VOLTAGE-CURRENT CHARACTERISTICS OF PLATE TYPE PRECIPITATOR GEOMETRY UNDER COMBINED DC/PULSE ENERGIZATIONS

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Abstract-An attempt has been made to study the voltage-current characteristics of a wire-plate precipitator geometry under clean air conditions. Helical wires have been used as corona electrodes. The studies were conducted with DC and DC superposed on nanosecond pulse respectively. The repetitive pulses with a rise time of the order of nanoseconds were generated from a MARX type impulse voltage generator. A comparative study of effect of pulse repetition rate, pulse width and effect of DC bias has been made on the voltage-current characteristics. The obtained results were discussed and compared with previous investigations.

INTRODUCTION

The Pulse charging of Electrostatic Precipitator (ESP) seems to be one of the possible solutions to overcome the back corona phenomenon resulting from the collection of high resistivity dust particles. In 1952, White [1] demonstrated the use of pulse voltage with a pulse width of $100 \mu s$ at 60 Hz, on a conventional precipitator and achieved higher corona currents and collection efficiency. Thomas and Williams [2], have shown that similar corona conditions as compared to DC can also be obtained with repetitive pulses of low duty cycles without affecting peak voltages. Milde [3] superposed the pulse voltage onto a DC bias and indicated that better performance of ESP is obtained due to enhancement of particle charge as a result of ion density concentration and more uniform corona current distribution along the length of the corona wire. Abdel Salam et al [4] have done investigations on helical wires and reported that the corona streamer pulses of given amplitude increase with the decrease in pulse repetition rate. Masuda et al [7] have discussed the performance of a precipitator, with direct energization of nanosecond pulses, generated by chopping of DC voltages by a rotating spark gap. However, no data is available in literature on the performance of a wire-plate geometry under nanosecond pulses superimposed on DC.

The paper presents data on the voltage-current (V-I) performance of one section of a practical precipitator, energized with nanosecond (ns) repetitive pulses superposed on DC, in clean air conditions. The data will be helpful for the design of the electrode system of a precipitator.

EXPERIMENTAL SET-UP

Wire-Plate Geometry

The wire-plate geometry used for the experiments corresponds to one section of a practical precipitator. It consists of two collector plates, 200cm high and 50cm wide, with provision for suspending five number of helical wires of length 183cm, each having a cross section of 2.5mm. Experiments were conducted first with one wire centrally suspended per section and then with two wires suspended at a wire-wire spacing of 90mm and 150mm, respectively. Provision was made to vary the wire-plate spacing from 50mm to 90mm. Experiments could not be conducted at larger wire-plate spacing due to limitations of pulse voltage magnitude.

High Voltage DC Power Supply

The DC set used for experiments consisted of two identical voltage doublers connected in cascade, to generate an output voltage of 250kV at 25mA. The unit generates voltages of both positive and negative polarities. The magnitude of DC voltage could be continuously varied from 10kV to 250kV. The output voltage of the DC set was determined by measuring the current through a microammeter, connected in series with a precision 300 $M\Omega$ resistor chain.

Repetitive Pulse Generator

Nanosecond rise time repetitive pulses are normally generated using the circuit developed by Masuda et al [7]. However, a Marx type impulse generator was used in the present work. The generator consists of seven stages of capacitors each of .007 uF. The capacitors are charged in parallel by a 30 kV DC power supply and then discharged in series. Discharging of capacitors is performed by a group of rotating and fixed electrodes. The impulse generator can produce pulse voltages of rise time 250ns and duration 700ns, with repetition rates of 50, 25 and 12.5 pulses per second respectively. During the experiments four stages of the generator were used for a maximum voltage of 120kV.

The output of the pulse generator was measured by a precision damped capacitance divider (Haefely, CZ-600) having a response time of 22ns. The low voltage output of the capacitance divider was connected through a co-axial cable to a surge oscilloscope (Haefely type-721) and a digital peak voltmeter (Type 64M).

EXPERIMENTAL PROCEDURE

DC Energization

The V-I characteristics were determined for the wire-plate geometry at negative polarity. The magnitude of the corona current flowing through the gap was determined at various DC voltages. The

corona current was measured by a milliammeter connected in series with the gap. The current was measured upto a maximum magnitude of 80 % of the sparkover voltage for a given gap. A mathematical model has been developed to determine the v-I characteristics under DC energization. The formulation of the model is based on the algorithm proposed by McDonald et al [8].

DC+Pulse Energization

For this set of experiments the output of the pulse generator was coupled to the testgap through a 9nf coupling capacitor, while the DC voltage was coupled through a 1MΩ resistance. The V-I characteristics were determined with negative DC/pulse voltages. Fig.1 shows the diagram of the measuring circuit. The average corona current was measured by a milliammeter connected in series with a grounded plate. Experiments were conducted by varying the pulse voltage upto a maximum of 80 % of the sparkover voltage. The DC bias voltage was varied from a magnitude below corona onset to that above corona onset. The characteristics were determined for different wire-plate and wire-wire spacings and at different pulse repetition rates.

