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Estimating the performance of wind-PV hybrid mini-grid systems for rural electrification in Africa

Thomas Huld (1), Irene Pinedo Pascua (1), Mario Marcello Miglietta (2), and Fabio Monforti-Ferrario (1)

(1) European Commission Joint Research Centre, Renewables and Energy Efficiency Unit, Ispra, Italy, (2) Institute of Atmospheric Sciences and Climate, National Research Council (ISAC-CNR), Lecce, Italy

Most rural populations in sub-Saharan Africa do not have access to electricity[1]. Extension of the national electricity grid in rural areas is in many countries slow and uneven. For this reason there is an increasing interest in local mini-grids to improve access to electricity for remote populations. Photovoltaic (PV) powered mini-grid systems with battery storage will often perform at lower cost than grid extension or diesel-powered mini-grids[2]. One disadvantage of PV-powered mini-grids is the lack of power at night, leading to increased battery storage size and more cycling of batteries. Wind generators, not being strongly influenced by daily cycles, could in may complement PV to achieve a better reliability of the hybrid systems. .

Hybrid mini-grids have been studied by a number of authors, see for instance[3]. However, such studies have focused on one or a few sites where good time series of wind and/or solar data are available. With the availability of solar radiation and wind data over large geographical areas it becomes feasible to study hybrid PV-wind systems for entire regions. Here we propose a calculation method to study and optimize PV-wind mini-grid systems using geospatial solar and wind data.

For the present study, solar radiation data have been calculated from satellite data by the CM SAF collaboration (www.cmsaf.eu), where several years of hourly solar radiation data (global and direct) are available at a spatial resolution of $\sim$3km[4]. The solar radiation data are combined with models for inclined-plane irradiance and PV performance models to calculate hourly PV energy output[5]. Hourly wind data have been obtained from the ECMWF integrated forecast system (IFS). In the analysed years (2012-2015), the model received relatively minor modifications and the output was available with the same grid spacing of 0.125°. A model for the turbine power is applied for each hour taking into account air density and the published wind power curve of the chosen turbine. The PV and wind power time series are then combined with data on battery performance and electricity consumption to calculate the performance and optimum configuration of hybrid mini-grid systems for the whole of Africa.

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