Galileo Ferraris A Life Dedicated to the Electrical Sciences

Galileo Ferraris: A Life Dedicated to the Electrical Sciences

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This article illustrates the life and work of Prof. Galileo Ferraris (1847-1897), an Italian engineer and scientist who dedicated his life to the study of electricity and its applications in the 19th century. His contributions to different engineering disciplines were remarkable, as were his efforts to develop and disseminate electrical knowledge. In this article, we will briefly discuss his publications and formidable laboratory experiences from 1870 to 1897. All the original works of Galileo Ferraris, his numerous papers and books, are available for free download from the digital repository of the central library of the Politecnico di Torino, the university that he contributed in creating.

His life

Galileo Ferraris was born on 30 October 1847 in Livorno Piemonte (Kingdom of Sardinia). At the age of 22, he obtained the master's degree in Civil Engineering, and decided to pursue an academic career. He became an assistant professor under the supervision of Prof. Codazza, within the Technical Physics Department of the Royal Industrial Museum of Turin, Italy. In 1877 he succeeded Prof. Codazza as a full professor of technical physics. Ferraris attended the International Conference in Paris, in 1882, as a delegate of the Italian Government. He was the vice-chair of the International Exposition in Vienna in 1883, and in 1884 he hosted the International Electrical Exhibition in Turin, Italy. During this event, he was also the chair of the award committee, which granted a prize to Gaulard and Gibbs for the invention of the transformer. In 1888, Prof. Ferraris founded the School of Electrotechnics with educational electrical laboratories (later on incorporated into the Politecnico di Torino), the first institution of its kind in Italy, and most likely in the world (Figure. 1) [1].

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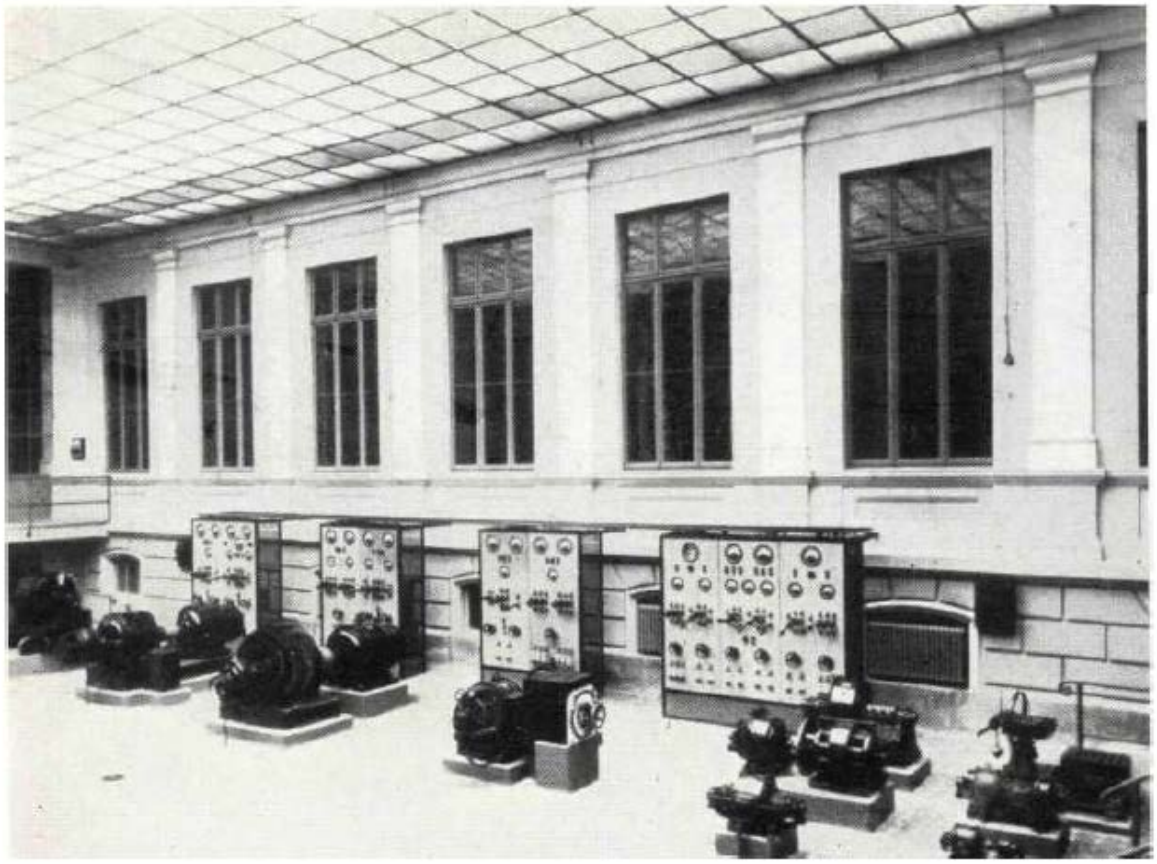

