



# An Integrated system for study of the local atmospheric currents and electric fields at a high altitude station at Shillong

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This program has been initiated to study the atmospheric and meteorological parameters at a high altitude sub Himalayan location (Shillong 25.58°N, 91.89°E), Shillong, Meghalaya to understand their interaction and bearing on the local climate. Design and fabrication of the integrated instrumentation for measurement and recording of atmospheric electric potential gradient, point discharge current, solar irradiance and meteorological parameters was implemented. The results obtained indicate satisfactorily the performance of the instrument in fair-weather and disturbed weather conditions.

**Keywords:** Potential gradient, Point discharge current, Meteorological parameters, Fair-weather

## 1 Introduction

The Earth's atmospheric electrical charge plays a very significant role in understanding the static and dynamic processes that govern atmospheric physics. The atmosphere of the Earth is an engine powered by the Sun and its own rotation. The intense radiation from the Sun ionizes the gases that constitute the composition of the atmosphere<sup>1</sup>. Combined with the dynamic forces generated by earth's rotation as well as the convective and advective forces, the free movement of the charge between Earth's surface, the various layers of atmosphere and the ionosphere generates what is known as the Global Electric Circuit (GEC). Lord Kelvin was the first to introduce the idea of the global electric circuit and explained how the Earth's atmosphere became electrified in fair-weather conditions<sup>2</sup>. The most fundamental parameters for studying the global atmospheric electric circuit are the vertical air-earth current also known as point discharge current and the atmospheric electric field termed as the potential gradient (PG)<sup>3</sup>. During fair-weather conditions, a downward current density of  $2 \times 10^{-12}$  A/m<sup>2</sup> and an atmospheric electric field of the order of 100 Vm<sup>-1</sup> exists on the earth's surface, which is driven by global thunderstorm activity, galactic cosmic rays, radioactive components and solar radiation<sup>4</sup>. This program was initiated to study the above parameters at a high altitude sub Himalayan location (Shillong) to understand their interaction, in the local context.

Point discharge current (PDC) is utilized to measure the atmospheric current. This is termed so, as it occurs due to the intense electric field at a pointed probe, where electrons are accelerated to ionize air molecules in its vicinity and thereby produce a corona discharge. Earlier studies concluded that the contribution of PDC towards the maintenance of a surplus of negative charges on the earth's surface is dominant. This negative charge on the surface of the Earth is mostly generated by trees and other similar sources on the surface. Chalmers, Schonland, Kirkman, Milner, Kamra, Jhavar, Rao have contributed to the fundamental understanding of PDC with parameters relating it with electric field and wind velocity<sup>5-11</sup>.

Potential Gradient (PG) or Atmospheric Electric Field is defined as the ratio of the local potential at height  $z$  to that height is given by,

$$PG = \frac{dV(z)}{dz} \quad \dots(1)$$

Where, PG is defined to be positive during fair weather (FW) days and is related to the vertical component of the atmospheric electric field by,

$$Ez = -PG \quad \dots(2)$$

Wilson proposed and conducted an experiment to measure the charge on a test-plate. The charge on an exposed Earth-connected conductor which is always maintained in the same position relative to the ground, is taken to be proportional to the charge per

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square centimeter of the neighboring level ground, or to the potential gradient<sup>12</sup>.

These two parameters at a given site are subject to influences from local factors such as aerosol pollution, space charge and natural radioactivity. The comparison of PG and PDC measurements from such a site could help identify common variations, which may be attributed to the global electric circuit in the absence of coincident local factors<sup>13</sup>.

The daily diurnal variation of PDC and PG measurements, representing local variations of the global circuit, could provide an opportunity for better understanding of the local factors controlling PG and PDC, and in turn helping advance understanding of a variety of geophysical processes. Studies involving the diurnal variation of PDC and PG of local and global effects are of vital importance in understanding the GEC<sup>14</sup>.

In order to carry out measurements of these two fundamental parameters of GEC, a detailed review of the available literature of the instruments already in use for such studies was first carried out.

