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REVISITING THE ELECTRICAL ENGINEERING HISTORY AND EDUCACIONAL PROPOSALS

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Abstract

There are blanks in the building of knowledge about Electrical Engineering history. Electricity has been latent in nature and human beings have discovered and developed its potential through millenniums. Electricity utilization by ancient civilizations such as Chinese, Sumerians and Parthians in the beginnings, its basic knowledge development and applications as well as the interconnection among Electricity's shapes in nature are true examples of development and they are covered in this project. The collaborations of this project are: the presentation of new facts about this history and fill in some blanks, the disclosure of key realities about Electricity that point out their benefits to human society; the assortment of reports about inventions and discoveries related to names and places along timeline, and to present new proposals about Electrical Engineering education. The Electrical Engineering's fundamentals are the base for the state-of-the-art up today and with a well endowed education course it cooperates to forming high level engineers.

Keywords: Mathematics, History, Electrical Engineering.

[REVISITANDO A HISTÓRIA DA ENGENHARIA ELÉTRICA E PROPOSTAS EDUCACIONAIS]

Resumo

Há lacunas na construção do conhecimento sobre a história da Engenharia Elétrica. A Eletricidade está latente na natureza e os seres humanos têm descoberto e desenvolvido o seu potencial através dos milênios. A utilização da Eletricidade por civilizações antigas como a dos Chineses, Sumérios e Pártias nos primórdios, o desenvolvimento de conhecimentos e aplicações básicos sobre ela, bem como o conhecimento sobre as inter-relações das formas de Eletricidade existentes na natureza são exemplos verdadeiros deste desenvolvimento, e são abordados neste projeto de pesquisa. As contribuições deste projeto são: apresentação de fatos não mencionados pela literatura sobre esta história e assim preencher algumas lacunas, a divulgação de realidades fundamentais sobre a Eletricidade que mostram seus benefícios para a sociedade humana; relatar em ordem cronológica algumas invenções e descobertas associadas a nomes de inventores e cientistas, bem como lugares importantes longo do tempo, e apresentar propostas novas sobre educação em Engenharia Elétrica. Os fundamentos da Engenharia Elétrica que são a base do estado-da-arte até nossos dias, também são ensinados em cursos de nível superior e cooperam para a formação de engenheiros de alto padrão.

Palavras-chave: Matemática, História, Engenharia Elétrica.

1. Introduction

With the aim to revisit the Electrical Engineering history, we will initially introduce in chronological sequence the development of Electricity knowledge and its applications by ancient civilizations in the beginnings, that have not been covered by Engineering literature. Thereafter, the process about development of Electrical Engineering's fundamentals will be presented as well as key stones of development for electrical measurement instruments in the beginnings. Relevant aspects about generation, transmission and distribution of electrical energy birth are presented as well as considerations concerning Electrical Engineering education arising.

Electrical Engineering curriculum was built by the first time in several countries in the world and the first appearance we have noticed was in Europe at École Polytechnique de Paris, France, in 18th century. Thereafter in the United States and Australia it happened in the 19th century as well as in Brazil and China it happened in the beginning of the 20th century. These actions were done in order to prepare students to attend to the local markets needs.

We have also noticed facts related to Electrical Engineering have been written on technical literature concerning a regional scope up to now. In other occasions, we have noticed key facts related to Electrical Engineering have been registered to cover a short period of time only. In order to enlarge our view on this subject, our task is to gather key new information from several continents, arrange them appropriately in a timeline, and share this whole thing with the academic community.

2. Beginnings of Electrical Engineering History

Before starting this project, the earliest reference we had was Thales of Miletus with his experiments with loadstone and amber in Greece. However, we have realized that knowledge about Electricity and its applications were much earlier than the period of time he lived.

The *Chinese* people knew about Electricity of magnetite rock and built magnetic needles around 2637 BC, in the period of Huan-Ti Emperor. Chinese writings dated on 1080 AC treats about magnetic compass, that is, one century before its first mention in Europe. According to the book *Ming Xi Bi Tan* written by the Chinese astronomer scientist

Shen Kua in the XI Century, there were several magnetic needle types on Chinese compasses such as: *floating fish-shaped iron leaf*, *loadstone spoon* – Figure 1, *dry-suspended* with a single-fiber of silk and the *wet*. They had built several kinds of compasses and the most used were Ssu-Nan compass during 475-221 BC, the San-He compass during 1127 BC and the Luo Pan compass which is the base of magnetic compasses used by Chinese people currently. They have also developed a technique to magnetize iron needles used to build more accurate compasses (NEEDHAM, 1962, p. 229-330)

