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Investigation into the use of Electret Effect in Nikola Tesla's Energy System

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Abstract

Ambient Energy Transducers are good alternative power sources if they are properly designed and fabricated. In this paper, we carry out investigation on Nikola Tesla's patents for Ambient Energy Transducers or Radiant Energy System, using locally available materials. We set up experiments using locally sourced materials, in an attempt to duplicate Tesla's system, and in the process, the electret effect was investigated. Results were obtained and analyzed, and it was found that the electret effect, which was not mentioned in Tesla's patents, seems to be the key to the success of his ambient energy transducer.

Keywords: energy transducers, energy harvesting, electret effect

1.0 Introduction

The quest for renewable energy is not new. From the intimidating hydro-electric dams to the humble solar panel, renewable energy systems have teased mankind with the possibility of obtaining more power at less cost or alleviate power supply problems [1, 2]. It is not news that the earth swims in an ocean of energy. The sun alone daily pours down 5.1×10^{14} kilowatts of energy, while the electrostatic field of the earth has been estimated to contain 1.7×10^{10} joules or 4.8 megawatt-hours of electrical energy [3,4]. The energy available from the earth's magnetic field has not been estimated. Then we have the energy from cosmic rays and other electromagnetic radiation pouring down to the earth from other celestial bodies and outer space, whose magnitude has not been estimated. Hence the environment in which man lives is saturated with more energy than he could ever use and thus the need for energy harvesting [5, 6] where there is supply without the need for batteries or cables [7]. Also, broadband energy harvesting can be carried out on different spectrum of frequencies where vibrations are of frequent occurrence [8].

Ambient energy transducers are devices that convert the energy in the environment (that is, the energy found between the ionosphere and the earth's surface) into a detectable, useable current and voltage [9]. The kind of energy found in our environment is a mixture of various wavelengths and frequencies of electromagnetic radiation from radio, television, telecommunication and power stations, our sun, other celestial bodies and even outer space, and cannot be used by our electrical systems without first being processed into useable form. Ambient energy transducers have been built to harness the lower frequency radiation (such as those found in the visible spectrum), but relatively few have been built to harness the higher frequency particles which are more abundant, and available for everyone all through the 24 hours of every day (see [10] for fundamentals of ambient energy transducers). Scientists like Nikola Tesla, Thomas Henry Moray, Thomas Bearden, John Bedini, Paul Clint and a few others have successfully built such systems, and their work forms a background for this paper.

Two particularly interesting (and relatively simple) methods of harnessing this energy were successfully developed by the father of modern electrical systems, Nikola Tesla. One of them, which he called "Apparatus for the Utilization of Radiant Energy" involves the use of an insulated metal plate to capture and convert the high-energy, high frequency particles from the sun and other celestial bodies that continuously bombard the earth from space by the action of the photoelectric effect [3] and the electret effect.

Over one hundred years ago, for the first time, earnest consideration was given to harnessing the rest of the cosmic radiation hitting the earth by Dr Nikola Tesla. He said: "Ere many generations pass, our machinery will be driven by a power obtainable at any point of the universe ..… throughout space there is energy. Is this energy static or kinetic? If static our hopes are in vain; if kinetic --- and this we know it is, for certain --- then it is a mere question of time when men

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will succeed in attaching their machinery to the very wheelwork of nature". Dr. Thomas Henry Moray described this energy (of which Tesla spoke) as cosmic energy, and he estimated that 1.016×10^{15} Kilowatts of this energy reaches the earth daily [11].

2.0 Harnessing the Earth's Ambient Energy: Nikola Tesla's Radiant Energy System

Nikola Tesla discovered radiant energy in 1901 [3], and proceeded to construct a simple system to harness this energy [4]. This system employed the photoelectric effect, and, unknown to many who read his patents, the electret effect. The photoelectric effect is already widely known, and solar photovoltaic panels (which are also a form of ambient energy transducer) have been built on this principle, achieving a maximum efficiency of 25%. Therefore this paper will not go into details about the photoelectric effect, but we will instead explain the little-known, and seldom talked-about electret effect.