RESULTS

Fig.2(a) shows the V-I characteristics under DC conditions at various wire configurations. The graphs have been drawn for a wire-plate spacing of 90mm. Fig.2(b) and Fig.2(c) gives the comparison of theoretical and experimental results. Fig.3 presents the effect of DC level on the V-I characteristics under combined DC/pulse application, for a pulse repetition rate of 25 pulses per second. Fig.4 represent the effect of pulse repetition rate on V-I characteristics for a wire-wire spacing of 90mm. The DC voltage was kept at corona onset level. Fig.5 shows the effect of wire-wire spacing on the V-I characteristics at a wire-plate spacing of 90 mm. Both the DC voltage (at corona onset) and the pulse repetition rate were maintained constant in this case.

DISCUSSION

DC Enetgization

Fig.2(a) shows typical exponentially increasing curves with DC energization. Similar trend has been observed at other wire-plate spacings. It is seen that the corona current is sensitive to the wire configurations. The current depends not only on the number of wires/section, but also on the wire-wire spacing. The maximum magnitude of the corona current is obtained with two wires/section and at a wire-wire spacing of 90 mm. Lowest current magnitude is obtained with a single wire/section. This phenomenon is due to the fact that the wire-wire spacing should be adjusted such that the corona envelope from adjacent wires should just touch each other. Too large a spacing between

wires, leaves a substantial space between corona envelopes and the configuration approaches that of a single wire/section. This can be confirmed by plotting the field between the wires and the plate.

The V-I characteristics were then simulated using a mathematical model. The model is based upon solving poisson's equation and current continuity equation simultaneously subject to existing boundary conditions. In the iteration procedure, the wire potential was gradually varied until the desired current density at the plate was reached. The space charge density near the wire was calculated and used as one of the boundary conditions.

As seen from Fig.2(b) and Fig.2(c), the developed model agrees well with the experimental results. The error in the estimation was less than 5% . But as the Wire-Plate spacing was increased, the error varies from 5-10% . This can be attributed to the various assumptions made in [8]. Efforts are being made to minimize the error.

DC+Pulse Energization

Effect of DC Level : The experimental results of Fig.3 indicates a linear increase in average current density with each DC level. This emphasises the fact that the current density can be independently controlled by the pulse voltage even when the DC voltage is kept constant. This provides an independent means other than DC voltage for controlling the precipitator current. Hence a precipitator can be operated at lower DC voltages but at the same time current density can be increased by superposing the pulse voltages. The experimental results with DC/nanosecond pulsing on the wire-plate geometry under clean air conditions, confirm the operating experience with practical precipitators [5], [6] and [7]. The results also indicate that a considerable corona current could be generated even with the DC voltage maintained below corona onset value. This behaviour was seen at other repetition rates also.

Effect of Pulse Repetition Rate : From Fig.4, with DC level maintained at corona onset, it is clearly seen that the maximum current density increases rapidly with increase in pulse repetition rate. Thus the pulse repetition rate is another parameter which can control the current density with DC level maintained constant. This trend was seen at other wire-wire spacings also.

Due to experimental limitations, the maximum pulse repetition rate used was 50 pulses per second. Since the curves in Fig.4 show an almost linear increase with the number of pulses per second, it is quite possible that the magnitude of corona current would increase further with an increase in pulse repetition rate. It is also seen that at the highest rate of 50 pulses per second, the current shows an exponential increase at pulse voltages higher than 80kV.

Effect of Wire-Wire Spacing : Fig.5 shows the effect of another important parameter namely the wire-wire spacing. Comparing Fig.2(a) and Fig.5, it can be observed that the effect of wire configuration is the same for DC and DC+pulse energizations. The lowest magnitude of corona current results with one wire per section and no appreciable change in corona current is observed when the wire spacing is increased from 90mm to 150mm, with two wires per section.

CONCLUSIONS

The results of DC superposed on nanosecond pulse energization of a wire-plate geometry are similar to that observed by other research workers.Combined DC and nanosecond repetitive pulsing permits' operation with large magnitudes of pulse voltage, control of precipitator current by variation of pulse repetition rate, pulse magnitude etc, . As a first approximation, the developed model for DC can be used to determine the effects of various parameters on the electrical conditions of the precipitator.

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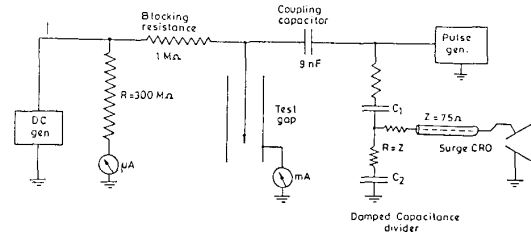
Fig.1 Experimental set-up for DC+Pulse energization
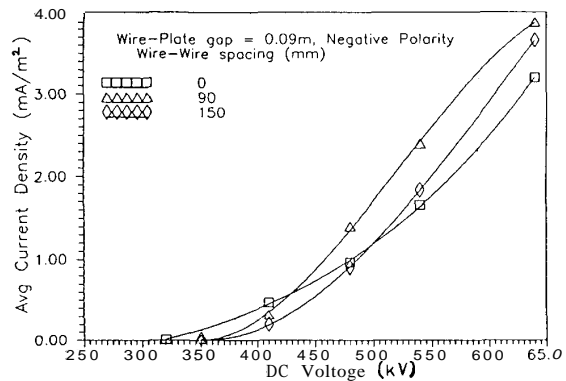

