Abstract

Over the past few decades, the methods of electrical generation such as by coal, nuclear fission, solar, wind, and geothermal have been studied and tested repeatedly, yet the mode of electrical transmission has remained the same: An electric grid of wires. However, at the turn of the 20th century, inventor and electrical pioneer Nikola Tesla attempted to build the Wardenclyffe Tower, a giant Tesla coil which he claimed could transmit power over large distances using induction. Unfortunately, funding for his research dried up and his claims have been dismissed. If Tesla's claims are true, the land and resource-consuming power grid can be eliminated.

The magnitude of Tesla's vision was not something we attempted to test physically; rather, we intended to apply the results of small-scale transmission from a Tesla coil to the large scale to measure its feasibility. For our tests, we built a Tesla coil and measured its power usage. Next, we measured the power of a fluorescent light bulb and the distance from the coil at which it glowed. Finally, we compared the power and costs of our Tesla coil to that of North Anna's nuclear facilities, which we used as an example power station.

Our results matched that of previous studies - the power output from a Tesla coil decreases dramatically with distance and thus would not be feasible as an efficient power transmitter. Although further research is needed on wireless effects on the large scale, the current electric grid remains the most efficient power transmission.

Question

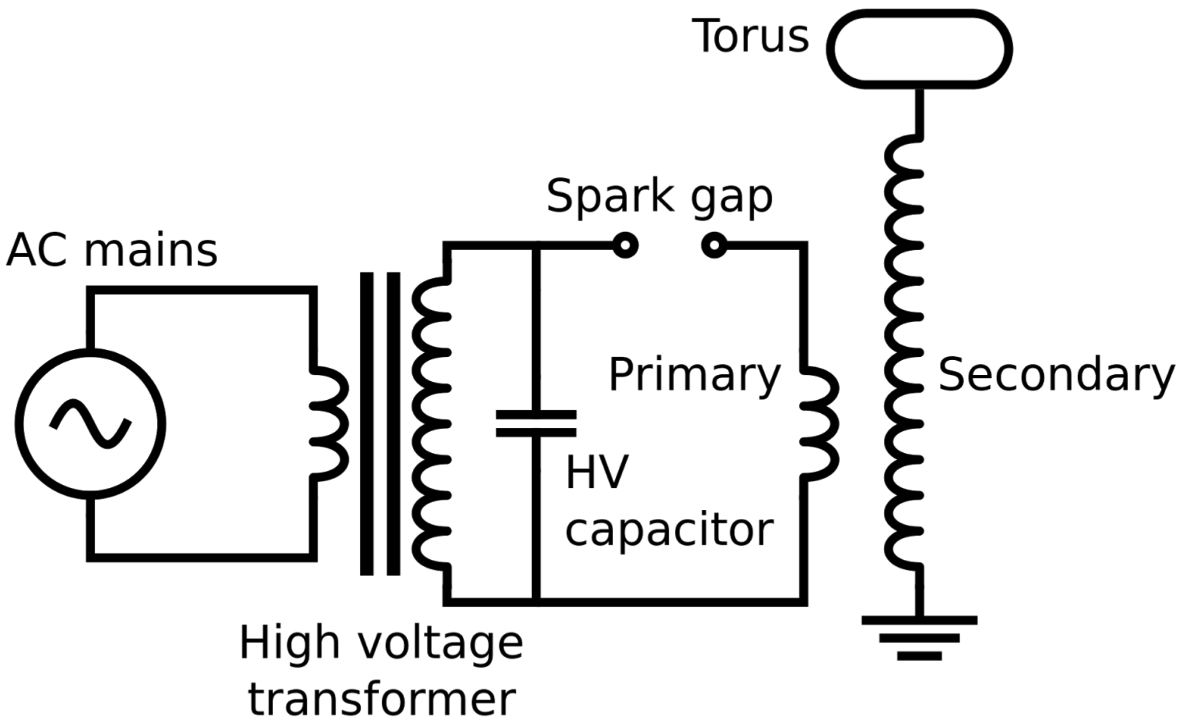
In the late 19th century, Edison’s mode of electrical transfer using wires, won out over Tesla’s dream of wireless electricity. However, instead of having to build and maintain these thousands of miles of power lines, an electric company could still potentially save costs and increase efficiency by using a Tesla Coil tower to transmit electricity. If Tesla’s predicted range of transmission is correct, electric plants could be located in more remote locations either for safety (nuclear power) or better electrical production (solar, wind). Power outages due to storms would become virtually non-existent, and our ecological footprint would be reduced by not having to clear swaths of land to put down power lines. Although not a solution to our energy crisis, a wireless transmission source would trump the current method in both safety and impact, and thus if viable should be developed.

