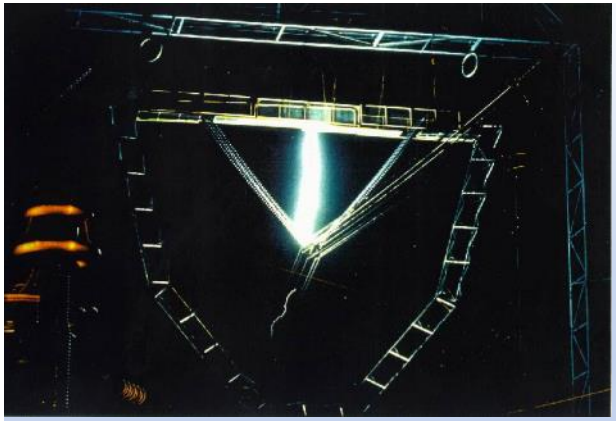
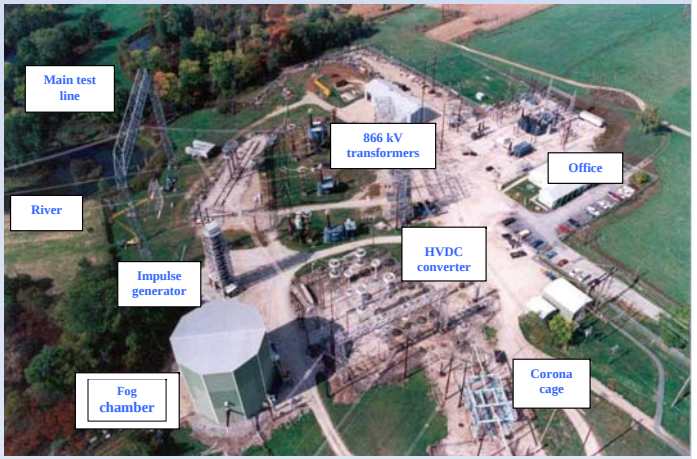


UHV Transmission lines worldwide
IEEE/PES Berkshire Chapter
Thursday, April 30, 2015

