Atmospheric Electric Field Monitoring For Power Generation

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***Abstract*— Atmosphere is the largest source of naturally produced energy on earth because of its atmospheric electricity. In this project, the energy that can be harvested from atmospheric electricity is estimated using a formula for energy per unit resistance by using the data for atmospheric electric field measured using Boltek EFM – 100 Atmospheric Electric Field Monitor. The atmospheric electric field is measured in three different weather conditions which are fair weather, cloudy and thunderstorm conditions. It is observed that higher electric field is detected during thunderstorm compared to the fair and cloudy weather. It has been proven that it is possible to generate energy from atmospheric electric field. This project also observed the relationship of an atmospheric electric field with the distance of lightning and thunderstorm.**

Keywords- atmosphere, electric field, thunderstorm, lightning, field mill, energy

I. INTRODUCTION

Energy crisis is a conflict between the generation and the utilisation of energy and the balance between them. It affects all aspects of life including economy, social and politics [1]. Currently majority of the energy produced, comes from the conventional resources, i.e. fossil fuels. As the depletion of the resources is imminent, people are increasingly concern of the consequences (social implication, economic crisis, reduction of energy generation). Possible renewable energies (i.e. solar, wind) are explored and being consider for the sustainability of energy generation. Atmosphere considered as the largest source of naturally produced energy on earth. This is because in the layer of atmosphere gases there is a regular diurnal variation of the Earth's atmospheric electromagnetic network which is called *atmospheric electricity* [1]. The electric field is generated from the cosmic rays, static electricity, lightning and thunderstorm activities in the cloud. Ideally high electricity can be generated by lightning. It is due to extremely high current, voltage and transient electric discharge produced by lightning. It is a transient discharge of static electricity which serves to re-establish the electrostatic equilibrium within a storm environment [1]. The Earth can be considered as a big battery while the thunderstorms will energize back the electrons that the earth gives off. The potential difference between ground and ionosphere, at fair weather regions, generates the atmospheric electric field on the order of 300kV [2]. Thunderstorm activity also can boost up the measurement of electric field which usually measured in kV/m thus can generate electricity. It has been estimated that one lightning strike has enough energy to light 150,000,0010 light bulbs or one strike can power a 100 watt light bulb for three months. These happen when the temperature in surrounding atmosphere rises to 15000°F (8316°C) – 60000°F (33316°C) when lightning strikes [2]. Therefore, it is not impossible to gather electricity from the atmosphere. In order to estimate energy generation from this source, the electric field generated from the atmospheric electric charge is measured using Boltek EFM-100 Electric Field Monitor. Electric field were measured in three different weathers condition which are fair weather, cloudy and thunderstorm conditions. The variation of electric field due to distribution of atmospheric charge is observed. Furthermore, the relationship between the electric field and occurrence and distance of lightning is observed.

II. METHODOLOGY

A. Configuration of field mill

The electric field is measured using Boltek EFM – 100. Electric Field Monitor. The electric field mill senses an electric field by repeatedly expose and shield a series of sense electrodes to the air. The electric field data displayed and graphed using the EFM – 100 display software, from the first approaching of thundercloud which gives a positive field reading, followed by a field reversal to a negative field as the cloud moves overhead.

Electric field mill uses a mechanical chopper to alternately shield and expose several sense plates to an electric field as shown in Figure 1. An electric charge is drawn from ground to the plates through a sense resistor when the sense plates are exposed to the electric field. The field charge is flows back to ground, again through the sense resistor when the sense plates are shielded from the field. This moving charge produced an electric current which is measured as an AC voltage across the sense resistor. The size of the voltage is proportional to the size of the electric field applied to the plates. Charges that flow onto and off of the sense electrodes will develop a voltage across the resistor. Thus, the reading will be detected and displayed in a monitor.

