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P3_1 Shocking Revelations

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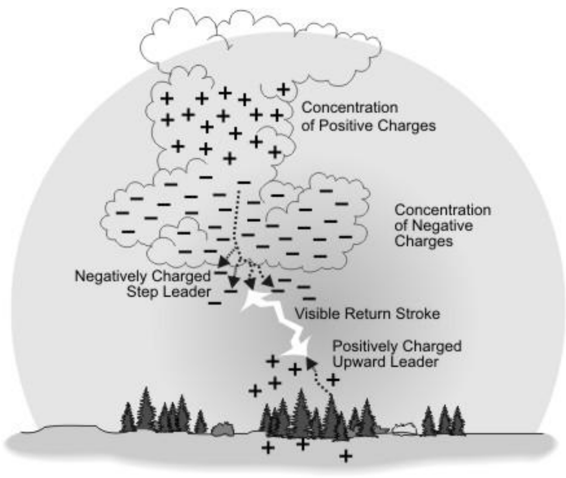
Abstract

The feasibility of using lightning as a renewable source of energy is studied. It was found that, while a good idea in practice, efficiently converting electricity into a useful product presents a problem as well as the rarity of lightning strikes themselves. It was calculated that even in a location that experiences lots of lightning, it would only get struck on average once per year. Due to this, it is unlikely that the power obtained from lightning itself would outweigh the expense of building a facility to efficiently harvest it.

Introduction

Billions of pounds are being invested into finding, developing and perfecting renewable sources of electricity. The latest research in this field has been to identify if controlled nuclear fusion on Earth is possible, however, there may be an easier way in which the electricity literally comes to you. This is the idea of collecting and storing lightning as electricity in order to power electrical devices.

Lightning is essentially a huge electrostatic discharge. It is thought that it is formed when large ice particles formed in clouds collide and break up into smaller ice particles, and through this process they become charged electrostatically. The larger particles tend to become more negatively charged and the smaller particles tend to become more positively charged[1]. This then allows them to form two distinct and separate layers as the larger, heavier particles will be attracted more strongly to the Earth and so will be pulled closer to the ground relative to the smaller, lighter particles. This is shown in Figure 1.



As this charge continues to build, a charge is induced in the air below the cloud as the large negative charge above acts to repel electrons away from it. Eventually, a positive charge is induced in the region of the ground below the cloud too. Currents, known as leaders, flow between the positively charged ground and the negatively charged region of the cloud. This is in an attempt to balance the charges and this forms a path for the lightning to follow down to the ground.

Figure 1[2] shows the formation of a thundercloud and the subsequent charge induced on the ground. Image from reference 2.

Theory

Attracting the lightning itself is relatively easy, all that is required is to extend a material up towards the thundercloud that is more conductive than the air through which it would normally pass. The bolt will always take the path of least resistance so if a highly conductive metal is extended up towards the charged cloud then the electrostatic discharge should pass through it provided it is closer to the cloud than any other object such as a tree or building.

In the 'Lightning Alley' in Florida the average number of thunderstorms annually is 20 per km^2[3], this is the ground flash density. A conductive object that is taller than the surrounding area exhibits a lightning attractive area greater than the ground surface area it occupies. Assuming a structure of length L = 40m, width W = 25m with a conductive tower built on top of height H = 55m which is approximately the height of an electricity pylon, the effective lightning attractive area is given by[4],

$$A = LW + 4H(L + W) + 4H^2\pi, \tag{1}$$

which for the dimensions given above, the effective area becomes 0.053km^2. The probability of a strike to the structure is given by the product of the lightning attractive area and the ground-flash density. Using the calculations above, there will be on average 1.06 strikes on the structure per year. This may be a little too low to justify building a facility to accommodate this.

The largest hurdle in utilizing electricity from a lightning bolt would be finding a way to effectively store or convert the energy into a useful form as once electricity has been generated it is generally difficult to store. This is especially true for high voltage sources like a lightning bolt, typically supplying around 1MV[2], and is why currently electricity is only generated to match demand. Lightning cannot be turned off and on to match demand so the only way it can be utilized as electricity would be to store or convert it in some way. In addition to this, another hurdle in using lightning directly as electricity is that it is a direct current (DC) and would need to be converted to an alternating current (AC) in order to be used with devices that are designed to be used with an AC, of which most devices are.

With these restrictions in mind, one potential way of harnessing the raw power of the lightning is by using it to stimulate the electrolysis of water into its constituent components, hydrogen and oxygen. These could then be used as a fuel source through combustion. Another solution would be to connect the conductor to a capacitor via a step-down inverter to firstly convert the DC power supply to an AC power supply and secondly to reduce the huge voltage, which would damage all electronic devices. One final idea may be to connect the conductive lightning rod to a very robust resistor. The current flowing through it will cause it to heat up and if a reservoir of water is placed in close proximity to it then it could evaporate the water into steam which could be used to generate electricity.

Conclusion

To conclude, while there is great potential for using lightning bolts in order to generate electricity, the act of actually accomplishing this is very difficult. The combination of the difficulties involved in efficiently utilising the energy supplied by the bolt, along with the rarity of the conditions conducive to lightning strikes, means that it in the majority of situations it is unfeasible. However, some areas where a lot of lightning is present, such as in 'Lightning Alley' in Florida, would be much better locations for a lightning powered power station, but even here it has been calculated that approximately only one strike per year will hit the structure. This could be increased by building a higher tower but it is perhaps unlikely that the power obtained in this manner would be worth building such a facility.

References

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