Charles Proteus Steinmetz - Pioneering Contributions in Electrical Engineering

Franz Pichler(✉)

Linz, Austria
telegraph.pichler@aon.at

1 Introduction

The development of electrical engineering, a century ago, can be considered as one of the most interesting chapters of the history of technology in Europe and North America. The inventors of this time, such as Edison, Tesla, Siemens, Marconi, Morse, Bell, Heaviside, Gramme, and others, are still of strong biographical interest to us.

The ideal profile of an inventor would be the union of a rational thinking scientist with an artist, who brings the subject to the right human dimensions and relations. Leonardo da Vinci and Albrecht Duerer might be mentioned here to represent the ideal combination of a scientist with an artist. This essay should bring the scientific work and the artistic life of a man to our rememberings, a man which is known in Europe only in special scientific circles: Charles Proteus Steinmetz, as he called himself with his Americanized first name.

This lecture should bring the scientific work and the life of a man to remember, a man which is known in Europe only in special scientific circles: Charles Proteus Steinmetz, as he called himself with his American name. Just as the famous Nikola Tesla, Steinmetz also received his fundamental scientific education in old Europe. However, the American continent gave him the chance to apply his talents in full breadth, not forcing him to a certain personal life style. In contrary, he could fully keep his most interesting individuality.

2 Alternating Current Against Direct Current

Similar to the second half of the 20th century being dominated of the computer as the "realization engine of Information Technology", electrical machines (in a very general sense) caused great excitement in the second half of the 19th century. An important step for the practical application of electricity was the invention of the "dynamoelectric principle" by Werner Siemens (1866) - and independently by the British scientist Charles Wheatstone - which made possible the generation of electrical power by dynamos without the use of permanent magnets. Dynamos of this kind replaced voltaic batteries to power galvanisation processes and carbon lights. They were built as direct current machines (D.C. machines). As soon as the invention of the multiphase generator by Tesla (1888) and the invention of the high power transformer (Zipernowsky

R. Moreno-Díaz et al. (Eds.): EUROCAST 2017, Part I, LNCS 10671, pp. 74–81, 2018.
https://doi.org/10.1007/978-3-319-74718-7_9

1885; Stanley 1886) was made, the generation of electrical power and its transportation across long distances became simpler and more efficient. The installation of a high voltage power line in Germany from Lauffen to Frankfurt (1891) by Oscar von Miller and the construction of the Niagara power plant (1895) by the Westinghouse Company - with Tesla as the designer of the alternating current generators established milestones in the practical use of alternating current. In North America, however, the replacement of D.C. technology by A.C. technology was not a simple task. The competing firms, the Edison General Electric Company (in support of D.C. technology) and the Westinghouse Company (which favoured A.C. technology) got into a long fight. It has been reported, that the Edison Company even supported the installation of the electric chair (New York 1889) to demonstrate the danger of the alternating current. The electrical exhibition in Frankfurt (1891) and the electrical exhibition at the world fair in Chicago (1893) brought a decision in favour of A.C. technology. In North America, this result was mainly achieved by the pioneering works of Nikola Tesla and Charles Proteus Steinmetz. In his important lecture on the "Application of complex numbers in Electrical Engineering" (which was published in German in the "Elektrotechnische Zeitschrift" at the same time (ETZ 1893)) Steinmetz was able to show that for alternating current phenomena the laws of Ohm and Kirchhoff were valid just in the same form as for direct current phemomena. By the "symbolic method" of Steinmetz it was possible to represent alternating currents by simple algebraic expressions. The computation of alternating current phenomena became just as easy as for direct current phenomena.

