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Assessment of effect of haze on photovoltaic systems in Malaysia due to open burning in Sumatra

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Abstract: In recent years, the strategic goals of many countries have included the achievement of high photovoltaic (PV) integration in electrical grids. Therefore, many governments have introduced incentive-based policies in an effort to encourage the private sector to invest in PV-related projects. However, these kinds of projects require a positive net present value (NPV) in order to be sponsored by non-governmental organisations. In this study, the authors investigate the impact of haze on PV systems in Malaysia due to open burning in Sumatra. As a developing country, Malaysia is aiming to increase the installation of renewable-energy (RE) sources, and thus it has implemented a feed-in tariff (FiT) mechanism. As the efficiency of PV cells increases and the cost/Wp decreases with time, the expected NPV, return-on-investment and payback period for PV systems installed in 2015 is expected to be significantly reduced. The FiT rate in Malaysia is significantly higher and the purchase agreement is longer compared with many similar countries; these make Malaysia a preferred choice for PV system investments. However, environmental disturbances such as haze have a negative impact on the yield of PV systems. During the months of September to October 2015, the transboundary haze episode in Kuala Lumpur reduced the power produced from PV systems by 17.8%. This study shows the impact of haze on PV systems, and analyses the effect of haze on the Malaysian RE action plan. This study proposes a method to estimate the reduction in power yield during the haze.

1 Introduction

The increased demand for power that has to be transferred over long distances as well as continual load growth make the integration of distribution energy resources (DERs) an effective and fast solution [1, 2]. DER features include: shortened electrical and physical distances between loads and generators, improved reactive power to enhance the grid voltage profile and power stability, the removal of bottlenecks from distribution and transmission lines, reduced transmission and distribution losses, improved utilisation of waste heat, extending the lifetimes of existing transmission lines and large power-generation plants, and minimising the carbon emission levels [1–3]. Photovoltaic (PV) sources are considered among the more attractive DERs because of advantages such as availability, zero carbon dioxide emission, and low running and maintenance cost [4]. Moreover, renewable-energy sources (RESs) reduce the energy dependence of nations by reducing the energy and fuel import requirements. These features have encouraged many governments to set ambitious goals for the supply of significant portions of their electrical grid from renewable energy sources (80% in Germany by 2050 [5]. Therefore, they have introduced a variety of rules and regulations to supply electrical grids from RESs. These rules include feed-in tariffs (FiTs), subsidies, and tax incentives [5, 6]. In 2011, Malaysia introduced FiTs [7], and the government encourages renewable-energy (RE) projects in order to supplement fossil-fuel electricity generation. Malaysia's RE targets is to realise generation of 2080 MW, which accounts for only 10% of the total generation capacity, by 2020. However, it will be difficult to achieve this target as in 2014, the RE capacity was around 234 MW [7]. This indicates that there is significant room for RE expansion. The FiT scheme is funded by a 1.6% levy on the electricity bill, which translates into approximately RM650M/year based on various estimates [8]. This would support ∼900–1000 MW of total RE capacity for the next 21 years [8].

The FiTs are among the most popular mechanisms employed to encourage an increase in the growth of RE. The FiT mechanism allows electricity produced from an indigenous RES to be sold to authorised power utility companies at a fixed premium price for a specific duration [9]. The basic rate paid in Malaysia is RM 1.2/kWh (0.286 $), with an additional bonus paid for systems that use locally manufactured PVs, and which are installed in buildings, which can increase the FiT to RM 1.71/kWh (0.41 $) [10].

Local weather events such as fog, rain, dust and haze can significantly affect the electricity generated by PV panels. Previous works have focused on the effects of abnormal weather effects on PV panel production [11–15]. The performance of PV systems in dusty weather was reported in [11]. The study shown that PV power generation decreased by 15% in October, November, and December during the dust storm, and during the automated PV cleaning, the system was shut down. From the performance rations, it is noted that as temperature increases, the performance ratio decreased. In [12, 13], the authors studied the effects of different dust types and specifications on PV system performance. The results indicated that the maximum losses of the output power due to the accumulation of dust on the fixed PV panels are about 23.1% for a 34-day period of accumulation, while the maximum losses of the output power for a PV panel with a two-axis tracking system are about 8.5% for the same period of accumulation.

In [14], it was found that haze, which is a typical climatic condition in numerous parts of the world, affects the performance ratios and short-circuit currents of PV systems. A detailed analysis of the haze event in Singapore in mid-June 2013 showed that a red shift of the solar spectrum arriving in the module plane was the main cause of variations in the performance ratio in the PV generated short-circuit currents. Therefore, PV systems with different semiconductor band gaps were affected in different ways. It was reported that the a-Si system performance ratio fell by 7% because it depends on shorter wavelength light (<650 nm). Conversely, because the multi-Si module has the highest SR at n near-infrared wavelengths, the performance ratio of the system improved by as much as 6%.

In [16], the authors found that during haze, the reduction in the PV system yield was between 15 and 25%. In [17], a 1-kWp PV