Increasing Dust Removal Efficiency Of Electrodynamic Screens Using Frequency Optimization Via COMSOL Multiphysics®

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Abstract

Utility-scale photovoltaic (PV) and concentrated solar power (CSP) generation facilities are located in desert environments throughout the world to take advantage of the high availability of sunlight in these areas. Unfortunately, naturally occurring sandstorms in these deserts often deposit layers of dust on PV panels and CSP mirrors, reducing the amount of sunlight reaching their surfaces and reducing their efficiencies. Current solutions to this problem include robotic equipment or spray cleaning, which are too electricity- and water-intensive, respectively, to be adequately scaled up. The electrodynamic screen (EDS) is a technology being developed to remove the dust off the surfaces of PV panels and CSP mirrors using no water and a minimum of power.

An EDS film consists of a series of parallel electrodes embedded between two thin dielectric layers. A voltage wave is applied across the electrodes resulting in oscillating potentials, generating a wave pattern in the electric field propagating across the EDS surface. This electric field charges dust particles on the film's surface, lifts the particles, and directs their motion off the film, and therefore off the PV panel or CSP mirror on which the EDS is installed. Since deserts across the world have different dust particle sizes and charges, EDS films used at different sites will need to have different designs. Therefore, in order to maximize the dust removal efficiency of an EDS deployed at any given site, a COMSOL® model was created to optimize the voltage wave frequency for any given particle size and charge.

A 2D, cross-sectional model of an EDS with 12 electrodes is created with parameterized values for the voltage wave's frequency and maximum potential. The AC/DC module is then used to conduct an electrostatic, frequency domain study to generate the EDS electric field. Next, the Fluid Flow module's Particle Tracing for Fluid Flow interface is used to model how dust particles interact with gravity, Coulomb force, dielectrophoresis, drag, and particle-particle interactions. At this point, the particle trajectories predicted by the model are compared against particle trajectories experimentally observed using high-speed cameras in order to ensure model validity. Once the model has been validated, the Optimization module is incorporated to determine what optimal frequency results in maximum dust removal efficiency.

The expected results of this work is a COMSOL® model which, for a specific electrode geometry and particle size and charge, can determine the optimal voltage wave frequency for maximum dust removal efficiency. Additional model validation will be used to determine whether the predicted optimal frequency results matches the optimal frequency observed in experimental tests. If successful, this model will be the first step in developing a method for designing EDS samples for best operation at specific geographic sites. Future work expanding the model would help determine the fundamental limits of the technology, allow for the optimization of even more parameters, and further improve the ability to design site-specific EDS samples.

Figures used in the abstract

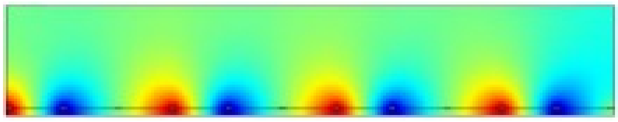

Figure 1 : Electric potential across the surface of an 3-phase EDS film