3 Steinmetz the Scientist

Of what kind were the important scientific contributions of Charles P. Steinmetz? How did it happen? Charles Proteus Steinmetz was born on April 9, 1865 in Breslau as Karl Rudolf Steinmetz. From childhood on handicapped by a hook and seemingly having a too big head for his short body and legs, he attended with great success the grammar school and the University of Breslau. There he studied mathematics and astronomy, showing also great interest in physics, philosophy, and the newly up-coming subject of electrical engineering. His doctoral thesis in pure mathematics titled "*Über unwillkürliche selbstreziproke Korrespondenzen im Raum, die bestimmt werden können durch ein dreidimensionales Linearsystem von Flächen der n'ten Ordnung*" had already been approved by the professors when things changed dramatically! Steinmetz was a member of a group of students which were in favour of socialism, which was not approved by the Prussian government and he also was a co-editor of the newspaper of the socialistic party, the "Voksstimme". From an anonymous friend he learned that his imprisonment was planned by the police. To escape, he fled via Vienna to Zurich in Switzerland. There his goal was to live there as a emigrant and to finish his studies at the "Eidgenössische Technische Hochschule". However things changed again. His Danish friend Oscar Asmussen persuaded him to join him in emigrating to the United States of America. Regardless of his poor knowledge of the English language, with no essential financial means but with a letter of recommendation by Mr. F. Uppenborn, the

publisher of the internationally recognized scientific journal, the "Elektrotechnische Zeitschrift", he got on board of the steamship "La Champagne" in Le Havre to leave for New York (Fig. 1).

Fig. 1. Charles Proteus Steinmetz: arrival in USA

With the help of the recommendation letter, he immediately found employment at the company Eickemeyer and Osterheld in Yonkers, New York, which manufactured electric machinery. As he worked in the drawing office, however, his boss very soon discovered his mathematical gift, and more and more he was consulted when difficult problems came up. One of the problems in electrical machinery of that time was the heating up of the electromagnets. Steinmetz took a strict scientific approach to that problem and he developed the theory of electromagnetic hysteresis, a theory which has kept its validity until today. In his lecture on January 19, 1892 at the meeting of the American Institute of Electrical Engineers (AIEE) in New York City he reported on his important findings. A rather voluminous paper on the subject of hysteresis in the "Elektrotechnische Zeitschrift" has preserved this result until today (ETZ 1892).

The General Electric Company, which was established in 1892 by the union of several companies of the Edison group, also bought the company of Eickemeyer and Osterheld and Steinmetz was now employee of general Electric. He moved to

Schenectady, headquarter of General Electric, a lovely town on the river Hudson in upstate New York. The General Electric Company supported Steinmetz in his research in the best way, giving him a great deal of independence at the same time. In his own laboratory near his living home at Wendell Avenue he could perform any kind of electrical research he wanted. Of special interest to him was artificial lightning to explore the properties of material when stroke by lightning and to analyze lightning arrestors. In 1902 he got an appointment as a professor for Electrical Engineering at the Union College and he served there as a chairman of the department until the year 1913. In 1903 Union College awarded him the doctor of philosophy (Ph.D.). The numerous textbooks which he published as result of his lecturing helped a generation of students in electrical engineering in their studies of fundamental scientific models of electrical systems. Besides of writing books, he was ambitious in lecturing on different meetings and in publishing special papers on his research (Fig. 2).

