Initial Response of Electric Field Monitoring System towards Measurement of Atmospheric Electric Field during Normal and Lightning Times

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Abstract- For over a considerable length of time, scientists have shown keen interest in studying the atmospheric dynamics. Especially when it comes to the investigation of the atmospheric electric field, the changes associated with it help the researcher fundamentally in characterizing other important parameters in the atmospheric studies additionally. These changes in the atmospheric and its response under fair weather or turbulent phases of climate become a promising source of investigation and may prove to be vital in early warning systems provided they are studied on the longer run on consistent basis.

In this paper, authors discuss a ground based method for analyzing and investigating the electric field variation in the atmosphere through the electric field mill system installed at the institutional premises of Madhav Institute of Technology and Science at Gwalior in the state of Madhya Pradesh (26° 14' N, 78° 10' E).

Index Terms- Atmospheric Electric Field, Electric Field Mill, Fair Weather

I. INTRODUCTION

The stochastic behavior of the atmosphere has always inspired researchers to indulge in long term investigation, in order to explore the complexities hidden in the atmosphere. In this context, the investigation of the atmospheric electric field has been a major point of consideration for research during different seasons. Atmospheric electricity plays significant role in the highly coupled system representing the Earth's atmosphere and the near Earth environment (Herman and Goldberg, 1978). Whether during rainfall or dusty clouds (Frier, 1960), or changes during abrupt geophysical conditions, these investigations have assisted, to a great extent in estimating and characterizing the electric field perturbation in the atmosphere during a long course of time. The global fair weather phenomena have been well studied using the Carnegie-curve as depicted by Bering et al. (1998). Electric field events in extreme weather conditions have been well synthesized in the past couple of decades subjected to various climatic regions and condition (Farman et al., 1985; Rycroft, 1990; Solomon, 1999). Measurements of electric current flowing upward during thunderstorm conditions have been illustrated by Kasemir (1979) and Blakaslee et al. (1989) earlier. A number of mathematical models have been suggested in this regard and could be found in past research papers (Hays and Roble, 1979; Volland, 1982; Ogawa, 1985). Considerable amount of work has been done previously in exploration of atmospheric electrodynamics through modeling by Markson (1979, 1983) where correlations have been attempted between electric field and solar influences and by Israelsson et al. (1987;1994) in investigating the various phenomena such as lightning activities and electrical discharges in the atmosphere and power plant harmonics in context to electric field measurement. Various methods are employed the detection of various phenomena associated with atmospheric parameters for example Time of Group of Arrival (TOGA) is a multiple lightning sensor network in the recent times being successfully run to detect lightning activities worldwide (Dowden et al., 2002; Rodger et al., 2006). Other significant works by Hoppel et al. (1986) and Tammet et al. (1992) have estimated the variation and characterization of the ions in the atmosphere in terms of their mobility with precision. Blanchard (1963) indicated at a much earlier stage that a large amount of current also flows from sea surface to atmosphere and cause the electric field enhancement. Based on the earlier platforms of such investigation the current paper is written with an objective of briefly discussing a ground based experimental technique to measure the atmospheric vertical electric field. In this context some results of extreme initial stage of installation of the set-up for a very short time period are also presented to give a very brief idea of the atmospheric electric field behaviour.

II. EXPERIMENTAL SET-UP

The experimental set-up is installed at Madhav Institute of Technology and Science at Gwalior, Madhya Pradesh (26° 14' N, 78° 10' E) and comprises of an electric field mill which is connected through interfacing and communication cables to the computational and recording facility in the laboratory as shown in Figure-1. A brushless motor with heavy-duty bearings along with a stainless steel shaft forms the part of the sensor unit. The working is based on the principle, when an uncharged sensor plate is exposed to an external electric field it then becomes charged. A detailed working of such experimentation could be found in similar research studies conducted by Murphy et al. (2008) and Ferro et al. (2011), which has further inspired the current manuscript to be written. Further, it is stated that the rate

and level of the activity measured by the field mill (popularly known as EFM-100 used in our present study) is being continuously recorded by the computer through suitable software as a raw data to be analyzed later on. The data is being recorded on daily basis as in the present case for long term comprehensive investigation. It is to be mentioned here that the equipment has been manufactured by Boltek Corp., USA under the funded project by All India Council for Technical Education (AICTE, New Delhi).

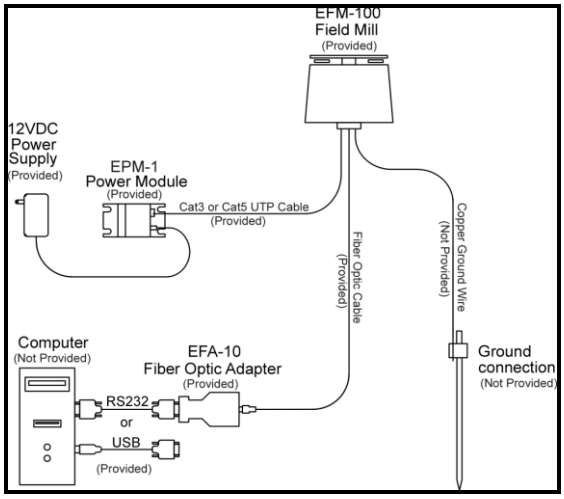

Figure 1 Experimental setup of the Electric field Monitoring system

III. Observational Results

As the continuous recording of data started in the first week of July, 2012, after proper installation, brief results are presented here for two days only. In this paper, fundamental test results have been presented to see short response of the electric field mill system mounted on the roof-top and exposed to open sky for best results.

