On Tesla

by
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A miracle happened. In the last decades of the nineteenth century, over the course of just a few years, a technological society based on the widespread application of electricity was born, both in Europe and the United States. An entire technology only recently adopted was replaced by another, more useful one. Coal-gas illumination was abandoned, gas works torn down, and the infrastructure of the new technology constructed in its place, all accomplished by 1900. Coal-gas barely made it into the twentieth century, tolerated only so long as electrical light and power was unavailable.

Less than thirty years before, this technology had not existed — and now those who lived in homes without it were pitied, were considered to be deeply deprived. One could live comfortably without a telephone, without indoor plumbing, but not without electricity. Within a few years, Americans even subsidized the electrification of rural homes. Electric power technology became the indispensable element in the twentieth century. The roots of this electric transformation lie between 1879 and 1895, and the most essential inventions of this brief era were the brainchildren of one man, Nikola Tesla.

This prodigious inventor, whose work included the first studies of radio and robotics, made his most important contributions early in his career: an efficient, reliable system of alternating-current generation, transmission, and use. The entirety of the alternating current system he created is the most compelling aspect. He did not invent just a piece, but the totality of it. This achievement rested not only on his own brilliance; he depended on the contributions of other scientists and inventors, first among them his rival Edison. It began with him and the search for a better method of illumination.

Coal-gas illumination was a product of the early nineteenth century. Experiments in utilizing coal or wood gas had been attempted as early as the seventeenth century in England without any practical result. It was not until Lebon's 1791 studies of wood gas in France that the potential for practical use became evident. Coal (or any other combustible material) baked in an oxygen-limiting environment will give off an inflammable gas (Natural gas should not be confused with coal-gas. Natural gas was not used until the end of the nineteenth century, when gas fields were discovered during the course of oil exploration.). William Murdock followed up on Lebon's experiments a year later in England. He demonstrated the practical use of coal-gas in illumination. A factory was lit by coal-gas illumination in 1802. In 1810 coal-gas illumination was installed in a house. The first centralized coal-gas works were built in Westminster, England in 1814. The use of the technology began to grow, caused by the availability of cheap coal and rapid urbanization. This is not to say that the technology was popular. It was used for lack of anything better.

> . . . the opinion of the consumer is best indicated by the prevalence of special ventilating pipes called perdifume, placed over the gas burners; the truth being that neither the quality of the gas itself, nor the precision with which fittings were made, nor the technical skill with which they were installed, was adequate to protect the consumer against serious discomfort in small rooms.[1]

This problem was still not solved by 1843, when the scientist Michael Faraday was consulted by the members of a posh London men's club on "how to mitigate what they called the stupefying effects of gas."[2] A gas-lamp that supplied adequate light was not invented until 1885. By that time electric lights were already a serious rival.

The use of this flawed technology, the cause of discomfort and even death by fire and suffocation, was the motivation for the search for alternatives. As early as

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1. T. K. Derry and Trevor I. Williams, *A Short History of Technology* (NY: Dover, 1961, 1993 reprint), 512.

2. Derry, 512.

1838 attempts were under way to find a usable incandescent electric light.[3] Inventors at an almost yearly pace introduced first one flawed variation after another. The theoretical work had already been done. Michael Faraday had discovered electromagnetic induction in 1831. He found that an electrical current could be created in a conducting wire when it was exposed to a moving magnetic field. The magnet and the wire need not touch for the current to flow.

> Faraday established the foundation for electrical engineering and the electrical industry with his discovery of induction; Maxwell, in predicting the propagation of electromagnetic fields through space, prepared the theoretical base for radio and its multitude of uses. With an understanding of the fundamental laws of electricity established, the times were ripe for the inventor, the entrepreneur, and the engineer.[4]

Edison was the first. He had already created a research center at Menlo Park, New Jersey. Before embarking on his search for an incandescent lamp, he inspected the idea. There were indications in the work of others that suggested a practical solution might be near. Edison also saw opportunity in the replacement of gas lighting with an alternative. A number of considerations entered into his decision to enter the field.[5] He succeeded in 1879.

