Available online www.unicrossjournals.com

UNICROSS JOURNAL OF SCIENCE AND TECHNOLOGY, UJOST

RESEARCH ARTICLE VOL. 2(1) MARCH, 2023 ISSN:2814-2241

Date Accepted: 31st March, 2023 Pages 85-94

A REVIEW ON HARNESSING CLOUD ELECTRICITY AS A RENEWABLE ENERGY RESOURCE

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Abstract

Atmospheric electricity gained considerable attention around the early 18th century. By 1751 Benjamin Franklin showed through experimental evidence that electricity could be taken from clouds via a tall metal with a sharp point. Since then several efforts have been made to obtain electrical supply from the atmosphere. This paper examines the progress made so far. The authors performed a review of the literature using google scholar data bank and google search engine from 1 January 1700, to 15 November, 2022. By applying key words, such as: Atmospheric electricity, cloud static charge, lightening energy, renewable energy from the atmosphere extracted only articles published in English. The destructive aspects of thunder bolt and lightning flashes were excluded from this review. The authors found that Literature on published works on atmospheric electricity is quite scanty which is attributable to the slow progress made so far; including the hazards involved and the massive failure of earlier attempts. There were no review papers found and 22 peer review published works were consulted. There were also articles found through google search engine containing useful information about prototypes for harnessing lightening electricity. Harnessing atmospheric electricity has suffered several setbacks due to the absence of appropriate materials and techniques for handling large quantity of charges delivered sporadically in a very short time at high voltages. For several years after earlier attempts the subject was abandoned until the need for renewable energy technologies came to the front burner. The atmosphere is a potential renewable energy resource which contains vast amount of electrical charges especially within the clouds and the electro-sphere. Electricity generation from the Atmosphere potent very high spatial and temporal benefits.

Key Words: Thunderstorm, Renewable Energy, Atmospheric Electricity, Electricity generation, electro-sphere.

Introduction

According to the United Nations Development Project, UNDP (2020), energy is central to sustainable development and poverty reduction efforts. Unfortunately, electricity generation is still a major problem to many developing nations. Yet, electricity supply remains a major index for assessing the development of nations and their technological advancement. A greater percentage of electricity supply in the world depends on hydrocarbons responsible massive production of greenhouse gases known for adverse effects on the climate system.

Energy researchers are therefore, focusing more on renewable energy technologies which are an eco-friendly means of power generation (EPRI, 2005). Unfortunately, most renewable energy transducers have not been able to convert enough energy to electricity to meet up with increasing energy demands (Ewona and Obeten, 2021). Ensuring energy security will require diversification of types and energy sources, with increasing focus on consumer needs, indigenous energy supplies, energy efficiency and regional interconnections. Atmospheric electricity guarantees all these benefits.

Electricity supply is a major factor for enhancing civilization and technological development. UNDP (2014) is of the view that energy is central to sustainable development and poverty reduction efforts. The short fall in supply is primarily due to the dearth of raw materials for electricity generation. The dwindling reserves of gas and the rising cost of electricity generation amidst insatiable demand for energy have given alternative energy sources an accelerated boost in recent years.

Many studies have already been undertaken that have exposed new knowledge in these areas and appropriate instrumentation developed. Even in urban cities where potentials for growth are higher, developments on the energy sector will definitely affect the quality of life of citizens and their economic potentials (Soton 2014).

There have been several interventions in the energy sector. The UNDP for instance has been helping developing countries to expand access to reliable and modern sources of energy in order to reduce poverty and to improve the health of their citizens, while at the same time promoting economic growth and mitigating climate change in many parts of the world. Investing in clean, efficient, affordable and reliable energy systems is driving the reawakening in the atmospheric electricity sector in recent times.

Ensuring energy security will require diversification of types and sources of energy, with increasing focus on consumer needs, on indigenous energy supplies, energy efficiency and regional interconnections (UNDP, 2014).

Researchers have been looking for a more sustainable eco-friendly and clean means of power generation. At the global level, researchers are looking at the cleanest way to generate power in a sustainable manner EPRI (2005). Renewing energy systems have therefore been encouraged in recent times to stem the adverse effects of climate change believed to be inflamed by carbon laden by-products of combustion.