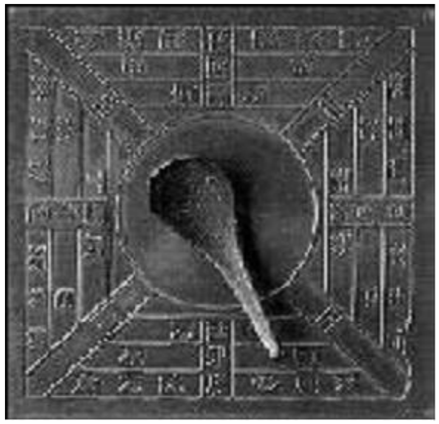

Figure 1
Ancient Chinese compass with magnetite spoon needle

The *Sumerians* had knowledge about Electricity and conductive materials such as copper, silver and iron, around 2500 BC. They used an electro deposition process to cover a copper pottery with silver skin, as per a pottery discovered at southern Iraq and checked by German archaeologist Dr. Wilhelm Konig (KANANI, 2004, p.168-203). This recent information about Electricity applications are worthy to be written in Electrical Engineering literature, even though the electrodeposition discovery has been assigned to Galvani in 1780 AC, approximately 4200 years after the Sumerians.

The *Parthian*, a dynasty descendant from Sumerians, had lived in Babylon during 3rd century BC. They had knowledge of Electricity, conductive materials such as copper and iron, insulating materials such as bitumen and dry argil, and they had built a so called Baghdad battery, Figure 2. The batteries were found at an archaeological site in the village of Khujut Rabu near Baghdad city, by the same archaeologist cited before (JARVIS, 1960, p. 356-357), even though the battery invention has been assigned to Volta in 1801 AC, approximately 2100 years after the Parthians.

Figure 2
Baghdad battery found in the village of Khujut Rabu

This is the period when Thales lived in Greece. The *Greek* also knew the magnetite and built the Greek compass during 624-558 BC that was used on ships for navigations around Mediterranean Sea. The knowledge of Electricity in the shape of magnetism and its applications were handled by Chinese and Greek people at that time. In the same period of time Greek knew a vegetal resin called amber. When it was fractioned, it acquired the property to attract light and tiny objects according to the writes of Thales of Miletus, one of the seven sages in ancient Greece. Then Electricity in the shape of electrostatic was known at that time. Historic writings have mentioned contacts among Greek – army of Alexander the great through India- and Chinese people during the 5th Century BC. At that time Chinese people knew about electrostatic properties of amber, because they brought it from Burma and Malaysia. Then Electricity in electrostatic shape was known in Asia. There were also contacts among Arabian and Chinese people in the Battle of Talas River, today in Uzbekistan region, during 751 AC and 9th Century at Canton e Hangchow colonies. The compass was brought by Arabian people from China to Middle East and then to Europe, and it became useful instrument for navigation; from that time and on Electricity in magnetic shape began to be investigated.

There are historical records the compass was already known to the Arabs when they invaded Spain in the 12th century (NEEDHAM, 1962, p. 229-330).

In *France* during 1269, Pierre Pèlerin de Maricourt made several experiments with magnets and wrote a letter called “Epistle of Magnet”. The letter was addressed to Suggerius his friend and neighbour. In this letter he explained how to identify the magnetic poles of a compass, described the laws of magnetic attraction and repulsion, and had a description of a magnetic compass that would lead people steps to cities, isles and everywhere. The vision Pièrre had and the knowledge he had forwarded to his friend

Sygerus de Foucaucourt, were outstanding at that time. Pièrre had improved a compass when he laid the magnetite needle on a pivot, and placed it on the center of a compass card with several geographic directions. This knowledge was spread out in Europe and was useful during the great navigations in the Middle Age period as well as it was the basis of magnetism studies development performed by William Gilbert in 16th Century (LOCKER, 2006, p. 44-45). Then it is necessary to point out that the experiments performed by Pièrre and spreading of the results in Europe are very important, so that his name should be written in Electrical Engineering literature, even though the magnetism studies have been assigned to Gilbert in 1801 AC, approximately 532 years after Pièrre.

In *England,* William Gilbert had confirmed the results Pièrre had written in his letter to his friend, and he developed the concept of magnetic field spectrum in 1801. Gilbert's experiments and results were important because they helped the visualization of magnetic lines surrounding the magnetic poles of a magnet. These results were a basis of Oersted research thereafter (RONAN, 1983, p. 133-381). Figure 3 illustrates the key facts related to this section concerning Electricity knowledge development and its applications.