Though commercial instruments are readily available for such measurements in the market, they are very expensive. Due to paucity of resources, an attempt was initiated to design and fabricate the necessary instrumentation required to carry out measurements of potential gradient and point discharge current in the laboratory. This is a cost effective approach and secondly, it also helps in generation of skilled human resources. This also ensures quick repairs if and when required on site. The integrated measurement setup was organized as shown in Fig. 1. All the sensor modules are connected to the DAQ as indicated under the software control of the host PC.

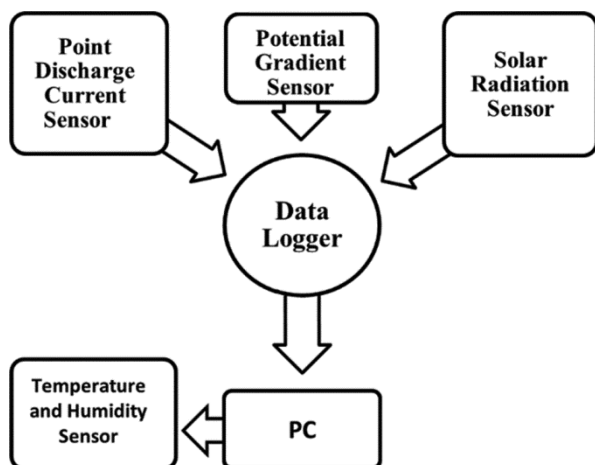


Fig. 1 — Layout of the measurement setup.

### 1.1 Potential gradient module

For the study of PG, the Wilson plate method was utilized, using a sensitive electrometer module as described by Bennett and Harrison<sup>15</sup>. This simple and innovative design could measure the potential gradient (PG) and vertical air-earth current density (Js) simultaneously. The electrometer was included on the board itself, utilized a high input impedance MOSFET operational amplifier [MAX407]<sup>16</sup>. Work reported by Brown to measure the vertical atmospheric electric field at the Earth's surface and its gradient variations also contributed to the setup of the sensor modules for this study<sup>17</sup>. This setup was placed on the third floor terrace of the School of Technology building at a height of 28 m above the ground.

The flat plate sensor was prepared as described above and placed on top of a Perspex sheet of the same dimension and attached to the sensor using double sided adhesive tape. The combined sensor board and Perspex sheet was then attached to PVC spacers and further to a supporting ceramic tile. The area of the sensor plate was calculated to be 738.27 cm<sup>2</sup>. Both of the sides of the glass epoxy plate were suitably tinned. The upper plate was used as the PG sensor and the lower plate was grounded. The combination functions as a capacitor accumulating atmospheric charge on the upper plate. In order to prevent leakage of surface charge, a suitable guard ring was also etched out on the board sensor area. The built in electrometer was used to measure the potential of the upper plate which is measured with respect to ground using a sensitive, ultra high impedance electrometer chip, which draws negligible bias current from the plate. This circuit was battery powered and preferred to a commercial design laboratory device, both because of the cost and the ease of replacing the front end amplifier chip if it is damaged by atmospheric transients. The schematic of the circuit is given below in Fig. 2.

The scale plot of the of the PG board is show in Fig. 3

The photograph of the board installed is shown in Fig. 4 and Fig. 5

### 1.2 Point discharge module

The PDC measurement was based on a design of an automatic monitoring system reported by Bhave<sup>18</sup>. The point discharge probe is made up of a metallic sharply pointed stainless steel needle of 0.5 mm diameter and about 30 cm long fixed in an inverted funnel with epoxy cement which in turn was fixed to

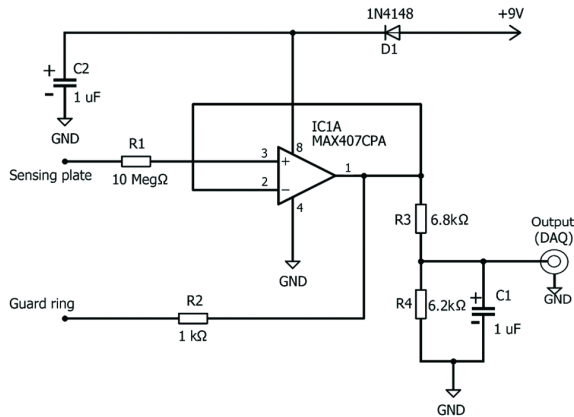


Fig. 2 — AEF circuit.