Hypothesis

We predict that the range of Tesla coils will be smaller than the current range of wired power companies, but within that range the transmission of electricity will be usable and minimally impactful. Cost-wise, the operation of even one Tesla tower will probably be about the same as maintaining power lines, but since the tower will be at the plant site, problems can be fixed more quickly at the source. However, the up-front cost of building a Tesla tower will likely be higher than setting up power lines. Altogether, we predict that Tesla Towers will be the better form of electrical transmission.

Background

Tesla coils were first invented by Nikola Tesla in 1891. After several experiments, he started building his Wardenclyffe Tower in 1901, but in 1904 his funding was cut and the project was never completed. As a result, no large-scale tests have been made using Tesla Coils to predict their range.
A Tesla coil is made up of a primary coil and a secondary coil. The primary coil is connected to an AC circuit with high-voltage capacitors and a spark gap, while the secondary coil is placed inside of the primary coil. Current is induced into the secondary coil due to the shift in magnetic flux, which is caused by the alternating current in the primary coil. See the diagram below for a more detailed view.



Materials

To build a Tesla coil, we reviewed online instructions and chose a source that used relatively cheap and accessible materials, found under the URL http://www.instructables.com/id/How-to-build-a-Tesla-Coil

For the inner (secondary) coil, we used 300 feet of 24 AWG copper wire wrapped around 2 feet of 1.5 inch - diameter PVC. This was connected via a PVC floor flange and bolts to a 4 square foot, square piece of plywood. The outer (primary) coil was made of 10 feet of thin copper tubing coiled helically around the inner coil and connected through the plywood base to the capacitors. We used 10 simple Leyden Jar capacitors out of glass Snapple bottles filled with saltwater (about 460 mL water and 6 grams salt per bottle) and wrapped in aluminum foil.

Procedure

After connecting the wires to a 9 kV transformer operating at 30 mA, we placed the fluorescent bulb on the same table next to a meter stick. Once we were safely behind glass, the Tesla coil was turned on and we observed the brightness of the fluorescent bulb. After several adjustments of the bulb, the maximum distance at which the bulb reached optimum brightness was recorded. We then measured other values such as capacitance and inductance within the coils and placed them in our data table for calculations.

Data & Results

	Jar Thickness (in)	Jar Height (in)	Jar Diameter (in)	Dielectric Constant	Capacitance (pF)
Snapple Bottle Capacitor	0.079	7.1	2.55	3.7	650.2988701

	Number of Turns	Coil Diameter (m)	Height of Coil (m)	Inductance (H)
Copper Tubing	5.5	0.18	0.17	0.0000056901076
Copper Wiring	1100	0.05	0.57	0.005237807522

Specifications of Coil

Volts (V)	Current (mA)	Capacitance (pF)	Frequency (Hz)	Reactance (Ohms)	Inductance (H)
9000	30	6502.988701	827377.6003	29.5803794	0.0000056901076

