Half-Bridge ZCS resonant inverter 및 Cockroft-Walton회로를 사용한 공기 청정기에 관한 연구

박종웅, 정종진, 정현주, 정종한, 김희제

ESP by using Half-bridge ZCS resonant inverter and Cockroft-Walton circuit

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Abstract - In this study, we propose a small high voltage power supply which use a half-bridge ZCS resonant and Cockroft-Walton circuit, for ESP (Electrostatic Precipitator). This power supply transfers energy from ZCS resonant inverter to step-up transformer and the transformer secondary is applied to the Cockroft-Walton circuit for generating high voltage as discharging source of electrodes. It is highly efficient because its amount of switching losses are reduced by virtue of the current resonant half-bridge inverter, and also due to the small size, low parasitic capacitance in the transformer stage owing to the low number of winding turns of the step up transformer secondary combined with the Cockroft-Walton circuit.

From these results, the best operational condition is obtained at the switching frequency of 9 kHz and the duty ratio of 50 % in this ESP.

KEY WORDS

ESP, pulsed power, switching frequency, duty ratio, corona discharge

1. Introduction

Recently, there are several important environmental problems in the world. One of them is air pollution arising from combustion flue gases produced by thermal power plants, factories and motor vehicles. At the present air filter methods are used as a the treatment of air pollution. Although these processes are effective and reliable, the initial and running costs are very high [1].

ESP and bag-house filters are the most common industrial scale particulate control systems. The state-of-the-art bag-house filters can capture particle well, however the pressure drop of the filter becomes unacceptably high for economical removal of the fine particulars [2].

An electrostatic precipitator is an air pollution control device that removes particles from a flowing gas with electric forces. ESP are used in industry coal-fired electric power plants, and indoors in homes and offices [3].

In this study, we fabricated small high power supply for ESP which uses a half-bridge ZCS resonant inverter and Cockroft-Walton voltage *multiplier*.

Experiments have been carried as a function of the switching frequency and duty ratio to investigate the smoke removing characteristics of ESP.

2. Experimental Method

The purpose of this study is to investigate the smoke removing characteristics. So we introduce dirty gas containing particulate pollutants into test chamber and investigate the smoke removing characteristics by adjust frequency and duty ratio from identical test environment. Fig. 1 shows a schematic diagram of experiment.

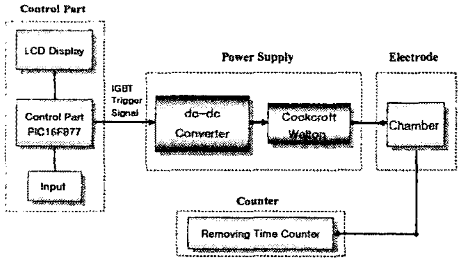

Fig. 1 Schematic diagram of experiment

2.1 The principle of dust collection

Increasing the voltage V beyond a certain threshold (the corona onset voltage) Vc, corona discharge begins to occur on the plate, accompanied by corona glow. These glows represent localized regions of gaseous ionization (partial breakdown), from which monopolar ions of the corona polarity are emitted toward the collecting electrode. These ions move across the interelectrode gap.[4]

2.2 Design

In this study, The ESP is composed of control part, electrodes, power supply, and measuring instrument.

2.2.1 Control part....

Fig. 2 shows a control circuit that is made up a keyboard, LCD (liquid crystal display), PIC one-chip microprocessor (16F877) and the driving circuit to turn on IGBT(Insulated gate bipolar transistor). In this control circuit, pulse repetition rate and duty ratio are controlled

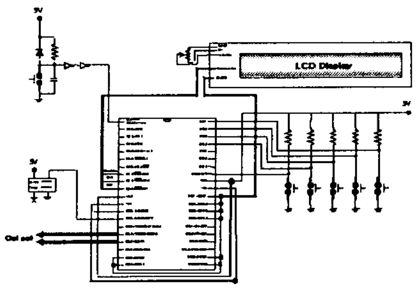

Fig. 2 Schematic diagram of control circuit

2.2.2 Discharge and collecting electrode.

Fig. 3 shows a schematic diagram of discharge electrode and collecting electrode. The type of electrode that is sealed double layers plate-plate devices made of stainless steel. The electrode is punched by triangle hole that is able to form uniform electric field. The size of the electrode is 140mm* 110mm.

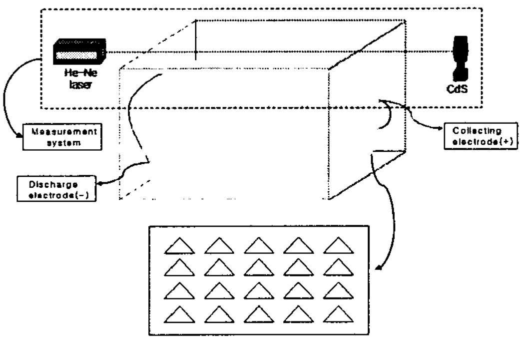

Fig. 3 Discharge and collecting electrodes

2.2.3 Power supply

Fig. 4 shows a schematic diagram of power supply with high voltage dc-dc converter. Our power supply was designed and fabricated to be suitable for the high frequency range and to reduce switching loss and noises. The circuit consists of a high power resonant inverter in half-bridge configuration, a high frequency step-up transformer and a high voltage rectifier using Cockcroft-Walton voltage multiplier. This combination guarantees small parasitic capacitance in the transformer stage, fast dynamic response. In particular, the ZCS series resonant inverter was used to decrease the loss by the tailing current generated on turning off an IGBT (Insulated gate bipolar transistor)

