静電気学会誌, 5, 6 (1981), 423-427

論　　文

Reversible Polarity Test for Combatting Time Dependent Performance Degradation in Hot Side ESP

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(Received September 4, 1981)

This paper reports the results of field trials with power supply polarity reversal as a means to eliminate the time dependent degradation in some hot side precipitators. Attempts to operate two full scale ESP's with positive polarity were unsuccessful because heavy sparking developed immediately upon corona inception. A pilot scale precipitator with an electrode system identical with one of the precipitators did not exhibit this spark limited behavior. Further work is indicated to determine the cause for this anomalous behavior.

1. Introduction

Laboratory research had verified the hypothesis of sodium depletion as the cause of the development of a high resistivity residual layer in a group of hot side precipitators. This high resistivity layer developed for a negative corona system by the movement of the positive sodium ions from fly ash adjacent to the collection electrode toward the corona wire. The laboratory study showed that a reversal of the polarity of the corona system would electrically move the sodium ions back into this depleted region and restore the resistivity to its initial value.[2]

Since this polarity reversible concept had been successful in the laboratory, field trials were conducted to test this potential solution for the time dependent degradation problem. Two attempts were made on full scale units and pilot scale tests were conducted after difficulties were encountered with the full scale precipitators.

This paper reports the results of these polarity reversal tests, and represents the third of the four series reports[1-3] on our research on the time dependent degradation in the hot side ESP's.

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2. Results of Tests

One electrical section of the electrostatic precipitator at the Lansing Smith Station of Gulf Power and four series fields (one entire precipitator) of the Hayden Station of Colorado Ute Electric Association were equipped with reversible polarity, high voltage power supplies. The single field supply was installed about six months prior to the complete conversion of one precipitator at the Hayden Station. Both of these tests failed in that sparking developed at very low voltages and current densities.

2.1 Full Scale Tests at Lansing Smith Station

The initial tests at the Lansing Smith Station developed sparking in the high voltage distribution system immediately upon positive excitation. This system was then inspected in detail and several sharp points were found. These points were fitted with corona suppression spheres to alleviate this problem. We were successful in eliminating the localized sparking in the distribution system but the sparking at low voltages and currents persisted even after this distribution problem was corrected.

The negative polarity voltage vs. current curves were normal while the positive polarity was not. The negative and positive polarity voltage vs. current curves for the Lansing

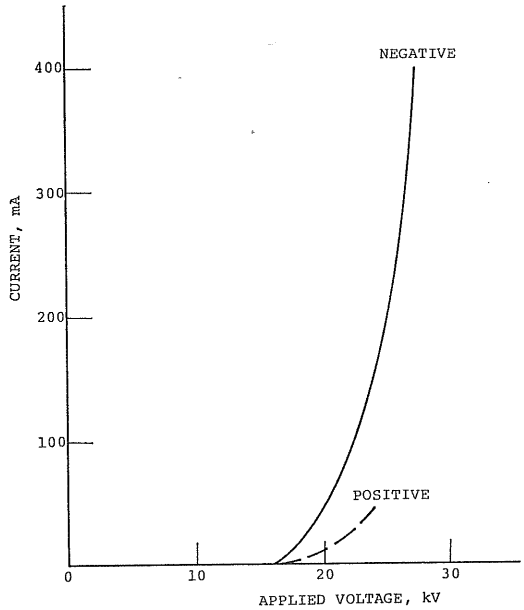

Fig. 1 Voltage vs. current for power set B, positive and negative polarity (one electrical section at Lansing Smith Station; gas temperature=360° C).

Smith Station are shown in Fig. 1. It was recognized that the sparkover characteristic for positive polarity would be different than for negative. However, it was not anticipated that sparkover would occur at the very low voltages and currents that were experienced.

We suspected that the high resistivity layer that was already established on the collection electrodes were responsible for this premature sparking. As a test, the positive polarity attempt was repeated immediately after the precipitator plates were washed. The premature sparking persisted even after washing.

