NIKOLA TESLA: 145 YEARS OF VISIONARY IDEAS

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(Introductory Lecture)

"Were we to seize and eliminate from our industrial world the results of Mr. Tesla's work, the wheels of industry would cease to turn, our electric cars and trains would stop, our towns would be dark, our mills would be dead and idle. Yes, so far reaching is his work that it has become the warp and woof of industry. The name of Tesla ... marks and epoch in the advance of electrical science. From that work has sprung a revolution." B. A. Behrend, engineer and colleague of Tesla, 1917

INTRODUCTION

Nikola Tesla was a visionary genius whose sometimes radical ideas established the basis for everything that now powers our world with energy and information. Without his inventions the widespread electrification that touched the majority of people on the planet would not have been possible. In writings about Tesla, one often finds statements such as that he "invented the twentieth century" or "the twenty first century", or even that he "invented the future".

Dr. James Corum, one of the scientists continuing Tesla's work, summarizes poetically Tesla's contributions: "*The electrical power flowing from our great generators, illuminating our vast cities, dispelling the inky blackness of the night, and the telecommunications cohesively linking the homes and businesses of our civilization, across continents, around the globe and through the distant reaches of space - these are all monuments testifying to the successful life of this little known, but uniquely admirable, scientist, inventor, engineer, futurist, and citizen of the world*." [1]

Tesla invented and created the polyphase alternating current energy transmission, system of motors and generators that powers the world. He also invented apparatus for radio transmission based on the use of resonance and a kind of spread-technique. Among the more than 700 of Tesla's other inventions/patents are the rotating magnetic field principle, polyphase alternating-current system, induction motor, wireless communication, fluorescent lights, use of high-frequency (h.f.) currents in medicine and remote control.

Tesla was also a visionary thinker, who conceived many ideas, some controversial, which are related to several of today's mainstream technologies ranging from wireless communication systems, radar, television broadcasting, robotics, computers, faxes, and even the U.S. Strategic Defense Initiative.

Recognized by his peers and neglected by his modern successors, Tesla's life illustrates a working definition of the word success. However, he is still not recognized for many of his fundamental inventions. Such is the case of radio for which even the U.S. Supreme Court in 1943 determined Tesla as inventor. Tesla is one of only two Americans to have a unit of electrical measurement named in his honor.

SHORT REVIEW OF MAJOR TESLA'S INVENTIONS

The Discovery of the Rotating Magnetic Field. Tesla's discovery of the rotating magnetic field produced by the interactions of two and three phase alternating currents in a motor winding was one of his most significant achievements, and formed the basis of his induction motor and polyphase system for the generation and transmission of electricity. Thanks to this invention, large amounts of electrical power could be generated and transmitted efficiently over long distances. To this day, the three-phase form of Tesla's polyphase system is used for the generation and transmission of electricity. Moreover, the conversion of electricity into mechanical power is made possible by updated versions of Tesla's three-phase and split phase motors.[3,4,9]

The Discovery of the Tesla Coil and Transformer. His experiments with high frequency and high potential alternating currents resulted in the development of the "Tesla coil" which is still used as a major component in numerous electronic devices. "Tesla coil" is a transformer with an air core that has both its primary and secondary tuned in resonance. As part of other experiments Tesla also developed the precursors of modern neon and florescent lights. These

elongated glass tubes filled with gas and coated with phosphor, were emitting light through excitation in his high voltage experiments. He also discovered that high voltage current could be made harmless by using alternating current scheme at very large frequencies and predicted that it could be used for medical purposes. [3,9,10]

