NIKOLA TESLA AND THE GLOBAL PROBLEMS OF HUMANKIND

> The scientific man does not aim at an immediate result. He does not expect that his advanced ideas will be readily taken up. His work is like that of the planter—for the future. His duty is to lay foundation for those who are to come, and point the way.
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> Nikola Tesla in "The Problem of Increasing Human Energy," June 1900.

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Summary

A pioneer in electrification, Nikola Tesla significantly influenced the technological development of our civilization by his invention of the polyphase system. This system is the cornerstone of the modern electro-energetic system of production, transmission, and usage of electrical currents.

Tesla also tried, at the beginning of the twentieth century, to establish wireless transmission of energy through the partially conducted globe and through the rarefied parts of the atmosphere. His work in that field represents a rare attempt by a lone, ingenious explorer to solve the problems of humankind in the supply of energy, and as such it is unprecedented in the history of human inventions. It is being discussed in this

paper first of all as a testimony that in history there have been attempts to direct contemporary civilization into a different frame of development.

In reviewing Tesla's theoretical considerations on energy and global problems of humanity, we can see that his suggestions were toward stopping the barbarous waste of fuel and finding ways of using renewable sources of energy like that of waterfalls. Regarding global problems of civilization he warned that material development should be stopped and many neglected social, moral, and spiritual problems addressed.

Tesla's socio-mechanical analogous method is used to consider the current and potential models of world development with the aim of better understanding its dynamics and possible ways of management.

1. Introduction

Nikola Tesla was one of the pioneers who, at the end of the nineteenth century, significantly influenced the technological development of our civilization by his inventions in the fields of electrification and communication. He is one of the last great individualists in scientific research. After him, systematic education and teamwork of inventors and engineers became an irreplaceable factor of our progress.

Like many other ingenious inventors, Tesla was not satisfied simply to play the role of a man who solves more or less important problems of technology. The independent nature of his mind made him think strategically about the problems of humankind and to direct his own researches in that way.

He is an international figure in the true sense of the word. A Serb and a Slav by origin, born in the southwestern part of the Balkan Peninsula, educated in Graz and Prague, he created his most prominent inventions in Budapest, Paris, and Strasbourg. However, it was not until he arrived in the United States that he succeeded in patenting and realizing these inventions. Tesla stayed in the US till the end of his life performing the researches for which he needed large amounts of money at that time. This background was reflected in the manner and quality of his thoughts.

2. The Life and Work of Nikola Tesla

Nikola Tesla was born on July 10, 1856, in the small village of Smiljan, in Lika, a military border province of the Austro-Hungarian Empire. Ever since the fifteenth century this area had been settled by Serbs fleeing from the Ottoman Empire as it gradually conquered the Balkans. Tesla's father, an Orthodox priest, was an erudite man. He had a library that contained, besides traditional Serbian folk poems, the poems of Goethe, Schiller and many other European writers.

Tesla finished elementary school in Gospic, in Lika, and the Real Gymnasium in Karlovac, in neighboring Croatia. Although his parents wanted him to become a priest, he managed to get his father's blessing to start technical studies. In autumn 1875 he went to Graz to study engineering at one of the best European universities—Joaneum.

From early childhood, he exhibited some characteristics of a genius. Like his illiterate mother, he could repeat by heart whole pages of poems or stories even if he had heard them only once. He easily multiplied four-figure numbers and claimed to possess a unique faculty to visualize things in his mind. This ability enabled him to "see" clear, movable mental images of the objects he was thinking about. This rare, today we could say, computer characteristic of the mind later became the essence of his research method, which did not need drawings, models or preliminary experiments.

In Graz, he showed brilliant success during the first two years of his studies. His average daily working time was 20 hours. Having lost the scholarship he had previously been awarded, he temporarily neglected his studies and fell into a period of youth crisis and disappointment. Nevertheless, after his father's death in 1879, he continued to study natural philosophy at the Karl's University in Prague. He finally abandoned his studies in 1881 and obtained employment as an engineer in the Central Telegraph Office in Budapest.

Budapest is connected with some of his most important inventions. While still a student, he began to think about the possibility of constructing an alternating-current commutatorless electromotor. Walking with a friend through the City Park of Budapest and quoting the verses from Goethe's Faust, in a moment of inspiration, he saw the solution in his mind—the creation of a rotating magnetic field by alternating currents. Within two months he had worked this principle into a system that he patented in the United States seven years later as a polyphase system of alternating currents. He moved to Paris in 1882 where he got a job with the Continental Edison Company, which installed direct-current power plants in many European cities. In 1883, in Strasbourg, where he spent six months on an engineering assignment, he made the first working model of his induction motor.

