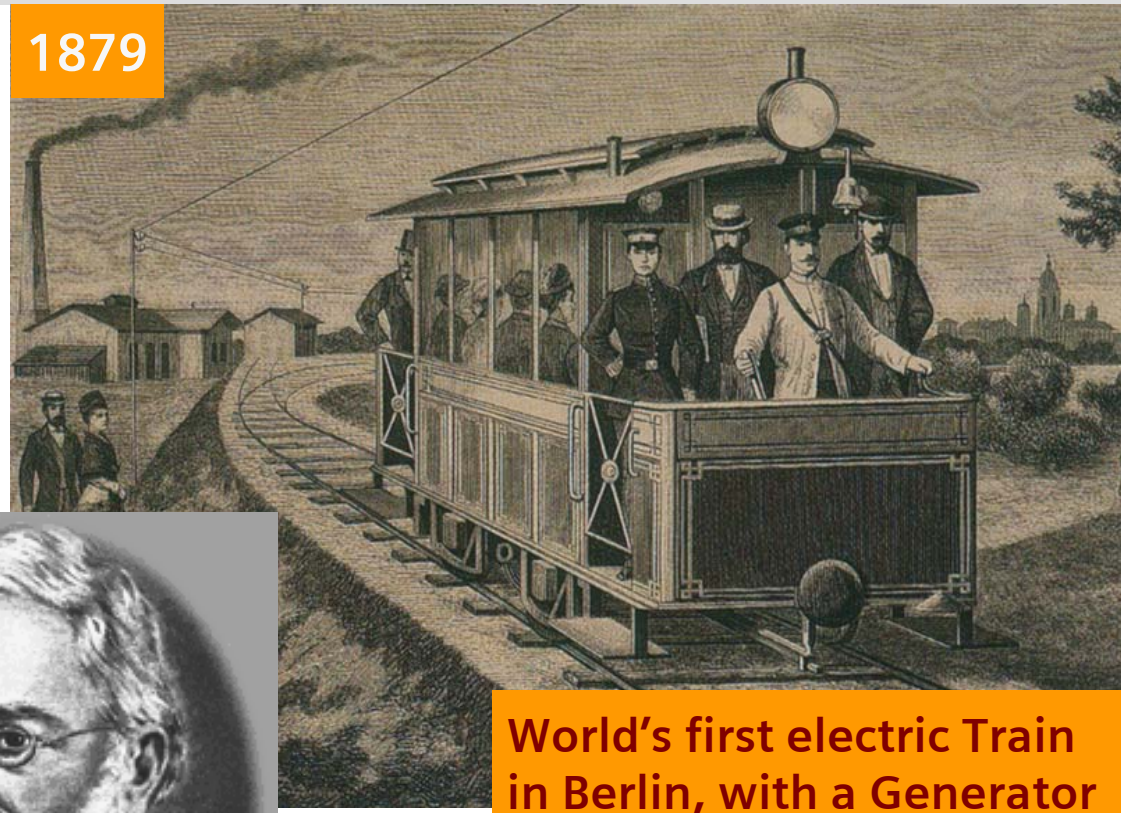
Development in AC & DC Transmission

SIEMENS

World's first steps towards Electrification

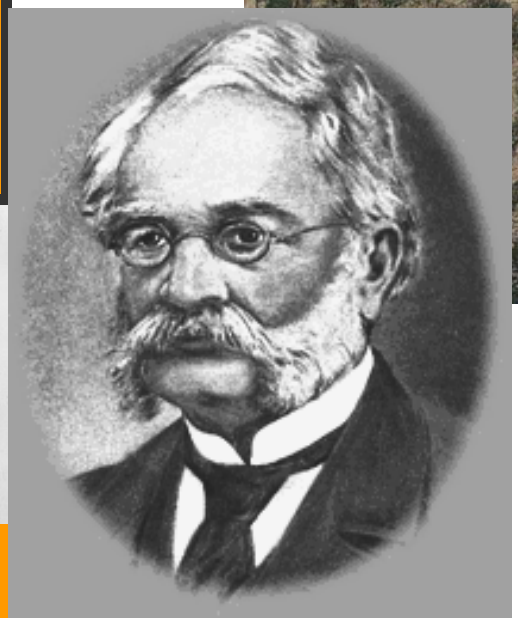
1879



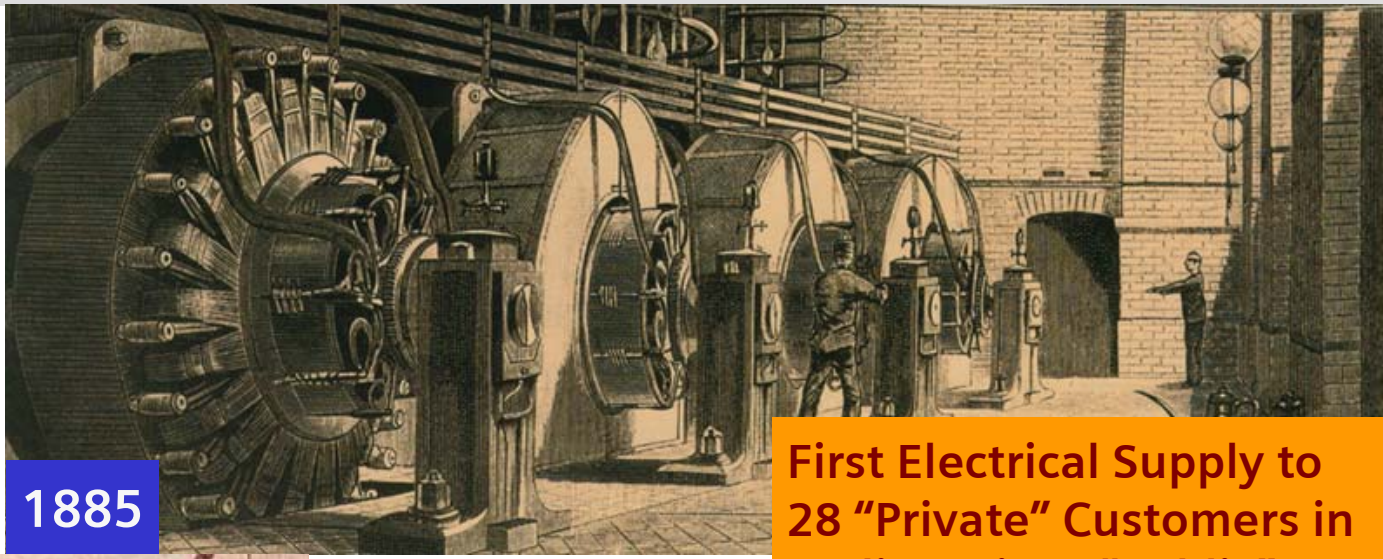