Figure 1 The Electric Machines laboratory at the School of Electrotechnics

(Photo courtesy of the Central Library of the Politecnico di Torino; www.polito.it)

Prof. Ferraris was a pioneer in the development the ac distribution system and the induction motor. He extensively published the experimental results of his work on crucial aspects of electrical engineering, which forever influenced the way we produce and transport electric energy today. In 1989 Galileo Ferraris (Turin), Erasmus Kittler (Darmstadt), William H. Lindley (Frankfurt), Friedrich Uppenborn (Berlin), Heinrich Friedrich Weber (Zürich) were asked by the authorities of Frankfurt to solve the problem of the city's electrical distribution system.

Prof. Ferraris was recognized, in 1891, at the Frankfurt Electrotechnical Exposition for his research on magnetic fields, where an electric system, including a 175 km transmission line represented a major accomplishment for electrical applications.

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Prof. Ferraris was the Italian delegate to the Chicago International Conference on Electricity in 1893, where his influence garnered group-member consensus on the definitions of the units of measurement: joule, watt and henry. In 1896, he represented Italy at the Geneva Conference, where he lectured on new and existing units of measurement. In the same year, he established the Italian Electrical Association (AEI), which continues his work, and now includes electronic and telecommunications disciplines as the Italian Electrical, Electronics, Automation and Telecommunication Association. In 1896 he was also appointed senator of the Italian Kingdom. Prof. Ferraris also served as a city alderman from 1887 to 1897 in Torino. From 1895 to 1897 he was a counselor in his home-town of Livorno Piemonte.

Despite his poor health, prof. Ferraris kept teaching, but on 1 February 1897, he had to stop his lecture. It is reported that he told his students: “Gentlemen, the machine is broken, I cannot continue my lecture”. One week later he died of pleural pneumonia.

His research activity

The impetuous urge to further develop electrical applications, the national and international initiatives and proposals promoted by expositions and conferences and autonomous ideas gave rise to an intense research activity. The scientific contribution of Ferraris sparked progress in the field of electrical applications, and today, even a century later, many advancements influenced by his work are still shared and discussed at national and international conferences. He is absolutely worth studying. The original Ferraris papers were written in Italian. They were collected and reprinted by AEI in 1902 [6], in 1903 [7] and in 1904 [8]. In order to attempt to summarize the most significant topics of his scientific research, a detailed list of the subjects that he treated is herein condensed:

- analysis of currents in conductors [12], [16]
- electric behavior of the telephone [13]-[15]
- electric and photometric measures [11], [22], [28]
- transformers behavior and models [17]-[20], [29]
- induction motor [21], [25]
- synchronous motor [23]
- ac electrical distribution [26], [27], [32], [39]
- electric lighting [26]-[28], [32], [39]
- electromagnetic fields [24]
- optics [35]-[37]

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- mechanics [34], [38].

In [3] a useful synthesis of Ferraris production is given (in English) in the book [3] which was prepared on the occasion of the centenary of his death.

Conferences reviews were given in [26]-[28], [30] and [31].

Ferraris' work focused on a machine that he defined as a "*secondary generator*", now universally known as a transformer, which was firstly introduced by Gaulard and Gibbs. The transformer had an open iron core, and he studied its behavior, and functionality and established the electrical calculation methodology under ac conditions. He understood and measured eddy and hysteresis currents, as well as the transformer efficiency. This work allowed him to better understand the improvements obtained by Zipernowsky, Déri and Blathy, who introduced the closed iron core transformer.