Charles Bachelor, Tesla's chief and a close associate of Edison, persuaded Tesla to move to the United States. In 1884 Tesla left Europe and thanks to Bachelor's letter of recommendation he obtained a job in the Edison Machine Works in New York. He waited for a chance to introduce his inventions to Edison, but Edison did not believe in the possibility of alternating currents and nine months later Tesla quit. Years of wandering and attempts were to follow and eventually in 1887, with help of Charles Peck and Alfred Brown, he founded the Tesla Electric Company. Peck and Brown ensured a modest starting capital to construct the first experimental alternating-current motors and to protect new inventions by patents. On May 16, 1888, he was invited to give a lecture before the American Institute of Electrical Engineers in New York. In this lecture, entitled "A New System of Alternate Currents Motors and Transformers," Tesla presented his new alternating-current commutatorless motors, generators, rotating transformers—that is to say, the complete system for generation, transmission, and utilization of alternating currents. George Westinghouse who, at that time, had already started a business with alternating-current electrification, having heard of Tesla's patents, hurried to purchase a license to use them. According to the contract, the rights to the first seven of Tesla's patents were sold for US$75 000 in cash plus a royalty of US$2.5 per horsepower of each motor constructed in the Westinghouse company.

Tesla spent the next year, 1889, in the Westinghouse plant at Pittsburgh helping Westinghouse's engineers to adjust his motors to the existing system of 133 cycles. Tesla suggested the standard of 60 cycles and it turned out later that he was right. Westinghouse gradually became the owner of the majority of Tesla's patents in the polyphase system. When Westinghouse applied Tesla's system to light the whole exhibition at the Chicago World Fair in 1893, the advantages of Tesla's system compared with the direct-current system were obvious. Soon after, Westinghouse signed a contract to build the first generators at the Niagara Falls powerhouse, a giant engineering project at that time.

From 1890 on, Tesla devoted himself to research on high-frequency currents. It was Heinrich Hertz who first drew attention to this new field of research. With his brilliant experiments he proved the existence of electromagnetic waves and confirmed the validity of Maxwell's electromagnetic theory. The first Tesla alternators were of mechanical type, designed on the working principle of his asynchronous motors and generators. They could deliver frequencies up to about 30 000 cycles a second.

Thanks to this inspiration, in 1891, he invented the oscillation transformer, known as the "Tesla coil." He took advantage of the fact that a condenser charged by a high-voltage generator and discharged through the spark-gap made very quick and irregular oscillations of thousands, even millions, per second. In 1842, Henry had already noticed this appearance on Leyden jars and, in 1853, Lord Kelvin formulated it mathematically. Here, as well as in the case of asynchronous motors, Tesla showed ingenuity combined with great practical skill. For his contemporaries the result of this discovery had scientific value only. But for Tesla this represented a possibility for development of the whole technology.

The basic patent was entitled "The System of Electrical Illumination" and described the working principle of the new device, the oscillation transformer; he applied for it on April 25, 1891, and on June 23, in the same year, he received patent No. 454 622. With this transformer he could produce continuous trains of high-frequency currents. Such high-frequency currents had not existed before this discovery because the then-known oscillation circuits could only produce packages of very damped high-frequency impulses. These new currents were soon called Tesla's currents and the device was called Tesla's coil. Over the next few years he constructed a large number of different types of this device for various purposes. The invention of Tesla's transformer had huge importance for the development of high-frequency currents technique.

On May 20, 1891, Tesla was invited to give his second lecture before the American Institute of Electrical Engineers, but this time at Columbia University in New York. The lecture, "Experiments with Alternating Currents of Very High-frequency and their Application to Methods of Artificial Illumination," was given before the large auditorium. In its scientific value it did not lag behind the 1888 lecture. In this lecture he presented his newest high-frequency current generators and demonstrated the originally designed vacuum tubes. For the first time he mentioned some other effects produced by his currents, such as the possibility of induction heating, ozone production, and effects on the human organism. He also presented the very important idea that oil can be successfully used for the insulation of high-voltage coils. The techniques of plasma production that he presented in this and some later lectures were the pioneer works in the field, and recently have become extremely important in the production of computer chips.