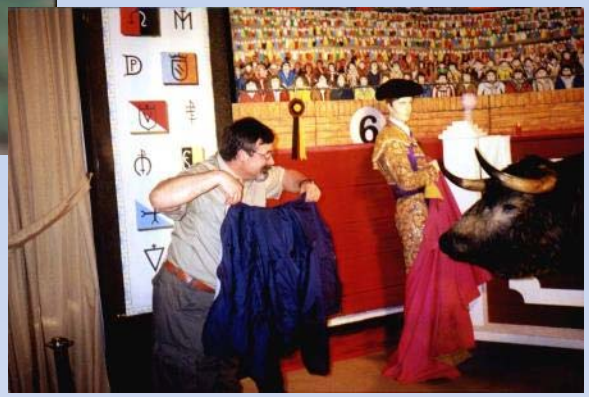
George Gela

BETC



BETC

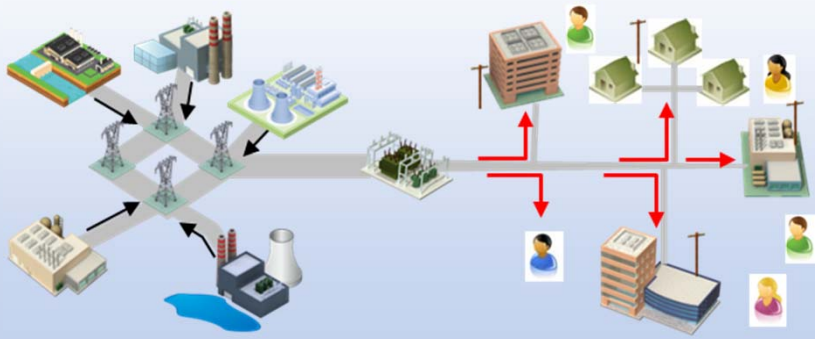
Introductions



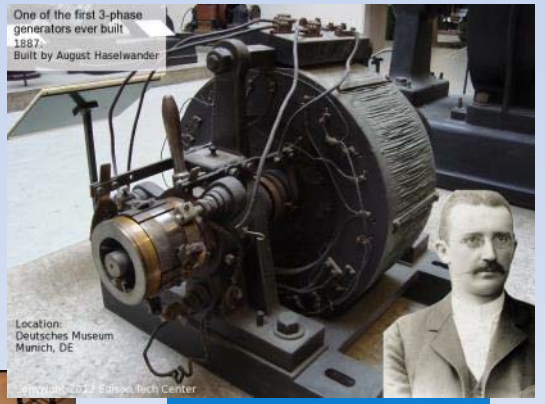
What is UHV? What is EHV?

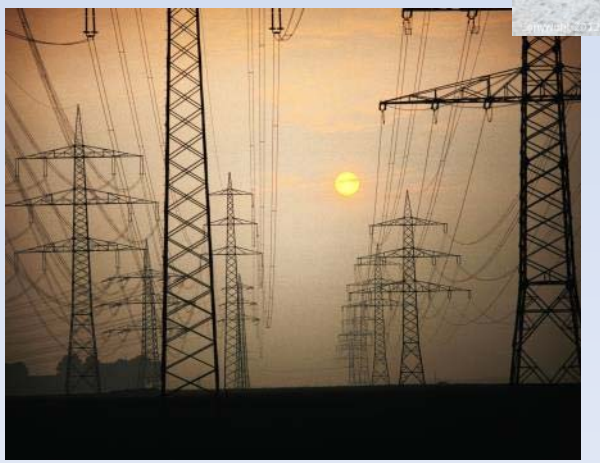
- HV stands for High Voltage
- EHV - over 230 kV, up to about 800 kV
- UHV - Ultra high voltage, higher than 800 kV
- kV stands for kilovolt = 1000 volt
- So, 800 kV is 800,000 V
- Your toaster is designed for 115 V
- 800 kV is about 7000 times the toaster voltage
- If you connect your toaster to 800 kV, what will we get? Very crispy toast, of course.

Why UHV?



- This has to do with power, current, losses
- When we toast bread, we consume power. The power is generated far away and is transmitted by a transmission line to our house





Why UHV?

$$P = I^2 R$$

- The transmission line can be long
- The line has resistance which produces loss of power (who pays for the loss?)
- Power loss increases as current increases, so we (utilities) try to minimize the current
- But power also increases as current increases
- So, what can power engineers do?
- Power also increases as voltage increases
- Therefore, boost the voltage – UHV!!!

