Computational modeling of a laboratory-scale ESP

David Branken
North-West University

Historically, the environmental legislation in South Africa with respect to emissions limits for listed industrial activities have not been as strict as that in developed countries but have recently been adjusted to correlate more closely with international trends. As a result, a significant reduction in the particulate matter (PM) emissions limits from the current 100 mg/Nm3 to 50 mg/Nm3 (relative to 10% O2) is to be implemented in 2020 [1]. The existing electrostatic precipitators (ESPs) at South African coal-fired power stations were designed for specific coal types, the quality of which have since declined as coal deposits have been exhausted. Consequently, the ESP PM collection efficiencies have also declined such that compliance with the future emissions limits are no longer possible. Although ESPs are gradually being phased out by retrofitting the plants with fabric filter units, upgrading the existing ESPs to improve the PM collection efficiency is a more cost-effective solution in the interim.

To allow cost-effective investigation of possible ESP design and operational changes that could be implemented to improve ESP collection efficiencies, a comprehensive computational ESP model was developed by incorporating the interacting phenomenon of fluid dynamics, particle dynamics and electrostatics using the commercial software STAR-CCM+® and the open source software package OpenFOAM®. The electrostatic equations were solved using OpenFOAM while particle charging and particle dynamics were solved using STAR-CCM+. The Euler-Lagrange approach was used to model the respective gas and particle flow, and turbulence were taken into account using the k-ε turbulence model. The developed computational model was intermittently validated with experimental results available in literature in terms of the electrostatic properties as well as particle collection efficiency, of which some of the results have been presented in the previous CCT conferences.

In this presentation, validation of the model with experimental results obtained using an in-house laboratory-scale ESP are discussed. Operation of the laboratory-scale ESP was simulated using the model for both wire-electrodes and spiked electrodes, and the modeled and experimentally measured V-I relationships and particle collection efficiencies were compared. Good agreement was achieved between the measured and modeled V-I relationships of the wire-electrodes, both under shielding and non-shielding conditions [2]. Consequently, the influence of shielding on the particle collection efficiency predicted with the computational model was also confirmed by the experimental measurement data under varying geometric parameters. Additionally, the experimental results obtained with a spiked electrode also confirmed the validity of the computational model with respect to modeling ESP operation with irregularly-shaped discharge electrodes.