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Technical and economic assessment of cleaning protocol for photovoltaic power plants: Case of Algerian Sahara sites

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ABSTRACT

This study is focused on technical and economic analysis of cleaning protocol of Photovoltaic panels in power plants as function of dust density translated into soiling level. Indeed, the accumulation of dusts on PV panels influences the conversion efficiency of PV modules. The design and operating simulation have been carried out with specific computer calculation code "Helioscope". The effects of soiling on these clean power plants have been studied for power capacities of 1 and 5 MW and two types of PV panels' technologies: Cadmium Telluride (CdTe) Thin Films and Monocrystalline Silicon (Mono-Si). By considering databases of environmental dust loads, soiling level of 10 and 15% allows to be close to conditions of two studied locations in Sahara desert of Algeria. The analysis of simulations results for performance index (PR) showed remarkable diminution when PV panels' fields are soiled. For estimating cleaning cost of PV fields, the design and simulations of PV power plants in Algerian Sahara sites of Adrar (1 MW) and Ouargla (5 MW) demonstrated the existence of soiling threshold allowing cleaning profitability which is situated around 7% in term of minimal level. Besides, it has been shown that the PV panel technologies are affecting sensibly this level and then can be decisive in the choice of the type of PV modules to install. Also, the feed in tariff (FIT) is critical on this soiling threshold.

1. Introduction

In order to satisfy the important needs of economic and demographic growth in Africa, renewable energies and particularly solar are increasingly applied (Sanoh et al., 2014). Among strategic and sustainable solutions implemented by public authorities there are incentives programs for renewable energy. For example, Algeria, targets 27% of electricity that will be generated from renewables for 2030 with a total capacity of 22 GW including 13.5 GW that will be done in PV technology. In this example of African country, there is a regulatory framework that allows the generated solar electricity to be sold by private companies to the electricity network distributor at a feed-in tariff (FIT) guaranteed for 20 years at 15 Da (0.123 Euros)/kW h in case of PV plants ground mounted and having capacities exceeding 1 MW (Griffiths, 2013). Several PV power plants will be erected and spread across various regions and many of which will be in the Sahara desert. A major benefit of these areas is an important solar irradiance reaching 2600 kW h/m^2/Year (Nia et al., 2013). However, it should be noted, two major drawbacks which are the high temperature and the soiling of PV panels due to sandy environment of the Sahara which will induce losses in annual energy production (Sarver et al., 2013). In order to diminish the negative effects of soiling on profitability for large scale PV power plants (≥1 MW), the assessment of the cleaning protocol frequency is examined and optimized to be cost effective. The region of North Africa and Middle East Area (MENA) is one of the most promising territories for the development of solar energy due to its exceptional solar irradiation potential (Qoaider and Liqreina, 2015); however, this region is known to be very dusty. The phenomenon of dust deposition from surrounding environment on the glazing of PV panels is a major constraint in the cost of the maintenance and operating (M & O) for solar plants (Lopez-Garcia et al., 2016). The Setting up of an annual plan for cleaning of solar panels must be optimized in term of earned profits. For that reason, a design study of two photovoltaic plants to install in Algerian desert regions is discussed by analyzing the effects of soiling levels on cleaning cycles. A first PV plant is designed and studied in the Adrar region with a capacity of 1 MW according to photovoltaic modules of monocrystalline Silicon (mono-Si) (Lee et al., 2013). Then, a second power plant was implemented in the region of Ouargla with 5 MW capacity; these localities and their irradiance potential are represented in Fig. 1. In PV plant of Ouargla, the module technology

