SPARKOVER CHARACTERISTICS OF PROTOTYPE PRECIPITATOR SUBJECTED TO DC/PULSE ENERGIZATION

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Abstract-The paper reports results of investigations on the behaviour of one section of a prototype electrostatic precipitator subjected to DC and repetitive pulse voltages under clean air conditions. The basic wire-plate precipitator geometry consisting of a helical wire was energized with DC, repetitive pulse and DC superposed on repetitive pulse voltage respectively. The results provide basic data on the behaviour of the geometry under these energizations. These results are of practical importance in the design of electrode systems of industrial electrostatic precipitators.

INTRODUCTION

It is well known that electrostatic precipitators with DC energization perform poorly while precipitating high resistivity dust particles, due to the phenomenon of backcorona [1]. Modern precipitators have tried to solve the problem of backcorona by superposing repetitive pulse voltages on DC [2-5]. One of the factors that contributes to the improved performance of a precipitator by the combined DC/pulse energization is the increased operating voltage gradient due to the application of short duration (millisecond (ms) to nanosecond (ns)) repetitive pulses.

It is essential to study the behaviour of wire-plate geometries (existing in precipitators) under the application of combined DC/pulse voltages, and the effect of parameters such as pulse repetition rate, DC level, pulse width etc., on the sparkover voltage. Precipitators have been operated with combined DC and pulse voltages of millisecond, microsecond and nanosecond duration. However detailed data are not available on the sparkover characteristics of airgaps under DC/pulse conditions. The paper gives details of the experiments carried out on a prototype helical wire-plate geometry of a precipitator under DC and DC/repetitive pulse voltage applications.

EXPERIMENTAL APPARATUS AND PROCEDURE

The prototype precipitator used for the experiment consists of two collector plates 200cm high and 50cm wide with provision for suspending 5 numbers of helical wires of length 183cm and wire cross section of 2.5mm. The overall diameter of the helical wire was 4cm with a pitch of 14cm. 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. The wire-plate spacing was varied from 50 to 90mm.

For DC energization, the wire-plate geometry was connected to a 250kV, 25mA DC power supply. The output voltage of the DC set was determined by measuring the current flowing through a precision 300M Ω resistor chain.

For Pulse energization, the precipitator was connected to a Marx type impulse generator which generates repetitive impulses of 250ns rise time and a pulse width of 700ns. The maximum output voltage of the pulse generator was 210kV. The generator produces pulses of repetition rate 50, 25 and 12.5 pulses per second respectively. The magnitude of the pulse voltage was measured by a precision damped capacitance divider (Haefely-CZ 600) connected to a surge oscilloscope and a digital peak voltmeter.

Fig.1(a) shows the schematic diagram of the DC+pulse energization. The pulse voltage was coupled to the testgap through a blocking capacitor while the DC voltage was coupled through a high resistance. Fig.1(b) shows the output voltage waveform of the 210 kV pulse generator.

RESULTS AND DISCUSSIONS

DC Energization

Experiments were conducted for both polarities of the applied DC voltage. The average of 20 sparkover voltage magnitudes was taken as the sparkover voltage of the gap. The wire-plate spacings were varied from 50 mm to 90 mm. For each of these spacings, sparkover voltages were determined at three wire configurations as mentioned below :

CASE 1 : Single helical wire at the centre of the plates

CASE 2 : Two helical wires with a wire-wire spacing of 90 mm

CASE 3 : Two helical wires with a wire-wire spacing of 150 mm

Table I shows the results of sparkover characteristics under DC energization. The results indicate a considerable decrease in sparkover voltage from negative to positive polarity. This is in accordance with the normal behaviour encountered in non-uniform field gaps. However, the results also indicate the influence of another important parameter viz. the wire-wire spacing. It is observed that the sparkover voltage is the lowest with one wire per section and it increases by as much as 15% for other wire configurations. This trend is seen at higher wire-plate spacings. Similar results have been discussed in detail by White [1]. The effect of wire-wire spacing is predominant at larger wire-plate spacings indicating that the ratio of wire-plate to wire-wire plays a major role in sparkover characteristics. At lower

ratios the system acts as uniform field and hence the wire-wire spacing does not have much influence.

