The world of electricity 1820-1904

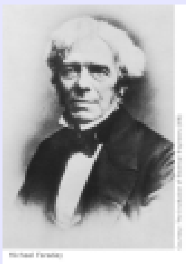
By Mark Frary

Following Alessandro Volta's experiments in 1800, which produced electricity by the mutual contact of discs of silver and zinc moistened with water, the study of electric current changed the direction of 19th century physics. In their search to find a continuous source of power, inventors in various parts of the world designed larger batteries but, as today, were defeated by the cost question. Mathematicians and physicists were engaged in a race to unravel the intimate relationship between electricity and magnetism. At the same time, inventors and engineers were trying to outdo each other with ingenious and ever more efficient devices and systems to produce, measure and harness it.

The "theoreticians"

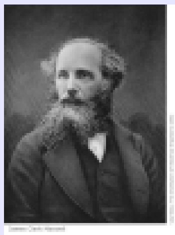
The theoretical basis for understanding electricity began in the 1800s. In 1820 a Danish physicist, H.C. Oersted, demonstrated that a current passing through a wire would deflect a compass needle. This experiment enabled him to discover the magnetic effect of an electric current. When the demonstration was repeated by Professor de la Rive at the Acad?mie des sciences in Paris, among those present was the distinguished mathematician Andr?-Marie Amp?re who began a series of researches on the phenomenon. Meanwhile, Georg Simon Ohm, a Bavarian physicist, established in 1827 the important relationship that the current through a circuit is proportional to the applied electromotive force and inversely proportional to the resistance.

The English chemist Sir Humphrey Davey, working to improve the safety of miners who relied on candles, had produced in 1802 the first electric arc lamp in which electricity was discharged between two pieces of carbon.



His laboratory assistant was Michael Faraday, who in 1831, while Director of the Laboratory of the Royal Institution, investigated what he called the "evolution of electricity from magnetism". Faraday made minute and accurate measurements of electric forces. He also conducted numerous experiments through a process of magnetization and demagnetization, for which two separate insulated coils wound round an iron ring enabled him to successfully demonstrate the complex phenomena of induction. This discovery was later to pave the way for the development of electric generators and alternators. Faraday's experimental disk generator became the first to produce a continuous electric current.

In a series of papers between 1855 and 1873, the theoretical physicist James Clerk Maxwell used the mathematics of incompressible fluids to express Faraday's lines of force, establishing his famous series of equations and speculating that electromagnetism bore a remarkable resemblance to the properties of light.



At the time, Maxwell said: "We can scarcely avoid the conclusion that light consists in the transverse undulations of the same medium which is the cause of electric and magnetic phenomena."

However, Maxwell who died in 1879 did not live to see the experimental proof of his theory. This was left to Heinrich Hertz. Between 1885 and 1889, Hertz was a professor at Karlsruhe Polytechnic in Germany and carried out experiments in which he discharged a condenser across a spark gap, creating radio waves that were then detected by means of a resonator with a similar gap. This was the first successful transmission and reception of radio waves and Hertz was able to measure their wavelength and frequency. He subsequently showed that radio waves were reflected and refracted in the same way as light.

Sir Charles Wheatstone, an English physicist and inventor, was professor of experimental philosophy at King's College London. While in Heidelberg, Germany, studying anatomy, he attended a lecture in 1836 during which Professor M?ncke demonstrated a single-needle telegraph. Impressed, Wheatstone designed the first commercially acceptable installation which two years later went into operation in England on the Great Western Railway. He also designed a workable ABC printing telegraph, which eventually failed to find a suitable market. In 1843 Wheatstone experimented with underwater telegraphy, but this model lacked the appropriate insulation for the conducting wires. Almost simultaneously, In the United States, Samuel Morse was conducting similar experiments and successfully operated a public service between Baltimore and Washington. Wheatstone is also remembered for having invented two new devices to measure and regulate electrical resistance and current: the rheostat and the Wheatstone bridge which is named after him.