In this section, two day results have been presented to observe the initial response of the set up during the month of July 2012. It is felt important to mention, that the month of July is considered to be primarily a monsoon month in which Gwalior records a considerable amount of rainfall. Figure 2 presents the twenty four hour result of the electric field variation along with local time for 11.07.2012. One could clrearly observe a very dormant nature of the electric field and the values of the electric field is just of the order of around 80 to 90 Volts/meter at most and the remaining time it is observed to be even lower. This is the state of the atmospheric electric field under normal conditions although the data is gathered only for a span of twenty four hours.

Figure 3 represents the electric field observation for 15.07.2012. There have been a marginal amount of rainfall recorded in the early hours of 15.07.2012 (around 8.5 mm of rainfall was recorded on the day) followed by heavy lightning activities. On analysis of the response of electric field variation from Figure 3., it is evident that there are some strong perturbation occuring in the early hours around 01:00:00 hrs Local Time when significant change is observed and the value reaches as high a 6000 Volts/meter in the negative Y-axis which is a drastic change. This is possibly attributable to the lightning events that have taken place in those hours in the closeby region as there have been evidences in past that support our theory (Williams et al., 1992;Harrison and Ingram, 2005). A similar situation arises later in the day around 16:00:00 hrs local time when the magnitude of the electric field varies between +2000 to -2000 Volts/meter and gradually returns to its normal value (of the order of a few Volts/meter) for the remaining period of the day. The results are confirmed in Figure 4 which shows that approximately 800 lightning strokes have been recorded during the whole day on the 15th of July 2012 which has possibly resulted in the sudden variation of the elcetric field of the atmosphere.

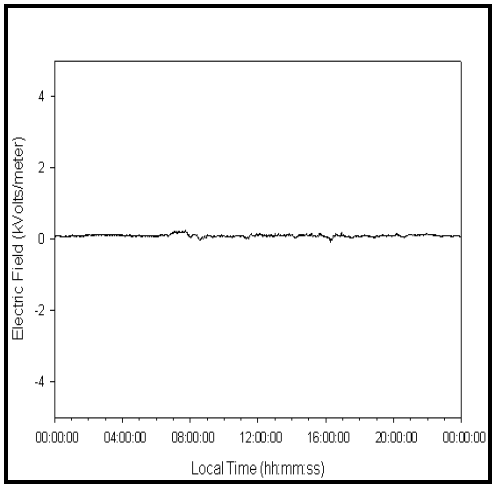

Figure 2 Atmospheric Electric field plot on 11 July 2012

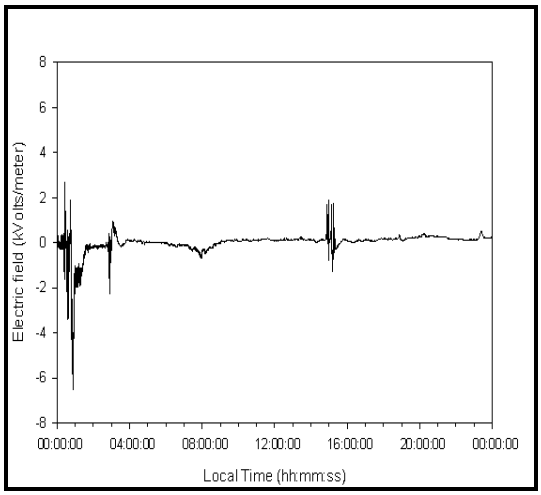

Figure 3 Atmospheric Electric field plot on 15 July 2012

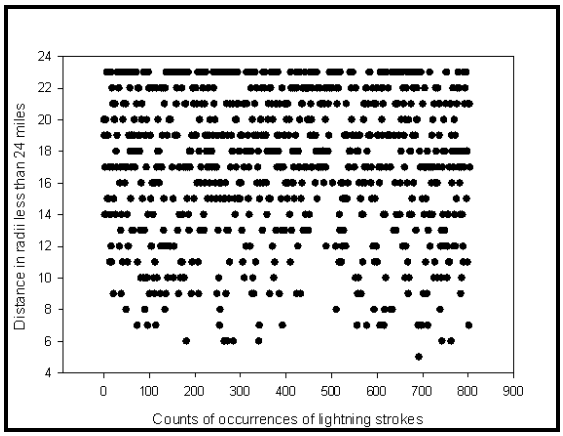

Figure 4 Occurrence of lightning strokes on 15 July 2012

IV. Discussion and Conclusion

The authors in this paper, have emphasized on the significance of the atmospheric electric field measuremnet system using the electric fill mill set up which is the first of its kind in the city of Gwalior which lies in the low-mid latitudnal region in the state of Madhya Pradesh and is subjected to extremity in the weather conditions in all seasons. In this context, the installation and brief methodology of the apparatus has been discussed followed by significant results to prove the authenticity and the vitality of the such measurements to be carried out. Two contrasting day results are presented which have been supported by a reasonable number of evidences (Rycroft et al.,2000; Cummer and Fullekrug, 2001; Williams, 2007). As in the first case, no variation is observed to indicate a fair weather day (Latha, 2003; Bennet and Harrison, 2006), the second case projects clearly the changes in the atmospheric electric field pertaining to moderate rainfall and also arising due to sudden lightning activities (Guha et al., 2010) that were recorded in the vicinity of 24 miles in radii from the location of the set-up. However, it is to be admitted that a large networking chain needs to be acquired if one wants to precisely locate the occurrence of the lightning activity in terms of the geographic coordinates which may also be attained using a Global Positioning System. However, the fact remains to be considered that in a hybrid of agricultural and commercially developing city like Gwalior, it is very essential to carry out long term studies by using such ground based and comparatively robust and ergonomical methods that can give us an idea about the characterisation of the atmospheric electric field and the installation of such an experimental technique at an initail stage holds no exception in laying a platform for the investigation of the atmospheric electric field which may also be useful in studying various other parameters..

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