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Walking in the Electrical Engineering History

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Abstract - This project presents some new contributions to the science evolution concerning the Electrical Engineering. The collaborations of this project have the task to disclosure key realities that point out benefits to human society, through the applications of Electricity and its teaching. Electricity has been latent in nature and human beings have discovered and developed its potential through millenniums. Electricity utilization by ancient civilizations in the beginnings, its basic knowledge development and applications, as well as the interconnection among Electricity's shapes in nature are true examples of that and are covered in this project. Electrical Engineering fundamentals have been some keystones to state of art. The Electrical Engineering's fundamentals are base for the state-of-the-art and the Electrical Engineering well endowed teaching has cooperated for a building-up of high level professional people.

Keywords : *electrical engineering, history, fundamentals, engineering education.*

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WALKING IN THE ELECTRICAL ENGINEERING HISTORY

Strictly as per the compliance and regulations of:

Walking in the Electrical Engineering History

Paulo David Battaglin [α] & Gilmar Barreto [σ]

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I. Introduction

ITH 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. Thereafter, the process about development of Electrical Engineering's fundamentals will be presented as well as the history of electrical measurement instruments used in Electrical Engineering. Key aspects about the history of generation, transmission and distribution of electrical energy are presented and considerations concerning Electrical Engineering education also.

We have noticed historical facts related to Electrical Engineering have been written on technical literature concerning regional scope up to now. In other occasions, we have noticed key historical facts related to Electrical Engineering have been registered to cover about a short period of time. In order to enlarge our historical view on this subject our task is to gather key information and organize them in a timeline.

II. Beginnings of Electrical Engineering History

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 [1]. 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 century III 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, Fig. 1. The batteries were found at an archaeological site in the village of Khujut Rabu near Baghdad city, by the same archaeologist cited before [2], even though the battery invention has been assigned to Volta in 1801 AC, approximately 2100 years after the Parthians.

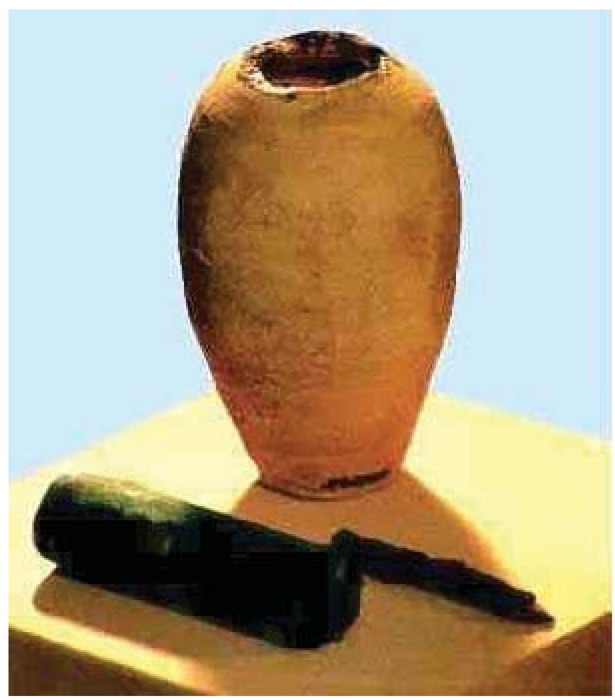

Figure 1 : Baghdad Battery

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

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Global Journal of Human Social Science (G) Volume XIII Issue IX Version I Year 2013

Century, there were several magnetic needle types on Chinese compasses such as: floating fish-shaped iron leaf, loadstone spoon – Fig. 2, 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 [3].

Figure 2 : Chinese compass with magnetite spoon needle

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 cultural contacts among Greek and Chinese people through India during the V-th 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. The compass was brought by Arabian people from China to Middle East and Europe, and it became useful instrument for navigation; from that time and on Electricity in magnetic shape began to be investigated. There were also contacts among Arabian and Chinese people in the Battle of Talas River, today in Uzbekistan region, during 751 AC and IX-th Century at Canton e Hangchow colonies [3].