The first international submarine cable service linking Dover with Calais was laid in 1851 by the British Electric Telegraph Company. In 1866, a British scientist, Lord Kelvin - who later became the first President of the International Electrotechnical Commission - went further and achieved worldwide fame with his Atlantic telegraph. Meanwhile, the mathematician Oliver Heaviside, who had worked as a telegraph operator, showed how Maxwell's equations could be reduced to more readily usable differential equations.

As public power generation became a practical reality, scientists turned their attention to the problems of dealing mathematically with electrical engineering. One of the key figures was Germany's Charles Steinmetz, who within three years of his arrival in the United States in 1889, had formulated the law of hysteresis, allowing electrical engineers to calculate and reduce power losses in motors, generators and transformers. Steinmetz went on to show how complex number theory could be used as an elegant means of predicting the behaviour of alternating currents in circuits.

The inventors

While the first half of the century belonged to the "theoreticians", the second half was a period of creativity in science and engineering. Important inventors from this era included Thomas Edison, Nikola Tesla, Gugliemo Marconi and Colonel Crompton.

In the United States, Thomas Edison, a former newsboy, started in business making telegraph instruments. Transmitting a single signal along a telegraph cable was time-consuming and costly. Edison's multiplex telegraph enabled more than one signal on a single cable. In 1877, Edison expanded his factory to manufacture complete generators and lighting systems including his own design of filament lamp. After commercial success with his invention of the phonograph, he went on to develop the first commercially successful incandescent light bulb.

Nikola Tesla was born in 1856 in Smiljan in Croatia (then part of the Austro-Hungarian Empire) to Serbian parents and emigrated to America in 1884. He held 112 patents in the US alone, including Patent 382,280 on the electrical transmission of power, for which he is best remembered.

In this Patent, Tesla wrote: "By producing an alternating current, each impulse of which involves a rise and fall of potential I reproduce in the motor the exact conditions of the generator, and by such currents and the consequent production of poles the progression of the poles will be continuous and not intermittent."

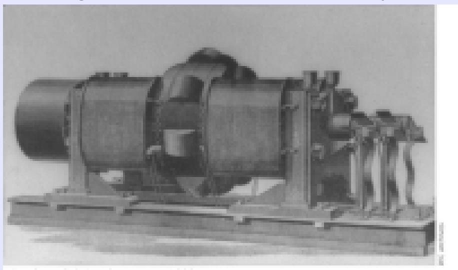
Guglielmo Marconi was born in Bologna, Italy, in 1874. By 1896, he had come to England and was helped in his experiments in wireless telegraphy by William Preece, the engineer-in-chief of the Post Office. In a letter to Preece in November of that year Marconi remarked that "this very rapid charging and discharging of the capacity throws the ether all around into vibrations which affect the conductor at the receiver". In April 1897, he

admitted to Preece that "I have not yet been able to find a satisfactory explanation as to how the signals get to the other side of the hills."

Colonel Crompton's interests ranged from automobiles, bicycles, military tanks and road engineering to electric lighting, power generation and electrical equipment. The English engineer went on to form one of the most successful engineering firms of the century, Crompton and Co. By the end of the century, despite military service in the Boer War, the proliferation of electricity and electrical devices brought him to appreciate the need for standardization at both the national and international level.

The "power" generation

The first practical dynamo-electric machine to appear on the market was invented by Z?nobe Gramme, a Belgian carpenter turned industrial model-maker, who in about 1870 improving upon existing machines produced his own design. Other makers followed Gramme's initiative including Siemens, in Germany and their offshoot in Britain as well as Emil B?rgin in Switzerland. In the United States, electric power came to the masses in autumn 1882 with the opening of Edison's Pearl Street generating station in lower Manhattan.



Brush arc lighting dynamo ca. 1882

Sebastian Ziani de Ferranti was born in Liverpool, England, in 1864. His precocious interest in electricity led him to design lighting for his father's photographic studio at the age of 13. At 16, he patented a dynamo and at 21 was made chief engineer of the London Electric Supply Corporation. It was in this role that he was instrumental in the design and construction of the world's first high voltage AC power station at Deptford in London. On its opening, the station generated power at 10 000 volts and supplied electricity to most of central London.