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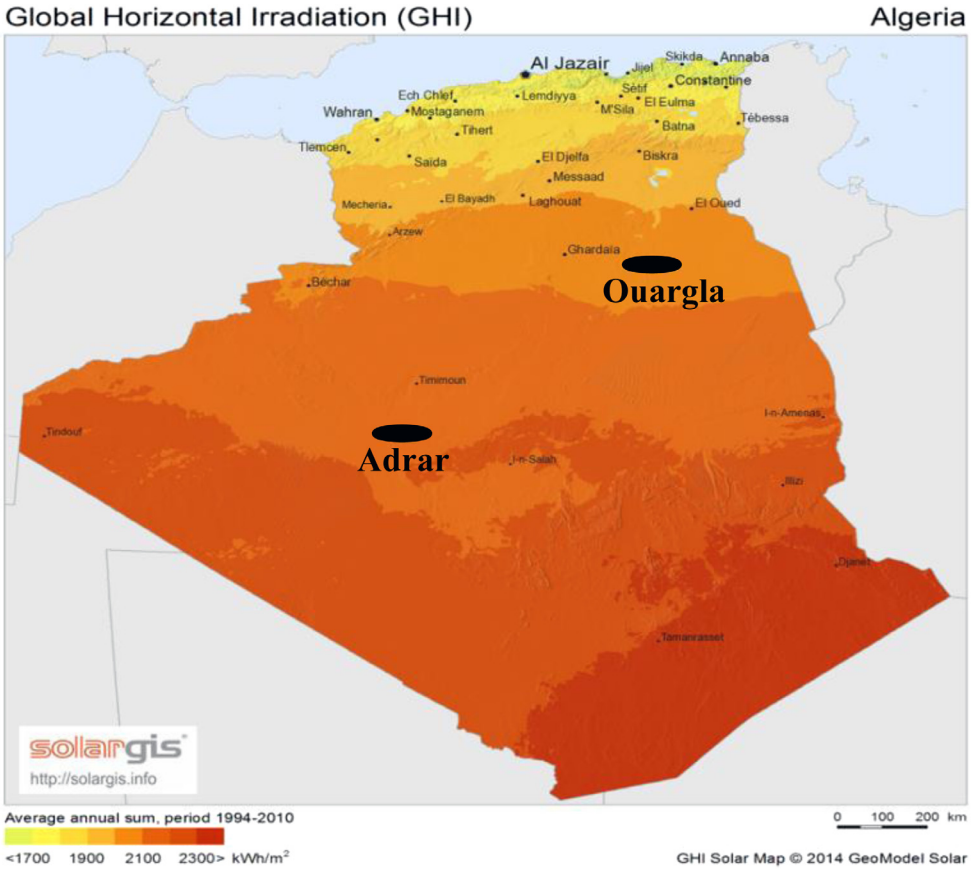

Fig. 1. Algeria global horizontal irradiation (http://solargis.com/products/maps-and-gis-data/free/download/algeria).

has been varied from mono-Si to thin films (CdTe) type (Green, 2011). These studies are conducted to increase performance and profits from these solar plants because of harsh environment in term of water scarcity, high levels of soiling and temperatures.

2. Estimated levels of soiling in Sahara regions and factors affecting cleaning cost of PV plants

2.1. Estimated levels of soiling in Algeria Sahara

To conduct this study, it was necessary to make the state of the art for estimation of the soiling level in these locations for better implementation of this parameter in PV plants design and then to optimize the cleaning frequency and its cost. The soiling is a dust deposition phenomenon from the surrounding atmosphere in a process that gives rise to grain particles deposition of 1–500 μm in diameter (Urrejola et al., 2016). The attachment of the dust particles depends on the humidity level, more this rate is high more the grain of dust sticks to the surface of the glazing of PV modules (Kalogirou et al., 2013). In case of dry weather, as in desert areas, the grain of sand or dust can be removed more easily by wind that deposits them just as easily. Previous studies, have estimated the soiling level in several region of the world (Ghazi et al., 2014). Algeria was classified as a level 4 region for dust concentration in the range of 65–96 $\mu g/m^3$. Also, it was reported that each g/m^2 of dust load conducts to light transmission decrease of about 4.1%, this corresponds to the parameter called soiling level in the computer simulation of PV plant energy production presented in Section 3 (Ghazi et al., 2014; Astitha et al., 2008; Appels et al., 2013; Boyle et al., 2015). However, in case of sand storm this level could be multiplied by 6–7 times (Ghazi et al., 2014), but for a limited period because the grain of sand is easily removed from glazing by winds in dry climate regions. In the simulation study presented in Section 3, soiling levels of 10 and 15% at maximum are considered in order to be close to real conditions. During the period 2003–2010, it was recorded an average level of soiling in Algeria of 75 $\mu g/m^3$ for dust concentration in atmosphere (Ghazi et al., 2014). The review of this parameter in other MENA countries compared, for example to, UK and USA, showed that the soiling in MENA countries is higher. Also, Algeria is at 5th position after Egypt; the 1st position showing the more dusty location is attributed to Sudan, where this parameter is doubled comparatively to Algeria for an average dust concentration in atmosphere at about 150 $\mu g/m^3$.

To confirm this soiling values it have been exploited a simulation tool SKIRON freely available from university of Athens for forecasting of dust loads (Astitha et al., 2008); it gives satellite maps in real time with forecast over several days for studying the evolution of the dust load (mg/m^2); Fig. 2 shows an example of forecasting or real time measurement of Dust loads by SKIRON simulator. From where, it had been noticed that even in the regions of southern Europe (Greece, Italy and Spain) may be affected by these dusty clouds as shown on the map of Fig. 2. This map shows that the northern border of the African Sahara is very exposed to sand storm and soiling, particularly in Algeria. These dust loads conduct to optical losses from 2 to 60% in the transmission of light through the glazing of PV modules and thus in the production of photoelectric energy in these regions (Appels et al., 2013). Where, also the level of rainfall plays a key role in the withdrawal and accumulation of deposited dust (Ghazi et al., 2014). The regions with low rainfall will make them more favorable to the accumula-