Coil Power Transference

Light Bulb Power (W)	Distance (m)
60	0.205
45	0.215
30	0.23
15	0.26

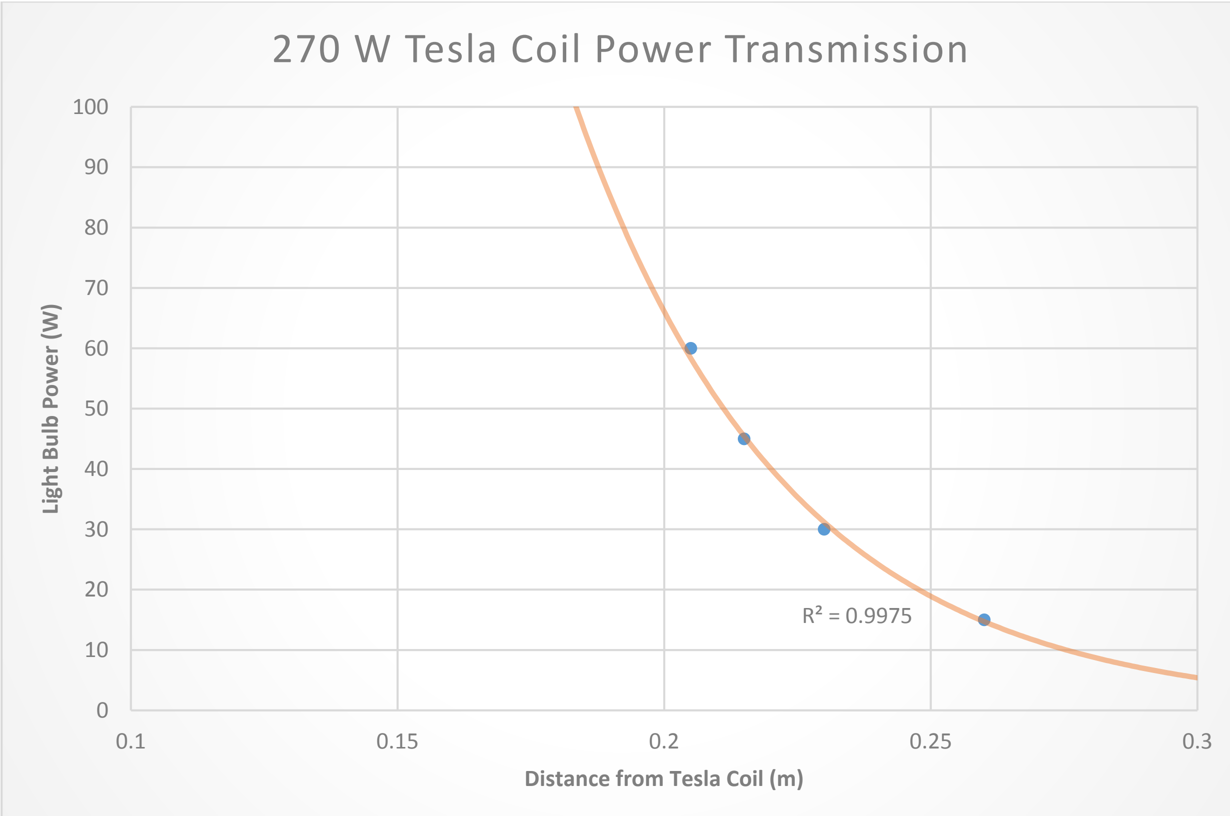


Figure 1 The graph above relates the results of our experiment into an equation. Clearly, after a certain distance, in this case about ¼ of a meter, the power transmission of the coil is too low to be usable.