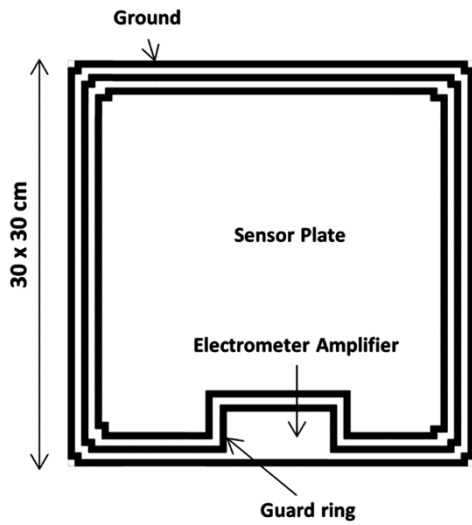


Fig. 3 — PCB pattern of PG Sensor (upper).

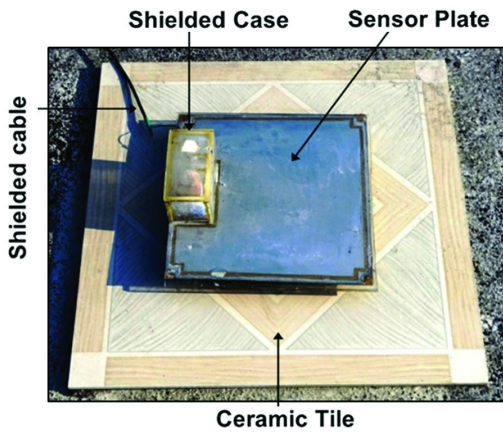


Fig. 4 — PG Module (plan view).

a weighted concrete block. Installation of the PDC unit is shown in Fig. 6.

This setup was placed on the third floor terrace of the School of Technology building at a height of 28 m above the ground. For measurement of PDC a

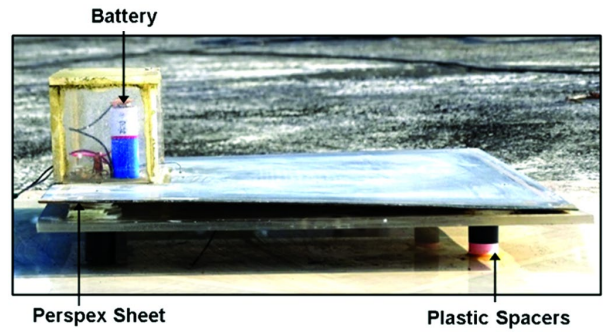


Fig. 5 — PG Module (side view).

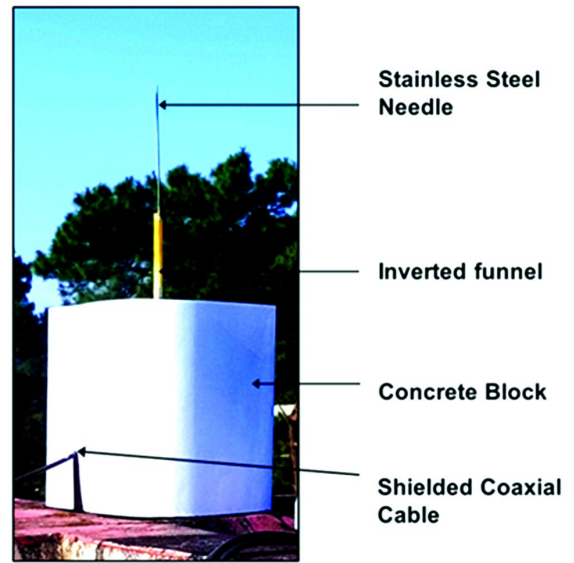


Fig. 6 — PDC unit.

sensitive electrometer was designed using a high impedance MOSFET operational amplifier [OPA111]<sup>19</sup>.

The atmospheric current flows through the tip at which the discharge occurs and then through a coaxial cable to the laboratory where it further flows through a 1 GΩ resistor connected to pin 3 of the operational amplifier, and finally to the ground.