3. Fundamentals of Electrical Engineering History

During the period of 18th and 19th Centuries, scientists and inventors in Europe and in North America were geographically closer than Greeks, Arabians and Chinese people in the beginnings; beyond that they had some faster communication methods than in the beginnings such as ships with improved magnetic compasses, electric telegraph and telephone. In this way, experiments and inventions results were disseminated throughout scientific environments at this period in Countries such as Germany, Croatia, Denmark, Scotland, United States, France, England, Italy and Russia with more efficiency. Consequently, these two aspects (shorter geographic distances and faster communication methods) contributed to speed up the development of Electricity knowledge and its applications.

This development through millenniums up to this period of time showed expansion of knowledge and its applications concerning the different shapes of Electricity like Electrostatics, Electrodynamics, Magnetism and Electromagnetism. These are *Fundamentals of Electrical Engineering* (GILLISPIE, 1970).

In the cited period of time it has been a development concerning mathematics modeling of phenomena of Electrical Engineering has dealt with. These are the *Descriptions of Electrical Engineering Fundamentals* such as the Maxwell's equations. Maxwell was a wise man who saw the whole scope concerning Electrostatics, Electrodynamics, Magnetism and Electromagnetism as well as he wrote mathematical equations to show the inter-relation of these shapes of Electricity. These equations have a broad reach and can be written in integral and differential formats. They were developed at the end of 19th Century (MAXWELL, 1954, p.327-482). The Figure 4 illustrates a Maxwell's picture.

BEGINNINGS OF ELECTRICAL ENGINEERING HISTORY											
China		**Sumeria**		**China**		**Greece**		**China**	**Babylon**		
First Record Compass		holy pottery Galvanization Copper and silver		Magnetite Magnetic Needle		Amber, Magnetite on Compass		Amber, Ssu-Nan Compass	Baghdad Battery		BC
2637 BC		2500 BC		1000 BC		624-558 BC		475-221 BC	300 BC		0
AC					Middle Age						
0						500			**Arabians contact Chinese**		1000
									Battle of Talas	Canton e Hangchow	
									751 AC	IX-th. Century	
					Renaissance						
	Period of Great Navigations							Modern Age			
			Pièrre		**Greece**	**Portugal**	**Gilbert**	**Von Guericke**	**S. Gray**	**Musschenbroek**	**F. Aepinus**
	China	**Arabia**	**France**	**Italy**			**England**	**Germany**	**England**	**Holland**	**Germany**
	San-He Compass	Compass with seeder stone	Magnetism *Epistle on the Magnet*	Compass with Sea Card	Compass with 12 directions	Compass and Magnetic Declination	Magnetic Field Spectrum	Electrostatics machine	Electrical Current	Electrical Condenser	Electrostatics Induction
	1127		1269	1300		1537	1601	1663	1729	1745	1760
1001	1190			1368	1405-1433		1620-1629	1706	1733	1752	1770
	1st Compass in Europe *Naturis Rerum*			Feng-Shui Chinese Compass	Chinese Navigations		Attraction of illuminated bodies	Electrical Machine built with glass	Positive and Negative Electricity	Lightning Rod Electrostatics Machine	Regulable Capacitor
	Neckman						**Nicolo Cabeo**	**Hawksbee**	**Du Fay**	**B. Franklin**	**H. Cavendish**
	England			**China**			**Italy**	**England**	**France**	**USA**	**England**

Figure 3
Beginnings of Electrical Engineering History: 2637 BC – 1770 AC

Figure 4
James Clerk Maxwell at his desk in Cambridge, England.

The parameters used in Electrical Engineering have been named along history and their names were assigned to celebrate inventors and researchers' names. International Committees with members from several Countries have gathered these parameters along of time as well as their units respectively, and have inserted them into the International Systems of Units or SI. These parameters and their descriptions are *Fundamentals of Electrical Engineering* (VALIVACH, 2009, p.350-358).

These fundamentals have been developed and used deeply over the last decades and new inventions and new discoveries are based on them. These results have been applied to products with the highest level of development which we know as *state of the art*. Some outstanding inventions in the period covered by this section are: direct current generators, telegraph, electric incandescent lamp, radio, telephone and alternating current system. Some outstanding inventions in the 20th Century are: electronic vacumm valve, semiconductors, integrated circuits, television and electronic computers.