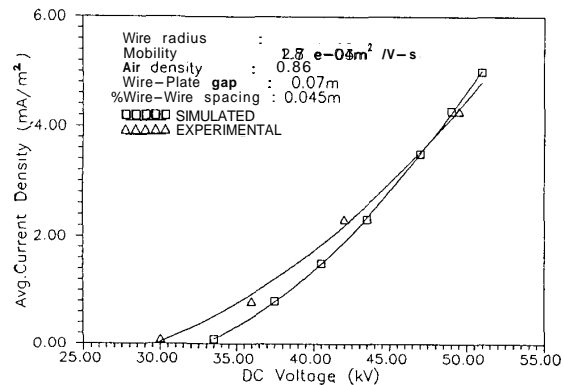Fig.2 (a) V-I Characteristics of Wire-Plate geometry under DC energization

Fig.2 (b) Theoretical and Experimental V-I Characteristics of Wire-Plate geometry under DC energization
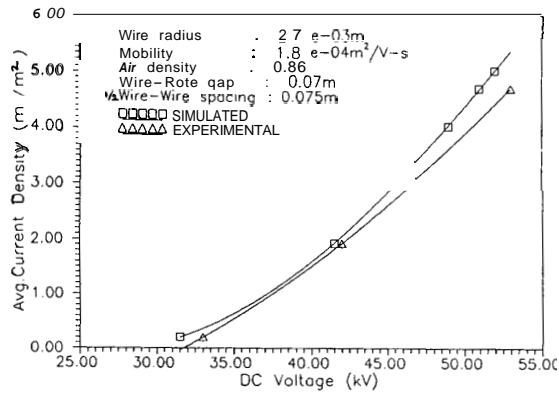(Wire-Wire spacing = 90mm)

Fig.2 (c) Theoretical and Experimental V-I Characteristics of Wire-Plate geometry under DC energization (Wire-Wire spacing = 150mm)
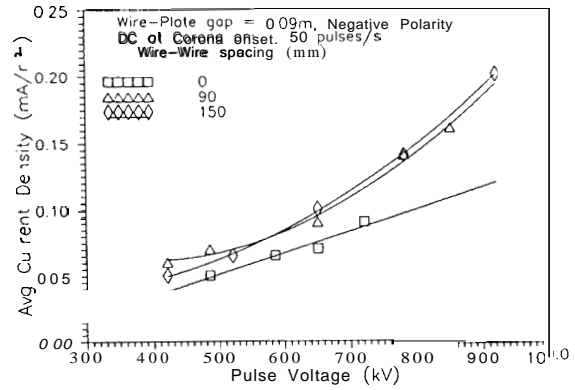

Fig.5 V-I Characteristics of Wire-Plate geometry under DC+Pulse energization (Effect of Wire—Wire spacing)
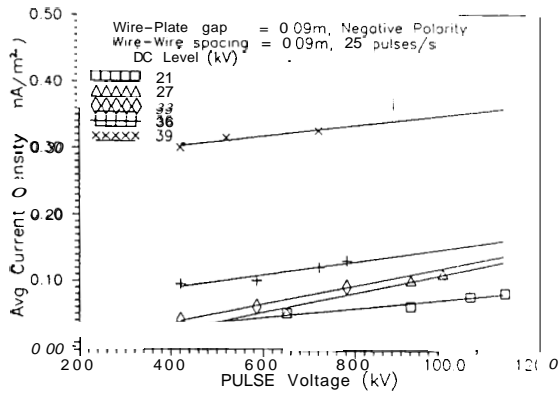

Fig.3 V-I Characteristics of Wire-Plate geometry under DC+Pulse energization (Effect of DC bias)
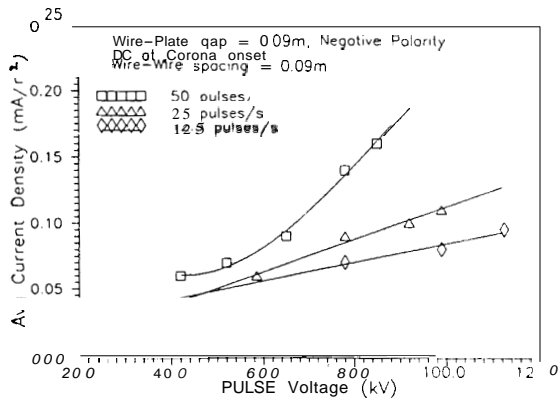

Fig.4 V-I Characteristics of Wire-Plate geometry under DC+Pulse energization (Effect of Pulse Repetition Rate)