That same year Charles Brush began his installation of carbon-arc lighting systems. Elihu Thomson and his friends also entered the field, establishing an arc-light

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3. Robert Friedel, Paul Israel, Bernard Finn, *Edison's Electric Light: Biography of an Invention* (New Brunswick, NJ: Rutgers U. Pr., 1986), 115.

4. John D. Ryder and Donald G. Fink, *Engineers and Electrons: A Century of Electrical Progress* (NY: IEEE Pr., 1984), 6.

5. Thomas Parke Hughes, "Thomas Alva Edison and the Rise of Electricity," *Technology in America*, C. W. Pursell, ed. (Cambridge: MIT Pr., 1981), 122-123.

company in 1883.

The electrical landscape of America was now cut up between competing systems. There was Brush's high voltage direct-current system for arc lights, which could not run motors or be used for household lighting. Edison's low-voltage direct-current system was good for incandescent houselights but little else and limited in distance. The single-phase alternating-current system of Thomson made house lighting at a distance from the power plant possible; yet it could not run motors.[6]

These problems were inherent in the technologies used, not particular to the devices or construction. Electricity was first studied through the use of batteries, which produce only direct current; that is, a one-way flow of electricity constant and unvarying in intensity or direction. Edison, from his early days in telegraphy, was intimately familiar with this type of electricity. Direct current is impossible to manipulate without converting it to alternating current (it was possible, using the technology of the time, to convert d.c. to a.c. and back again through a rotary motor-generator setup). At low voltages (the "pressure" of the electricity) direct current will not travel long distances through wires because the losses to electrical resistance are too great. Alternating current can be manipulated using transformers, shifting low volt, high amperage (the ampere is the measure of the "volume" of the current) current to a high volt, low amp current for transmission over long distances, and then back again for use. Unfortunately, single-phase or even two-phase generators just did not put out the kind of power at the needed efficiency levels for industrial use. Tesla's three-phase (or

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[6]. Kenneth M. Swezey, "Nikola Tesla," *Science*, v. 127, n. 3307, 16 May 1958, 1149-1150.

polyphase) generators could produce fifty percent more electrical power than a two-phase generator (a "phase" refers to the wire windings in a generator, the rotating magnetic fields, and the induced current in the windings).

Direct current could not be used over long distances. Edison's pilot plant in New York City could only serve customers within a few blocks of the plant. Practical motors were not possible, so mechanical and industrial uses were precluded. With multiple competing systems, no one could deliver on the needs of every customer. This was the state of things when Tesla entered the scene.

Nikola Tesla was born in July 1856 of Serbian parents, at Smiljan, Croatia, then a part of the Austro-Hungarian Empire. He was a precocious boy, possessing a keen intelligence and an eidetic memory. At only fifteen (c. 1871), he was sent to the Higher Real Gymnasium at Carlstadt — a prep school specializing in the hard sciences. After graduation he lost at least a year and perhaps three to illness and what was probably a successful attempt to evade the Imperial draft. He entered the Polytechnic Institute at Graz, Austria when he was nineteen. It was there, in 1878, that he had his first inspiration for an alternating-current electrical system, while observing an experiment with a direct-current dynamo. The sparking caused by the brushes against the commutator (direct-current generators and motors have to have physical connections) struck Tesla as highly inefficient. A generator using Faraday's induction principal would be much more efficient, since there would be no need for brushes or commutators. However, induction generators could only generate alternating current. He worked at the problem during spare moments over the next several years. He graduated early from the Polytechnic, choosing then to continue his studies at the University of Prague. A family financial crisis in 1881 forced him to withdraw from the university after only a year. He found work as the chief electrician for the fledgling Budapest telephone company. His formal education in mathematics and physics, even though cut short, was important to Tesla's later career. It gave him the intellectual tools necessary to conceive and shape the concepts involved in alternating-current generation. Taking nothing away from Edison, it can still be said that a lack of these same tools contributed to Edison's inability to accept alternating current's advantages. What he could not understand, he could not utilize.

Tesla's moment of epiphany came while on an idle stroll in a Budapest park in 1882. The complete system of alternating-current generation came into his head in one bright flash of inspiration. He later claimed to have sketched the essentials out in the dirt.