War of the Currents. In May 1885, George Westinghouse, head of the Westinghouse Electric Company in Pittsburgh, bought the patent rights to Tesla's polyphase system of alternating-current (AC) dynamos, transformers, and motors. Peck and Brown agreed to sell the Tesla patents to Westinghouse for $25,000 in cash, $50,000 in notes and a royalty of $2.50 per horsepower for each motor. Agreement meant that Westinghouse would pay Tesla, Peck, and Brown $315,000 over the 17 year life of the patents. The transaction precipitated a titanic power struggle between Edison's direct-current systems and the Tesla-Westinghouse alternating-current approach, which eventually won out. Thanks to the media blitz that he orchestrated, Thomas Alva Edison become a familiar household name linked to the electrification of the U.S. In reality, Edison did not create or develop the alternating current system. He fought its adoption bitterly, choosing instead to promote a system of direct current that had already been invented by others. It was Thomas Edison who invented the electric chair to frighten people away from the use of Tesla's AC system of electricity. In short, Edison's brief role in the electrical power industry was that of an entrepreneur who failed, rather than an inventor. It was Nikola Tesla's discovery of the rotating magnetic field principle in 1882 and patented in 1888 that gave us our modern-day system of electrical power distribution. [2,5,7,11]

Niagara Falls. In October 1893 the Niagara Falls Commission awarded Westinghouse a contract to build the power plant at the Falls, using the generators that Tesla has designed. Those dynamos of 5000 horsepower were the largest ever built thus far. General Electric (who by that time took over Edison, Thompson-Houston, and other companies), licensing certain number of Tesla's patents, was awarded a contract to build 22 miles of transmission lines to Buffalo, a city near the Niagara Falls. Tesla's polyphase system would be used throughout the project. The first three Niagara AC generators went on line November 16, 1896. "*The evolution of electric power, from the discovery of Faradey in 1831 to the initial great installation of the Tesla polyphase system in 1896, is undoubtedly the most tremendous event in all engineering history*" (Charles E. Scott, 1943) [7]

The Great Radio Controversy. Marconi was the first to send a message across the ocean, and thus, he is partly responsible for 'developing' radio...but he did NOT invent it. Tesla did. Otis Pond, an engineer then working for Tesla, said*, "Looks as if Marconi got the jump on you."* Tesla replied*, "Marconi is a good fellow. Let him continue. He is using seventeen of my patents.*" Most people are unaware of what happened June 21, 1943: The United States Supreme Court made a landmark decision that essentially settled the long dispute between Marchese Guglielmo Marconi and Nikola Tesla. The court's decision, Case No. 369, identified as "Marconi Wireless Telegraph Company of America vs. United States," rendered invalid Marconi's basic patent No. 763,772 dated June 28, 1904. Tesla's patent No. 645,576 of March 20, 1900, and its subdivision patent for apparatus No. 649,621 dated May 15, 1900, had priority. Still, in a special journal issue, celebrating 100 years of radio, International Telecommunication Union did not mention Tesla among "the six great inventors of radio" (Faraday, Maxwell, Branly, Lodge, Popov, Marconi). [2,5,7]

Remote Control and Automation. In 1898, at the first Electrical Exhibition in Madison Square Garden, Tesla demonstrated the world's first radio-controlled robot boat. Tesla applied his receivers and transmitters in remote ship control, and he was granted a patent in 1898 for *"The Method of and Apparatus for Controlling Mechanism of Moving Vessels or Vehicles*"- Tesla's patent No. 613,809 of November 8, 1898. This invention made Tesla an originator of remote control. Unfortunately, as with many of Tesla's inventions, this invention was so far ahead of its time that those who observed it could not imagine its practical applications.[2,5,7,8]

The Great Smithsonian Controversy. The Smithsonian Institution published in 1978 "The Smithsonian Book of Invention"[16] where it presented America's greatest inventors and their inventions. Tesla's name does not appear anywhere in that publication. One wonders how such an august institution could possibly ignore Tesla's contributions in the evolution of electric power and radio. In another Smithsonian's publication "Lighting a Revolution" [17], in the section "The Beginning of the Electrical Age" the history of electricity from Volta to Edison is presented, naming 43 significant contributors, yet Nikola Tesla's name is missing. Instead, the publication shows pictures of the Niagara Falls Power project, and readers are carefully guided into believing that this was the work of Edison. Yet it was Tesla's polyphase AC system that the power commission adopted and licenses had to be issued to use Tesla's patents. Money for this publication came from the Thomas Alva Edison Foundation, and is another proof that The War of Currents is not over yet. [5,6]