2.1 Electrostatics and the Electret Effect

The electret effect is an important contributor to the success of Tesla's Radiant Energy Transducer. Any ordinary antenna will collect a charge, but without the electret effect, most of it is dissipated before it can be tapped. The electret effect is a phenomenon whereby the surface between a conductor and a dielectric in intimate contact acquires a permanent electric field, especially when the insulator and the conductor are joined in the presence of an electric field. This electric field arises from the permanent polarization of dielectric when it is heated and cooled in the presence of a strong electric field. Such a permanently polarized dielectric is called an electret, and it is the electrostatic analogue of the magnet. The electric field created by the electret effect attracts positively charged ions from the surrounding atmosphere, which induces a negative charge of static electricity that builds up in the conductor and is trapped therein. Under most circumstances, the conductor in a cable is connected to a circuit and the electrostatic current is absorbed without notice. But if the conductor is connected to a spark plug (whose threads are grounded) it will produce an electric arc across the spark gap each time the voltage in the cable rises to the limit of the spark plug's air gap. Thus, a treated piece of insulated conductor left out in the wind will act as a Van de Graaff high voltage generator, accumulating charges on itself from the atmosphere through natural processes such as:

2.1.1 Induction Charging: Both the natural electric field of the earth (typically 100-200 Volts/metre) and that of the cable interact to produce an effect called the *induction charging mechanism*. This effect is a physical process involving the collision of pairs of charged particles in an ambient electric field. The electric charge induced on a particle's surface by the ambient electric field is made available for transfer when two such particles come into contact. This results in a subsequent differential particle motion (influenced by gravity) which leads to a large scale charge separation at the interface between the cable and its insulating layer.

2.1.2 Double layer effect: This is a phenomenon whereby double layers of electric dipoles appear on the interface between two layers of a substance (in this case, the layer between the conductor and insulator), when there is a single layer of electric dipoles (whose axes have an average orientation normal to the surface) on the outer surface of one of the substances (which in this case, is the insulator). They arise whenever media with different electron affinities are in intimate contact, and if dipoles are available. Thus a net potential difference exists across the double layer. This effect is demonstrated in the super capacitor. Therefore, such an insulated conductor will act like a high-capacity super capacitor.

2.1.3 Aerosol Effect: Particles of dust or water form dipoles when they pick up charges in the atmosphere as they float along. Aerosols carry hundreds to tens of thousands of units of charge, as opposed to ions which carry only single or double units of charge. When these aerosols get attracted to an insulated conductor, they deposit their accumulated charges on its surface.

It has been found that static electricity that is generated on a properly treated insulated wire will produce more than a kilowatt of energy, even in a light wind, due to the electret effect [12]. Virtually any insulated wire exhibits this effect, and it is a problem to the engineers involved in the manufacture of coaxial cable. This problem arises from the process used to make insulated wire.

2.2 *Voltage, Capacitance and Energy generated in an Electret*

For the purposes of analysis, we shall treat the electret like a capacitor (see [13]). Now, consider a metal plate coated with two transparent layers of an electrets, same as that used in [3]. The voltage and capacitance for the entire plate is given by equations (1) and (2)

$$V = \frac{QD}{A\varepsilon} = \frac{\sigma d}{A\varepsilon_0\varepsilon_r} = 2\,\frac{\sigma d}{A\varepsilon_0\varepsilon_r} \qquad (1)$$

$$C = \frac{Q}{V} = 2\,\frac{A\varepsilon_0\varepsilon_r}{\sigma d} \qquad (2)$$

where d = thickness of plate, E = electric field intensity, A = area of plate, σ = surface charge density and ε_r= relative permittivity.

