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Bipolar Logarithmic Amplifier for the Measurement of Point Discharge Currents & Potential Gradients in Atmosphere

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The details of an electronic instrument, viz. bipolar logarithmic amplifier that can efficiently measure point discharge currents associated with positive and negative potential gradients are described. The device uses a reversely biased double diode (6H6) valve for the measurement of point discharge currents and potential gradients are calculated using standard formulae. Currents in the range 10^{-9} - 10^{-5}A for both the polarities can be measured with this device which, hence, can be used during both fair weather and disturbed conditions in the atmosphere.

1. Introduction

MEASUREMENTS of point discharge currents (PDC) permit the evaluation of the potential gradients (PG) at the discharge point in the atmosphere with respect to earth. PDCs exist during fair weather conditions as well as disturbed conditions. Under fair weather conditions, positive PGs exist in the lower atmosphere and the point located for measurement of discharge currents attracts positive ions and repels negative ions. Under disturbed conditions, strong negative fields existing at the earth's surface produce strong PDCs of opposite sign. It is well established that these PDCs play an important role in the electrical constitution of the atmosphere.

It is well known that ionic current is produced in the atmosphere by ions produced mainly by radioactive substances and cosmic rays. Each small ion so produced travels in the electric field until it combines with an ion of opposite polarity. The PDCs are produced when the two following conditions about a point are satisfied : (i) the ionization by collision should be confined to a small volume near the point; and (ii) the field around the point is sufficiently strong so that the density of electric flux ending at the point is sufficient[1]. Colladon[2] first measured the current by connecting a measuring instrument in between the exposed point and earth. Other earlier workers measured PDCs by using kites and captive balloons. Wilson[3] suggested that point discharge might be a very important factor in the transfer of charge between clouds and the earth. Wormell[4] measured PDC by using a metal point and a microvoltmeter. Shonland[5], with the help of a galvanometer, conducted experiments on a tree which was supported by insulators. Simpson and Scrase[6] and Simpson and Robinson[7] used an alti-electrograph for the determination of the direction of the currents. Kirkman and Chalmers[8] observed PDCs by treating a stainless steel rod of 0.15 cm diameter as an isolated point; and the variations of currents were measured by using a galvanometer. In this paper the details of an instrument, namely, a bipolar logarithmic amplifier for the measurement of PDC are reported.

2. Experimental Arrangement

2.1 Circuit

The circuit consisting of a logarithmic amplifier and a dc amplifier is shown in Fig. 1.

2.2 Logarithmic Amplifier

The logarithmic amplifier consists of a double diode tube in which the logarithmic relationship between the retarding voltage and current holds good. A current is fed in the input and the voltage, proportional to the logarithm of the current, is measured at the output (indicating instrument). Various experimenters[9-11] have constructed logarithmic amplifiers based on this principle. It should be noted that in the logarithmic instrument developed by us the range

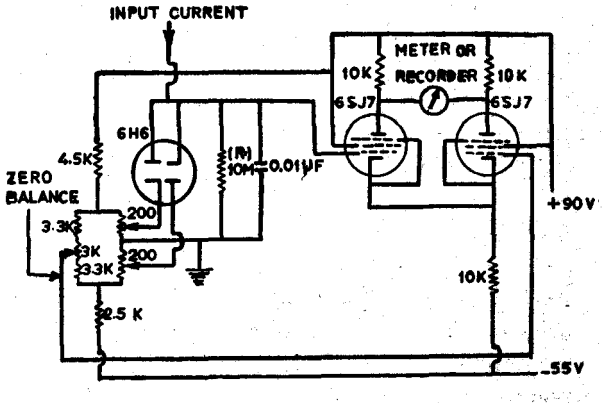

Fig. 1—Circuit diagram of bipolar logarithmic amplifier

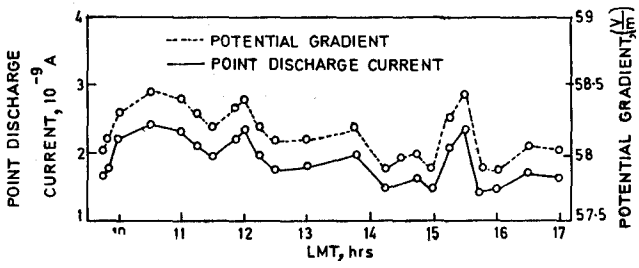

Fig. 2—Hourly variations of point discharge current and potential gradient during a typical fair weather day (20 Feb. 1971)

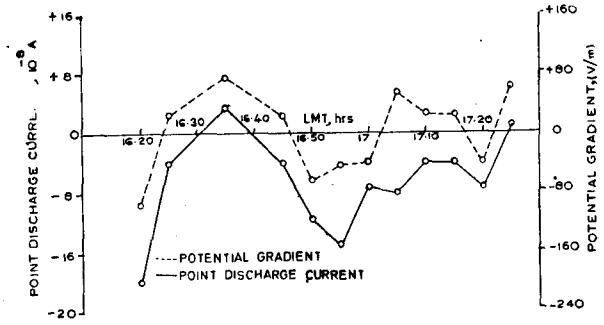

Fig. 3—Hourly variation of point discharge current and potential gradient during a typical disturbed weather day (11 May 1971)

of measurement is wider as compared to the earlier types.

The experimental investigations showed that the diode 6H6 is most suited for measurement of PDCs. The response characteristics of the tube were studied for four different filament voltages, with a view to having the most suitable filament voltage so that the relationship referred to above is quite sensitive and also highly linear on the logarithmic scale. It was observed that the sensitivity is poor with higher filament voltages (3.5 and 4 V) though the linear relationship of the characteristics remained unaffected and for the filament voltages as low as 2.6 V the linear relationship was seriously affected. A filament voltage of 3 V was found to be the most suitable as it permits the simultaneous realization of good sensitivity and linearity.

Since the tube has a very high resistance at small currents, the subsequent stage measuring the output voltage must have a high input resistance. For this purpose, a dc amplifier is used [Fig. 1]. The subsequent output of the instrument is connected to a 0-1 mA zero-centre Esterline Angus recorder or a 0-500 μA dc microammeter.

The instrument is calibrated for different known input currents. From the calibration curve it was evident that the instrument has the capacity of measuring currents between 10^{-9} and 10^{-5} A for both polarities. By adjusting the shunting resistor R or by adjusting the biases applied to the 6H6 tube, the range of the instrument can be extended maintaining the linearity.

2.3 Measurements

The measurements are made in open air by keeping the discharge point on a mast of 8 m height above the ground level. The discharge point is a specially prepared steel point of 6 in length, tapering at one end and fixed on good insulating material. Further, the point is kept away from the natural discharging elements like long trees, houses, mountain peaks and electrical cables, etc. The circuit is kept isolated from electrostatic and magnetic fields by enclosing it in a metal box. The filament voltages are provided by using dry batteries so as to ensure the stability and reliability of the measurements.

3. Results

PDC measurements are made under different atmospheric conditions that could be typically classified either as disturbed weather or as fair weather. Figs. 2 and 3 represent two typical conditions prevailing over Visakhapatnam, a tropical station on the east coast of India. PGs computed using formulae of Whipple and Scrase[12] are also presented in the same figures.

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