In the United States the inventor George Westinghouse was particularly interested in the area of safety. He devised the world's first air brakes, automatic signals for railways and a system for transporting natural gas safely, but in 1884 he turned his attention to electrical power generation.

Westinghouse had followed developments in AC power generation in Europe with interest. Employing the newly arrived Nikola Tesla to develop AC generators and motors, Westinghouse opened a hydroelectric power station at Niagara Falls in 1895, starting the trend for siting generating capacity at a distance from consumption - something for which AC was better suited.

Tesla A.C. motor ca. 1888

Emergence of regional electrotechnical societies

The rapid pace of change at that period is particularly reflected in the growth of the learned societies between 1870 and 1890. Countries in various parts of the world started forming their own electrotechnical societies. In 1871, the Society of Telegraph Engineers was founded in London. The overlap between telegraphy and electrical engineering then led to the society broadening its name nine years later to become the Society of Telegraph Engineers and Electricians. That name lasted even less time and in 1888 it became the Institution of Electrical Engineers (IEE), the name it retains today.

In 1883, the Soci?t? Internationale des Electriciens was formed in France and the Elektrotechnischer Verein in Vienna, Austro-Hungary. The following year saw the establishment of the American Institute of Electrical Engineers. The Canadian Electrical Association appeared in 1891, followed two years later by Germany's Verband Deutscher Elektrotechniker and in 1897 by Italy's Associazione Elettrotecnica Italiana.

The British Association for the Advancement of Science appointed in 1861 a specialized committee under Lord Kelvin (then William Thomson) to study the question of electrical units. Foremost to recognize their importance, Kelvin insisted that 'when you can measure what you are speaking about, and express it in numbers, you know something about it'. The following year, as well as recommending the use of the metric system, he emphasized the need for a coherent set of electrical units.

At the 1881 Paris Congress, although lacking precise definitions, the ampere, volt, and ohm were recommended as practical units. Kelvin's pioneer work in the British Association and at the series of International Congresses contributed to the establishment of a solid foundation of electrical units and standards, and up to his death he more than any other, paved the way for their international adoption.In 1967 the unit 'kelvin' (symbol K) was assigned to the unit of thermodynamic temperature as one of the base units of the International System of Units.

International standardization

Although the importance of electrical measuring units had been universally recognized, by the end of the 19th century the lack of standardization of electrical equipment had become a worldwide problem. With the development of economic generators, filament lamps, fittings and reliable cables, local authorities and distributors for the first time could choose between the merits of different designs. But in the absence of agreed ratings and recognized performance criteria they were often obliged to follow the advice of experienced consultants. Manufacturers, on the other hand, began to appreciate that to facilitate repetitive production, simplification of designs was essential especially in reducing cost for the consumer, meeting competition from foreign producers, and providing recognized guarantees.

In Britain a committee set up under the auspices of the Institution of Civil Engineers in 1901 considered the advisability of standardizing iron and steel sections. One year later the committee was enlarged to include electrical plant. It was this committee under Sir John Wolfe Barry that finally emerged as the British Standards Institution. The American Institute of Electrical Engineers (IEEE) had already set up a committee in 1897 to deal with electrical standardization but it was not until 1918 that the American Standards Engineering Institute (later ANSI) came into existence.

Electrical engineers in the early 20th century began to see the need for closer collaboration embracing terminology, testing, safety and internationally agreed specifications. While the 19th century had been the era of electrotechnical innovation, the emphasis was now on consolidation and standardization. While the series of International Electrical Congresses, particularly those between 1881 and 1900, had been solely concerned with electric units and standards, it was at the St. Louis, USA, Congress, held in 1904 that, in the interests of commercial transactions and trade, the proposal was made for the setting up of a permanent international commission to study the unification of electrical machines and apparatus.

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The IEC would like to thank Paul Tunbridge for his contribution to this article.

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