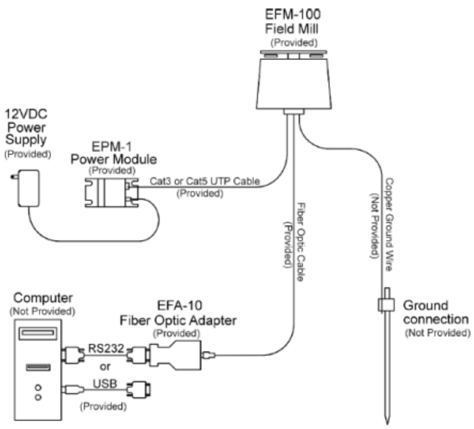

Figure 1: EFM-100 Connection Diagram

B. Interpreting Data To Be Used In Future Work

The data obtained from Boltek EFM-100 Electric Field Monitor is used to estimate the energy that can be harvested using a formula based on the concept of capacitance. This is similarly used to express the work done by battery. The formulas that will be used to get the energy per unit resistance are:

$$C = \frac{\varepsilon_0 A}{d} \quad (1)$$

where C is the capacitance in Farads of two parallel plate to store an electrical charge, ε_0 is electric constant ($\varepsilon_0 \approx 8.854 \times 10^{-12} F\ m^{-1}$), A is the area of plates in square metres (m^2) and d is the distance between two plates.

Magnitude of charge on the plate is given by:

$$Q = CV \quad (2)$$

where $V$is the voltage. Electric field can be calculated using

$$E = \frac{V}{d} \quad (3)$$

$$\therefore V = Ed \quad (4)$$

Thus, voltage, V is proportional to electric field, E.
Differentiating charge, Q and voltage, V over time, dt gived:

$$\frac{dQ}{dt} = C\frac{dV}{dt} \quad (5)$$

where $\frac{dQ}{dt}$ is the charge, rate of change and $\frac{dV}{dt}$ is the instantaneous rate of voltage change (volts per second)

Substituting Eq (1) and Eq (5) into Eq (4):

$$\frac{dQ}{dt} = \frac{\varepsilon_0 A}{d} \cdot \frac{dV}{dt} \quad (6)$$

Since current;

$$i = \varepsilon_0 A\frac{dE}{dt} \quad (7)$$

and energy;

$$W = \int_0^t i^2 R\, dt \quad (8)$$

where R is resistance, the
Energy per unit Resistance $J\Omega^{-1}$, can be calculated:

$$\frac{W}{R} = \int_0^t i^2\, dt = \int_0^t \varepsilon_0{}^2 A^2 \left(\frac{dE}{dt}\right)^2 dt = \varepsilon_0{}^2 A^2 \int_0^t \left(\frac{dE}{dt}\right)^2 dt \quad (9)$$

III. RESULTS AND DISCUSSION

The EFM-100 display software is attempted to establish and maintain a network connection with the remote computer's in order to remote a received data from field mill. The differences of atmospheric energy data can be seen differently from those various weathers. This software provides an ideal way to view an electric field data in reference to alarm annunciator, amplitude range selector, time range selector and other relevant geographic features of interest in real time. The history graph and current field reading can be viewed inside the EFM-100 display software.

Different type of weather will affect the electric field readings. This research is focused in Peninsular Malaysia which is coordinated on N 2°59'19" latitude and E101°43'29" longitude where the field mill is mounted at. The atmospheric electric field data will later be analyzed by comparing with the peak current of lightning data gained from TNB Research for a validation purposes using MATLAB software and numerical method analysis.

The result in Figure 1 shows the strength of an electric field on 26th March 2013. It shows the fluctuation of an electric field variation in the early morning detected in thunder weather. The thunderstorm happened once after the other. The first one happened not very far from the field mill monitor spot, though the electric field fluctuations were relatively small which only 10kV/m lightning detection with 13 miles from the field mill location. Then, the reading of an electric field gets the maximum reading; about 20kV/m with the lightning detection was only 6 miles away from the field mill location as shown in field mill monitor system compared to the rest of the reading taken on that day. The charge structure of thunderstorm is mostly in dipolar and in negative polarity of electric field. Besides, it also produced main negative discharge and active of the activity of the cloud- to ground flash [13].In the evening, it shows that the electric field variation in cloudy to overcast day which is about 5kV/m. This electric field detection is almost the same as detected in Beijing atmosphere during thunder weather [14].