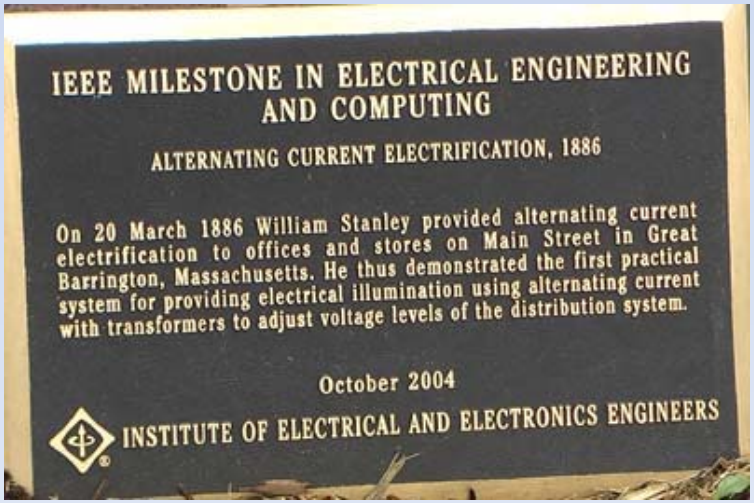
$$P = V \cdot I$$

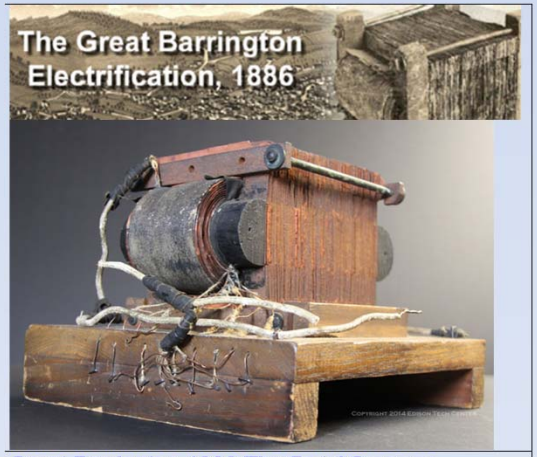
What are the highest line voltages?

- Hydro-Québec 735-kV lines in Canada
- AEP 765-kV lines in the U.S.
- 750kV and 1150kV lines (USSR-Russia) (the 1150 kV line now operates at 500 kV)
- EDELCA (Venezuela) 765-kV lines
- FURNAS (Brazil) 750-kV lines
- NYPA (U.S.A.) 765-kV lines (operates at 345 kV)
- Eskom 765-kV lines in South Africa
- POWERGRID (India) 765kV lines
- KEPCO 765-kV lines in South Korea
- TEPCO (Japan) 1000-kV lines
- 1000 kV lines in China
- 1200 kV line in India

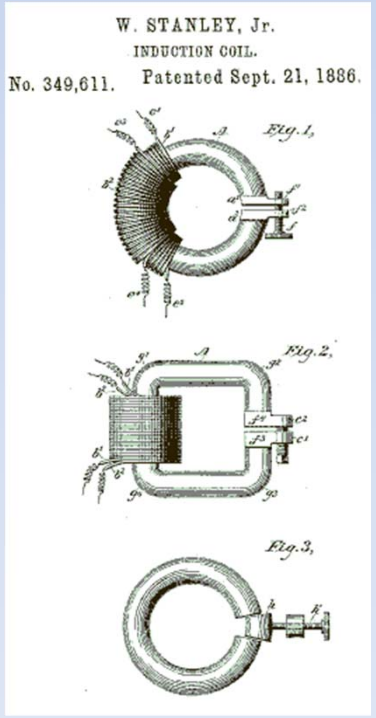
It all started here and in other labs

- We should be proud – UHV technology was developed decades ago in Pittsfield-Lenox, and other labs (BPA, AEP, Hydro-Quebec, etc.)
- Pittsfield and Lenox produced several Reference Book on AC and DC





Great Barrington 1886 The first AC power distribution system using transformers (top) Stanley developed the prototype transformer (bottom) in 1885, it was robust, reliable and was a significant leap forward in technology.



Recognize anyone?

- 1959 - today

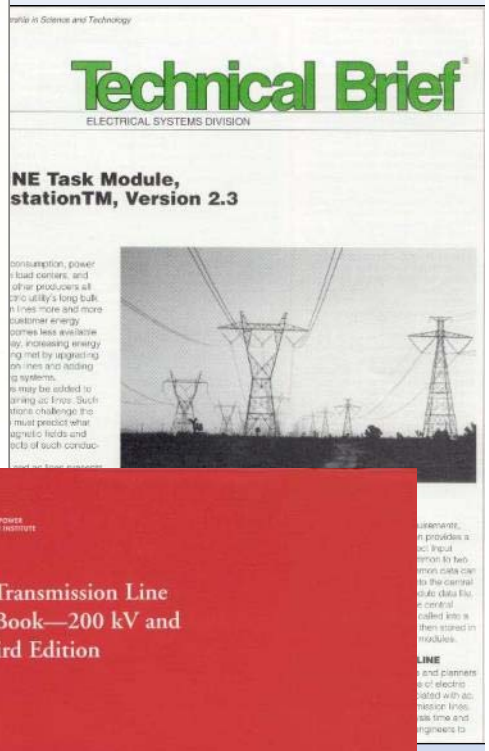
Passive Shielding System for the NYPA 345 kV Cross-State Corridor