The Electrical Engineering Fundamentals' process of development presented in this section and its development in the following Century are illustrated in Figures 5 and 6.

FUNDAMENTALS-1 OF ELECTRICAL ENGINEERING

C.A.Coulomb **France** Electrostatic Forces and Electric Field	**J. Watt** **Scotland** Steam Condenser Power		**A.G.A.A.Volta** **Italy** Electric Battery			**H. C. Oersted** **Denmark** Magnetic Field Electrical Current	**M. Faraday** **England** Magnetic Induction Laws of Electrolysis Electrostatics	**A. M. Ampère** **France** Electrical current Electromagnetic Forces	
1736	1765		1801			1820	1821	1822	
		1780	1802	1803	1811	1820	1821	1824	1825
		L. Galvani **Italy** Galvanization	**H. Davy** **England** Electrochemical Theory	**Vasilli V. Petrov** **Russia** Electric Arc	**S. D. Poisson** **France** Electrostatic Potential	**J. Schweigger** **I. Pogendorff** **Germany** Electrical Multiplier Effect - N turns	**Thomas Seebeck** **Prussia** Thermoelectricity	**F.J.D. Arago** **France** Electromagne- tization	**W.Sturgeon** **England** Electromagnet
G. S. Ohm **Germany** Electric Resistance Resistivity	**J. Henry** **USA** Self and mutual Inductances	**W. E. Weber** **Germany** Magnetic Flux	**C. F. Gauss** **Germany** Magnetic and Electrostatic Fluxes	**J. P. Joule** **England** Heat Mechanical Theory	**J. C. Maxwell** **Scotland** Electromagnetism Equations	**W. von Siemens** **Germany** Conductivity Electrical Generator	**H. R. Hertz** **Germany** Electromagnetic Waves Electrical frequency	**N. Tesla** **Croatia** Alternating Current Generator	
1826	1830	1833	1838	1842	1855	1866	1888	1894	
1827	1833	1834	1845	1847	1855	1858	1859	1868	1876
J. B. Biot **F. Savart** **France**	**W. Ritchie** **England**	**H. F. Lenz** **Russia**	**G. R. Kirchhoff** **Germany**	**H. Helmholtz** **Germany**	**J.B.L. Foucault** **France**	**North America-Europe**	**Gaston Plante** **France**	**C.Wheatstone** **England**	**J.B.Kerze** **Russia**
Magnetic Field and electric current	Permanent Magnet Generator	Induced Electromotive Force	Current Law Voltage Law	Conservation of Energy Law	Parasitic Currents	First Transatlantic electrical cable between America and Europe	Lead-Acid Electrical Battery	Loud-speaker	Voltaic-Arc Lamp

Figure 5
Fundamentals of Electrical Engineering: 1785-1876

FUNDAMENTALS-2 OF ELECTRICAL ENGINEERING

1876	1878	1890	1891	1906	1909	1911	1913	1918	1920	1924	1922
A.Graham Bell USA	**T. A. Edison USA**	**London England**	**M. O. Dolivo Dobrovolskii Russia**	**Lee DeForest R. von Lieben USA-Germany**	**R. Marconi K. F. Braun Italy-Germany**	**G. Westinghouse USA**	**H. K. Onnes Netherlands**	**H. A. Lorentz Holland**	**URSS**	**Louis de Broglie France**	**Neils Bohr Denmark**
Electrical Telephone	Incandescent Electric Lamp Direct Current Power System	Underground Electric Railroad	Threephase System Asynchronous Motor	Vacuum tube thermionic Valve	Wireless Telegraphy	Alternating Current Power System	Superconductivity	Magnetic Field and radiations	Automatic Telephone	Quantum Mechanics	Atomic Model

1925	1936	1948	1954	1955	1956	1967	1971	1983	2000	2008
J. L. Baird Scotland	**Osram**	**IBM USA**	**Bell USA**	**USA**	**J. Bardeen W. H. Brattain W. B. Schockley USA**	**France**	**Intel USA**	**USA**	**J.S. Kilby USA**	**Hewlett-Packard USA**
Analogical Television	Fluorescent Lamp	Electronic Computer with Vacuum tubes and Relays	Solar Cell	Electric Power generation from nuclear fuel	Semiconductors and Transistor	Electric Power generation from tides	Semiconductor electronic Microprocessor	Electric Power generation from Aeolian power	Integrated Circuits	Memristor

Figure 6
Fundamentals of Electrical Engineering: 1876-2008

4. Electrical Engineering Measurements History

Electrical Measurements is a knowledge area of Electrical Engineering that will always demand research and development with the aim to improve its quality on applications which need information processing. Modern techniques have been developed on Electrical Measurements and they have been given a significant contribution to get the best design solution.

