Research Article

Effect of Industrial Dust Deposition on Photovoltaic Module Performance: Experimental Measurements in the Tropical Region

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Dust particle accumulation affects outdoor photovoltaic module transmittance of solar cell glazing and thus leads to significant degradation of conversion efficiency owing to lower irradiance reaching the surface. In this study, the sensitivity of the polycrystalline silicon photovoltaic module towards industrial dust deposition was experimentally investigated under the tropical climatic condition of Arusha, Tanzania. Dust involved in the study came from fertilizer, gypsum, aggregate crusher, and coal mine industries. The experimental measurements were outdoor conducted under 720 W/m^2, 800 W/m^2, and 900 W/m^2 solar irradiances. Results indicated that dust accumulation on the polycrystalline silicon photovoltaic module negatively affected output power as well as short-circuit current, however having no significant impact on open-circuit voltage. Maximum module efficiency loss was observed to be 64%, 42%, 30%, and 29% for coal, aggregate, gypsum, and organic fertilizer dust, respectively; hence, coal dust was the most affecting dust among the four. It was also demonstrated that PV module performance deteriorated with temperature rise owing to heat dissipation caused by dust accumulation.

1. Introduction

Global climate change, energy security, and potential exhaustion of fossil fuel reserves have attracted renewable energy technology development [1, 2]. Approximately 80% of energy consumption in the world is from fossil fuels which significantly contributed to climate change [3]. Application of renewable energy technology is valuable due to less impact on environmental degradation as well as the unlimited resource availability [4]. Away from being sustainable, solar energy symbolizes the most favorable renewable energy resources [5]. Solar energy harvesting through the use of photovoltaic (PV) systems for the production of electricity is well thought out as one of the potential markets in the field of renewable energy [6, 7]. Electricity production through the conversion of solar radiation into electricity materializes as a result of photovoltaic effect [8–10]. Energy conversion through the use of PV technologies does not cause serious environmental challenges as compared to conventional power generation sources, such as fossil fuels [11]. The present conversion efficiency of PV systems is approximated at different efficiencies ranging between 7 and 40% [12, 13]. PV system operations encompass features such as module technology, battery type, and converter topology. Despite these features, the PV system is exposed to environmental agents such as aging, radiation, shading, temperature variations, wind, and dust accumulation [14–16]. Climate change contributes to sunlight availability variation causing rises in air temperature, which may always affect performance efficiency of the PV module. Solar tracking technology has emerged to assist PV systems in capturing maximum solar irradiance thus an increase of power output [17]. Dust is among the factors that affect the performance efficiency of PV module worldwide output [18–20]. The smallest particle size of less than 500 μm is termed as dust [21, 22]. The morphological structure, composition, and deposition of dust always depend on location characteristics [23]. Reduction in PV module performance highly depends on particle size and surface density of dust deposited over the modules [24]. Deposition of dust on a panel influences the solar cell