TR-111718

Final Report, November 1998

Prepared for
New York Power Authority (NYPA)
1633 Broadway
New York, New York 10019

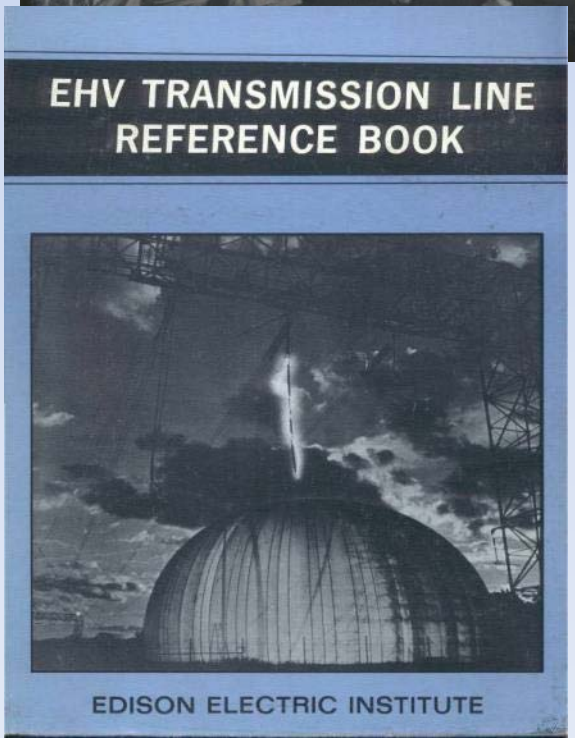
NYPA Project Managers



Technical Brief

ELECTRICAL SYSTEMS DIVISION

NE Task Module, stationTM, Version 2.3



EHV TRANSMISSION LINE REFERENCE BOOK

EDISON ELECTRIC INSTITUTE

HVDC Transmission Line Reference Book

TR-102764
Research Project 2472-03

Final Report, September 1993

Prepared by
HIGH VOLTAGE TRANSMISSION RESEARCH CENTER
A Research Facility of the Electric Power Research Institute
Operated by
GE
1000 East New Lenox Road
Lenox, Massachusetts 01240-2216

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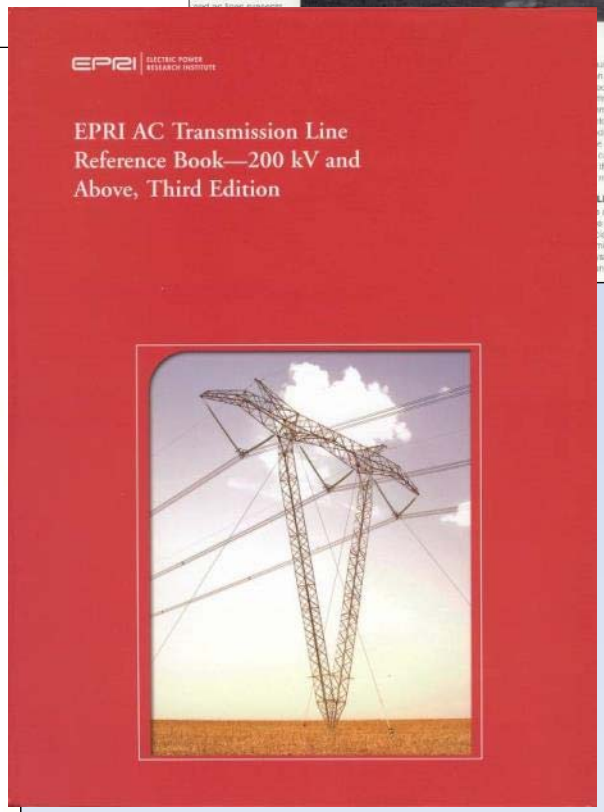
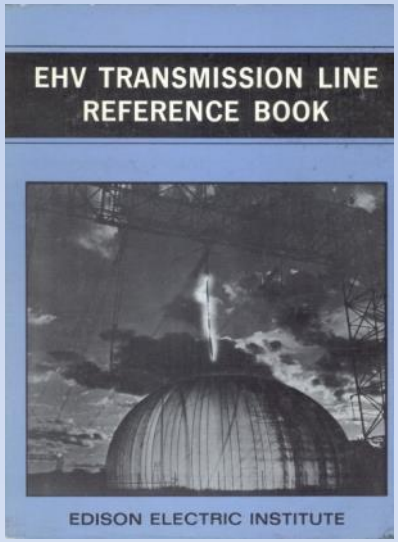