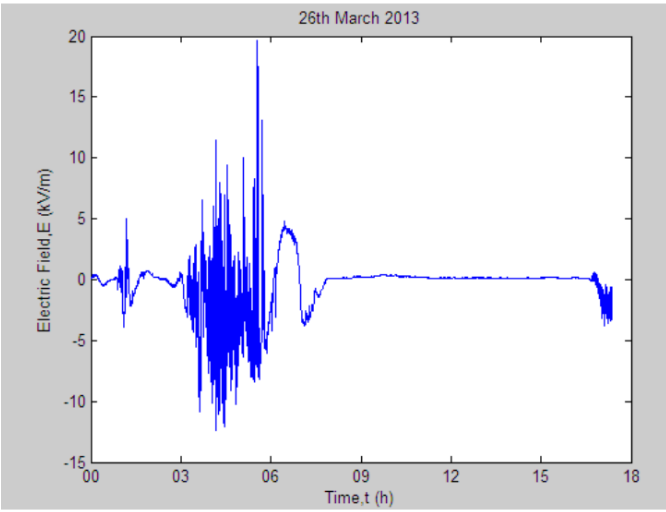

Figure 1: Curve of Electric Field, E (kV/m) against Time,t (h) on 26th March 2013

Figure 2 and Figure 3 shows the atmospheric electric field strength detected by field mill in a fine weather before the fluctuations of electric field occurred when thunderstorm in that day. The curve recorded by field mill is nearly straight line with almost 0 kV/m strength of electric field. Even if there is low of electric field detected, there is still lightning detection in 23 miles away from the field mill located.

Generally, the average of electric field strength in sunny days is about 0.13kV/m [15], but in different places and position of the electric field sensor is being installed, the value is not same. Typically, the electric field strength is positively correlated with aerosol content, vapour, temperature, and other weather factors, but negatively correlated with atmospheric conductivity in fine weather [14]. To add, on that day, thunderstorm happened once in a whole day with 10kV/m strength of electric field with lightning detected 10 miles away from where the field mill is mounted at.

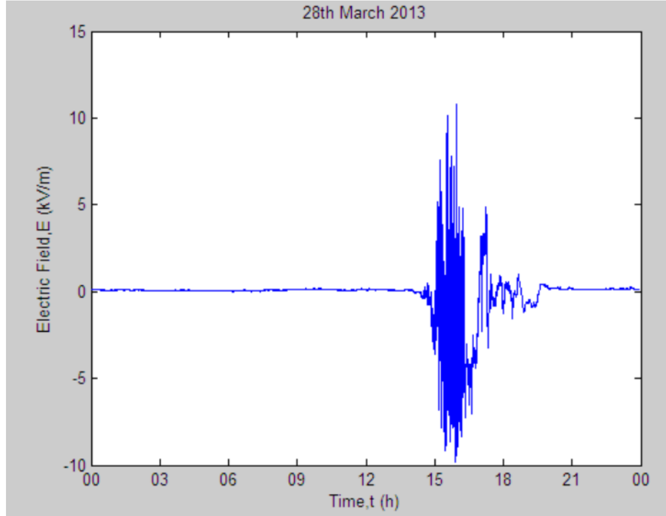

Figure 2: Curve of Electric Field, E (kV/m) against Time, t (h) on 29th March 2013

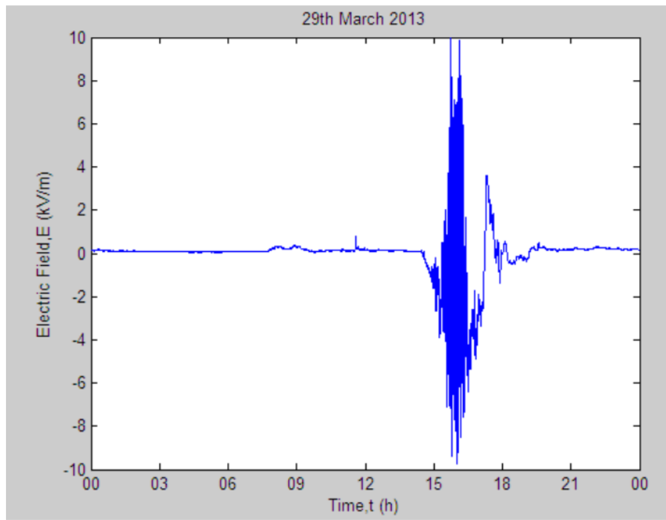

Figure 3: Curve of Electric Field, E (kV/m) against Time, t (h) on 29th March 2013