From 18th Century up to now there have been huge developments of electrical measurements theory, measurement methods and quality concept of measurement which have been put on the electrical instruments (SYDENHAM, 1986, p. 655-672).

Electrical measurement instruments were called electrometers and electroscopes in the 18th Century. Some of them were designed and built by scientists such as Musschenbroek (Leiden Jar), Lichtenberg (Lichtenberg's camera), Coulomb (Torsion balance and Proof plane), who evidenced these instruments were concentrated in the Electrostatics area of knowledge.

The quantitative experiments performed with Electricity and its effects on bodies electrically charged allowed the scientists to establish Electrostatics units of measurements. For instance, it was established the unit of electrical charge measurement and it was called Coulomb some time later.

Electrical measurement instruments designed and built in 19th Century by scientists such as Poggendorf and Schweigger (galvanometer multiplier), Thompson and Harris (Quadrant Electrometer), D'Arsonval and Deprez (moving coil galvanometer), Ohm (electrical resistance coil), Wheatstone and Thompson (bridge of resistances) and Ampère (differential galvanometer) gave their contributions on Electrodynamics measurement area or Electrical Current (MAXWELL, 1954, p. 327-482; WESTINGHOUSE ELECTRIC CORPORATION, 1964, p. 551-552)

The amount of Electricity (common used word at that time) that flew through an electrical conductor was measured. Based on experiments and this kind of measurement it was possible to establish a scale of intensities for a meter of Electricity flow by unit of time. The amount of Electricity flow by unit of time was established and it was called Ampere some time later It was possible to establish the difficulty an electrical conductor offered to Electricity flow, that was called electrical resistance, as well as it was possible to establish electrical unit of measurement for this parameter. For instance, the electrical resistance unit was established and called Ohm some time later.

The Alternating Current was discovered at the end of 19th. Century as well as scientists and inventors' attention were concentrated on electrical meters design development and building, concerning this new type of electrical current.

Some outstanding scientists and inventors of alternating current meters are: Oliver Shallenberger (voltmeter), Maxwell and Wien (impedance bridge with resistance, inductance and capacitance), Galileo Ferraris (Electrical energy meter). Wattmeters and frequency meters were invented in this period of time also. These meters were introduced in Standard Laboratories and Electrical Industry at 19th Century end (FLOYD II. NENNINGER, 1997).

In the beginning of 20th Century some components of electrical meters were replaced by electronic circuits with vacuum valves. Thereafter, several components of electrical meters were replaced by electronic devices gradually and these instruments' accomplishment and accuracy were improved. Electronic methods of measurements were implemented and have shown they were more accurate, fast and flexible in measuring on experiments than those measuring obtained by electromechanical meters before.

In 1971, semiconductor components were invented and new technologies were included in the electrical measurement instruments especially on the sensors that detect the signal to be measured.

We have noticed scientists concern of electrical measurement meters accuracy that was used during their experiments, because scientists were searching for a real measuring of the parameter under observation.

The improvements made on the meters, the establishment of standards of measurements, the design and build of calibration instruments and the creation of the International System of Units – SI – they were very important results and they were very important answers to that search for accuracy in measurements.

When solid state technology was invented and it was added to circuits of electrical meters some decades ago, a high improvement of performance was reached concerning detection and processing of electrical signals, and cost reduction as well.

There are several applications on which electrical meters are used and they are connected to transducers. In this way, any physical parameter can be measured. However, there are natural phenomena not measurable yet, due to the lack of appropriated electrical meters. Therefore, the electrical measurement area requires research and development.

The subjects covered in this section and other meters used in Electrical Engineering are illustrated in Figure7.