This lecture, published in *Electrical World* on July 11, 1891, and in *Transactions, A. I. E. E.*, and reprinted in all major world languages, greatly impressed a few significant inventors and scientists. Among those who were immediately inspired by Tesla at Columbia University were Nobel laureate Robert Milliken and the inventor McFarlan Moore, who commercialized "cool light" in the United States, at the beginning of the twentieth century. The lecture particularly impressed European audiences. In Paris, D'Arsonval started to experiment with the application of high-frequency currents in curing certain diseases. In England, Ayerton and Silvanus Thompson were keeping contact with Tesla informing their scientific audience about the latest development of his researches. Soon after, Tesla received an invitation to give lectures before the most eminent English and French institutions.

In London, in February 1892, Tesla delivered the lecture "Experiments with Alternate Currents of High Potential and High Frequency," first before the Institute of Electrical Engineers and then before the Royal Institution. He presented the same lecture one month later in Paris before the French Society of Physicians and the International Society of Electricians. In December, the same year, he was honored with a rare recognition from the English scientists—he was unanimously named a Member of the Royal Institution.

The series of brilliant lectures by Tesla terminated in 1893 when he gave a lecture "On Light and Other High Frequency Phenomena," first before the Franklin Institute in Philadelphia and then in St. Louis before the National Electric Light Association. In addition to the many new and, at that time, sensational experiments, such as one million volts of high-frequency electricity passing through his own body, or wireless lighting of gas-filled tubes, the lecture would remain memorable for its basic plan for wireless radio telegraphy. The plan comprised the ground sending and receiving station, antennas and the resonance between the transmitter and receiver.

On March 13, 1895, fire destroyed Tesla's laboratory in Fifth South Avenue in New York, burning collections of early devices, inventions, and documents. Among other things, fire burned the collection of 400 induction motors, 100 lamps and the manuscript of his just completed book *The Story of 1001 Induction Motor*. In 1896, having created a new laboratory in Houston Street, Tesla devoted himself for some time to research on the recently discovered Roentgen rays. In the following year, he delivered a lecture entitled "The Streams of Lenard and Roentgen and Novel Apparatus for their Production" before the New York Academy of Science. In the same year, 1897, he patented his "System of Four Tuned Circuits" wherein he presented all the basic technical elements needed to realize wireless telegraphy. This patent was used in the court trial between the United States Government and Marconi Wireless Telegraph Co., as a crucial argument to prove that Tesla, with his system of four tuned circuits in resonance, had anticipated Marconi's system, which was not patented until 1904, in the US.

In the spring of 1898, the US entered a war with Spain for the sake of a small Spanish colony on the island of Cuba in the Caribbean Sea. The reason for war was the sinking of the American warship *Maine*, which had been anchored in Havana harbor with a crew of 260. At that time, Tesla revealed his new discovery, the remote control boat, which could have been used as a torpedo. He had already patented this discovery, which was approved by the Washington Patent Office only after they had personally convinced themselves of the functioning of the model remote-controlled boat. The patent was presented in detail in a large number of scientific journals in America and Europe. It initiated various reactions, but mostly the doubt was about the consequences of the technique. Most of the reactions and criticisms were provoked by Tesla's statements in which, as he was inclined to do, he anticipated the technology, having just demonstrated its pioneering steps: "We shall be able, by availing ourselves of this advance, to send a projectile at much greater distance, it will not be limited in any way by weight or amount of explosive charge, we shall be able to submerge it at command, to arrest it in its flight, and call it back, and to send it out again and explode it at will, and more than this, it will never make a miss, since all chance in this regard if hitting the object of attack were at all required, is eliminated. But the chief feature of such a weapon is still to be told; namely, it may be made to respond only to a certain note or tune, it may be endowed with selective power."

The remote control was just one of his inventions developed over the next few years that was ahead of its time. If he had devoted himself, at that moment, to commercial exploitation of wireless telegraphy, he would probably have become famous as an inventor and founder of telecommunications. But ever since the beginning of his work on high-frequency currents he had been interested in realization of wireless transmission of power and not only of the signals. Tesla estimated that Marconi and others who were performing experiments in wireless telegraphy could not achieve results of greater importance with the devices reported to be used by them. Thus, in 1899, he moved to Colorado Springs in order to test his scientific hypotheses on the possibility of wireless power transmission.

Figure 1. Nikola Tesla at the age of forty-five.

In an improvised laboratory he constructed his greatest 12 million volts transformer, known in the literature as "Tesla's oscillatory transformer with extra coil." Here Tesla conducted numerous measures of electrical features of the planet Earth and discovered its basic resonant frequencies. With his oscillator, he delivered spectacular discharges 30 m long, explored the origin of lightning balls, produced artificial fog, and registered the regular signals of unknown genesis which he thought were coming from an extraterrestrial civilization. In Colorado, he improved the system of selective signal reception, a technique he called “art of individualization” and which is today known as the “spread spectrum technique.” He filed four patent applications describing this technique.