Figure 4 shows the electric field fluctuations on a cloudy day (without rain) on 31th March 2013 in Serdang. It shows a small electric field strength at 0.45kV/m there is a lightning detection around them. This small variation detection of electric field is most probably affected by the location of field mill which is mounted near the ground. The electric field value is getting increases when the height of field mills mounted is rises around the building. Since, the atmospheric electric field is approximately well proportioned in a planar area near the ground [16].

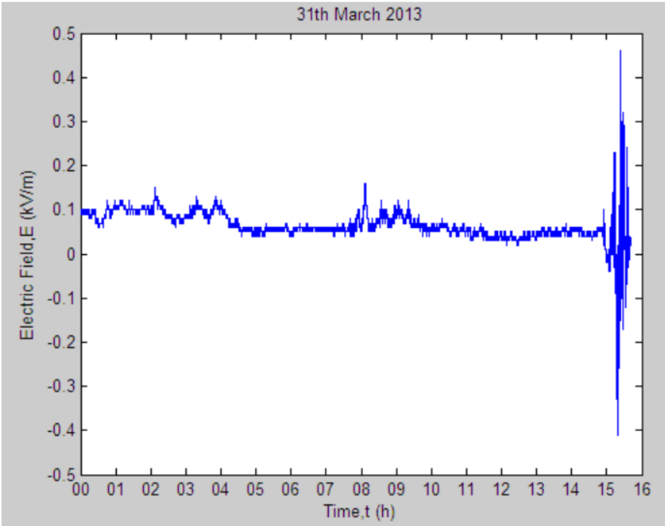

Figure 4: Curve of Electric Field, E (kV/m) against Time, t (h) on 31th March 2013

It can be seen that, the atmospheric electric field produced higher electric field reading when there a lightning occurred especially during thunderstorm and cloudy weather. By monitoring the atmospheric electric field using field mill, an information about lightning forecast, accuracy of weather forecast in a local region validation, and the dependability of lightning protection validation also can be measured

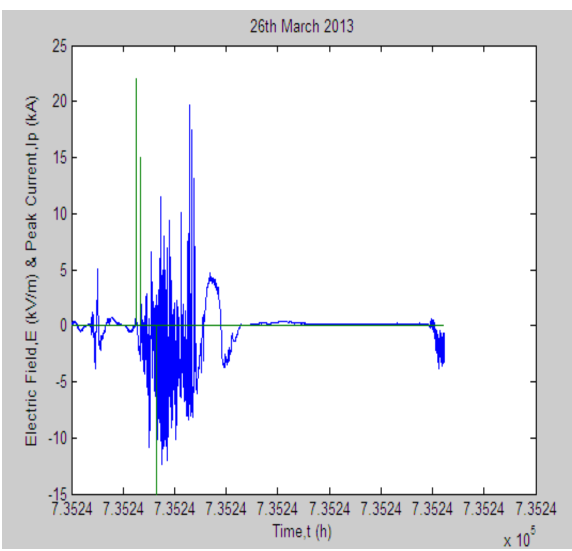

Figure 5 : Atmospheric Electric Field and Peak Current of Lightning on 26th April 2013

Figure 5 shows the atmospheric electric field and peak current of lightning. It shows the relationship between electric field and peak current. The peak current is reached more than 20 kilo amperes (kA) when the electric field is high on that time. Generally, typical lightning bolt may transfer 10^{20} electrons in a fraction of a second, developing a peak current of up to 10 kA.