ELECTRICAL ENGINEERING MEASUREMENTS HISTORY

1777	1785		1820	1834-1867	1844	1852
Lichtenberg Germany	**Coulomb France**	**Coulomb France**	**J. Schweigger I. Poggendorff Germany**	**Harris e Thompson England**	**C. Wheatstone England**	**W. Thompson England**
Lichtenberg's camera	Torsion balance	Proof Plane	Multiplying Galvanometer	Electrostatic Voltmeter	DC Bridge	DC Bridge
High Voltage meter	Electrostatic forces meter	Surface electricity Density meter	Moving coil meter	Electrical potential meter	Electric resistance in Direct current meter	Small Electric resistance Direct current meter
1878	**1882**	**1882**	**1885**	**1886**	**1892**	**1930**
J. B. Fuller USA	**D'Arsonval - Deprez France**	**Edison Electric Company USA**	**Galileo Ferraris Italy**	**O. Schallenberger USA**	**Weston Cell England**	**Thomas Standard England**
Lamp-hour meter for Alternating current Voltaic Arc lamp	Galvanometer Electric direct current	Ampere-hour meter for Direct current Incandescent lamps Chemical meter type	Electrical energy Watt-hour meter for Alternating current Induction meter type	Alternating current Voltmeter Induction meter type	Electric Voltage Standard of measurement	Electric Resistance Standard of measurement

Figure7
Electrical Engineering Measurements History: 1745 - 1930.

5. Electrical Engineering Generation, Transmission and Distribution History

The first electrical power systems in Europe were installed in the 19th Century. The first electrical generators were galvanic cells which generated electrical voltage and current with direct current shape. Physicists and Chemists who lived in the first part of that Century, they worked with galvanic batteries and built devices and electrical measurement instruments that were fed by these batteries. They were also intended to design and build an electrical direct current generator with more power.

The best result with electrical D.C. generation and transmission was attained through the Thury system in 1889: 4.65 megawatt was generated and transmitted at 57.6 kilovolt line from Moutier to Lyon, France. The distance between these cities was 180 kilometers (KOSTENKO. PIOTROVSKY, 1977, p. 18-30)

In Brazil the first D.C. system with generation, transmission and distribution of electrical energy was installed in Diamantina, Minas Gerais State, in 1883 (MORAES, 2005, p. 239-261).

In 1887, in the United States of America, Nikolas Tesla established a contract with George Westinghouse. Tesla had shown to American government the advantages to implement an alternating current system as well as had suggested this system to be adopted as a standard for generation, transmission and distribution of electrical energy. Thomas Alva Edison was against Tesla's proposal, because he had supported a direct current standard for electrical systems. Tesla was a former Edison's employee. In 1888, Tesla received the patents of a polyphase electrical system with generators, transformers, transmission line and alternating current motors. The alternating current induction motor is the electrical machine most used in the world. In Europe Tesla worked with several scientists and inventors; among them is Galileo Ferraris in Italy, who was developing a theory for biphase electrical motor, and Mikhail Dobrovolskii in Russia, who was developing a theory for induction polyphase electrical motor (GILLISPIE, 1970). George Westinghouse bought the patents from Tesla and became the first innovator to introduce the first alternating current system in the United States. The first electrical power station with alternating current, in the United States, was built in Great Barrington, Massachusetts. A large hydro-electric power station was built in Niagara Falls, New York, and it was an extraordinary result at the end of 19th Century, in 1898 (BRITTAIN, 2004, p. 1347-1349).

In Europe, in 1891, a triphase transmission line was built with alternating current for the International Electrical Engineering Fair in Frankfurt, Germany. The power station had an electrical generator built by Braun. The voltage generated was elevated by an electrical transformer at 15 kV and the energy was transmitted through a line of 170 km long up to the Fair; another electrical transformer lowered the voltage at 113 volt and fed an induction alternating current motor of 75 kW; this motor was connected to a water-pump (KOSTENKO. PIOTROVSKY, 1977, p. 18-30).

These electrical systems cited were the first steps for the development of a large power stations, transmission lines and distribution circuits, such as the ones we have today.

The subjects about generation, transmission and distribution covered by this section and other key information of this matter in 20th Century are illustrated in Figure 8.