Pulse Energization

Table II present results of pulse energization. An additional parameter studied was the effect of pulse repetition rate. The results are presented for three pulse repetition rates viz. 50, 25 and 12.5 pulses per second respectively. For positive polarity, a pulse repetition rate of 12.5 pulses per second produces the highest sparkover voltage at larger wire-plate spacings. However, with negative polarity, the effect of pulse repetition rate was less significant. For a given set of conditions sparkover voltage varied linearly with wire-plate spacings. Another important observation from this table is that the sparkover voltage with positive polarity is appreciably higher than that under negative polarity, a trend opposite to that observed with DC application. This is particularly noticeable at larger wire-plate spacings and at low pulse repetition rates. This may be due to very short duration of the applied pulses which may not be able to influence the streamer formation from the positive electrode. Further the effect of wire-wire spacing is not very appreciable.

DC + Pulse Energization

Table III shows results of DC superposed on nanosecond pulses. This clearly approaches the practical conditions that exist in an industrial precipitator. The sparkover voltage increases linearly with wire-plate spacings for both polarities. For a given polarity, no definite trend about the effect of pulse repetition rate on sparkover voltage is seen. Further a single wire per section results in the lowest sparkover voltage. The results again indicate that the sparkover voltage with positive polarity is higher than that with negative polarity, an effect opposite to that observed with DC energization. The effect of DC level on the total sparkover voltage is clearly indicated in Table IV for different wire-plate spacings at a repetition rate of 50 pulses per second. The results indicate that the total sparkover voltage remain constant for DC levels above corona threshold. This confirms the fact that the pulse voltage is most effective at DC levels below corona threshold [6-7]. Similar trends have been obtained at 25 and 12.5 pulses per second respectively.

To illustrate the relative effects of various energizations, data from Tables II-IV have been plotted in Figs.2-3, at both polarities. It is seen from the figures that the positive polarity sparkover voltage under DC is less than that under negative polarity. However pulse and DC+pulse energizations show a reverse trend, with positive polarity sparkover voltage being higher than that under negative polarity. Further the effect of pulse is most predominant under positive polarity conditions particularly

at higher wire-plate spacings.

CONCLUSIONS

The experimental results reveal that :

1.The sparkover characteristics of wire-plate geometry are appreciably affected by the superposition of the nanosecond repetitive pulse voltages. The sparkover voltage for repetitive pulses increases nearly by 20-60 % as compared to DC.

2.The sparkover voltage under DC energization is lowest for one wire per section and increases by about 15 % for other wire-wire spacings. The effect of wire-wire spacing is most predominant at larger wire-plate spacings and for negative polarity.

3.The effect of pulse repetition rate on sparkover voltage is polarity dependent. With positive polarity, the sparkover voltage increases appreciably with decrease in repetition rate, however, the pulse repetition rate is less significant under negative polarity conditions.

4.The total sparkover voltage remains constant for DC levels higher than corona threshold. Pulse energization is most effective with DC levels below corona onset and results in highest sparkover voltage.

5.The superposition of pulse over DC is effective only at higher wire-plate spacings for positive polarity. With negative polarity, the superposition of pulse voltages is uniformly effective at all wire-plate spacings. This is of great practical significance as applied to an industrial precipitator.