World's first electric Train in Berlin, with a Generator from Siemens

Werner von Siemens invents the Dynamo: The "Kick-off" for Electrical Power Supply

1866



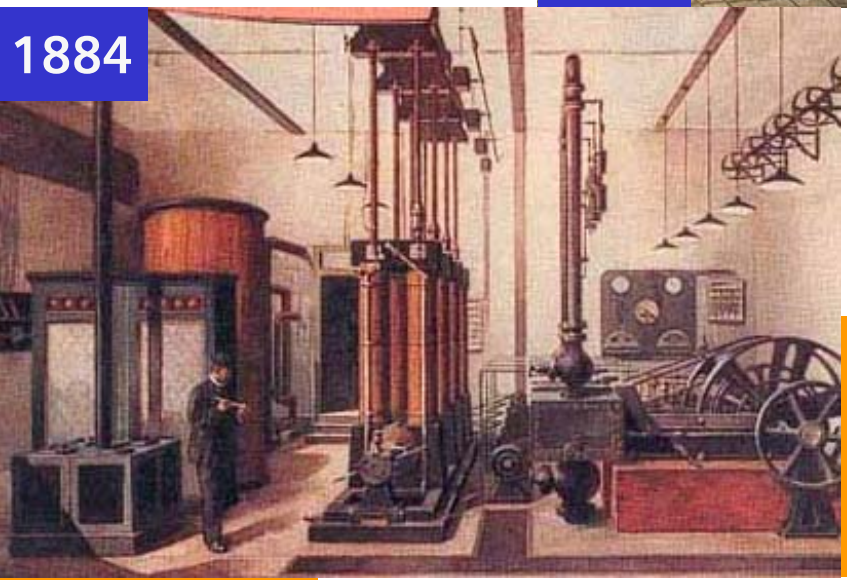
Next Steps - Power Delivery to Industrial and Private Customers