For an electret, typical values of surface charge density, σ, is 10^{-6} C/m^2, and relative permittivity is usually high, ranging from 12 to 100,000; depending on the degree of polarization and type of material involved [14]. Note that, the permanent polarization of the dielectric has the effect of increasing its relative permittivity. Thus an unpolarized dielectric with a relative permittivity of 3 can have a relative permittivity of up to 10,000; if it were to be permanently polarized at high temperatures under the influence of a strong electric field.

In this paper, a cylindrical electret such as found in the co-axial cable was used to investigation the implication of the electret effect in ambient energy transducers. The voltage and capacitance used is derived from the voltage and capacitance of a co-axial cable, is given by equations (3) and (4) respectively, while equation (5) represents the energy per unit volume of the electret.

$$V = \frac{Q}{2\pi\varepsilon_0\varepsilon_r} log_e\left(\frac{b}{a}\right) \quad (3)$$

$$C = \frac{Q}{V} = \frac{2\pi\varepsilon_0\varepsilon_r}{log_e\left(\frac{b}{a}\right)} \ F/m \quad (4)$$

$$W = \frac{1}{2}CV^2 = \frac{1}{2}\varepsilon E^2 = \frac{1}{2}DE = \frac{D^2}{2\varepsilon} \ joules/m^3 \quad (5)$$

where D = electric flux density.

Equation (5) is similar to the energy stored per unit volume in a magnetic field (remember that the electret is the analogue of the magnet), also the expression $\frac{1}{2}DE$ is similar to $\frac{1}{2}\ stress \times strain$, which is used for calculating the mechanical energy stored per unit body subjected to elastic stress.

The energy generated in an Ambient Energy Transducer can easily be collected in a capacitor, or used to charge a battery if a spark-gap and silicon- controlled rectifier are used to break up the (expectedly) high dc voltages into pulses to charge the battery.

2.3. Efficiency of an Ambient Energy Transducer

The energy conversion efficiency η, of an ambient energy transducer (such as a metal plate or photovoltaic cell), is the percentage of power converted from the absorbed radiation (P_m) to electrical energy and collected, when the transducer is connected to an electrical circuit. This term is calculated using the ratio of P_m, divided by the input irradiance (E, in W/m²) under standard test conditions and the *surface area* of the collecting plate (A_c in m²) [15].

$$\eta = \frac{P_m}{E \times A_c} \quad (6)$$

2.4 Mechanism of Tesla's Radiant Energy Transducer

In order to capture the energy liberated by the interaction of these rays as they strike a copper (or any other metal) plate, Tesla used a metal plate that was insulated with some transparent (and probably permanently polarized) material, in order to create the electret effect. This, combined with the area of the conducting plates (as seen from equation 2.4) determines, to a large extent, how much of the cosmic radiation is converted to electrical energy. Also, the metal plate must be elevated to a considerable height. Tesla connected the metal plate to one terminal of a capacitor, and connected the other terminal of the capacitor to an earth connection (whose only purpose was to serve as a negative terminal for the system, since the earth is a vast reservoir of electrons and thus has a net negative charge). The potential difference between metal plate (which is positive with respect to earth) and the earth, charged the capacitor; and by connecting across the capacitor a switching device so that the capacitor is discharged at periodic intervals, he obtained an oscillating electric output [16].

3.0 Experimental Design, Construction and Performance.

An ambient energy transducer was built after Tesla's design as shown in Figure 1. Thus, the required components were arbitrarily selected and prepared, bearing the same theoretical facts in mind, as outlined in section 2.