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 XVI-th Century[4]. 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 [5]. Fig. 3 illustrates the key facts related to this section concerning Electricity knowledge development and its applications.

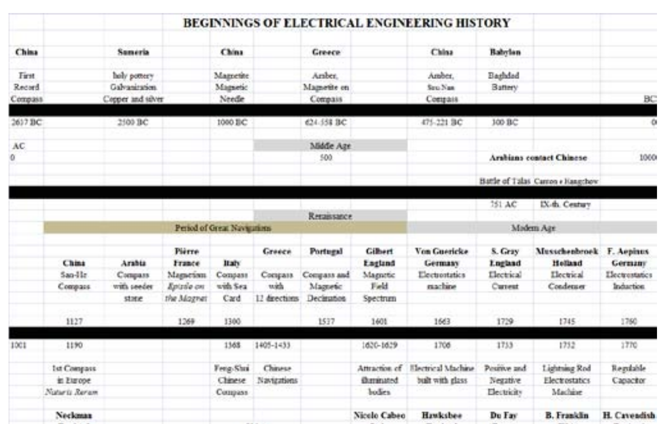

Figure 3 : Beginnings of Electrical Engineering History: 2637 BC – 1770 AC

III. Fundamentals of Electrical Engineering

During the period of XVIII-th and XIX-th 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 [6].

In the cited period of time it has been a development concerning mathematics modeling of phenomena Electrical Engineering has dealt with, these are the Descriptions of Electrical Engineering Fundamentals such as the Maxwell's equations. These equations have a broad reach and were developed at the end of XIX-th Century. [7]. The Fig. 4 illustrates a Maxwell's picture.

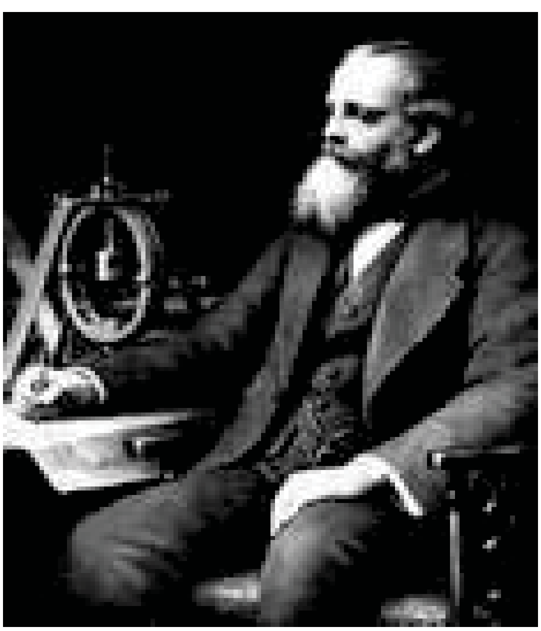

Figure 4 : James Clerk Maxwell

The parameters used in Electrical Engineering have been named along history and their names were assigned to celebrate inventors and researchers' 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 [8].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 XX-th Century are: electronic vacuum 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 Fig. 5 and 6. The Fig. 7 illustrates a Faraday's picture.