1885

First Electrical Supply to 28 “Private” Customers in Berlin – via a “public” Power Plant delivered by Siemens

1884



First Electrical Supply to “Industrial” Customers in Berlin – with Generators from Siemens

Now: World's first Steps towards DC and AC "Long Distance" Transmission

1945: DC

First commercial DC Transmission by Siemens and AEG: 115 km Cable, Mercury-Arc based Link with 60 MW / ± 200 kV Ratings, ready for Commissioning, but then transported to Russia ...

1891: AC

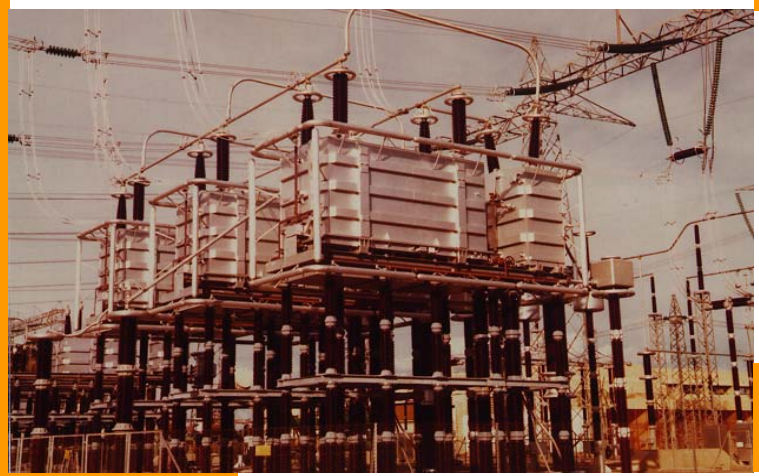
Oskar von Miller and Michael v. Dolivo-Dobrowolski achieved a Breakthrough with the first Three-Phase AC Transmission System from the Hydropower Station in the German town of Lauffen (by the River Neckar), covering a Distance of 178 km with 25 kV to Frankfurt am Main

1882: DC

World's first DC Transmission Prototype from Miesbach to Munich – by Oskar von Miller and Marcel Deprez: 57 km, 1.4 kV

Cahora Bassa: World's first Long-Distance OHL DC Transmission with Thyristors: 1,500 km

1977



Siemens, AEG & BBC

Summary - Developments in HVDC Technology

HVDC - History

- First "HVDC" Installation 1882, 57 km (Miesbach - München), 1.4 kV
- 1890 - 1910, 70 - 200 km (various Installations), 6 - 60 kV, ≤ 4.5 MW

Rotating Converters (Machines)

Mercury-Arc Valves

- 1935 - 1944, various Installations, B2B & LDT (30 km): near Hannover, at Henningsdorf, Wettingen-Zurich & Berlin; 50 - 100 kV, 1.5 - 40 MW

By Siemens and AEG

- 1945, 1st commercial Cable-HVDC, 115 km, Power Station Elbe/Elektrowerke AG-Bewag/Berlin, ± 200 kV, 60 MW. Was completed after the End of the 2nd World War, then however, transported to Russia as "Sample" for:

  - Prototype Installation Kashira-Moscow, 200 kV, 30 MW, 1951
- 1954, 100 km See Cable, Sweden-Gotland, 100 kV, 20 MW
- 1970 Pacific Intertie (Columbia River - Los Angeles), 1350 km, ± 400 kV, 1440 MW

Thyristor Valves

By Siemens, AEG & BBC

- 1970 Thyristor-Upgrade Sweden-Gotland, 150 kV, 30 MW
- 1977 Cahora Bassa - World's first Thyristor LDT with OHL (Mozambique-RSA, Songo-Johannesburg), 1500 km, ± 533 kV, 1920 MW

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Developments in FACTS Technology