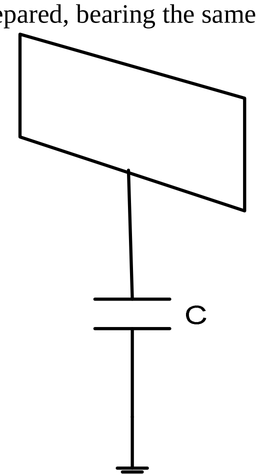

Figure 1: Schematic diagram of ambient energy transducer

The components were selected and treated as follows:

3.1 Metal Plate or Collector

Copper was selected as the metal to be used as the collector because it is one of the best conductors of heat and electricity available and it has threshold frequency in the ultra-violet region. This serves our purposes well, since the energy we are trying to harness is of such frequencies and higher. The plate was insulated to introduce the electret effect using transparent cello-tape and care was taken to remove any air packets trapped between the cello-tape and the plate. However, spray plastic would have been the best option, since it allows no ingress of water once dry and it can also take care of any shallow contours the plate might have; it was not readily available. Unfortunately, due to lack of adequate information as at the time of constructing the plate, it was not further treated in a manner that would ensure the presence of the electret effect. A test plate dimension of 46.7cm × 29.7 cm was used, giving a surface area of 0.138 m^2. Since both sides of the plate were exposed to the rays, we can multiply this by 2, which yield 0.276 m^2. The thickness of the copper was 0.5mm.

If we divide the total radiant energy reaching the earth (which includes radiation from other sources apart from our sun) as estimated by T.H. Moray, by the total surface area of the earth, we find that the energy falling on the earth per square metre is 1,993W/m^2. Based on equation (6) we calculated the approximate efficiency of conversion η of the transducer after measuring the voltage accumulated in the capacitor, thus the energy was calculated. A single-core cable (0.9mm) was attached to the insulated copper plate by means of an aluminium rivet, after which it was suspended at a height of approximately 50 feet, in order to provide an increased exposure to the rays.

3.2 The Capacitor

Tesla recommended that a capacitor of considerable electrostatic capacity and of the best quality mica should be used. He also recommended that the capacitor should be completely evacuated of air. This is because capacitors loose their charge both through the insulation between the plates and through the air surrounding the capacitor. It has been found from experience that most capacitors tend to self-discharge to about 50% in about 15 minutes. The loss of charge (leakage) to the air can be controlled by increasing the distance between the terminals, by placing them in a vacuum, by placing caps on the terminals or by keeping the capacitor in a less humid environment. It was not possible to use the type of capacitor (polypropylene and polystyrene) Tesla recommended because it was not readily available, we used instead an ordinary electrolytic, 35V, 3300μf capacitor was chosen, after experimenting with an ac capacitor of 400 V, 40μf, and finding it unsatisfactory. The large capacitance of the 35V capacitor is desirable for storing a lot of charge.

3.3 The Earth Connection.

The earth connection was made by driving a 12-foot copper-plated iron rod into the ground by means of a hammer. Care was not taken to reduce the earthing resistance to a minimum because the purpose of the earth connection was not to dissipate excess currents. In fact, earthing resistance in this case is actually desirable to reduce the possibility of the accumulated charge leaking away to the earth. Hence, the only function of the earth terminal in this application is to provide a negative terminal, and earthing resistance was not a critical consideration.

3.4 Performance of Initial Set-up

After the experimental set up of Figure 1, results obtained are shown in Table 1.

Table 1: Results from initial set-up of ambient energy transducer without electret insulator

	Parameter Investigated	**Voltage (dc)**	**Time (Hrs)**
1	Voltage of antenna to ground	0.30 V ac	0.00 (i.e at start)
2	Voltage across Capacitor	0.27 V	0.00 (i.e at start)
3	Voltage across Capacitor	0.44 V	0.30
4	Voltage across Capacitor	0.69 V	1.10
5	Voltage across Capacitor	0.80 V	1.50
6	Voltage across Capacitor	0. 26 V	17.55
7	Voltage across Capacitor	0.62 V	18.45
8	Voltage across Capacitor	0.64 V	19.20
9	Voltage across Capacitor	0.83 V	20.35
10	Voltage across Capacitor	0.835 V	21.25

The capacitor used in Figure 1 was a 40μf, 400V ac capacitor. From Table 1, we find that it charged up from 0.27 V to 0.8V in 1hr 50 minutes, although the capacitor charging started at about 4:00pm local time. By the next day, the capacitor had self-discharged to 0.26 V. The leads were checked for any leakages to earth. Some naked portions were found and taped off, and the capacitor was charged up again to 0.835 V in about 4 hrs.