Having successfully completed his experiments in Colorado, Tesla returned to New York ready to get into commercial application of his inventions. Receiving US$150 000 financial help from J. P. Morgan, Tesla began building the World Telegraph Center on Long Island. Originally Tesla planned to realize the world’s distribution of the news and later the world system of energy distribution. However, in the spring of 1901, the New York Stock Exchange suffered great turbulence, shares and money went down, and Tesla lost a great deal of the sum intended for the construction of his system. In December, the same year, secretly using Tesla’s system of four tuned circuits in resonance, Marconi succeeded in transmitting the letter “S” across the ocean, from Cornwall in England to Newfoundland in Canada. Such transatlantic wireless signal transmission was much cheaper and simpler than Tesla’s proposed system and consequently he could not attract financiers for the continuation of his project.

Criticized for being impractical and ridiculed for his daring statements, Tesla turned his attention to mechanical engineering in order to earn the necessary money and return to his project on Long Island. His basic invention in mechanical engineering was a new principle of utilization of adhesive and viscosity forces of fluids in the process of energy exchange in the working circuit. Tesla’s turbo machines consist of parallel, mounted plates without blades or kindred devices. Gas or fluid passes between the plates and by means of shear viscosity forces draws them, producing a kind of whirling fluid field in the runner.

At that time, Tesla met a rich industrialist, John Hadley, the owner of American and British Manufacturing Company, with whom he cooperated in the course of the next four years. In the workshops of Hadley’s company in Bridgeport and Carliss, several prototypes of Tesla’s turbo machines were constructed—pump, compressor, blower, turbo-pump, steam, water, and gas turbines. Over US$100 000 were spent on the development of these machines, but their efficiency was not as high as Tesla had expected. He changed the style of his work. In 165 Broadway Street, he founded an office in which several technical draftsmen and two secretaries worked for him. He conducted the works and tests in distant factories by means of letters and drawings addressed to the engineers in change. He would come to the spot only when all preliminary activities were finished. Organizing himself this way, he minimized his time waste and could work on several projects at the same time.

When his association with Hadley ended in 1913, Tesla, with the assistance of John Hammond, an extremely wealthy mining engineer of high standing, initiated an ambitious project to patent the new mechanical principle in all the bigger world industrial centers. At that time, Tesla received many orders for his various turbo-machines but he did not have much success in this business. The greatest successes in all his attempts to commercialize his discoveries were obtained with his small speedometers, which were, by dimensions and other features, more suitable for the application of the new principle. In the period between 1916 and 1920 he was granted the patents for automobile and boat speedometers, and on the same principle he based his devices for measuring flow and frequency. His speedometers were constructed in large numbers by Waltham Watch Co., which had bought the rights for their production. For such patent rights, Tesla received a large sum of money at that time, about US$100 000.

In the years that followed, Tesla continued with his attempts to commercially exploit his turbo-machines, first with Allis Charmers Co., one of the largest turbine producers in America, and then with Budd Co., which produced automobiles, but unsuccessfully.

By the end of the 1920s Tesla had quit his work in mechanical engineering. A great economic crisis in the US contributed to his decision. During the next few years he worked on the project of telegeodynamics (the spreading of mechanical waves through the earth) and death rays. He tried to get some big companies and even the governments of some countries, such as England, Yugoslavia, Russia, and others interested in his work. He gave extraordinary interviews on his birthday announcing sensational inventions and criticizing contemporary civilization. After the celebration of his 80th birthday in Yugoslavia, he received a regular monthly pension from the Yugoslav government. During his last years, the FBI followed him because of his contacts with the representatives of foreign governments.

Tesla died on January 7, 1943, in the hotel New Yorker in New York, where he had lived for the last fifteen years of his life. By the decision of the American court, Tesla's complete inheritance passed to his nephew, Sava Kosanovic, who brought it to Belgrade in 1951. It is treasured in the Nikola Tesla Museum together with his ashes.

Figure 2. Nikola Tesla Museum in Belgrade preserves 155 000 original documents from Tesla's heritage.

Tesla's inheritance, among other things, contains 155 000 original documents and more than 40 000 of them are related to his scientific work. These documents are registered and classified but have not been published as yet.

2.1 The Importance of Tesla's Work

During his career as an inventor, engineer, and scientist, Tesla obtained 118 original patents, 112 in the United States and 6 in Great Britain. He also obtained over 100 patents that were repatented in countries all over the world on all five continents. The exact number of submitted but unregistered patents, not submitted patents in preparation, and drafts of his ideas, is not known.