FACTS - History

- 1974 1st SVCs, Nebraska, USA, GE & 1975, Minnesota, Westinghouse*
- 1984 1st EHV FACTS (500 kV NGH, SSR-Damping), California, Siemens
- 1992 1st TCSC (for Load-Flow Control), Kayenta, Siemens
- 1995 1st STATCOM, Sullivan, USA, Westinghouse*
- 1998 1st UPFC, Inez, USA, Westinghouse*
- 2001 Worlds largest SFC, Richmond, USA, Siemens
- 2001/2003 1st CSC (Convertible Static Compensator), Marcy, USA, Siemens

*now Siemens

Siemens - a Leader in FACTS Technology since its early Beginning

Overview - FACTS

FACTS - the most common Devices

- **FSC** Fixed Series Compensation
- **SVC** Static Var Compensator
- **TCSC/TPSC** Thyristor Controlled/Protected Series Compensation
- **STATCOM** Static Synchronous Compensator
- **UPFC** Unified Power Flow Controller
- **S^3C** Solid-State Series Compensator
- **CSC** Convertible Synchronous Compensator

FACTS - Specific Devices

- **SFC** Static Frequency Converter
- **TSBR** Thyristor Switched Breaking Resistor
- **TCVL** Thyristor Controlled Voltage Limiter
- **SMES** Superconducting Magnetic Energy Storage (in combination with Power Electronics)
- **SCCL** Short-Circuit Current Limiter

"Distribution FACTS" - for Custom Power

- **DVR** Dynamic Voltage Restorer
- **DSTATCOM** Distribution STATCOM

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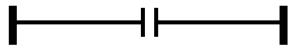
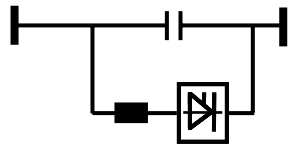
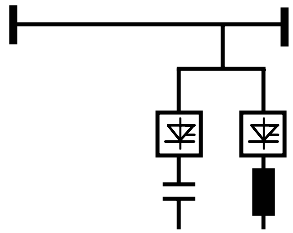
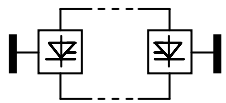
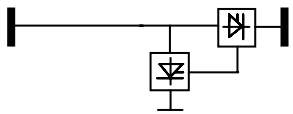
FACTS & HVDC – Overview of Functions & "Ranking"

Principle	Devices	Scheme	Impact on System Performance		
			Load Flow	Stability	Voltage Quality
Variation of the Line Impedance: Series Compensation	FSC (Fixed Series Compensation)		●	● ● ●	●
	TPSC (Thryristor Protected Series Compensation)		●	● ● ●	●
	TCSC (Thyristor Controlled Series Compensation)		● ●	● ● ●	●
Voltage Control: Shunt Compensation	SVC (Static Var Compensator)		○	● ●	● ● ●
	STATCOM (Static Synchronous Compensator)		○	● ●	● ● ●
Load-Flow Control	HVDC (B2B, LDT)		● ● ●	● ● ●	● ●
	UPFC (Unified Power Flow Controller)		● ● ●	● ● ●	● ● ●