2.0 Cloud electricity as renewable energy resource

Both the clouds and the electro-sphere contain vast amount of electrical charges which are often discharge through lightning.

are a potential renewable energy resource The atmosphere is, therefore, a potential renewable energy resource. Thunderstorms act as a giant battery charging up and maintaining the electro-sphere to about 400,000 volts with respect to the earth's surface. When fully charged, a large electric current flow along the plasma channel from the cloud to the ground, in the form of lightening; neutralizing the positive ground charge as electrons flow away from a lightning strike (Wikipedia 2020).

As far back as 18th century, Franklin (1751) hypothesized that electricity could be taken from clouds via a tall metal with a sharp point. Franklin drew sparks from a key attached to the conducting string of his electrical kite that was insulated from ground by silk ribbon and concluded that thunderclouds are electrified. He also believed that silent discharges from one or more sharp points may reduce or eliminate the electricity in the clouds above, thereby reducing or eliminating the chances of the structure being struck by lightning (Krider, 2006). Unfortunately, research and development efforts are yet to reach appreciable levels, principally due to the large electrocuting nature of thunder strikes in the one hand, and the lack of materials and technology to handle the vast amount of currents and voltages associated with thunderstorms, on the other.

3.0 Lightning and Thunderstorms

The existence of spikes accompanying a single lightening discharge is indicative of the possibility of splitting of a discharge into different paths. This is essential in encouraging research in cloud Fourier analyses to breakdown large voltages and currents to smaller values within the threshold of modern technology.

It is common see a lightning channel split and strike two or more points on the ground, as shown in photo 1a and 1b. The multiple ground points can range in separation distances from a few metres to kilometres apart. The lightning strokes normally occur in quick successions. It is not clear if this can happen simultaneously, as well. The possibility is suggested given that different ionization channels can be developed from a single step leader (See photograghs 1a and 1b, Robinson 2022).

Photo 1a: By Dan Robinson - Editor/Photographer (Robinson 2022).

Photo 1b: Photograph © 2003 by Appalachian Skies Photography (Robinson 2022).

Atmospheric/Cloud electricity, manifested in the form of thunder and lightning, may offer a great renewable energy resource.

Atmospheric electricity involves both cloud thunderstorms, which create lightning discharged paths to drain huge amounts of excess charge stored in storm clouds to the earth, and the continual electrification of the air due to various sources of charged particles from the earth including ionization from cosmic rays and natural radioactivity.

Thunderstorms act as a giant battery in the atmosphere, charging up the ionosphere to about 400,000 volts with respect to the earth's surface. The induced potential difference, p.d., sets up an electric field throughout the atmosphere. Atmospheric ions move in the electric field, (constituting a very weak current of about 2 pico-Amperes per square metre) throughout the atmosphere, even in the absence of clouds (Defer et al, 2015). The thunder cloud to ground P.d. on the other hand can reach up to about 3 X 106V just before discharge. The thunderstorm generator hypothesis proposed by Wilson,1920 (in Kelley, 2014) was based on his observations that, beneath the thundercloud, negative charge is transferred to the Earth and above the thundercloud; positive charge is transferred to the conducting upper atmosphere.

The works of Sengupta, (2020) show that during thunderstorms, there is always charge imbalance between atmosphere and ground, which gets partially released through electron flow between the two media in the form of "cloud-to-ground" lightning. Estimates show that a single lightning event can dissipate as high as 109 J of energy, thereby raising the surrounding air temperature instantaneously to a very high value (~105 K). When such lightning strikes the Earth's crust, the target gets heated up at an enormously high rate (≥1000 K/s) and the temperature can go even beyond ~3000 K (or even higher, ~10,000–30,000 K, in the lightning channel) over a period of less than 1 ms. Lightning travels up to 60,000 miles per hour with a flash that is over one billion watts (brighter than five million 200-watt light bulbs). This wattage is as much power as is produced by all of the electricity plants in the United States and with a voltage of up to 300 million volts. It is this tremendous power within lightning that has prevented any successful effort at collecting the electrical energy within it. This is far too extreme for current technology to handle.

