Efficient Energy Delivery Condition from Pulse Generation Circuit to Corona Discharge Reactor

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Received April 12, 1999; revised December 7, 1999

The energy transfer efficiency from pulse generation circuit to corona discharge reactor was investigated. To find the optimum energy transfer condition, we varied the value of the pulse-forming capacitor in pulse generation circuit. Maximum energy transfer from pulse generation circuit to corona discharge reactor was achieved when the ratio of the pulse-forming capacitance to the geometric capacitance of the reactor was around 3.0. From the analyses of the voltage and current waveforms, we found that the capacitance of the reactor increases about three times, due to the corona development. This increase is the reason why the maximum energy transfer occurs when the pulse-forming capacitance is three times larger than the initial capacitance of the reactor. The energy consumption for removal of nitric oxide was also minimized at this capacitance ratio.

KEY WORDS: Corona discharge; pulse-forming capacitor; optimum energy transfer.

1. INTRODUCTION

Recently, emphasis on the stringent emission control of SO₂ and NOₓ has led to an interest in efficient technologies for flue gas cleaning. Positive pulsed corona discharge process is an emerging technology capable of simultaneously removing SO₂ and NOₓ from a variety of process gas streams.  

Pulsed corona discharge can be produced by the application of fast-rising narrow high-voltage pulses to nonuniform electrode geometry. It creates high-energy electrons in the range of 5 to 10 eV. The free electrons gain energy from an imposed electric field and during their drift they lose energy through collisions with neutral gas molecules. The collisions of energetic electrons with neutral gas molecules cause the formation of chemically active species to initiate chemical reactions, leading to the removal of gaseous pollutants.

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One of the important problems in this process is to increase the overall energy transfer efficiency from pulse generation circuit to reactor load. To increase the energy transfer efficiency, the pulse generation circuit should be designed so as to consider matching of the pulse generation circuit to the reactor load. The principle of pulse generation is based on charging of the pulse-forming capacitor and discharging to reactor load. Therefore, the pulse-forming capacitor plays a crucial role in the performance of the pulse generation circuit. In principle, the value of the pulse-forming capacitor should be equal to the capacitance of the reactor to deliver all the charge stored to the reactor. As a matter of fact, the capacitance of the reactor during corona development is very different from the initial capacitance before corona onset. Therefore, one should determine the value of the pulse-forming capacitor for maximum energy transfer considering the change of the capacitance of the reactor.

In this study, we investigated the relation between the value of the pulse-forming capacitor and the energy transfer efficiency from the pulse-generation circuit to the reactor load. The experimental results were analyzed in terms of the ratio of the pulse-forming capacitance to the initial capacitance of the reactor to find maximum energy transfer condition. The capacitance change of the reactor during corona development was estimated by analyzing voltage and current waveforms. At the optimum energy transfer condition, the energy consumption for removal of an air pollutant should be minimized. We carried out experiments for the removal of nitric oxide to verify whether the amount of nitric oxide removed per unit energy is proportional to the energy transfer efficiency.

2. EXPERIMENTAL PROCEDURE

The corona discharge reactor used has wire-plate electrode structure, as depicted in Fig. 1. Both the wire and plate were made of stainless steel. Positive high-voltage is applied to the wire and the plate is grounded. The diameter of the wire is 0.8 mm, the height of the plate is 90 mm, and the effective length of the plate is 810 mm. The distance between the two plates is 30 mm and the wires are evenly placed between the two plates at intervals of 15 mm.

Figure 2 shows the spark gap pulse voltage generator used. The pulse-forming capacitor $C_P$ is charged by a negative dc high-voltage power supply (Glassmann High Voltage Inc.). As the voltage on the capacitor reaches the spark-over voltage of the spark gap electrode, the charge stored on the capacitor $C_P$ flows through a stray inductance to charge the reactor electrode structure. When the voltage between the wire and plate exceeds the corona onset value, corona discharge occurs from the wires after statistical