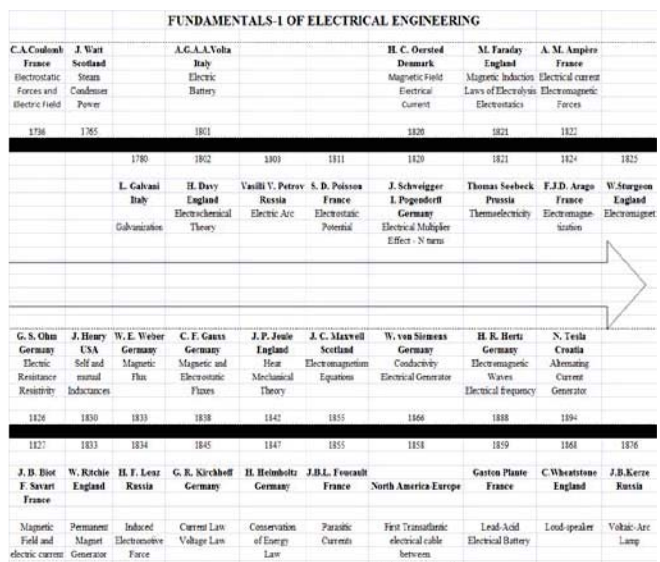

Figure 5 : Fundamentals of Electrical Engineering: 1785-1876

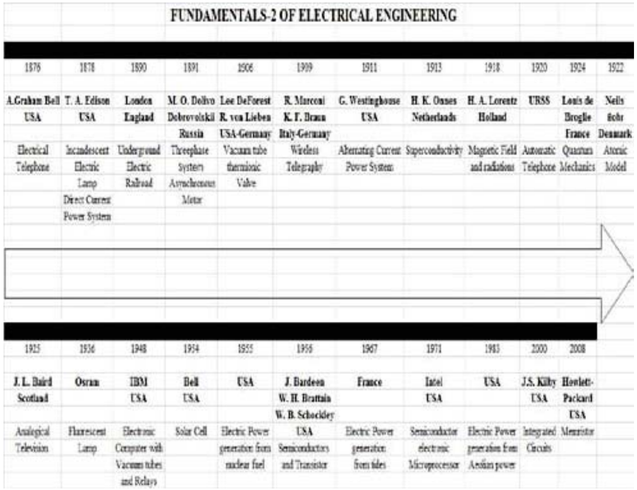

Figure 6 : Fundamentals of Electrical Engineering: 1876-2008

Figure 7 : Michael Faraday

IV. 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 XVIII-th 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 [9].

Electrical measurement instruments were called electrometers and electroscopes in the XVIII-th Century. Some of them were designed and built by scientists such as Musschenbroek (Leiden Jar), Lichtenberg (Lichtenberg's camera), and 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 XIX-th Century by scientists such as Poggendorf and Schweigger (galvanometer multiplier), Thompson and Harris (Quadrant Electrometer), D' Arsonval and Depress (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 [7], [10].

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 XIX-th. 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 XIX-th Century end [11].

In the beginning of XX-th 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 Fig.8.

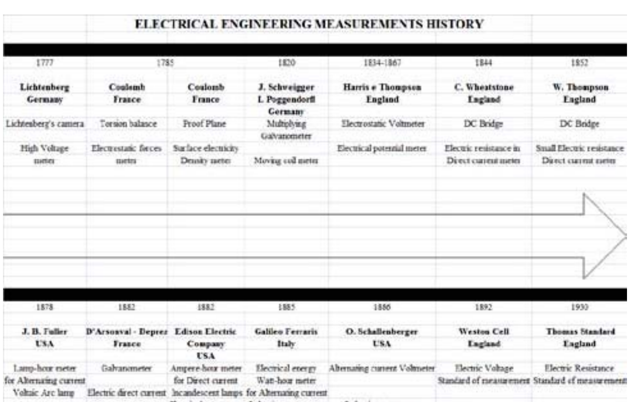

Figure 8 : Electrical Engineering Measurements History 1745 - 1930

V. Electrical Energy Generation, Transmission and Distribution History

The first electrical power systems in Europe were installed in the XIX-th 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. [12]

In Brazil the first D.C. system with generation, transmission and distribution of electrical energy was installed in Diamantina, Minas Gerais State, in 1883 [13]. 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 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 Edison had supported a direct current standard for electrical systems. Tesla was a former Edison's employee in France and he was transferred to Edison's Company in the USA. In Europe Tesla worked with several scientists and inventors; among them are Galileo Ferraris in Italy,

Who was developing a theory for biphasic electrical motor and Mikhail Dolivo-Dobrovolskii in Russia, who was developing a theory for induction polyphase electrical motor [6]? The alternating current induction motor is the electrical machine most used in the world. In 1888, Tesla received the patents of a polyphase electrical system with generators, transformers, transmission line and alternating current motors. 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 XIX-th Century, in 1898 [14].

