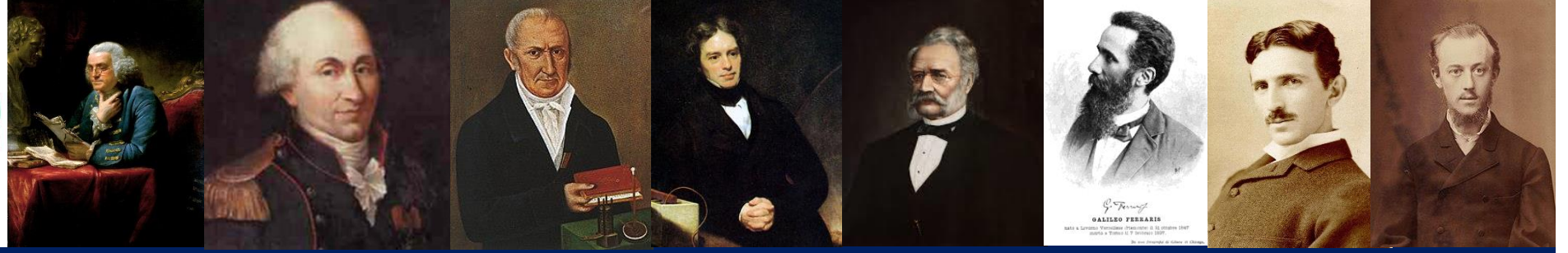
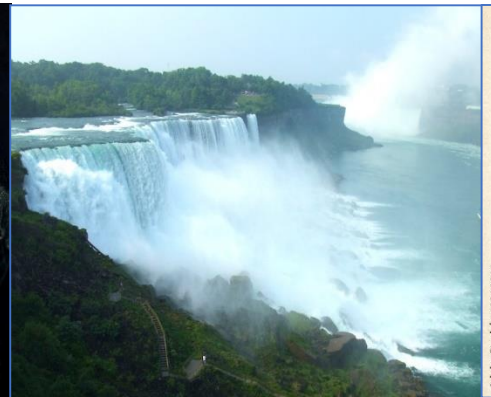


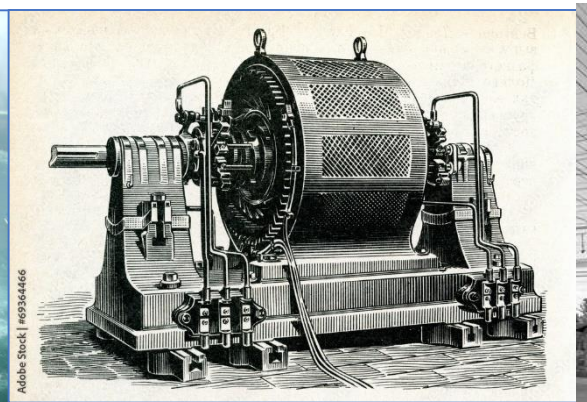
VIENNA HISTORY PANEL

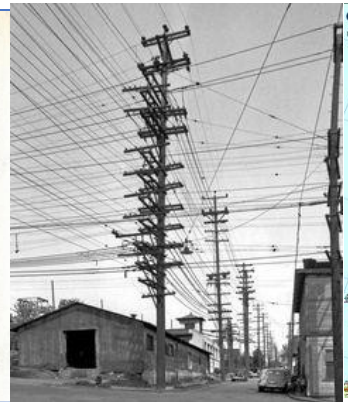
Cognitive history of AC polyphase power systems development and progress in Central Europe

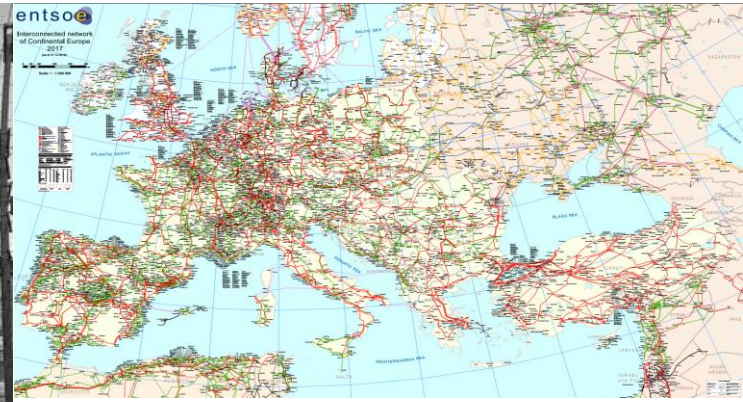
Krešimir Bakič, Honorary member of CIGRE