3.5 Modifications to the Set-up

During the experimentation, it was observed that there may be further leakage to earth due to the metal plate (when the potential of the capacitor rises above that of the plate); apart from the earlier-discovered leakage due to damaged insulation in the earth wires. It was also suggested that an electrolytic capacitor be used instead. This led to the addition of diodes to the set up, as shown in Figure 2, and changing the capacitor to 35V, 3,300µf.

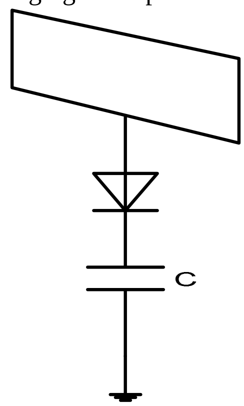

Figure 2: Modified Figure 1 to reduce leakages

Capacitor charging started again at about 11:00am, and the results are presented in Table 2.

Table 2: Modified initial set-up of ambient energy transducer without an electret insulator

	Parameter Investigated	Voltage (dc)	Time (Hrs)
1	Voltage of antenna to ground	0.03 V ac	0.00 (i.e at start)
2	Voltage Across Capacitor	0.08 V	0.00 (i.e at start)
3	Voltage Across Capacitor	0.22 V	0.25
4	Voltage Across Capacitor	1.41 V	45.05
5	Voltage Across Capacitor	1.25 V	48.45
6	Voltage Across Capacitor	1.40V	67.00
7	Voltage Across Capacitor	1.31 V	75.00
8	Voltage Across Capacitor	1.49 V	91.50

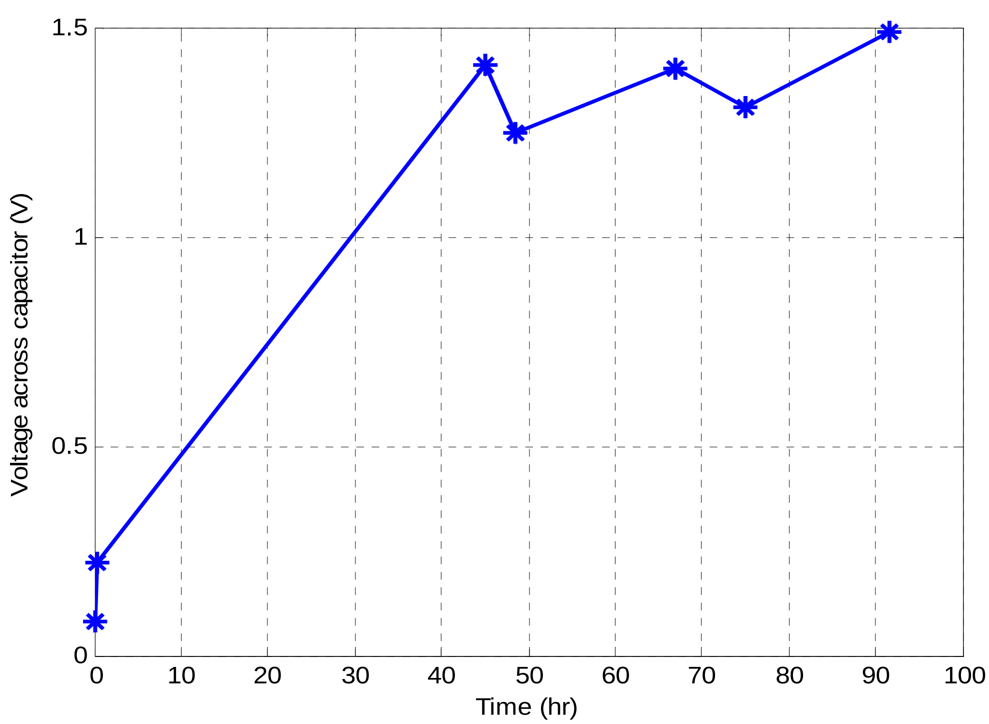

Figure 3: Plot of voltage across capacitor against time for the modified ambient energy transducer without electret effect.