Out of 118 original patents, 40 are related to energetics, 50 to the field of high-frequency currents, 17 to mechanical engineering and the rest to various technical fields. The most important patents are the ones in the field of energetics, that is electrification, because their importance was proved in everyday practice. Westinghouse Company, the owner of these patents, won, without exception, in all trials concerning the priority of discoveries in this field. Tesla had sold to Westinghouse not only the rights to utilize his patents but also the rights to produce his inventions under his name. Later on, Westinghouse Company had to share this monopoly with General Electric and some other big companies. Lack of systematic advertising and investment was the reason why Tesla's name undeservingly fell into second place when compared to producers and promoters. In Europe many inventors and companies took advantage of the fact that Tesla's inventions were not well protected by patents to make use of them in some form.

For some reason, Tesla's merits in the field of high-frequency currents are not well known today. The only exception is Tesla's coil, which can be found in better-equipped physics laboratories in the world. His other inventions, such as the system of four resonant circuits, the principle of selectivity in radio, logical "i" circuit, production of plasma, remote control, work on vacuum, phosphorescent and fluorescent light, remained in the shadow of Marconi, Hammond, Moor and others who repeated and perfected Tesla's inventions.

In mechanical engineering, since Tesla's death a large number of tests have been performed on Tesla's turbo machines; his bladeless pumps have today a limited application, and in many professional and scientific works Tesla is cited as a pioneer in this field.

During his life Tesla received many awards from world universities and institutions. The first recognition came already at the end of the nineteenth century, when he was given the Elliott Cresson gold medal, from the Franklin Institute, for his researches on high-frequency currents, and his first honorary doctorate degree from the Columbia University, and soon after from the Yale University. Later on he received many honors from European and American scientific institutions. The most valuable recognition was granted to him posthumously. Today the unit of electromagnetic induction is called the tesla.

2.2 The Polyphase System and the Use of the Hydro-Power Base for Sustainable Technological Development of the World

The generation and transmission of electrical power are the crucial elements on which, production, traffic, trade, tourism, communication, scientific development depend—in one word, all the remaining factors that influence the development of the world. No matter what power is used at the start of a system, production, transmission and utilization are most often performed in the same way: current is produced in generators, by systems of transformers, and under high voltage is transmitted to distant places where it is transformed to lower working voltages and used for motors or for lighting.

According to records issued by the World Bank in 1999, electrical current is, today, mostly produced by exploitation of coal. In countries with low-income economies, 48% of electrical power is generated by burning coal, 27% by harnessing hydro-power, 16% from natural gas, 7% from oil and 2% by nuclear power. The more developed the countries are, the lower is the percentage of coal and hydro-power, and the larger is the contribution of nuclear energy in the total balance of usage of primary energy for the production of electricity. Thus, in countries with high-income economies, 38% of electrical power is produced from coal, 15% from hydro-power, 13% from gas, 7% from oil, 25% from nuclear power and 2% from alternative sources such as geothermal, solar, wind, and tide and wave energy.

On average, between one-fourth and one-fifth of electrical power in the world is generated by hydro-power. The alternative power sources make only a minor contribution. This is important if we take three facts into consideration: first, by using hydro-power we spend a restorable power source, which is not the case with coal, oil, gas, or nuclear fuel. Among all other important power sources, hydro-power is the only one that is naturally renewed. One day, coal, oil, and gas will be exhausted. We will be able to use nuclear power for a long time but its exploitation is connected to the great risks concerning not only the production but also the storage of nuclear waste. The second important aspect of usage of hydro-power is ecological—it does not pollute the environment like other sources. The third important fact is its efficiency.

We may conclude that until we find some more perfect way of energy production, hydro-power represents one of the most important energetic bases for sustainable development of the world.

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Biographical Sketch

Jovanovic S. Branimir is the senior curator of the Nikola Tesla Museum, Belgrade, Yugoslavia. He was born in 1955, in Belgrade, Yugoslavia. He holds a mechanical engineering degree (1981) from the Mechanical Faculty, University of Belgrade, a postgraduate degree in history and philosophy of sciences (1987) from the University of Zagreb, and Ph.D. in mechanical engineering (1995) from the University of Belgrade, Yugoslavia. From the beginning of his career, he has worked in the Nikola Tesla Museum, first as an archivist, then curator and scientific advisor. From 1996–2000 he was the director of the Museum. He specialized in the history of science. His special field of interest is Nikola Tesla's work in science and technology.