Vienna, 1st June 2022



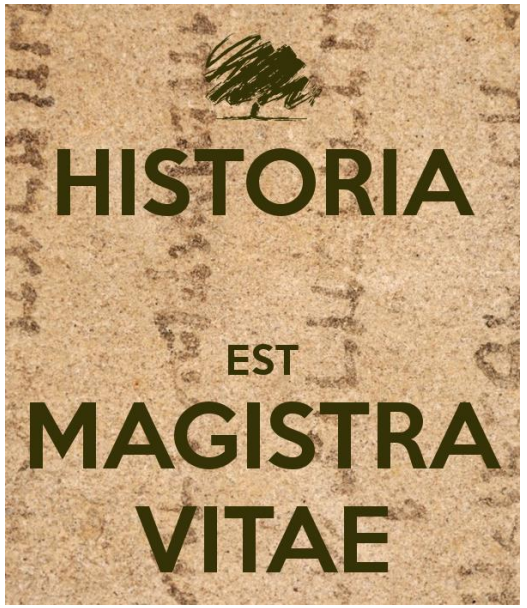






Introduction

1	Early electrification up to creation CIGRE	**1881 - 1921**
2	CIGRE - Beginning of the system's concepts - Frequency, voltages, insulation, generators, interconnections, conductors, switchgears	**1921 - 1951**
3	Time of rising interconnected systems	**1951 – 1999**
4.	Electrification after liberalization of the market	**2000 - 2020**



First History Panel we decided to be focused to early electrification and introducing polyphase electrical system (2-phase or 3-phase) in the SEERC Region.
Many of details one could find in the book SEERC CIGRE HISTORY, published in 2020.

Title of panel:

Cognitive history of AC polyphase power systems development and progress in Central Europe

a) Austrian Case
b) Croatia Case and
c) Slovenian Case

Early electrification – crucial events

1881 – First International Exhibition and Congress **in Paris**. Organized by French Government.

- It was first ever comprehensive international gathering of electrical technologies to take place, discussing on different topics of springing up electricity science.
- Congress was attended by most advanced world's scientists from 27 countries, e.g. *Werner Siemens, H. Helmholtz, G. R. Kirchhoff, Z. Gramme, Jablochoff, H. Fontaine, M. Deprez, Lord Kelvin, G. Ferraris, etc.*
- They recommended the **ampere, volt** and **ohm** as practical units for current, voltage and resistance, which were generally adopted by electrical engineers.
- Congress showed very advanced stage of study of the development of the **DC machines.**

1882 – Second International Exhibition and Congress **in Munich.** Demonstration of electric power transmission with DC on long-distance of 57 km, from Miesbach to Munich. The project used voltage level of 2 kV, with power transmitted 2.5 kW. The project designed by **Marcel Deprez** and **Oscar von Müller**.

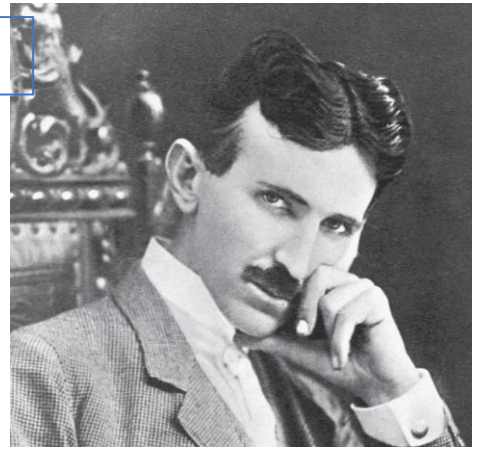
1883 – 3rd International Exhibition and Congress **in Vienna** had enormous impact to all states in Region. More than 50% exhibited electric lamps were incandescent and many other electrical use (boat, train, tram...). On 17 Sep was set up scientific commission leaded by Prof. **Josef Stefan** (Vienna) to study of electrical measurements and conducting scientific research at the Exhibition.