1) Resonant inverter

The ZCS series resonant inverter consists of two IGBTs(S1,S2), a leakage inductor(Llk), blocking capacitor(C3), and charging capacitors (C1,C2).
The output of the ZCS series resonant inverter is

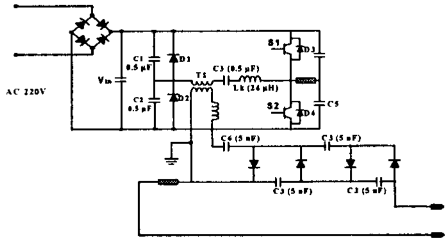

Fig. 4 power supply with high voltage dc-dc converter

where is the operating frequency, C the capacitance of charging capacitor, and Vin the input voltage. According to this formula, it is found that there are two ways to control the power density of the resonant inverter. One is to vary the input voltage Vin at a constant pulse width and frequency, and the other is adjust the switching frequency .

In case of the inverter switches, there are different configurations at any given time; 1) S1 must be closed(on) while S2 open(off), 2) S2 must be open while S1 is close, or 3) two switches may be off.

2) Cockcroft-Walton Voltage Multiplier

A 2 stage Cockcroft-Walton voltage multiplier serves as high voltage generator to carry the corona discharge in the electrode. This multiplier is one of the most commonly used ac-dc high voltage converter. A 2 stage cascade rectifier, in this circuit, can provide a dc output voltage of more than 15kV under no load condition and the input voltage of 50V.

2.2.4 Measuring instrument

In order to investigate the smoke removing characteristics of our ESP, we have carried out the smoke removing experiment as the function of the elapsed time from the initial voltage.

Fig. 5 shows the schematic diagram of measuring instrument circuit used for measuring the smoke removing time. We are able to monitoring the degree of turbidity through the change of the He-Ne laser broad light intensity. When the degree of turbidity in experimental chamber is changed, CdS sensor is able to obtain the change of the He-Ne laser broad light intensity which follows the turbidity in chamber.

Using this system, we can count the smoke removing time.

3. Results and Discussion

In this study, if the initial applied voltage is much higher than 50V, the smoke removing time is too short and we cannot count removing time. So initial applied voltage is 50 V.

Fig.6 shows the smoke removing time by adjusting switching frequency. The least smoke removing time is obtained at 2.56s at the switching frequency of 9 kHz.

Fig.7 shows the smoke removing time by adjusting

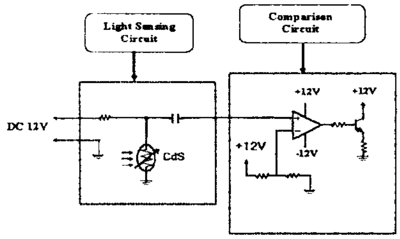

Fig. 5 Schematic diagram of test equipment circuit

duty ratio at the 9 kHz. The least smoking removing time is 2.56s at the 50% duty ratio.

Fig.8 shows the inverter input current by varying switching frequency at a fixed an input voltage of 50 V. As a result, the highest current of 186mA was obtained at the switching frequency of 9 kHz. Inverter input current increases with increasing the frequency because the input power is proportional to the switching frequency and the system output efficiency is almost the same. It means that a switching loss is very low.

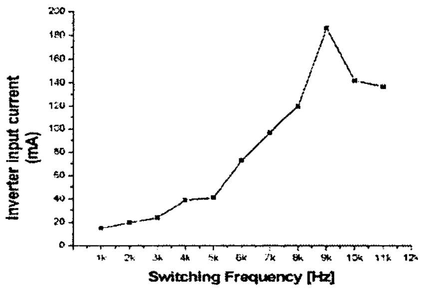

Fig.8 Inverter input current versus switching frequency

4. Conclusions

In this study, we have proposed electrostatic precipitator (ESP) adopted dc-dc converter system with the current resonant half-bridge inverter and the Cockcroft-Walton circuit.

We investigated the smoke removing characteristics of this ESP as a function of a switching frequency and a duty ratio. We have found the best switching frequency and duty ratio in our system. The obtained results are as follows.

1. As the switching frequency changes from 2 to 12 kHz, the least smoke removing time is obtained at the switching frequency of 9 kHz at the condition of all the duty ratios and the applied voltage of 3.4 kV.
2. As the duty ratio changes from 20 to 80% at the condition of switching frequency (9 kHz), the least smoke removing time is obtained 2.56s at the duty ratio of 50% and the applied voltage of 3.4 kV.
3. From these experimental results, the best operational condition is obtained at the switching frequency of 9 kHz and the duty ratio of 50 % in this ESP.

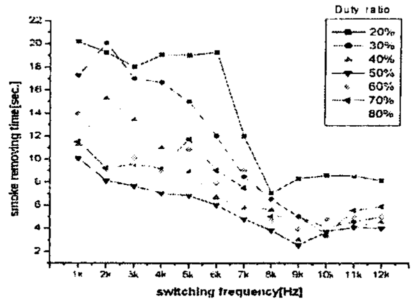

Fig. 6 The smoke removing time versus switching frequency

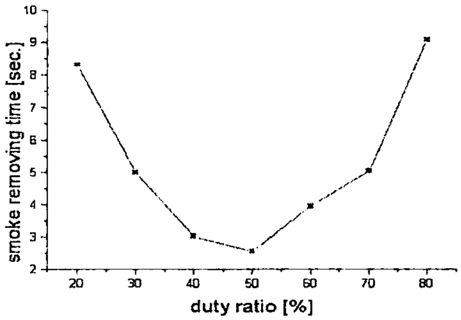

Fig.7 The smoke removing time versus duty ratio

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