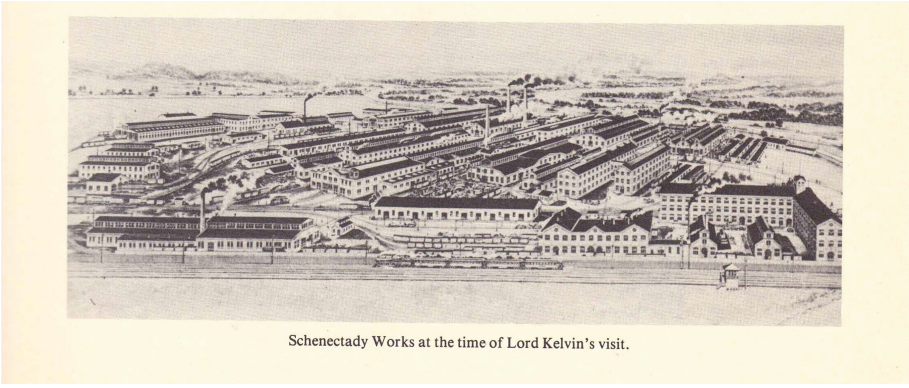

Fig. 2. General electric plant Schenectady 1902

4 Steinmetz in His Private Life

To have a full picture on Charles Proteus Steinmetz we have to look also into his life from a less scientific point of view. To start with that, let us quote Anton Zischka. Zischka writes "*He was a close friend of Marconi and Edison. To communicate with Edison in his later years he would use the Morse-code knocking it to Edisons legs. The American press called Steinmetz because of his artificial lightning experiments the "modern Jupiter". Although he was one of the great scientists he lived all the time the life of a boy: he ordered an exotic green house for his home and since he himself was a cripple he had the strangest animals such as lizards, exotic fishes, and birds in his house. The mirrors of his house were lighted by mercury-light lamps so that the visitors could see themselves with swollen violet lips and looking like having drowned in water. The doors of his house were usually electrified and occasionally he organized "Lightning days" destroying in his laboratory little houses made of cardboards. He loved to go by his canoe, he went regularly to crime-movies (especially he liked to see*

the actor Douglas Fairbanks) and he read numerous adventure stories. During night he would develop new mathematical formulas and perform computations which brought general Electric millions of dollars" (Figs. 3 and 4).

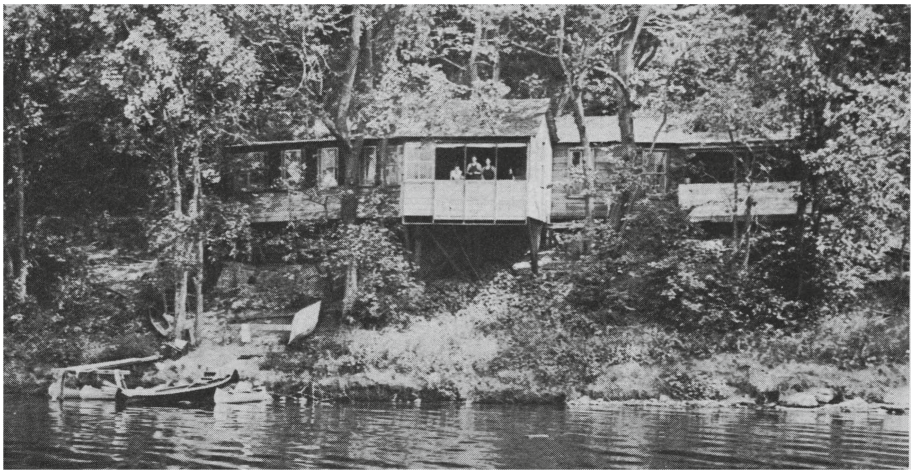

Fig. 3. "Camp Mohawk" on Viele's creek

Fig. 4. Steinmetz in his garden

Although we must admit that Zischka reports with some phantasy here, he sketches the situation correctly. Steinmetz lived in fact a boy's life. He loved his "camp Mohawk" on Viele's creek and he loved to work on difficult mathematical problems by drifting in his canoe. He hated formalities in dressing and he would welcome also eminent visitors at "camp Mohawk" in his red bathing suit and wearing a T-shirt. Since he stayed a bachelor for all his life, to have a family, he adopted Mr. and Mrs. Hayden and finally he had also three grandchildren. He never gave up to be fond of socialism and he engaged himself in different social projects of the city of Schenectady (Figs. 5 and 6).