Penney[4] of Carnegie Mellon University and Cooperman[5] of Fairleigh Dickinson University had conducted research into positive polarity behavior of electrostatic precipitators. Penney had determined that the sparkover characteristics for positive polarity systems operating at near atmospheric pressure will be somewhat less than that for a negative system. He states that the sparkover initiates at the positive electrode. Since for the positive corona system the high electric field is adjacent to the positive (corona) electrode, any flare that develops will tend to grow and propagate into a sparkover. In the negative system, the positive electrode is located in a region of a lower field. Thus, it was expected that sparkover would result at a lower current and voltage for positive than for negative polarity operation. But it was not anticipated that sparkover would begin immediately upon corona inception as was experienced in the full scale precipitators under positive polarity operation.

2.2 Pilot Scale Tests at Lansing Smith Station

The small scale pilot precipitator was installed at the Lansing Smith Station in an attempt to evaluate the cause of the limitation in performance under positive polarity. The voltage vs. current characteristics for the pilot scale device more nearly matched the expected performance than did the full scale unit. The pilot scale voltage vs. current curves are shown in Fig. 2. Therefore, the direct cause of the premature sparking was not determined.

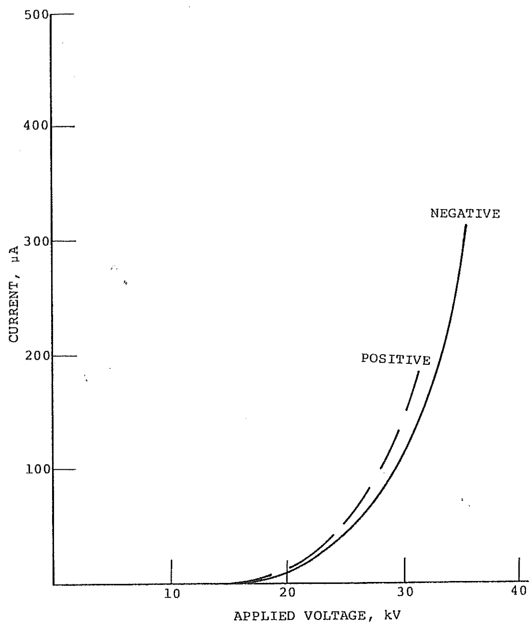

Fig. 2 Voltage vs. current for pilot scale ESP, positive and negative parameters (Lansing Smith Station; T=250°C).

Further tests at Lansing Smith was delayed until comparable tests could be conducted at the Hayden Station of the Colorado Ute Electric Association. It was hypothesized that the interaction between the inlet field operating at positive polarity with the second field operating with negative polarity was leading to a sparkover between the corona wire support frames. This hypothesis, however, proved to be in error.

2.3 Full Scale Tests at Hayden Station

The four reversible polarity transformer-rectifier sets were installed in the Hayden Station. Attempts were made to operate these sets on positive polarity for about one week. It was apparent that acceptable positive polarity operation could not be achieved at either Hayden or Lansing Smith Stations.

The voltage vs. current curves exhibited characteristics that were not at all typical of a stable corona with positive polarity. Figure 3 shows a composite positive and negative polarity voltage vs. current curve. The negative polarity curve is typical of that for a conventional electrostatic precipitator while the positive portion definitely is not. There was no evidence of back corona while in the negative mode and the operation was very stable and readily repeatable.

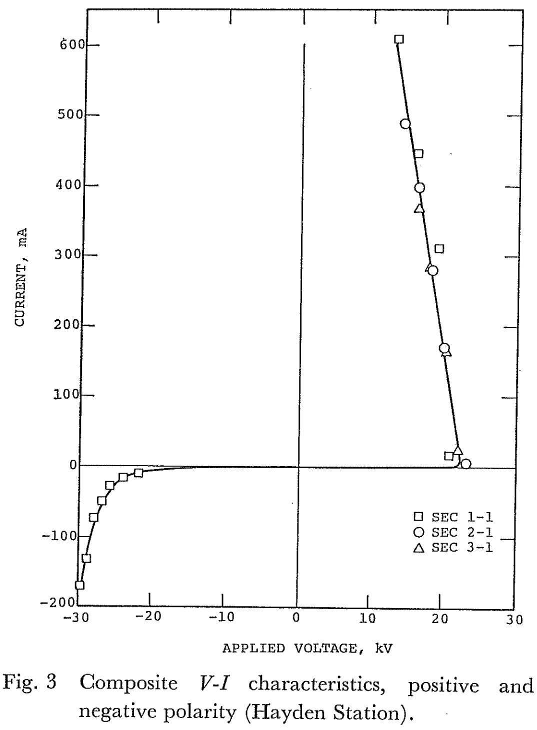

Fig. 3 Composite *V-I* characteristics, positive and negative polarity (Hayden Station).