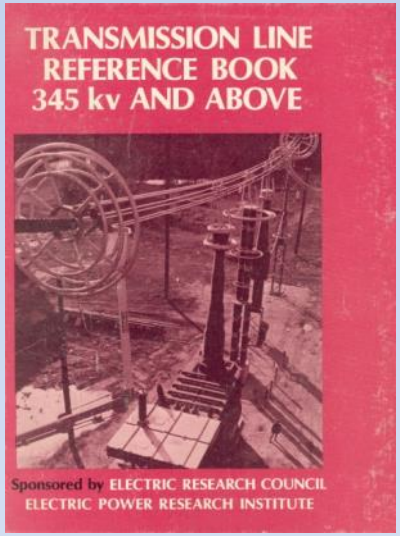
EPRI | ELECTRIC POWER RESEARCH INSTITUTE

EPRI AC Transmission Line Reference Book—200 kV and Above, Third Edition

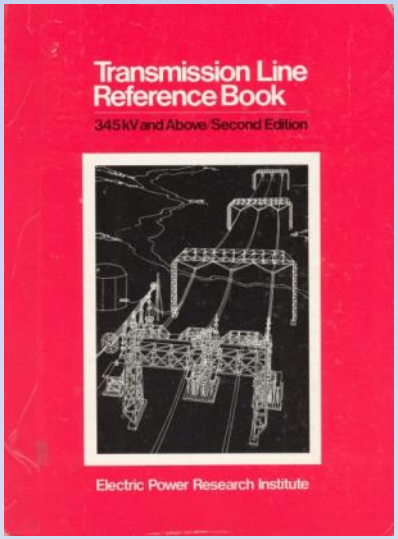
History of the R&D at Lenox, and Evolution of the Redbook