The current through the resistor generates a corresponding voltage across it which is then coupled to the electrometer amplifier. The pins 2, 3 are surrounded by a small guard ring on the board, which is then connected to pin 8 and ground, to ensure low leakage currents in the measurements. This has the advantage of buffering the input to the output of the operational amplifier and provides low output impedance which is then fed to the data logger.

Both the front end modules were supplied with 9V batteries to avoid 50Hz stray pick up from the mains. One 9V battery was utilized for the PG module and two 9V batteries for the PDC module.

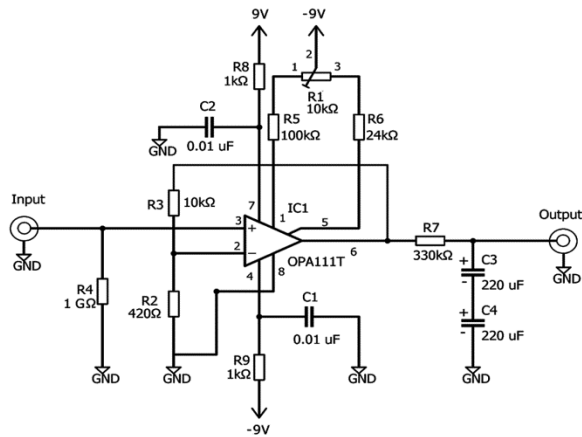


Fig. 7 — PDC circuit diagram.

The electrometer amplifier circuit was fabricated in the laboratory and has high input impedance and the input currents obtained are very small, of the order of few pico amperes. Detailed study of disturbed weather and fair weather PDC was carried out in this study. The diurnal variation of PDC of either polarity was also recorded for analysis related to any occurrences of thunderstorm activity during the day.

The schematic diagram of the circuit is given in Fig.7.

After recording the data on PDC and PG for a couple of months, it was clear that the solar irradiance was also essential to study the possible influence on the atmospheric parameters. Similarly, it became apparent that temperature and humidity data was also essential. Thus, for the study of possible linkages of above parameters with meteorological parameters, an Arduino based temperature and relative humidity sensor was also installed.

The data logger used for the experiment was a DAQ USB-201 whose output was fed to a dedicated PC. The DAQ device provides analog input, digital and counter functions. The analog input consists of 8 channels with 12 bit resolution having a maximum sampling rate of 100 kc/s (100 kHz), with voltage range of  $\pm 10$  V and with multiplexed sampling rate. In the study the sampling rate was kept at 100 Hz, using only two analog input channels i.e. for PDC and PG.

The data logger was adjusted to acquire data at a rate of 1 sample per sec during the entire period of measurement and was enabled to record the voltage in the range of  $\pm 10$  V. The Data Logger was accurately calibrated before its installation for these measurements.

The DC accuracy of the data logger in the voltage range  $\pm 10$  V has an offset error of 11 mV, with