Tesla joined the Continental Edison Company in Paris a year later. While in their employ as a troubleshooter, he constructed an induction motor in his spare time. His work for the company so impressed his employers, he was given a letter of recommendation to Edison and shipped over to New York. Tesla lasted only a year working for Edison. He quit in disgust. That same year, 1885, George Westinghouse bought the English patent rights to the Garland and Gibbs alternating-current system. The "War of the Currents" then began in earnest. Edison gave demonstrations of the lethality of alternating current by electrocuting all manner of animals. His people even conspired to introduce a new term for the electric chair: it was to be called "the westinghouse."[7]

Tesla's attempt at business was an abysmal failure. The arc-light company he had started left him with little more than a worthless stock certificate. He worked at any job he could find for the next two years, no matter how menial, until he found backers in 1887 who would fund a laboratory. By October of that year he had submitted patent applications for a complete alternating-current system. They were granted May 1, 1888. Two weeks later, he disclosed his new system in a speech to the American Institute of Electrical Engineering. The title of the speech: "A New System of Alternating Current Motors and Transformers." Westinghouse purchased the rights to Tesla's patents two weeks after the speech. He also hired Tesla. Just as at Edison's, Tesla quit after only a year, to return to his New York laboratory.

The next two years were to test Westinghouse's commitment to alternating current. The "War of the Currents" was not going his way. He even had to go hat-in-hand back to Tesla, to ask the inventor to forego royalties on his patents. The added cost had priced the Westinghouse/Tesla systems nearly out of the market. Cities and companies were skeptical of the new system, doubtful it was as effective as stated. Three events saved Westinghouse and Tesla.

First, in 1890. Telluride, Colorado signed a contract with Westinghouse for installation of the new system for use by mining companies. The power plant was in operation a year later.

Second, in August 1891. Tesla's polyphase alternating-current system was

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7. Neil Baldwin, Edison, Inventing the Century (NY: Hyperion, 1995), 202.

demonstrated at the Frankfort Exhibition. The power plant for the demonstration was located in Lauffen, over 108 miles away. Long-distance power line transmission was now proven.

Lastly, the 1893 Chicago World's Fair. Westinghouse knew he needed a forum, so he underbid Edison for the lighting contract. Westinghouse made the lights of the fair a testimonial to alternating current. Further, he had a working model of Tesla's power system on display. Tesla even contributed to the event by having his own separate exhibit.

The "War of the Currents" was won. In October Westinghouse was awarded the contract for the Niagara power plant. Niagara went online in 1895.

Tesla was a hero. He was showered with awards and praise; yet by 1898, he was being attacked in the scientific press for his sensationalist claims. Though he continued his experiments, making several discoveries and filing patents for a variety of inventions, he began to slide into obscurity. Even history seemed to have forgotten him.

The foremost reason for this descent was his own personality. He had always been somewhat of an eccentric. The wild claims and sensationalistic language only alienated the scientific press. How else were they to react to claims of extraterrestrial communication, vast energies in the crust of the Earth waiting to be tapped, and even hints of the supernatural?

Second, Tesla was always willing to cut off his nose to spite his face. His place in the history of electrical technology would have been secure had he not quit the position at Westinghouse. A few years later, General Electric offered him a similar post, which he refused. Perhaps he thought Edison was still in charge, which was untrue; Edison had long since sold his holdings in G.E. In his personality he always took on the characteristics of a hermit — or a monk. He lived for the last decades of his life in a room at the Hotel New Yorker, in occasional destitution.

Third, many of his greatest achievements were marred by almost constant litigation. His alternating current patents were challenged until 1900, when they were finally upheld. His patents on the radio were not upheld until 1943, the year of his death.

History is sometimes unfair in its judgments. The man who invented the essential devices of the electric power industry deserved better than he received.