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Fig.1 (a) Circuit Diagram of DC+Pulse energization

Fig.1 (b) Voltage Waveform of 210kV Pulse Generator
X-axis : 250ns/division
Pulse rise time : 250ns ; Width : 700ns

Fig.2 Sparkover Characteristics of Wire-Plate Geometry under different energizations (negative polarity)

Fig.3 Sparkover Characteristics of Wire-Plate Geometry under different energizations (positive polarity)

TABLE I
SPARKOVER CHARACTERISTICS OF WIRE-PLATE GEOMETRY UNDER DC ENERGIZATION

Wire-plate gap (mm)	Sparkover voltage (kV)					
	Case 1		Case 2		Case 3	
	Positive polarity	Negative polarity	Positive polarity	Negative polarity	Positive polarity	Negative polarity
50	34	44	30	40	27	42
70	41	73	36	66	38	73
80	50	70	40	73	50	89
90	54	84	45	91	54	97

TABLE II
SPARKOVER CHARACTERISTICS OF WIRE-PLATE GEOMETRY UNDER PULSE ENERGIZATION

a) Negative Sparkover voltage (kV)									
Wire-plate gap (mm)	Case 1			Case 2			Case 3		
	Pulses Per Second			Pulses Per Second			Pulses Per Second		
	50	25	12.5	50	25	12.5	50	25	12.5
50	62	59	*	66	67	*	62	66	*
70	97	96	110	107	103	106	105	104	105
80	107	123	*	125	130	*	124	129	*

b) Positive Sparkover voltage (kV)									
Wire-plate gap (mm)	Case 1			Case 2			Case 3		
	Pulses Per Second			Pulses Per Second			Pulses Per Second		
	50	25	12.5	50	25	12.5	50	25	12.5
50	66	70	*	71	73	*	65	75	*
60	83	92	*	95	94	*	87	104	*
70	97	125	129	115	129	*	115	131	*

* Values not obtained due to experimental limitations

TABLE III
SPARKOVER CHARACTERISTICS OF WIRE-PLATE GEOMETRY UNDER DC+PULSE ENERGIZATION

a) Negative Sparkover voltage (kV)									
Wire-plate gap (mm)	Case 1			Case 2			Case 3		
	Pulses Per Second			Pulses Per Second			Pulses Per Second		
	50	25	12.5	50	25	12.5	50	25	12.5
50	59	72	*	60	60	*	60	64	*
70	85	92	86	93	93	96	98	98	100
80	97	108	110	120	120	125	125	120	130
90	120	140	142	148	160	147	147	160	165

b) Positive Sparkover voltage (kV)									
Wire-plate gap (mm)	Case 1			Case 2			Case 3		
	Pulses Per Second			Pulses Per Second			Pulses Per Second		
	50	25	12.5	50	25	12.5	50	25	12.5
50	64	70	*	77	*	*	*	*	*
60	*	*	*	107	*	*	*	*	*
70	109	128	111	140	137	153	136	137	156
80	138	130	147	*	*	*	*	*	*

* Values not obtained due to experimental limitations

NOTE : In DC+PULSE Energization the DC voltage is set at corona onset level.

TABLE IV
SPARKOVER CHARACTERISTICS OF WIRE-PLATE GEOMETRY UNDER DC+PULSE ENERGIZATION

Effect of DC on total Sparkover Voltage
(50 pulses per second, -Ve polarity)

CASE :1			CASE :2			CASE : 3		
W-P Gap (mm)	DC level (kV)	S.O.V (kV)	W-P Gap (mm)	DC level (kV)	S.O.V (kV)	W-P Gap (mm)	DC level (kV)	S.O.V (kV)
50	15	64	50	15	62	50	15	64
	21 #	59		21 #	50		23 #	60
	27	60		30	59		30	60
70	15	101	70	15	99	70	15	102
	21	91		21	99		24 #	98
	27 #	a5		29 #	93		33	96
	33	85		33	93		45	96
	45	a3		45	92			
80	24	101	80	24	126	80	24	125
	30 #	97		30 #	120		30 #	125
	45	96		45	110		45	117
	54	a5		54	110		60	116
90	24	130	90	27	154	90	27	165
	30 #	120		33 #	148		33 #	157
	45	109		45	122		45	125
	60	108		60	120		60	123

corona onset voltage : W-P = Wire-Plate : S.O.V = Sparkover voltage