HIGHLIGHTS OF ELECTRICAL ENERGY GENERATION, TRANSMISSION AND DISTRIBUTION HISTORY							
1831-1851	1851-1867	1867-1871	1871-1886	1883	1883	1884	1885
P.M. Alternating current synchronous generator	**Werner von Siemens** **Germany** Generator with double T armature	**S. Hjorth** Self-excitation generator	**Yablochkov-Gramme** **Wilde** Single-phase synchronous generator	**M. Deprez** **Europe** Direct current transmission line	**Diamantina - MG** **Brazil** D.C. Generation, transmission and distribution	**N. Tesla** **France** Induction motor and Alternating current Power System design	**L.Gaulard-J.Gibbs** **Europe** Alternating current transformer
W. Ritchie Direct current generator with commutator	**Antonio Pacinotti** **Italy** Generator with ring armature	**Maxwell : Theory** **Scotland** **Siemens-Wheatstone**: Generator applications	**Dolivo-Dobrovolsky** **Russia** Polyphase synchronous generator	**DeVal** Thermoelectric generation from fossil fuel	**Santiago** **Chile** Thermoelectric power plant		
1891	1895	1901	1947	1955	1952	1967	1984
Dolivo-Dobrovolsky **Russia** Dry Triphase Transformer	**G. Westinghouse** **USA** Alternating current generation, transmission and distribution	**Light São Paulo P.C.** **Brazil** Alternating current generation, transmission and distribution Santana do Parnaiba-SP	**Companhia Light** **Brazil** Alternating current transmission line interconnects Rio and São Paulo	**CHESF** **Brazil** Paulo Afonso - BA Alternating current power system	**CEMIG and Furnas** **Brazil** Três Marias and Furnas - MG Alternating current power systems	**CESP** **Brazil** Urubupungá MS-SP Alternating current power system	**Itaipu and Tucuruí** **Brazil** Itaipu-PR, AC/DC and Tucurui-PA, AC power systems
			USA Aeolian-electrical generation	**USA** Thermoelectric Generation from nuclear fuel		**France** Generation of electrical power from tides	**USA** Generation of electrical power from solar energy

Figure 8
Generation, Transmission and Distribution of Electrical Energy: 1831 - 1984

6. Electrical Engineering Education History

At the 16th Century disciplines like physics, chemicals, mechanics, mathematics, arts, law, medicine, etc were offered in universities like Genoa, Toulouse, Colonia and Oxford. Scientists and inventors were Academy of Sciences' members in their Countries. Some became visiting-members in Academies in other Countries (GILLISPIE, 1970).

In the Industrial Revolution of 19th Century, Electricity applications were electrical installations and equipments, and they required specific designs to be manufactured; they also required to be tested, installed and have some maintenance. These requirements determined the beginning of Electrical Engineering formal education that occurred in parallel with manufacturing electrical industry of wires, lamps, telephones, telegraph, motors, trains, etc. This industry required well-trained personnel on specific skills and activities. The origins of the formal education in Electrical Engineering are based on disciplines called optional or autonomous offered by Schools and Universities. They were related to "Electricity applications" and were inserted in curriculum offered by Physics Departments and Engineering Departments.

In order to fulfill the market needs the École Polytechnique de Paris in France started offering these disciplines in 1797. The Massachusetts Institute of Technology in the United States started disciplines at Physics Department in 1882. In 1901 the Escola Politécnica da Universidade de São Paulo in Brazil created a discipline called Electrotechnics, and the University of Xi'an Jiaotong started an Electrical Engineering in China, in 1908 (MORAES, 2005, p. 239-261; TERMAN, 1998, p. 1792-1800; BROOKER, 1961, p. 15-36; FENG, 2007, p.1).

Since that time universities were created all over the five continents. They have offered a fundamental curriculum of Electrical Engineering education and disciplines related to specific areas of this knowledge also. These specific disciplines depended on local market needs in the context where universities were located. As these markets developed, electrical engineering education was motivated to develop also and it was focused on direct current and alternative current circuits in the first two decades of 20th century. In the decades ahead the Electronic technology was incorporated to Electrical Engineering education and new disciplines reinforced its curriculum of graduation. Master's degree and doctor's degree programs were developed as extensions of graduation course for students who wished to continue the technical carrier as researchers in industry or professors in Universities. The teaching techniques have been improved within Electrical Engineering courses and have progressed so forth the education learning level of students. This improvement has also motivated students to go ahead and enroll themselves in post-graduation programs and to aim an academic profession for their lives.

The topics mentioned in this section and other key information about Electrical Engineering education in the world are illustrated in Figure 9.