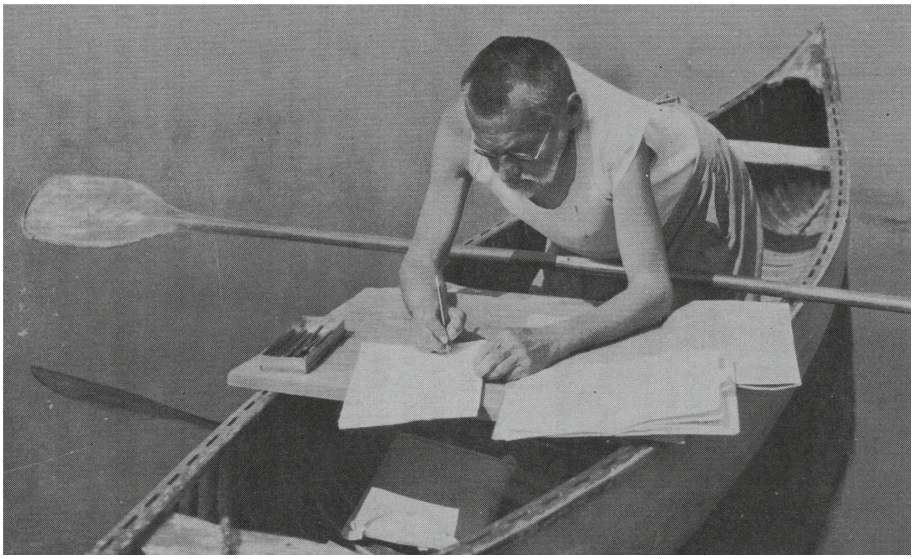

Fig. 5. Research work in the canoe

Charles Proteus Steinmetz passing away on October 16, 1923 after a heart attack was unexpected for everyone. The major American newspapers would bring reports on him. Herbert Hoover, later president of the United States of America on this occasion gave the following tribute:

> "*His mathematical reasoning broke the path for many of the advances in electrical engineering in recent years and solved problems which were vital to the progress of industry. In his writing he has left engineers a heritage of mathematics that will endue, and as a man he has set us all an example of physical courage and of devotion to our life work.*"

Fig. 6. Steinmetz and Albert Einstein

5 Summary

Charles Proteus Steinmetz was certainly one of the important scientists and engineers who, by their research and inventive contributions, helped to design electrical systems and to analyze electrical phenomena by sound scientific methods. Similar to Nikola Tesla, Steinmetz received his education at a European University. Contrary to Tesla, who had to fight all his life long to get support for his research and inventions, Steinmetz was lucky to get permanent and generous support for his research by the General Electric Company.

His work and inventions concerned the problems which had to be solved by the advent of the practical use of alternating currents. In electrical machinery, in the construction of dynamos and motors it became necessary to fight against eddy currents which caused losses of power. Steinmetz with his early work on the hysteresis of the iron cores of such machines contributed to the solution. Another important problem which occurred in the use of alternating currents was the design of proper networks for transmission. Steinmetz showed that, by the use of complex numbers a new characterization of resistors, inductances and capacitors was possible, such that the Ohm's law and the laws of Kirchhoff were also valid to allow an effective computation. In the history of the General Electric Company the time of 1902, where General Electric was founded and Steinmetz joined the company, until the year 1923, the year in which Steinmetz died, has been called the "Steinmetz era". His inventions, his many books,

written for his students at the Union College in Schenectady give enough reasons to consider Charles Proteus Steinmetz as one of the most important electrical engineers of the past (compare with the list "Monographies and Text Books by Steinmetz" of the References).

Besides of his professional interest he had many private and rather artistic interests. They fit to his middle name "Proteus" given to him as nick-name by his friends at the grammar school in Breslau, the multi-faced gnome of Homer's Odyssee. We find Steinmetz here as a ever-lasting young boy, always ready for jokes, reading adventure stories, going to crime movies, but serious engaged in public social affairs - in one word - living a full life.

References

Important Papers Published by Steinmetz (in German)

Das Gesetz der magnetischen Hysteresis und verwandte Phänomene des magnetischen Kreislaufes. ETZ, XIII. Jahrgang, Berlin (1892)
Die Anwendung komplexer Groessen in der Elektrotechnik: ETZ XIV. Jahrgang, Berlin (1893)

Monographies and Text Books by Steinmetz

Theory and Calculation of Alternating Current Phenomena, New York (1897)
Theory and Calculation of Transient Electric Phenomena and Oscillations, New York (1909)
Radiation, Light and Illumination, New York (1909)
Electric Discharges, Waves and Impulses, New York (1914)
Theory and Calculation of Alternating Current Phenomena, New York (1916)
Theory and Calculation of Electrical Circuits, New York (1917)
Engineering Mathematics, New York (1917)
Four Lectures on Relativity and Space, New York (1923)