The upper right portion of this curve represents the positive polarity behavior. This characteristic exhibits a negative slope immediately upon the inception of corona current flow. Although fluctuation in both current and voltage occurred throughout the measurement process, the shape of the curve was readily reproducible and consistent among all the reversible transformer rectifier sets at the Hayden Station.

This negative slope did not appear to be associated with back corona. This is based upon two observations: first, the conventional description of back corona requires that the electric field in the layer must be sufficiently large to cause a localized breakdown of the gas. Since this did not occur for negative polarity for current densities much greater than corona initiation, the behavior at corona inception for positive polarity was not associated with back corona. The negative slope developed well below stable operating points for negative polarity.

The second point supporting the conclusion of no back corona is that no hysteresis was detected in the voltage vs. current curves.

It should not be expected that the electrical characteristics be symmetric with respect to polarity reversal[5]; however, it is possible to generate a well-behaved positive corona discharge using conventional electrode geometries (see Fig. 6). The positive half of the curve shown in Fig. 3 is not typical of a proper corona discharge, even taking into account the possibility of back corona. The particle collection efficiency of the ESP in the positive mode was extremely poor at that test site because a high level of opacity in the effluent (approximately 60%) was observed compared with that for the negative mode (less than 20 %). A possible explanation for these results is that most of the current delivered by the power supplies in the positive mode is either highly localized, or bypasses the ESP entirely. If a current bypass mechanism is involved, it clearly must be one that is sensitive to polarity.

Since the load for a particular power supply includes not only the corona wires, but also the high voltage bushings, supports, *etc.*, it was not possible to determine from external voltage and current readings the locations of spurious or undesirable discharges. In this instance, however, it was reasonable to conclude that anomalous effects such as structural defects or misalignment were not significant. The observed behavior was very consistent and reproducible; therefore, the problem of developing a poor operating mode in positive polarity was common to all four reversible sections.

In general, operation in the normal mode,

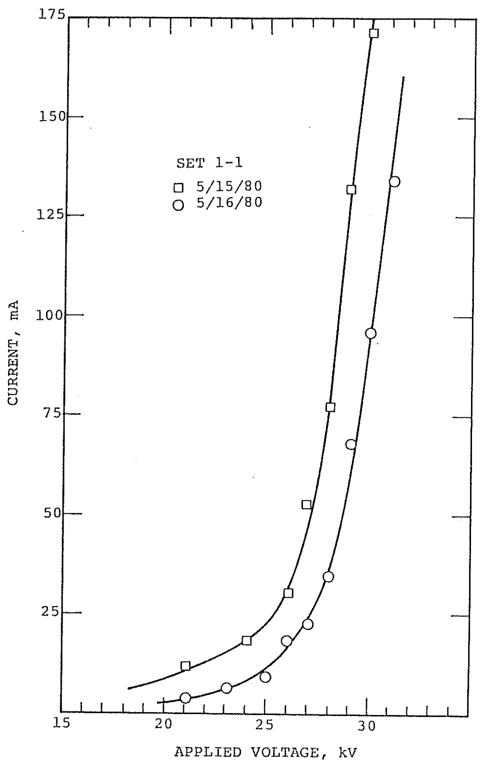

Fig. 4 Negative *V-I* characteristics for section 1-1 (Hayden Station). Note that curve displaced to the right was determined at a time approximately 28 hours later than was the other curve.

with negative excitation applied to the corona wires, was characterized by very steady values of voltage and current. During the test period there was no strong evidence of back corona behavior.

Figure 4 shows a negative *V-I* characteristics for a selected section equipped with a reversible power supply. The two curves shown were determined at separate times: the first about 10 hours after the precipitator was turned on, and the second approximately 28 hours later. In each instance the curve determined at the later time exhibits a displacement to the right from the curve established earlier, suggesting an increase in the layer resistivity.