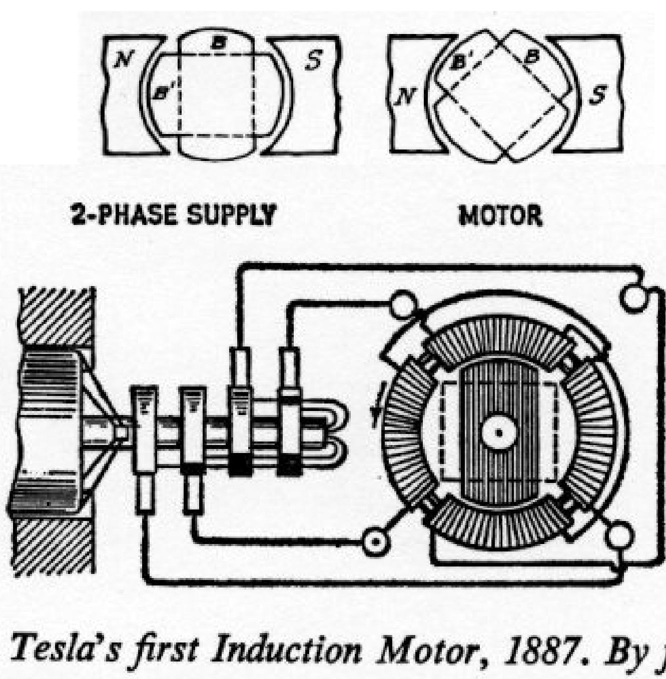

Fig. 27. Tesla's first Induction Motor, 1887. By feeding a two-phase current into two pairs of field coils at right angles, Tesla produced a rotating field. The rotor built up of iron discs carried externally closed circuit conductors.

IF YOU WISH TO READ MORE ABOUT TESLA

Four sources for Tesla were used for this essay. I will comment on each in turn.

Cheney, Margaret. *Tesla: Man out of Time*. NY: Prentice Hall, 1981. This is perhaps the most well-researched of the Tesla biographies. It is not well-written. The many short paragraphs and sudden shifts in subject give the book a jerky, ill-considered feel. Technical matters are not explained, or are inadequately explained. Even such a simple matter as the type of schools the young Tesla attended is a matter of confusion for the author. This is unacceptable, since even a cursory peek in an unabridged dictionary would explain the meaning of central European school terms (such as "Real," or "Gymnasium"). Overall there is a sense of laziness on the author's part. The world being as it is, the author has been rewarded for this sloppiness with a paperback reprint just released.

O'Neill, John J. *Prodigal Genius: The Life of Nikola Tesla*. Hollywood: Angriff Pr., 1981 reprint. Originally written c. 1943. This work has no footnotes or bibliography. It is written in the manner of a gushy popular biography. The author can be forgiven this fault, since he was a friend of Tesla.

Hunt, Inez and Draper, Wanetta W. *Lightning in His Hand: The Life Story of Nikola Tesla*. Hawthorne, California: Omni Publ., 1964. This is the best of the biographies. It also has its faults; the authors are primarily authorities on the Old West, so the technical details are weak. They do try to supply the historical context of Tesla's work, mentioning at length Westinghouse and Edison. The notes at the end of each chapter are helpful to the scholar, as is the extensive bibliography. They tell Tesla's story without the too-partisan tone of Cheney and without her writing faults.

Swezey, Kenneth M. "Nikola Tesla." *Science*, v. 127, n. 3307, 16 May 1958. 1147-1159. This is a straightforward academic paper dealing with Tesla's contributions to the electric power industry. It was quite refreshing to read something with an historical focus and a straightforward approach. This article is invaluable for the understanding of the events, the technology, and the impact of Tesla's inventions. Without it to rely on, the researcher would be lost in the howling wilderness of bad writing and sensationalistic pseudojournalism that typifies much of the writing in the biographies.

A WARNING TO THE READER

These biographies all suffered from one central fault: they focused too much on Tesla's life after Niagara and not enough on his achievements. His eccentricities, the bizarre rumors, the hints of the supernatural — they all have large parts in the biographies, which miss the point. Tesla's latter days contain much that is sensational, poignant, and pathetic; this detracts from the historically important periods in Tesla's life. It is as if someone were writing a biography of Merriweather Lewis and decided to exclude the famous expedition from consideration.

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A short essay I wrote for my students in a college class on American history, circa 1998. Put up as an example of my nonfiction work, and for the fun of it. This work is copyrighted, not to be used without my permission.

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