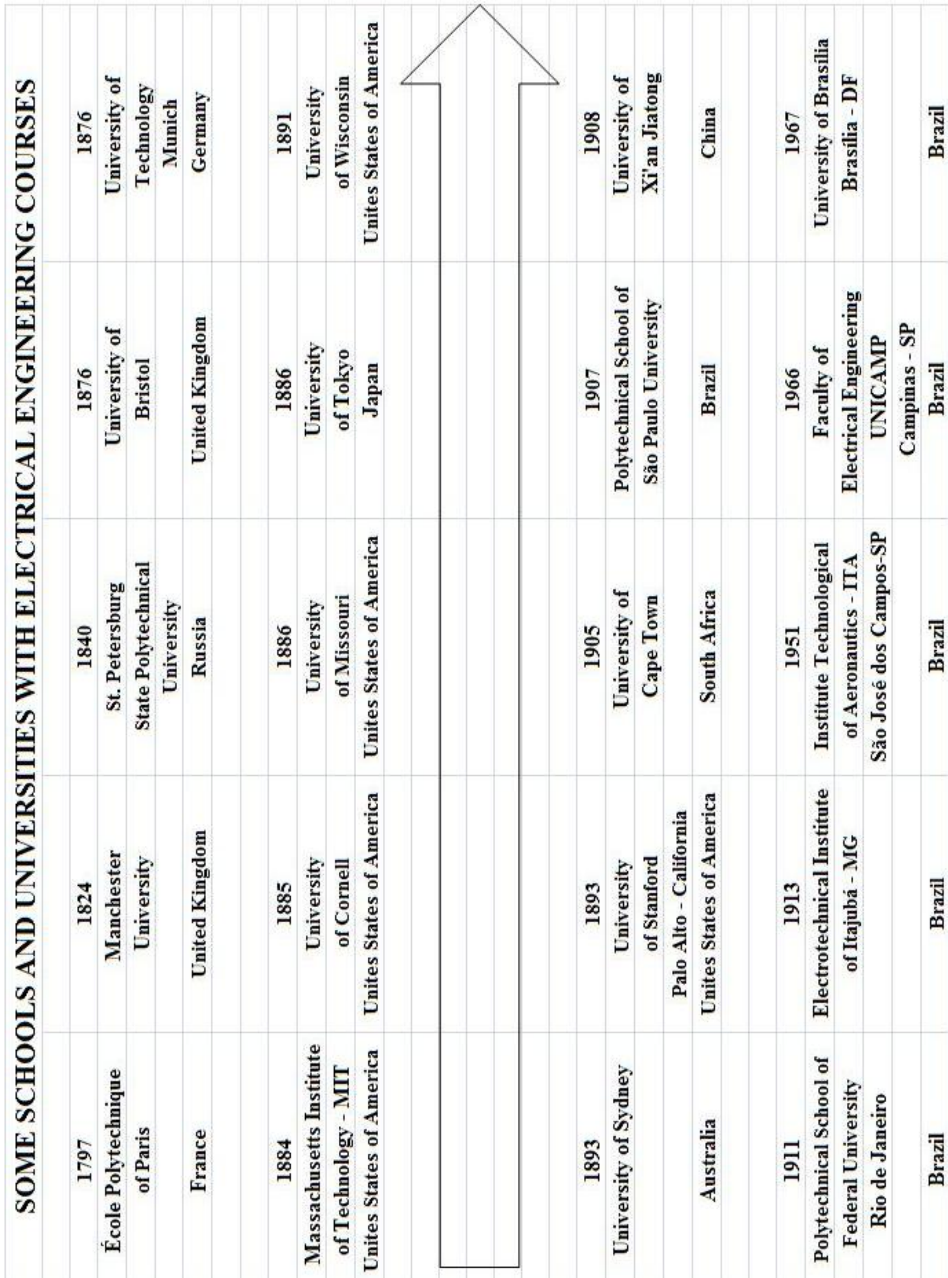

Figure 9
Electrical Engineering Education History: 1797 - 1967

7. Conclusions and Proposals

The Electrical Engineering history continues as the time goes by and new discoveries and inventions will be shown up also. The Electrical Engineering education continues to prepare students to be professional committed to the market and to academic carriers too.

Based on the sections presented in this paper we believe that an improvement of Electrical Engineering teaching at graduation level can occur, concerning the formulation and implementation of two proposals as follow (BATTAGLIN. BARRETO, 2010, p. 25-240), (BATTAGLIN. BARRETO, 2010, thesis):

1) Creation of a discipline called "History of Electrical Engineering".

The purpose is to motivate the creation of a discipline at each Electrical Engineering College or University in the five continents in order to motivate students to fond this Engineering graduation studies.

This discipline may have a program to increase graduation students' comprehension about historical process of Electrical Engineering such as the one presented in this paper.

2) Creation of an "Electrical Engineering Museum".

The purpose is to create a museum at each Electrical Engineering College or University in the five continents in order to motivate students and local community to understand this Engineering history and its benefits to the society in general.

The creation of a special place to preserve, study and show to students as well as to local academic community a collection of scientific works, cultural assets and technological developments such as we can see in some cities in the world.

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