4.0 Advances in harnessing cloud electricity

Atmospheric electricity is always present, and during fair weather away from thunderstorms, the air above the surface of the Earth is positively charged, while the Earth's surface charge is negative. It can be understood in terms of a difference in potential between a point on the Earth's surface, and a point somewhere in the air above it. Because the atmospheric electric field is negatively (upwards) directed in fair weather, the convention is to refer to the potential gradient, which has the opposite sign and is about 100V/m at the surface. There is a weak conduction current of atmospheric ions moving in the atmospheric electric field, about 2 pico-Amperes per square metre, and the air is weakly conductive due to the presence of these atmospheric ions. Defer et al (2015) have shown that the surface electrostatic field can be used to detect the presence of charge overhead within a cloud.

Harnessing energy from the thunder cloud and or lightening has been one of the most difficult research areas man has ever undertaken. There have been many attempts especially during the 18th century when atmospheric electricity was first gained considerable attention (Hunting, 2020). With the evidence of lightning s electrical discharge from the clouds, scientists became interested in harnessing the electrical energy inherent in the atmosphere. Both laboratory (Wall 1708) and field experiments (Franklin 1751; Dalibart 1752; de Romas 1753; Cavallo 1776; Lemonnier 1752; Nicoll 2012) were used to test this possibility. A lot of understanding into the nature and characteristics of atmospheric electricity was gained. One of which was the concept of Global Electric Circuit (GEC) which shows that atmospheric electrical phenomena are primarily driven by thunderstorms and shower cloud activity. While thunder cloud holds static electricity, lightning discharge comes as a mixture of electron and ion current electricity flowing at great speeds and at extremely high voltages and currents from one point to the other depending on the direction of the potential difference (Wilson 1906, 1920).

In spite of the above efforts, it was not possible to harness atmospheric electricity in a substantial way, perhaps, until recently. There have been renewed attempts in the last two decades to investigate the possibility of harvesting lightning energy in a more substantive way. (SEFE, 2020), claims that its product which is made of a String (1,000 feet long of insulated wire placed 10 feet above ground level) can collect enough static electricity from a balloon or an aircraft launched far into the air, possibly beyond normal sight, to charge a deep cycle battery in about 12 hours. The challenge of launching such air-crafts and maintaining them in the air just to charge a battery for 12 hours may not be sufficient alternative to the energy problem in terms of time, cost and convenience.

Recent works confirm that a single bolt of lightning carries a relatively large amount of energy (Jump, 2022) delivered at an extremely short period of time in the order of microseconds (Shiraishi and Otsuka, 2006); hence, an extremely high amount of electrical power is involved in the order of 5 to 10 gigajoules over 10 microseconds or 500 terawatts (Williams 1988). Because lightning bolts vary in voltage and current, a more average calculation would be 10 gigawatts (Dvorak, 2016). It has been suggested that lightning can be used to generate hydrogen from water, to harness the energy from rapid heating of water due to lightning or to use a group of lightning arresters to harness a strike, either directly or by converting it to heat or mechanical energy, (Knowledge, Dr 2022) or to use inductors spaced far enough away so that a safe fraction of the energy might be captured (Helman, 2011). Several schemes have been proposed, but the ever-changing energy involved in each lightning bolt renders lightning power harvesting from ground-based rods impractical: too high and it will damage the storage; too low and it may not work. One challenge is that it is difficult to convert high-voltage electrical power that is sporadic as lightning to lower-voltage power that can be stored (Knowledge, Dr 2022). Another major challenge when attempting to harvest energy from lightning is the impossibility of predicting when and where thunderstorms will occur. Even during a storm, it is very difficult to tell where exactly lightning will strike (Jump, 2022).

In 2007, an alternative energy company called Alternate Energy Holdings, Inc. (AEHI) were reportedly able to power a 60-watt light bulb for 20 minutes using the energy captured from a small flash of artificial lightning. The method involved a tower, a means of shunting off a large portion of the incoming energy, and a capacitor to store the rest.

However, the co-director of the Lightning Research Laboratory at the University of Florida dismissed the idea as unprofitable saying that, even the brightest flash, contains very little energy, and dozens of lightning towers like those used in the system tested by AEHI would be needed to operate five 100-watt light bulbs for the course of a year (Uman, 1986).