1884 – 4th International Exhibition and Congress **in Turin**. Prof. **Galileo Ferraris** made a single-phase AC transmission of 20 kW, 2000V on 40 km distance, but without a motor. The efficiency of this long-distance transmission was 89%. The open question was the AC motor for polyphase electrical system.

Period from 1882 to 1892 was the most innovatory period in history, which enabled later the development of massive electricity use.

Early electrification – crucial events - 2

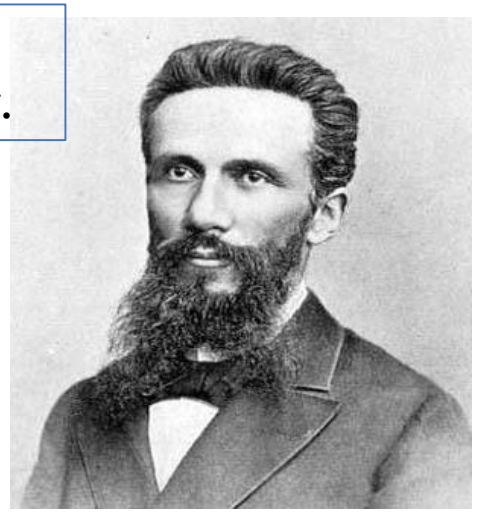
First ideas of an operation of electrical systems, using **polyphase AC systems** were in 1882.



Nikola Tesla (1856 – 1943)

First attempt of this approach belongs to the inventor **Nikola Tesla**, who worked in Budapest, in 1882, where he watching Danube River bathing in the sun from Budim Fisherman's bastion and recognized the waves on water were flowing synchronously with sunshine glitters atop of each wave. 26 years old Tesla suddenly got an idea about similarities of transmitting power of Danube water with power in electrical machines by electro-magnetic waves. He was obsessed with the idea of **multi-wave systems** and the thought of making it. Later, he developed model in his mind and in 1884 just before left to USA presented the model of **2-phase synchronous** generator and motor connected with 4 conductors, in Strasbourg.

In 1885, **Galileo Ferraris** presented construction and tests with 2-phase induction motor, but his interpretation was that this motor isn't efficient as we can read from **Dolivo-Dobrovolsky**.



Galileo Ferraris (1847 – 1897)
Prof. at Turin University

Later in 1887, Tesla applied US Patents on el. mag motor and transmission of Power, and granted all 7 patents on **May 1, 1888**. 2 weeks later Tesla had lecture at Columbus University, NYC: "**A new system of AC motors and transformers**", before the AIEE.

Authors of the first ever 3-phase Transmission of electric power, in August 1891, in Germany, were: **Mikhail Dolivo-Dobrovolsky** (1862-1919), **Oskar von Miller** (1855-1934) and **Charles Lancelot Brown** (1863-1924)

Early electrification – crucial events - 3

Date	Researcher	Inventions, Patents,
Feb 1882	Tesla	First idea and concept of polyphase system power transmission.
Mar 1884	Tesla	Model of 2-phase synchronous generator and motor presented in Strasbourg.
1885	Ferraris	Construction and tests with 2-phase induction motor.
6th Mar1885	Blathy, Deri, Zipernowski	Granted patent, DRP 40414, via parallel connection of generators, transformers and consumers; **first use of the word transformer**. (Presentation at Budapest Exhibition).
8th May 1887	Bradley	First patent filed in USA (390439) of 2-phase synchronous machine with/without exciter.
12th Oct 1887	Haselwander	First public operation of 3-phase model generator with self-excitation (2,8kW, 32 Hz).
12th Oct 1887	**Tesla**	**Applies US Patents 381 968 (el. mag. motor) & 382 280 (transmission of power).**
30th Nov 1887	Tesla	Applies US Patent Office for 3 new patents: polyphase motors with short-circuited rotor.
23rd Dec 1887	Tesla	Applies US Patent Office for 2 new patents: application in distribution.
18th Mar 1888	Ferraris	Lecture in Turin on his tests with 2-phase induction motor.
1st May 1888	**Tesla**	**Granted with all 7 patents applied in 1887.**
16th May 1888	Tesla	Invited lecture at Columbus University, NYC: "*A new system of AC motors and transformers*", before the AIEE (American Institute of Electrical Engineers).