As the result of his experiments started in 1885, in 1888 prof. Ferraris presented the prototype of the induction machine with a horizontal axis, which he jokingly named the "grille" (Figures 2 and 3) to the Royal Academy of Sciences in Turin, Italy.

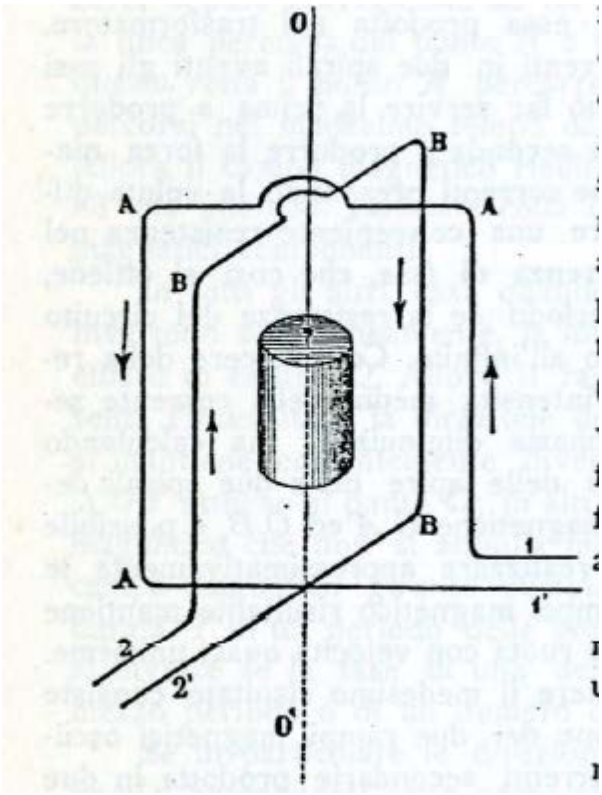

Fig. 2 Basic idea of a rotating field and the two-phase rotating machine

(Photo courtesy of the Central Library of the Politecnico di Torino; www.polito.it)

The basic idea of the *magnetic revolving field* came to him from the polarization of light waves; he firstly conceived a two-phase induction motor.