Tesla Award. The IEEE, which considers Tesla one of the 12 "apostles" of electrical science, continues to offer an annual prize in the field of power engineering in his name:

"The IEEE Nikola Tesla Award was established in 1975 through agreement between the IEEE Power Engineering Society and the Board of Directors of the Institute of Electrical and Electronics Engineers, Inc. The award consists of a plaque and a cash prize. It maybe awarded each year by the Board of Directors on the recommendation of the Technical Field Awards Council of the Awards Board to an individual, or group of individuals, who have made outstanding contributions to the field of Generation and Utilization of Electric Power. The Award is named in honor of Nikola Tesla, an electrical engineer, a distinguished Yugoslav-American inventor, and a pioneer in many fields, who is most renowned for the development of the coil that bears his name and the a-c induction motor." [18]

Until 1990 the IEEE Nikola Tesla Award included the golden plaque of Yugoslav Nikola Tesla Association for the Promotion of Scientific Knowledge and golden coins with Tesla's feature and plaque of Yugoslav Power Industries

The Unit of Magnetic Flux Density. In 1956, Tesla's peers at the Electrotechnical Conference in Munich acknowledged his monumental contributions to science by designating his name to represent a unit of magnetic measurement. Thus, the "tesla" (T) became the Unit of Magnetic Flux Density in the MKS system. Throughout the entire history of electrical science only fifteen men worldwide have received this honor. [5,7]

TESLA'S VISIONARY IDEAS

"*The present is theirs; the future, for which I really worked, is mine*." TESLA

In his visionary ideas Tesla was so far ahead of his time, so much a visionary, that his contemporary scientists really didn't understand what he was doing. We witness today realization of some of Tesla's visionary ideas, that he envisioned at the end of 19th and the beginning of 20th century. Many times he was misunderstood, or looked upon as an eccentric or even a lunatic. This created a great difficulty for Tesla and his ability to attract investors who would fund his research work. Only in few cases (such as collaboration with Westinghouse) he was able to fully complete his visions. In 1900, Tesla began construction on Long Island of a wireless world broadcasting tower (Wardenclyffe Tower), with $150,000 capital from the American financier J. Pierpont Morgan. Tesla was planning to provide worldwide communication with ability to send pictures, messages, weather warnings, and stock reports. The project was abandoned because of a financial panic, and Morgan's withdrawal of support.

Several Tesla's biographers point out that Tesla was a true scientist who lacked ability to broadly commercialize his work. Tesla needed money to do his research, while Edison used his inventions to earn a lot of money. W. Bernard Carlson, professor of history at the University of Virginia, who is currently writing a book on Tesla, titled "Nikola Tesla, Illusion, and Invention in Nineteenth-Century Electricity" points out [11]:

> "*Throughout his career, Tesla strove to find the ideal principle on which to base a new revolutionary invention, whether it be the principle of a rotating magnetic field at the heart of his AC motor or the concept of tuning radio waves in his remote control boat. Having identified the grand idea behind an invention, Tesla was willing to write it up in a patent and he took great delight in demonstrating it to the public. However, once he had demonstrated an invention, Tesla was not interested in the nitty-gritty work of converting his invention into a practical, money-making product. With the remote-control boat as well as his other inventions, Tesla assumed that someone else would take care of the messy realities of manufacturing and marketing."*

Among many Tesla's visionary ideas, we will mention only few that came to realization only recently, or are still waiting to be utilized: (a) Global wireless system for transmission of signals and energy, (b) Remote control foundations, (c) Vertical takeoff aircraft (VTOL), (d) Pump design suited for micromachines, (e) Use of geothermal energy, and (f) Vision of "electrical" future. [12]

(a) Vision of Wireless Communication (Magnifying Transmitter patented 1914). In early 1990's Tesla wrote *"... a telephone subscriber here may call up and talk to any other subscriber on the Globe. An inexpensive receiver, no bigger than a watch, will enable him to listen anywhere, on land or sea, to a speech delivered, or music played in some other place, however distant."* Sounds familiar? It took a better part of the 20th century for this Tesla vision to be realized. He had three goals: to develop a transmitter of great power, to perfect means for individualizing and isolating the energy transmitted (e.g., signals), to establish the laws of propagation of currents through the earth and the atmosphere. [13, 14]