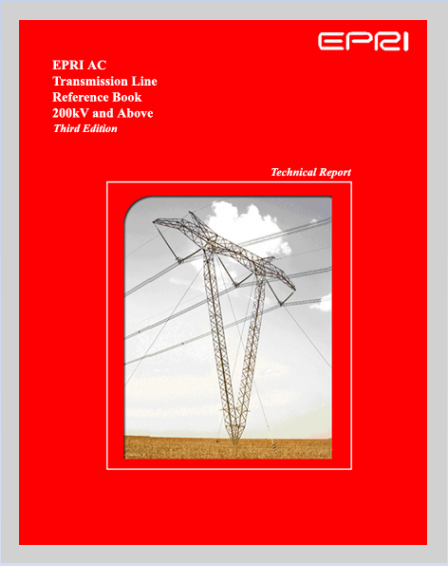
1968



1975

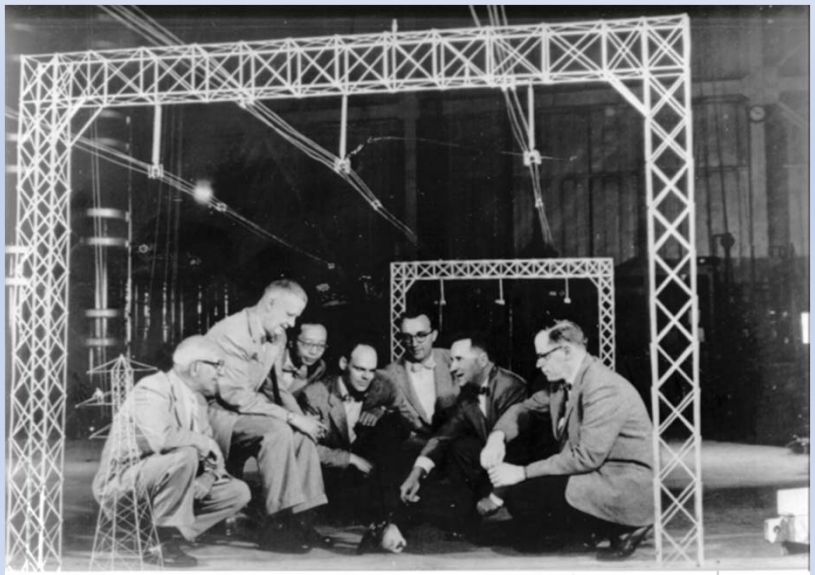


1982



2006

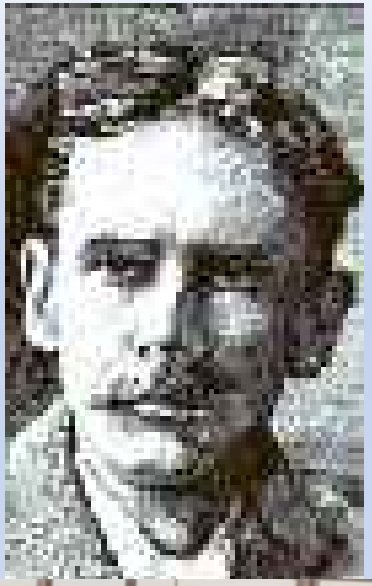
Recognize anyone?



The High Voltage Transmission Research Facility has its roots in Project EHV (Extra High Voltage). A 4-mile experimental line from the present site to the town of Lee was built in 1959 to study 500 kV and 700 kV AC transmission. Prominent high voltage engineers of General Electric Company participated in this project. Photographed in 1960 under a model of the EHV test line are from left to right:

Sam Minneci	-	Facility Engineer
Julius Hagenguth	-	Manager of the Pittsfield GE High Voltage Laboratory
Charlie Liao	-	who later became Manager of the High Voltage Laboratory of the GE Insulator Department in Baltimore
Carl Lindh	-	who participated in the development of many HVDC projects
James LaForest	-	the Editor of EPRI's "AC Transmission Line Reference Book - 345 kV and Above"
Pier Abetti	-	First Manager of Project EHV
John Anderson	-	Manager of Project UHV from 1967 to 1972

