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COLLECTION OF VARIOUS PARTICULATE MATTER USING AN ELECTROSTATIC PRECIPITATOR

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Over the past century, electrostatic precipitators (ESPs) have been widely applied in industry for the capture and separation of particulate matter due to their high collection efficiency and relatively low operational costs [1,2]. The current stage of ESP technology development — including its theoretical foundations, design structure, mathematical modeling approaches, electrical operating principles, power supply systems, gas conditioning techniques, hybrid precipitation technologies, and industrial applications — has been extensively covered in recent ESP conferences [3]. Furthermore, worldwide modernization efforts aimed at enhancing ESP performance have achieved important results in reducing particulate matter (PM) emissions and improving energy efficiency. Studies conducted at large-scale power plants in China [4] have demonstrated that nearly all ESP systems require upgrades to comply with PM2.5 (particulate matter with aerodynamic diameter below 2.5 μm) emission control targets. According to industrial field observations, a key reason for decreased ESP performance is insufficient particle charging at the inlet section, or a combination of such factors.

For ESPs with a 400 mm gas passage gap, the output voltage of a typical three-phase transformer-rectifier (TR) set is approximately 82 kV and the output current reaches around 2.0 A. These values often exceed the operational limits of switch-mode power supplies (SMPS). Our experimental studies carried out at coal-fired boilers rated at 125 MW, 300 MW and 600 MW in China have shown that upgrading conventional single-phase TR systems installed at the ESP inlet substantially improves corona discharge power and particle collection efficiency.

Typically, the specific collection area (SCA) at the inlet of an ESP ranges between 10–20 $m^2/(m^3/s)$ [6]. However, current research data concerning PM2.5 emission behavior remain insufficient. As a result, the key design parameters required for

energy-efficient ESP modernization — including collection surface properties, physical characteristics of particulates, and high-voltage power supply configurations — have not yet been fully optimized.

The hybrid precipitator illustrated in Figure 1 consists of two stages:

1. an electrostatic precipitator (ESP), and
2. a fabric filter (FF).

This hybrid unit is installed in parallel with a full-scale FF system and enables gas flow rate adjustment from 20,000 Nm³/h to 40,000 Nm³/h. The flue gas first passes through the ESP stage and subsequently enters the FF stage. The hybrid precipitator was carefully engineered to ensure uniform gas distribution and to minimize system pressure drop. This configuration has been successfully implemented in coal-fired generators with capacities of up to 600 MW. In addition, the system has been operating efficiently for more than two years at a 30 MW domestic coal-fired thermal power plant.

The distance (gap) between ESP collecting plates is 400 mm, while the unit length and height are 2500 mm and 4200 mm, respectively. Ribbed strike-type discharge electrodes are used for corona generation. Under a maximum volumetric gas flow rate of 40,000 Nm³/h at 110 °C, the internal gas velocity of the ESP reaches 1.15 m/s. The technical specifications of the pilot-scale unit are summarized in Figure 1.

Figure 1. Photograph of the pilot-scale test unit.

When redesigning (resizing) an ESP for the purpose of reducing mass emission concentration, it is not appropriate to use the migration velocity from the previous design as a simplified parameter for the new configuration, since migration velocity is highly dependent on particle size.

Replacing the single-phase TR set at the ESP inlet with a three-phase TR enables an increase in mass collection efficiency from approximately 80–85% to 90–95%..

Literatures

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