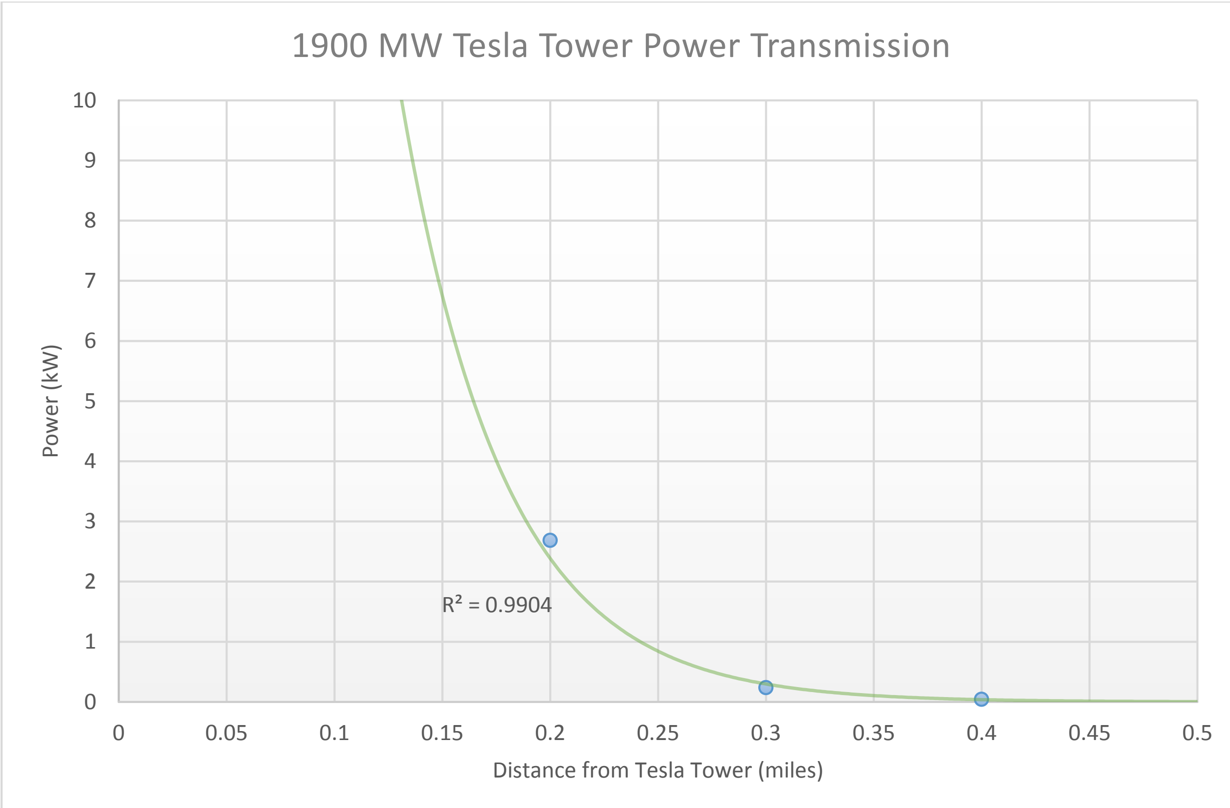


Figure 2 Although within about 500 feet of the Tesla Tower the power transmitted is quite large, the usable range of the Tesla Tower covers an area less than half a square mile, which is about 120 city blocks. This data uses the results of our experiment and the following equation

$$P_2 = \frac{P_1 Q_1 Q_2 e_1 e_2 r_1^3 r_2^3}{x^6}$$

in which the power transmitted is proportional to the power input, coupling coefficients, efficiencies, and radii of the transmitting coils, and inversely proportional to the distance from the transmitter to the sixth power.

Research

For our comparison of the typical power plant in terms of range and power output, we used Dominion Power's North Anna Power Station in Louisa County, Virginia. This plant generates about 1892 megawatts of electricity, which is enough to power over 450,000 homes. Using Dominion Power's total power output of 24,900 megawatts, we used proportions to infer that North Anna services an area of approximately 2100 square miles, with a radius of 45.8 miles. This area comprises of about 486 miles of transmission lines (which carry high voltage electricity) and 4330 miles of distribution lines (which carry low voltage electricity to our homes.) At about $300,000 per mile of transmission line and $200,000 per mile of distribution line, the total cost of constructing this electric grid would be about $1 billion.

Assuming that the cost to build a Tesla tower would be comparable to the cost of building a cell tower, each Tesla tower could require only about $200,000. Cell towers have an approximate range radius of 45 miles, almost exactly that of the power station. However, using the results from our experimentation, the efficiency of the Tesla Tower is such that power transmission decreases exponentially with distance. As a result, Tesla Towers built to operate at about 1900 megawatts would have a range of only 0.4 miles, covering an area of about 0.45 square miles. Dividing this up among the 2100 square miles of the power station, there would need to be about 4600 Tesla Towers at a total cost of $900 million.

Conclusion

Despite the surprisingly low-cost alternative that Tesla Towers provide, it must be taken into consideration the fact that the resulting power loss would be disastrous both economically and environmentally. In order to make up for this, more energy would need to be generated in the plant. Therefore, expensive and complex as it may be, the existing electric grid is more useful than a Tesla Tower grid in that it provides efficient power transmission even at the loss of land and resources.

Future Directions

Although the results of the small-scale experiments were discouraging, the fact that Tesla coils have not been tested on a large scale still opens up the possibility of long-range fields behaving differently than short-range ones. For instance, the voltage between Earth's surface and upper atmosphere is extremely high, so a tall tower that could harness this power could in theory provide power for a much larger range than previously accounted for. Also, given the relative cheapness of the project (the Plekhanov brothers claim they can build a Tesla Tower for under $1 million), it still remains feasibly within reach of well-funded experimenters. Despite the failure of this type of wireless transmission, other experiments using microwaves have been successful at transferring power across several miles, which could be utilized for power transfer through space.