The results show that the performance of the system was somewhat improved, as the capacitor charged up to 1.41V in 45 hrs. It must be noted here that a plot of the results in Table 2, shown in Figure 3 indicated that the capacitor repeatedly charged and self-discharged over the time in which it was observed, so we do not have an accurate measure of the energy delivered by the ambient energy transducer to the system. However, for the purpose of analysis, we will take the best recorded performance of this system and analyze it. Thus we pick the 0.8V which the 40µf capacitor acquired in 1hr 50 mins (from Table 1).

From equation (5), energy stored in a capacitor is $E = \frac{1}{2}CV^2 = 1.28 \times 10^{-5}J$, but power generated is $P_m = \frac{128 \times 10^{-5}}{6600} = 1.9 \times 10^{-9}W$. Using equation (6) based on area of plates exposed (A_c) which was 0.139m^2 and energy falling on earth per m^2 of 1993W, the efficiency of our transducer was 6.8×10^{-12} *or* 6.8×10^{-10}%. It is obvious from the above values that this transducer generated nothing, and was unable to convert the energy from the atmosphere.

Thus, there must have been something that Tesla did that was not done in this set-up, which made his system more successful than this one. One such thing is the capacitor, another is the area of the plates, which is rather too small for practical purposes, as revealed by the calculated efficiency. One other thing that was not taken into consideration is the electret effect. Thus, the need to consider a transducer that employed a measure of the electret effect and see if it performs any better.

3.6. Investigation of the Electret Effect.

The results obtained from the modifications effected in Figure 2 were still not encouraging, and the set-up was re-evaluated to determine the source of the problem. During this process, it was discovered that the electret effect was not taken into consideration in the preparation of the antenna plate was the reason for poor performance. Hence the importance of the electret effect in ambient energy generation was investigated using an ordinary co-axial cable 150 ft. or 45.72 metres long (see Figure 4).

The cable was strung along a wall, about 10 feet off the ground, and hooked up to a battery as shown in Figure 4. The voltage to ground was recorded after some hours, and also the voltage increase on the battery.

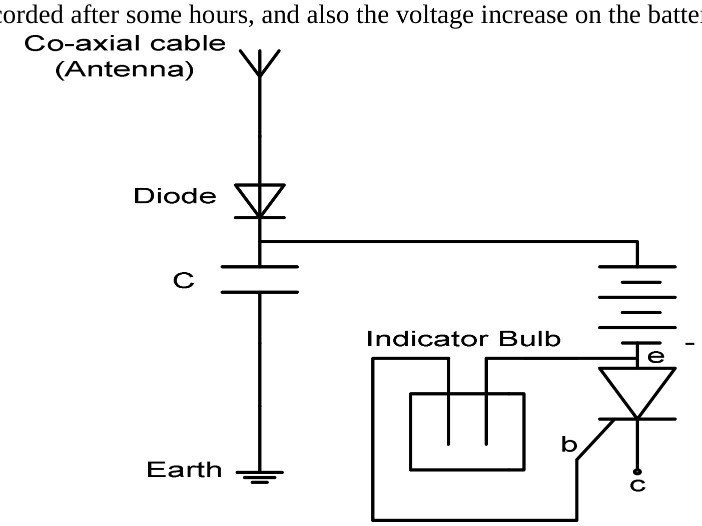

Figure 4: Ambient energy generation using co-axial cable – investigating the electret effect

The results of this investigation are presented in Table 3 based on using co-axial cable with outer plastic sheath present.