Influence: *

○ no or low
● small
● ● medium
● ● ● strong

* Based on Studies & practical Experience

Impact of FACTS and HVDC on System Performance – now in Details

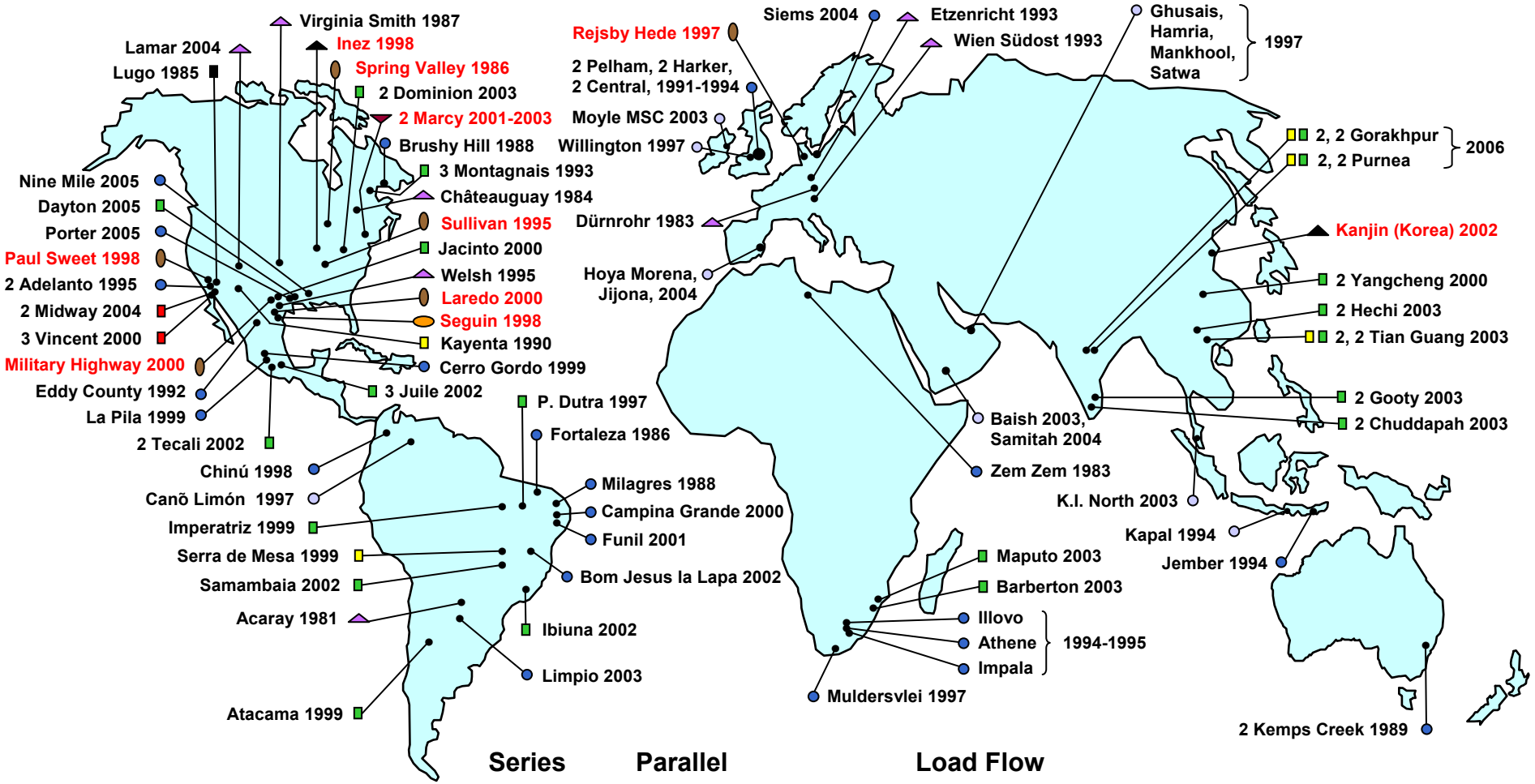
	FSC	SVC/SVG STATCOM	TCSC GTO-CSC*	PST	UPFC	HVDC
Voltage Quality	●	● ● ●	●	●	● ● ●	● ●
Load Flow Control (Meshed System)	●	○	● ●	● ● ●	● ● ●	● ● ●
Transient Stability (Bulk Power System)	● ●	●	● ● ●	● ●	● ● ●	● ● ●
Oscillation Damping (Transmission System)	●	● ●	● ● ●	● ●	● ● ●	● ● ●
Oscillation Damping (Meshed System)	●	●	●	● ●	● ● ●	● ● ●

○ no or low influence
● small influence
● ● medium influence
● ● ● strong influence

*S^{3}C Solid-State Series Compensator

FSC	Fixed Series Compensation
SVC/SVG	Static Var Compensator/Generator
TCSC	Thyristor Controlled Series Compensation
PST	Phase Shifting Transformer
UPFC	Unified Power Flow Controller
STATCOM	Static Synchronous Compensator

FACTS & HVDC worldwide – Example Siemens



Status: 07-2004

Plus 14 Projects for HVDC-Long Distance Transmission

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