Tesla envisioned global system of multimedia communication that included: world-wide wireless transmission of signals, pictures, and messages; integration with existing communication equipment; the universal distribution of general news, by telegraph or telephone, in connection with the Press (Internet); the interconnection of the existing telegraph/telephone exchanges or offices in the world; the interconnection and operation of all stock tickers of the world; global weather warning; the establishment of intelligence transmission for exclusive private use; the establishment of secret and secure government telegraph service; the global positioning system. He also talked about using the same system to transmit energy, making it a free resource (J. P. Morgan was not happy about this Tesla's idea).

(b) Remote control foundations (Patented in 1898). Tesla laid the foundation of remote control systems (what he called teleautomation) in 1898 at the first Electrical Exhibition in Madison Square Garden. He demonstrated how the ships and mechanical gadgets could be controlled remotely using a wireless principle. In Tesla's own words we can recognize the basis for what we call today "Computers" and even one step further "Artificial Intelligence": *"[it will be able to follow a course laid out ...or obey commands given far in advance, it will be capable between what it ought and what it ought not to do ... and of recording impressions which will definitely affect its subsequent actions*".

(c) Vertical takeoff aircraft -VTOL (Patented in 1928). The initial idea appears in 1921. He envisioned a vertical take-off and landing aircraft, with combined helicopter and airplane features. Although he gave a thrust analysis of VTOL, it was never built by Tesla. However, VTOLs are in military use today (V-22 Osprey, for example). Tesla also envisioned a horseshoe-shaped VTOL with a horizontally placed turbine, which rides on a thin layer of air. Tesla never built it, but similarly designed hovercraft is commercially available today. [12]

(d) Pump design suited for micromachines (Patented in 1920). Traditional method of controlling fluid flow with valves is imperfect due to: mechanical wear of moving parts, inability to control rapid flow "impulses", inability to control the flow when the fluid is highly heated or corrosive. Tesla proposed an ingenious conduit without moving parts, that could be defined as a "fluid diode". It has clearly defined "direct vs. reverse" flows, such that the resistance in the reverse flow is several hundred times larger than in the direct flow. It could be easily constructed and modularly expanded. It is ideally suited for micromachines, due to high reliability, and no interference with parts. Possible applications include

medical applications: such as drug dispensing in the body. [12]

(e) Use of geothermal power. In 1931 Tesla discussed the design of the power plants based on the geothermal energy. The geothermal power today has a great role as one of the renewable energy sources.

(f) Vision of "electrical" future. Tesla's prediction include: The widespread use of hydro-electric power generation and of AC for transmission; electrical control of atmospheric moisture (not yet accomplished); use in appliances (refrigeration, etc.), lighting, and propulsion; use in agricultural domain: pest control, elimination of microbes, …; collision-preventing instruments; "*In a time not too distant it will be possible to flash any image formed in thought on a screen and render it visible at any place desired*"; a voice-operated typewriter; picture/text transmission (fax); electric guns and teleautomatic aerial torpedoes (cruise missile?). [12]

It is interesting to point out that the widespread electrification was chosen as the greatest engineering achievement of the 20th century by the U.S. National Academy of Engineering (NAE), which organized the selection of the top 20 engineering feats [15]:

> "*In the 20th century, widespread electrification gave us power for our cities, factories, farms, and homes - and forever changed our lives. Thousands of engineers made it happen, with innovative work in fuel sources, power generating techniques, and transmission grids. From street lights to supercomputers, electric power makes our lives safer, healthier, and more convenient."*

On their Web site (http://www.greatachievements.org/) in the history of the electrification, NAE emphasized: "*The work of engineers such as Nikola Tesla and Charles Steinmetz led to the successful commercialization of alternating current (AC), which enabled transmission of high-voltage power over large distances*."

CONCLUSIONS

We will conclude our short presentation with the words of E.H. Armstrong, FM Radio Pioneer:

> *"The world, I think, will wait a long time for Nikola Tesla's equal in achievement and imagination."*

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