Table 3: Electret effect using co-axial cable with outer plastic sheath

	Parameter Investigated	Voltage (dc)	Time (Hrs)
1	Voltage of antenna to ground	2.19 V ac	15.08
2	Voltage across battery terminals	3.25 V	0.00 (i.e at start)
3	Voltage across battery terminals	3.38 V	15.08

Again, the results of Table 3 were not encouraging, and so the cable was treated by peeling off the entire outer plastic sheath and heating it to about 100ºC, after which 10kV dc was applied to the cable until it cooled to room temperature. However, the treatment was not very successful, as the insulation melted in some portions of the cable (which was not supposed to be), the voltage was not applied while the heating was going on, the cable cooled too quickly, which is contrary to the recommendations for treating the cable, and only 10kV was applied, instead of the 30kV recommended [12].

The results obtained after treating and hanging two co-axial cables, one of 150 ft. (45.72m) and another of 48 ft. (14.6m) are presented in Table 4.

Table 4: Electret effect using a treated co-axial cable without its outer plastic sheet

	Parameter Investigated	**Voltage (dc)**		**Time (Hrs)**
		150 ft. Cable	48 ft. Cable	
1	Voltage of antenna to ground	3.83 V ac		45:27
2	Voltage across battery terminals	9.29 V		0.00 (i.e. at start)
3	Voltage across battery terminals	9.57 V		18:25
4	Voltage across battery terminals		9.57 V	18:25
5	Voltage across battery terminals		9.59 V	21: 47
6	Voltage across battery terminals		9.62 V	38:57
7	Voltage across battery terminals		9.64V	45:27

From Table 4, it is obvious that the 150 ft. (45.72 m) cable performed better than the 48 ft. (14.6m) cable, adding 0.28 volts to the battery in 18 hrs. We do not know the relative permittivity ε_r of the 'electret' layer we have created, hence we cannot use the capacitance of this cable to determine the energy generated. But we do know that the battery we are charging is rated 12V, 45W, which implies that every volt is equivalent to 45/12 W or 3.75W. Hence 0.28 volts could be seen as being responsible for adding 0.28 × 3.75 W or 1.05W to the battery. Let us take this as $P_{m.}$

Now, let us take the area exposed to this energy as the outer surface area of the cable. Recall that, surface area of a cylinder is $2\pi rl$. The outer radius, r, of this cable was 2.25 mm or 0.0025m, l = 45.72m, and π = 3.142. Hence the surface area of this cable was 0.718m^2 and this resulted in an efficiency of 7.34×10^{-4} *or* 0.07%. Although this efficiency value is still very low, however it is a tremendous improvement over the earlier experiments. This shows that the presence of the electret effect, no matter how small, accounts for a large part of the success of Tesla's Ambient Energy Transducer, apart from the other factors mentioned earlier.

4.0 Conclusion/Recommendation

In this paper, the Ambient Energy Transducer under consideration was intended to duplicate Tesla's success at generating energy from all that is available in the environment in which we live. This effort was not successful, largely because the electret effect was absent in the antenna plate and in addition to the fact that its area was relatively small. The capacitor is not an important factor in the success of this system, as a battery could have been used instead, if we had sufficient voltage on the antenna. In conclusion, we can say that the electret effect which was not mentioned in Tesla's work was the reason for the success of his work.

However, further work will be carried out on the antenna plate to create the electret effect of Tesla's work and also to increase its area. If this work is done properly, we conjecture that a total surface area of only 0.958m^2 will yield an average of 1000W, which translates to an efficiency of 0.524 or 52.4%. This beats the maximum efficiency of about 35% being offered by the best photovoltaic (PV) panels available today, and will therefore be a great means of obtaining renewable energy.

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