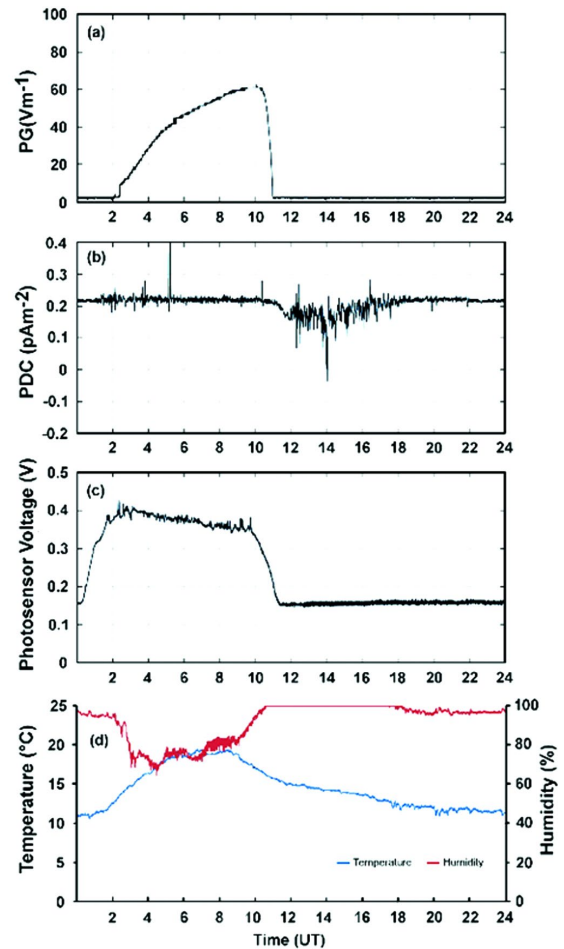


Fig. 8 — Fair-weather plot observed on 8 December 2017. (a) and (b) show PG and PDC. (c) shows the Photosensor output (solar irradiance) and (d) Temperature and Humidity.

absolute accuracy at full scale of 20 mV. The data was saved for further analysis and plotting was done using MATLAB R2015 software. The variable parameters are then individually monitored and digitally plotted.

The continuous recording of PDC and PG along with temperature, humidity started from January 2017 and solar irradiance measurements started simultaneously along with all the above mentioned parameters from April 2017.

Since May 2017, continuous data recording is in progress at the Atmospheric Laboratory in the School of Technology, NEHU, Shillong.

## 2 Results & Discussion

A sample record of both PDC and PG on a fair weather day along with other meteorological parameters observed on 8 December 2017 is indicated in Fig. 8 and sample record of PDC and PG on a



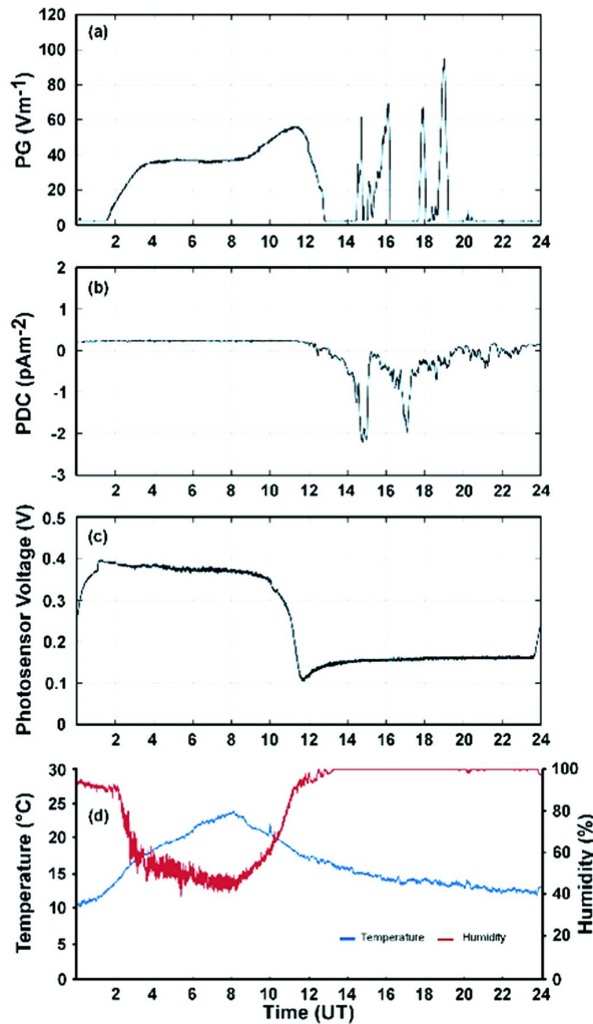


Fig. 9 — Disturbed weather plot observed on 26 October 2017. (a) and (b) show PG and PDC. (c) shows the Photosensor output (solar irradiance) and (d) Temperature and Humidity.

disturbed day observed on 26 October 2017 is shown in Fig. 9. The records obtained indicate the influence of the height of the recording station and the effect of sunrise and sunset effects on the PG & PDC.

Preliminary response and analysis of the measurements showed a considerable correlation between the observed parameters<sup>20-21</sup>.

It was obvious from the preliminary measurements that further extended studies and analysis of the local atmospheric electric parameters together with other meteorological parameters, would substantially contribute

to understand the local weather dynamics and activity over this sub Himalayan region.

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