Early electrification – crucial events - 4

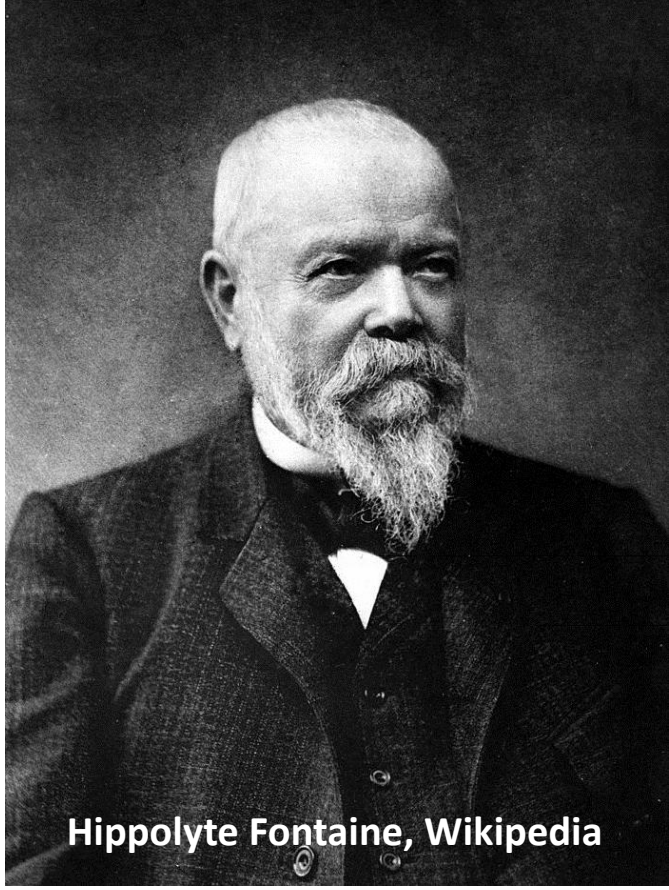
21st July 1888	Haselwander	Filed patents on polyphase motors.
Autumn 1888	Dobrowolski	Beginning of construction of the first inductive motor with rotating magnetic field.
5th Oct 1888	Bradly	Filed patent 404 465; 2-phase induction motor with caged armature.
20th Oct 1888	Bradly	Filed patent 409 450; 3-phase synchronous generator and motor.
Feb 1889	Dobrowolski	Testing AC 3-phase motor with rotating field.
8th Mar 1889	Dobrowolski	Filed patent (DRP 51083) for squirrel-cage induction motors.
9th Apr 1889	Wenström	Filed UK patent 5423 on rotating field systems
29th Aug 1889	Dobrowolski	Filed patent DRP56359 on arrangement of the cores and yoke of 3-phase transformers
5th Dec 1889	Dobrowolski	Filed UK patent 19554 on 3-phase connection, star/wye, delta for windings
8th Jan 1890	C.L. Brown	First patent on three-phase transformer is filed in Switzerland.
24th Jan 1891	C.L. Brown	HV tests in Oerlikon Fabrik for 20 kV & 30 kV transmission with bare conductors.
28th Aug 1891	**Dobrowolski Brown Miller**	First operation of 3-phase transmission system Lauffen-Frankfurt on distance 176 km, 15 kV; 42 Hz with generator 300 KM and at exhibition side was motor 100 KM; η= 75%.

After 1884 many worldwide scientists were dealing with polyphase systems and motors. Many of them deserve to be remembered because the world would be different without these researchers and great geniuses: **Nikola Tesla, Galileo Ferraris, Friedrich August Haselwander, Charles Bradley, Michael Dolivo-Dobrovolsky, Charles L. Brown, Jonas Wenström, Blathy, Deri, Zipernowski and Abraham Ganz.**

STORY: Who invented transmission of electric power?

