Characterizing solar resource potential for photovoltaic applications in Kenya with focus on variability using Meteosat satellite data

(Meteosat衛星を用いたケニアにおける太陽光発電ポテンシャル量の変動性の特徴)

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Abstract

To address the rising, global, electricity demand, while maintaining a clean environment, renewable energy (RE) resources offers the best solution. Solar photovoltaic (PV) is one of the most suitable RE option for Kenya, owing to the favorable geographical location, as well as the global reduction in PV installation costs seen in the recent past. Solar resource assessment studies, providing information on both the available amount and the variability of solar radiation in a given location, are useful in promoting PV deployment. However, unfortunately, previous studies did not adequately address the variability in Kenya. Therefore, the impetus of this study is to characterize solar radiation in Kenya with a focus on variability. For this purpose, a long term (19 years,1995-2013) Meteosat satellite dataset of hourly global horizontal irradiance (GHI) and direct normal irradiance (DNI) was utilized.

A validation of GHI using reference ground measurement revealed moderate correlation of 0.5 and mean bias error (MBE) of 25kWh/m^2/day for GHI while an overestimation of satellite-derived solar radiation was found in five out of the six ground measurement stations. Firstly, the available amount of GHI and DNI were analyzed. Most parts of the country records GHI potential above 6kWh/m^2/day. DNI potential is lower, with most parts recording below 6kWh/m^2/day. This limits deployment of solar concentrating PV systems in Kenya, since they perform optimally with DNI at 6kWh/m^2/day and above. Secondly, coefficient of variability (COV) was used for the analysis of temporal and spatial variability of GHI and DNI. For spatial variability, the study area was organized into 7×7 (1225km^2) and 15×15 (5625km^2) grid matrices, to see how solar radiation within these areas differs. Low spatial COV for GHI (0-6%) was recorded in many parts of the country for areas within 1225km^2 while DNI indicated higher spatial COV (2-24%). Therefore, within these areas, measurement of GHI in most locations can be representative of others. As expected, when the area was increased to 5625km^2, variations between locations increased significantly in most parts. Temporal variability analysis was done at interannual timescales. GHI interannual variability is significantly low (COV is 2-4%) in most parts of the country with an exception of the mountainous regions because of the topographic effect on cloud frequency. This indicates that one year ground-based GHI measurement in regions with low COV can be used to represent consequent years. On the flip side, high interannual variability of DNI (COV is 3-30%) was recorded. Thirdly, daily timescale variability analysis was done for highly populated 22 locations in Kenya. The daily differences lying below 5th and above 95th percentiles are defined as ramp down and ramp up events, respectively. It is found that the eastern region has quite a dynamic seasonal variation of ramp events frequency. In the western region, stable and moderate frequency was recorded while the coast region is characterized with a high frequency of ramp events throughout the year. Cloud images obtained from MODIS suggested that stratus cloud has a great impact on ramp events since the stratus clouds have a wide horizontal extent and therefore cloudiness change occurs very slowly affecting solar PV variation in daily timescale. Further analysis revealed that 7 years of GHI and DNI Measurement in Kenya would be enough to characterize climatology. This helps in reducing the cost and the length of measurement. Results obtained in this study illustrate the nature of available amount and variability of solar radiation over Kenya providing readers a quick visual aid and guide on how long and to what extent ground-based measurements should be taken for a particular application. Further, daily variability results here offers guiding information on sizing of storage systems which can dampen sudden changes in solar PV output.

Key words: Renewable energy, solar PV, Variability, Global horizontal irradiance (GHI), Direct normal irradiance (DNI).