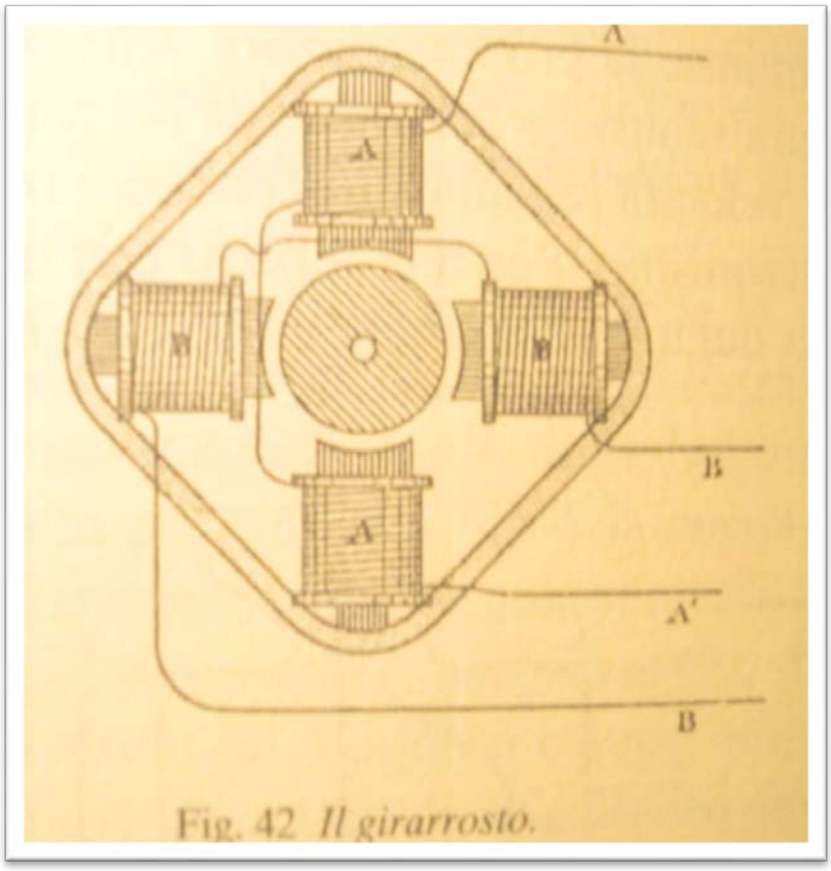

Figure 3 First schematic of the induction machine

(Photo courtesy of the Central Library of the Politecnico di Torino; www.polito.it)

In a preliminary experiment on 1885, the revolving field was generated by two stationary coils, installed perpendicular to each other, through which two currents of the same frequency circulated but were displaced by a phase angle of 90°. A copper cylinder immersed in the revolving field was consequently moved to produce mechanical work, due to the interactions between the resulting electromagnetic forces and induced currents. In 1888 three years after the first experiments, the inventor published the paper [21] where he formally demonstrated the basic principles of the machine's behavior.

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IEEE Industry Appl ications Magazine, Sept.|Oct. 2016, pp. 8-11.

The invention of the induction machine and the use of transformers became the fundamental pillars of the ac electrical revolution. The experiments performed on the occasion of the Torino exposition confirmed the importance of electric energy due to the relative simplicity of its transport and regulation, which were the basis for following technological developments. A visionary and coherent description of an electric power system is found in [39]. In this paper a new application of an asynchronous machine was proposed for the so called *phase rotation transformer* (Fig. 4).

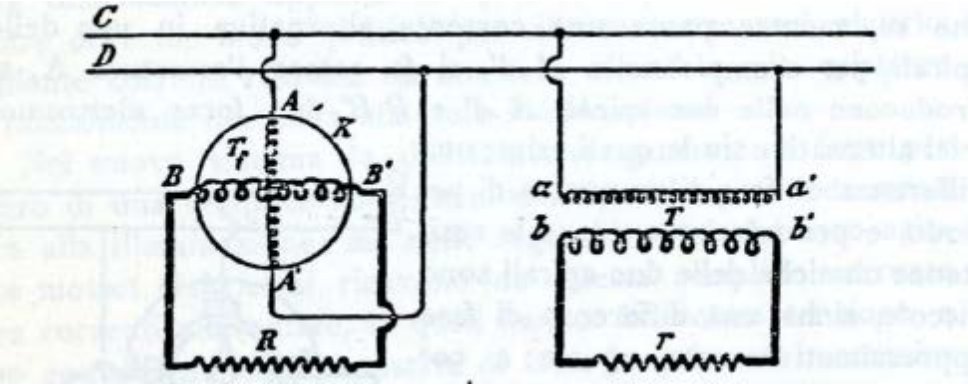

Figure 4 An induction machine used as a phase-rotation transformer [39]

(Photo courtesy of the Central Library of the Politecnico di Torino; www.polito.it).

In Fig. 4, two electric machines are used to generate a two-phase ac system: an ordinary transformer ***T*** and a phase-rotation transformer $\boldsymbol{T_f}$. The use of asynchronous machine to obtain voltages with different phases became popular in electric laboratories, and Ferraris' idea consisted [39] of the use of a rotor to generate a revolving field in the BB' winding (Fig. 4), instead of the usual application of a rotor winding installed according to the wanted phase rotation.

His publications

In our opinion, the use of the Italian language was, and is, a limiting factor for the dissemination of Ferraris' scientific production. For this reason, in this article all the titles of his publications have been translated in English. The Central Library of the Politecnico di Torino provides access to all his original work (http://digit.biblio.polito.it/view/percorsi/GFERRARIS.html). The chance to read the complete mathematical formulations included in Ferraris' work, may allow today's IEEE

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Industry Applications Society members, and electrical engineers at large to better understand his monumental work.

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1 The Secondary Generator was the first name attributed to Transformers.

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