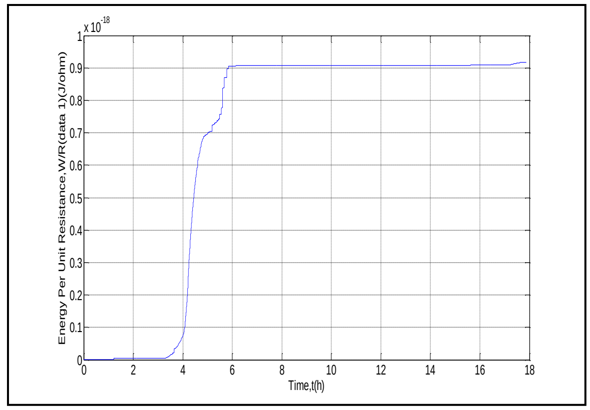

Figure 6 : Energy per unit resistance

Figure 6 shows the energy per unit resistance on 26th April 2013where the energy produced is quite small which is about 1×10^{-18}J/ohm even during the occurrence of lightning or thunderstorm activity.

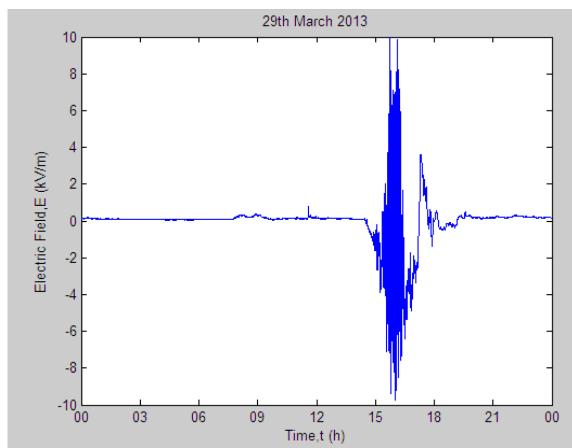

Figure 7 : Atmospheric Electric Field

Figure 7 shows the atmospheric electric field strength detected by field mill in a fine weather before the fluctuations of electric field occurred when thunderstorm in that day. Even when there is low of electric field detected, there is still lightning detection in 23 miles away from the field mill located. Typically, the electric field strength is positively correlated with aerosol content, vapour, temperature, and other weather factors, but negatively correlated with atmospheric conductivity in fine weather.

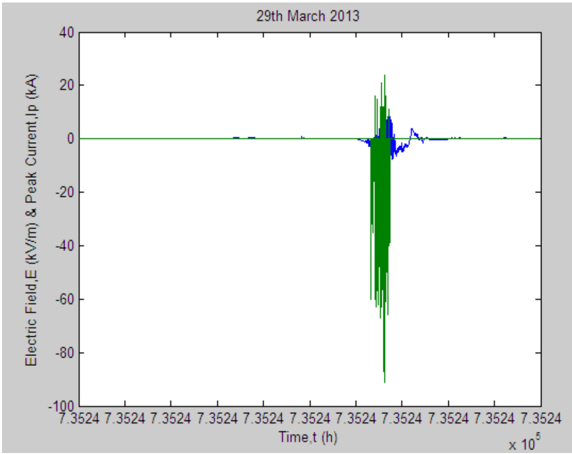

Figure 8 : Atmospheric Electric Field and Peak Current of Lightning

Figure 8 shows the peak current of lightning proportional to the value of electric field in a fine weather where the reading is 20kA. The magnetizing effects of large currents on rock and was able to scale those experiments to estimate the current associated with the lightning.