*Frenchman **Hippolyte Fontaine** (1833-1910) was assistant engineer of the famous Belgian inventor Zenobe Gramme (note: Dynamo invented by Gramme has been the first in the world to provide a higher voltage and more stable direct current). At the **World's Fair of 1873 in Vienna**, H. Fontaine wanted to show visitors how a water pump could operate powered by an electromagnetic machine using DC electricity produced by new invented Dynamo. In the beginning water pump didn't work properly. From neighboring exhibitors than he borrowed missing copper wire (it was approx. **2 km long**), connected dynamo with DC motor nearby to the water pump, and finally the pump started working properly. **After this experiment, said Fontaine, he got an idea how mechanical power could be transmitted to distant places by electricity**. He wrote an article about it in a French newspaper.*

*Fontaine's idea was first used by the French factory-owners **Felix and Chretien** in **1878**, at its factory for sugar in Sermaizeu. Since the processing of sugar beet is seasonal work and except for one month in the rest of the year their steam machines usually stay unproductive. So, they decided to use its steam engines for useful work, for transfer of electrical power from factory halls to plowing fields. At a steam machine they installed dynamo to produce DC electricity and used flexible cable at a distance of 800 m (from the factory to the fields) to transmit power to the DC motor, which was specially developed for the plow plowing. **This was the transmission of electrical power into the electric plowing in France, in 1878**. That example found many imitators in France and elsewhere, in particular because of the economic efficiency. Fontaine was also one of the organizers of the First World Electrotechnical Exhibition in Paris in 1881.*



Hippolyte Fontaine, Wikipedia

4 types of power transmission:

1. **Mechanical**
2. **Electrical,**
3. **Hydraulic,**
4. **Pneumatic**

Summary of milestones of growing electric power system before CIGRE was established

- **1800,** Alessandro Volta was credited as the inventor of the electric battery, first source of **current (galvanic) electricity**. Today, we can say that this invention completely changed mankind.
- **1831,** Michael Faraday, invented the principles of **electromagnetic induction**, enabling many applications in electricity such as transformers, electric motors, and generators.
- **1865**, James Clerk Maxwell publication "*A Dynamical Theory of the Electromagnetic Field*", which summarized knowledge of electromagnetism with 20 fundamental equations. Around 1882, Oliver Heaviside uses vector calculus and reduces it to 4 equations with 4 variables. Those equations fully **describe the theory of electrical engineering**.
- **1866,** Werner Siemens develops the **dynamo-electric machine** based on the double-T armature. This invention makes the current electricity useful and the story begins. Siemens coined a new word "electro-technique". Later Zenobe Gramme (1871) and Friedrich von Hefner-Alteneck (1873) improved a dynamo machine to produce a smooth DC voltage. In 1879 incandescent light bulb (Edison, Swan) was invented and opened a new application for wide use of electricity.
- **1881,** First International Electrotechnical Congress and Exhibition in Paris has made a big progress in electricity thinking, in electrical circuit principles and experts agreed on the first units, etc.
- **1882,** Beginning of commercialization of electricity (Edison's Plant "Pearl Street" in New York).
- **1882-1892,** *Historical decade of innovations.* **Nikola Tesla, Galileo Ferraris, Charles Bradley, Fredrich August Haselwander, Michael Dolivo-Dobrovolsky, Charles L. Brown** created polyphase AC system, which widely opened door to global electrification.
- **1891,** First demonstration of long-distance 3-phase electric system between Lauffen and Frankfurt in Germany.
- **1900-1920,** plenty of innovations in insulation, suspension insulators (1907), ACSR conductors (1907), electrical generators (bar windings by Ludwig Roebel, 1912), beginning of standardization (terminology, rotating machinery, graphical symbols, overhead electrical conductors, etc.), needs for international collaboration of technology development open the door for a permanent international conference for sharing knowledge of power system expertise.
- **In 1921 CIGRE in Paris, France was born**.


Let‘s start with 3 presentations