The shape of the voltage vs. current curve associated with the operation of each power supply in the positive polarity mode indicated a very heavy, non-linear loading. Although the source of the loading remains unknown, it is important to note that the sharp rise in current with a negative slope occurs at a voltage for which the corona current is extremely small. That fact, in conjunction with the very poor collection efficiency during operation in the positive mode leads to the conclusion that positive corona was not achieved to any significant degree. Since positive corona has been demonstrated under various similar conditions of temperature and pressure in the laboratory and in small pilot scale devices, it appears unlikely that the problem arises from localized current in the wire-plate structure. A more plausible explanation was that an intense discharge occurs from the high voltage distribution links between the TR sets and the corona wires.

2.4 Pilot Scale Tests at Hayden Station

The behavior of the full scale electrostatic precipitator under reverse polarity operation is contrasted with a similar measurement made with a small pilot scale precipitator installed at the Hayden Station. The slip stream device illustrated schematically in Fig. 5 was utilized for this comparison. The pilot unit consisted of a single lane of collection electrodes identical with those installed in the full scale unit.

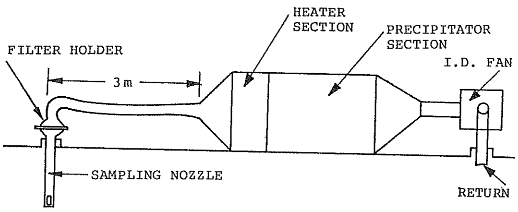

Fig. 5 Schematic illustration of test apparatus (Hayden Station).

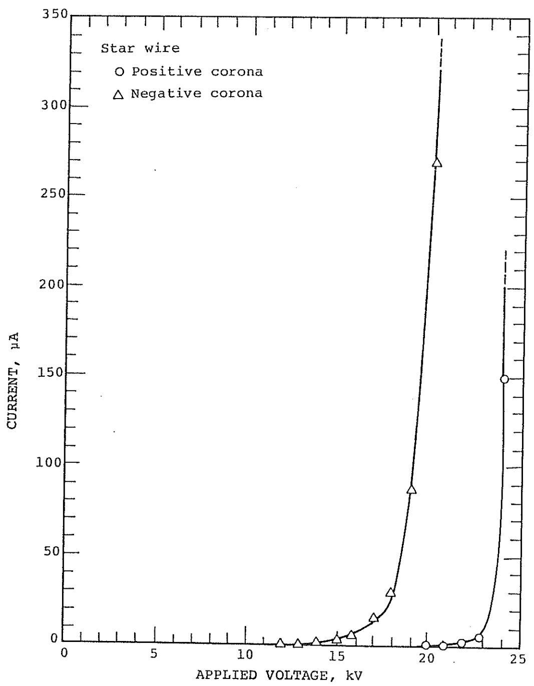

Fig. 6 Comparison of positive and negative corona in the pilot device under otherwise identical conditions (Hayden Station).

A set of star shaped corona electrodes were installed in this device at this time. The voltage vs. current curves shown in Fig. 6 were recorded for this experiment.

It is evident that stable corona was established for both positive and negative polarity in this experiment. One must infer that the anomalous positive polarity behavior of the full scale precipitator must be related to something other than the wire and plate system, perhaps something unusual about the high voltage distribution system since the pilot scale performed as expected.

Because of the limited scope of this research program, further studies involving the determination of the causes of the anomalous behavior of positive polarity in the full scale precipitator were not continued. The use of polarity reversal was considered to be a probable solution for existing installed precipitators, rather than as a modification of the design of new installations. Since the two precipitators tested were designed by different manufacturers, it was expected that this problem was a generic rather than a vendor specific one.

A study of the cause for the anomalous behavior of the full scale precipitator with positive polarity is planned for 1982 or 1983. These tests are planned for the 1,000 m^3/min pilot scale precipitator that Southern Research Institute is operating for the U.S. Environmental Protection Agency near Oak Ridge, Tennessee, at the Bull Run Station of the Tennessee Valley Authority.

3. Conclusion

Even though the full scale ESP's could not be operated successfully with positive corona, the pilot scale unit indicated that the sparking limitations were not imposed by the corona and collection electrode system. Further work is required to investigate the cause of the spark limited performance in the full scale units upon corona initiation.

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