Malavika and Vishal (2013) showed that a thunder arrestor rod provides a path of least resistance for the lightning to the ground. The energy can be tapped through a tesla coil through a step down transformer reducing the energy into smaller voltages. (Malavika and Vishal, 2013). Their major challenge was the unpredictability of the next point a lightning will strike. Even during a storm, it is very difficult to tell where exactly lightning will strike (Sudagoni, et al., 2020).

Currently, there is a lot of progress made in the area of harnessing cloud electricity through what is called artificial trigger-discharge. There are two methods involved namely: Rocket and Laser. Uman and his team are reported to have created thunder bolts by triggering a rocket 6-feet rocket to a grounded copper spool(winding) into the heart of the thundercloud. The copper wire provides the path for the clouds to discharge its negative charges to the ground (Patel, 2015).

Another method proposed by … is the electrolysis of water through the use of electro-ceramics. If a conductor is bonded in between the step down tesla transformer and water body it gets the water ionized and produces ionized steam. The resulting effect is that the water cannot be reused. The researchers instead replaced the conductor rod with a ceramic plate. This plate releases heat without any ionizing the water.

For the purposes of safety, artificial thunder bolts are developed from a Tesla coil in the laboratory. The Equivalent capacitance for MMC's is given by:

$$\text{Ceq.} = \frac{1}{2\pi f \frac{V}{I}}$$

There will be a bleeder resistor for each capacitor in order to discharge the capacitor. The resonant frequency for tuning the Tesla Coil is given by:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

To handle the kind of instantaneous power associated with thunder bolts, the authors suggest that heavy conduction rods ultra-heavy-duty electrical circuits and storage super-capacitors will be required. The entire set up would have to handle the extreme amount of charge in only around 30 milliseconds (approximate duration of a lighting strike). Although we do not have that technology in electrical energy storage yet, they believe that with the current development, the days are fast approaching when lightning can provide a solution for all our power crisis issues Sudagoni, et al., 2021)

5.0 Methodology

The authors performed a review of the literature using from google scholar data bank and google search engine from 1 January 1980, to 15 December, 2022. The main inclusion criterion for this review was data on Atmospheric electricity, cloud statics charges, current electricity. The following keywords were used to search the databases: Atmospheric electricity, voltage divider, current divider cloud static charges and harnessing lightening energy, Renewable energy from lightening.

Destructive events about thunder bolt and lightning flashes were excluded from this review. To provide progressive efforts in harnessing cloud electricity, we preferred to include relevant articles from the beginning of the discovery of cloud electricity. Only publications in English were consulted in this review. There were no review papers found and 20research papers were cited including unpublished papers about lightening prototypes for lightening electricity.

6.0 Conclusion

Electricity generation from the Atmosphere potent very high spatial and temporal benefits and investing in clean, efficient, affordable and reliable energy systems is indispensable for a prosperous, environmentally sustainable future. Renewable energy systems rely on a knowledge and understanding of the resource, the converter technology and the balance of system. Appreciable level of research progress has been made in the areas of solar energy and wind technology to developed electricity. The problem, however still lies on the low conversion factor of available transducers. Hence, current renewable energy technology is still far from meeting global demand.

Various attempts have been made in the past four centuries to harness the vast electric charges in the cloud with just little progress recorded. These attempts dates back to 1775 when Franklin first discovered that electric current flowed through a string from a thunder cloud to the earth. The major setback has been availability of appropriate techniques and a suitable technology. This may account for the paucity of research works and journal articles. These failures are largely due to the dearth of materials which are able to handle large voltages and currents without burning out in the one hand and scientific knowledge required to step down the large voltages and currents to manageable levels now known with electronic circuits. These may not unconnected with the hazard involved and the massive failure of earlier attempts. However, the last two decades have witnessed renewed efforts in this direction.

The presence of circuit theories and current and voltage dividers may provide another dimension of approach. It is, therefore, recommended that a comprehensive analyses of cloud static electricity including discharge processes be further studied to enable researchers determine the possibility of stepping down the voltage to manageable levels. Through Laboratory technology to study the development and discharge of lightening with a view to developing simulations that will result in the appropriate voltage dividers and storage systems, harnessing of cloud electricity in sufficient quantity for new sustainable renewable energy resource will be possible.

The development processes may involve the study of atmospheric electricity development and discharge processes. By applying voltage and current theories the energy inherent in the thundercloud (or lightening) can be harnessed substantially.

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