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 [12].

Global Journal of Human Social Science (G) Volume XIII Issue IX Version I Year 2013

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 XX-th Century are illustrated in Fig. 9.

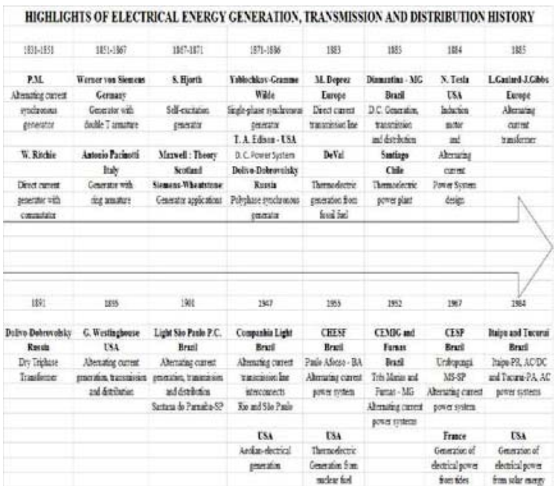

Figure 9 : Generation, Transmission and Distribution of Electrical Energy – 1831 - 1984

VI. Electrical Engineering Education History

At the XVI-the 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 [6].

In the Industrial Revolution of XIX-th 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 Cole Poly technique 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 Electrotechnic, and the University of Xi'an Jiao tong started an Electrical Engineering in China, in 1908 [13], [15], [16], [17].

Since that time universities were created all over the five continents. They have offered a fundamental curriculum of Electrical Engineering and disciplines related to specific areas of this knowledge also. These specific disciplines depend on local context where universities are located.

The teaching techniques have been improved within Electrical Engineering courses, and have progressed so forth the education learning level of students in graduation courses. This improvement has also motivated students to go ahead and enroll 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 is illustrated in Fig. 10.

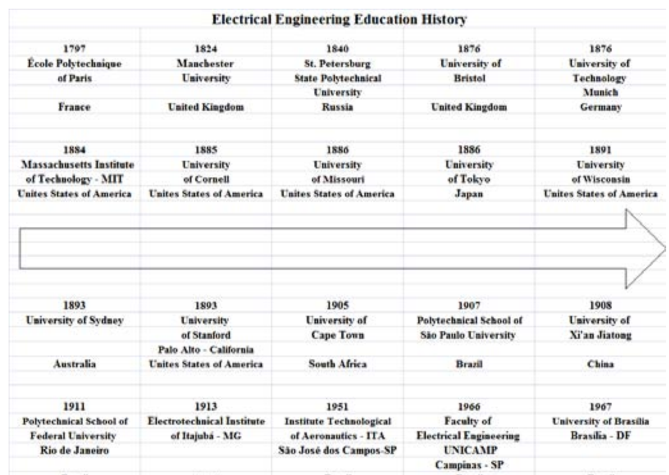

Figure 10 : Electrical Engineering Education History – 1797 - 1967

VII. Conclusions

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 these two proposals [18], [19]:

1. Creation of a discipline called "History of Electrical Engineering".
2. The purpose is to create a discipline at each Electrical Engineering College in the five continents in order to motivate students to fond this Engineering graduation studies.
3. This discipline may have a program to increase graduation students' comprehension about historical process of Electrical Engineering such as presented in this paper.

Global Journal of Human Social Science (G) Volume XIII Issue IX Version I Year 2013

4. Creation of an "Electrical Engineering Museum".
5. The purpose is to create a museum at each Electrical Engineering College in the five continents in order to motivate students and local community to fond this Engineering history.

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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