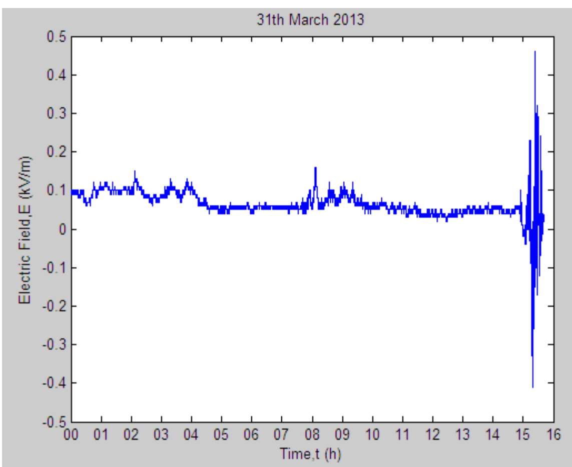

Figure 9 : Atmospheric Electric Field

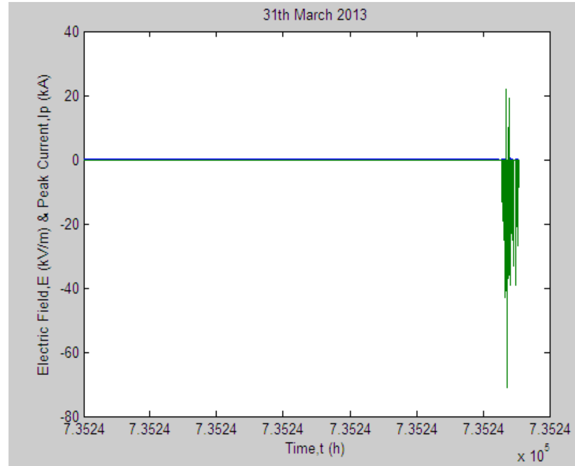

Figure 10 : Atmospheric Electric Field and Peak Current of Lightning

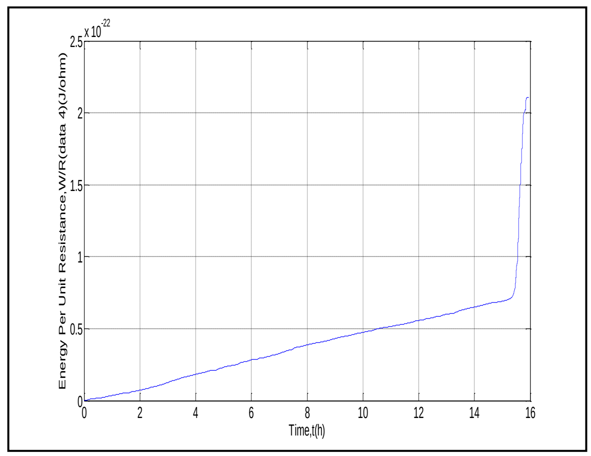

Figure 2 : Energy per unit resistance

Figure 9 shows the electric field fluctuations on a cloudy day (without rain) on 31th March 2013 in Serdang. This small variation detection of electric field is most probably affected by the location of field mill which is mounted near the ground. The electric field value is getting increases when the height of field mills mounted is rises around the building. Figure 10 shows the relationship of peak current and electric field on 31th April 2013. The graph is smooth at first before the lightning occurs. Thus the peak current is also increased when the electric field variation is high. Other than magnetic detector based on Ampere's law allows the deduction of current. Figure 11 shows the energy per unit resistance on 31th April 2013 with only 2.5 x J/ohm.

The energy produced supposed to be high since the electric field detected by field mill is high. Unfortunately, the graph below shows a very small of energy produced even the electric field detected is high. This is due to the small area of a plates and no distance included in this estimation process. Besides that, regarding the electric field effects towards a distance of a lightning detected by the field mill sensor, as the electric field strength detected is small, the distance of lightning detection will getting far . This condition is mostly affected by the location of the field mill's being mounted on the ground. The electric field on the buildings is much higher that on the ground [4].

IV. Conclusion

The study of this project has served its purposes and objectives. The variation of an atmospheric electric field near the ground is obtained and the reading is quite high. The intensity of electric field runs successfully during the whole period of thunderstorm besides on fine weather and cloudy. The distance of lightning detection also gets far as the electric field slows down. It is proven that electric field on the atmosphere is proportional to the occurrence of lightning. Last but not least, the estimation of energy per unit resistance is too small since there is no distance included during the estimation. Therefore, it is suggested to apply the plate on a roof with large area in order to have a sizable energy.

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