1960

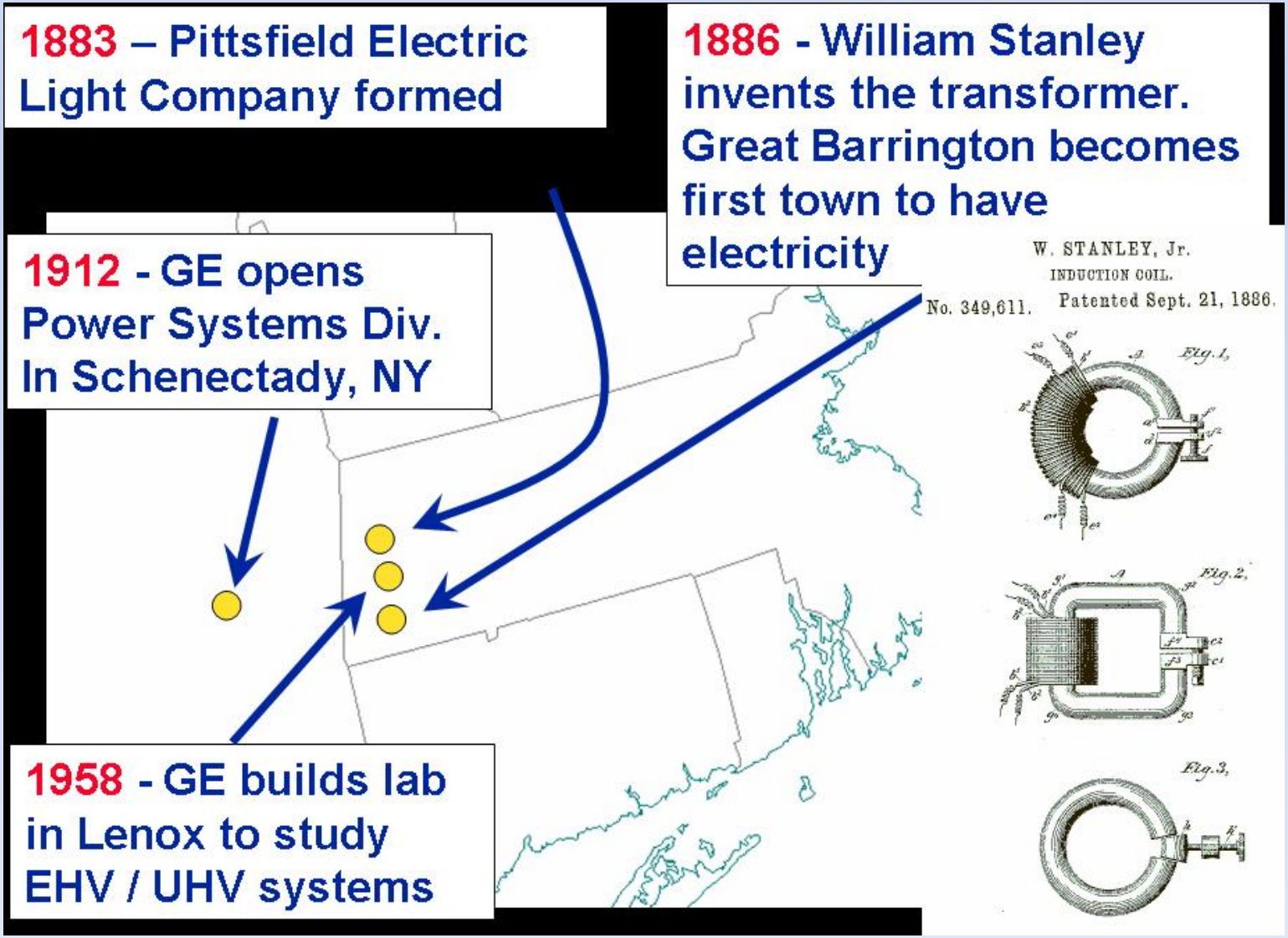


Project UHV (Ultra High Voltage) was started in 1967 under the sponsorship of the Electric Research Council with funds provided by the Edison Electric Institute and the Bonneville Power Administration. The scope of Project UHV was to study AC transmission at voltages between 1000 kV to 1500 kV. Much of the work performed was also applied to voltages from 345 kV to 765 kV. The staff of Project UHV is shown in a 1971 photo. From left to right:

Roland Devoe, Joe Doyle, Cliff Waite, Ed O'Brien, Luciano Zaffanella, John Anderson (Manager), Jasper DiMartino, David Milone, Gerhard Juette, Mikio Kawai, Fred Wood, Jim LaForest, Edna Dunbar, and (partially covered) George Baer.

The GE Transformer Plant : 1950
Looks familiar?

EPRI Lenox High Voltage Laboratory – Origins



The Beginnings

- In 1906 the GE Pittsfield Works started its operation. For many years (before it closed down in 1985) it was the largest transformer factory in the world.

- In 1912 a High Voltage Laboratory was built. Its Manager was Frank Peek, a legendary figure in High Voltage engineering. He studied not only the insulation systems of transformers but made also the first flashover tests on insulators for high voltage lines and studied corona from high voltage conductors.

$$E_0 = 30M\delta\left[1+\frac{0.3}{\sqrt{\delta r}}\right]$$

(Peek's Formula)

Project UHV

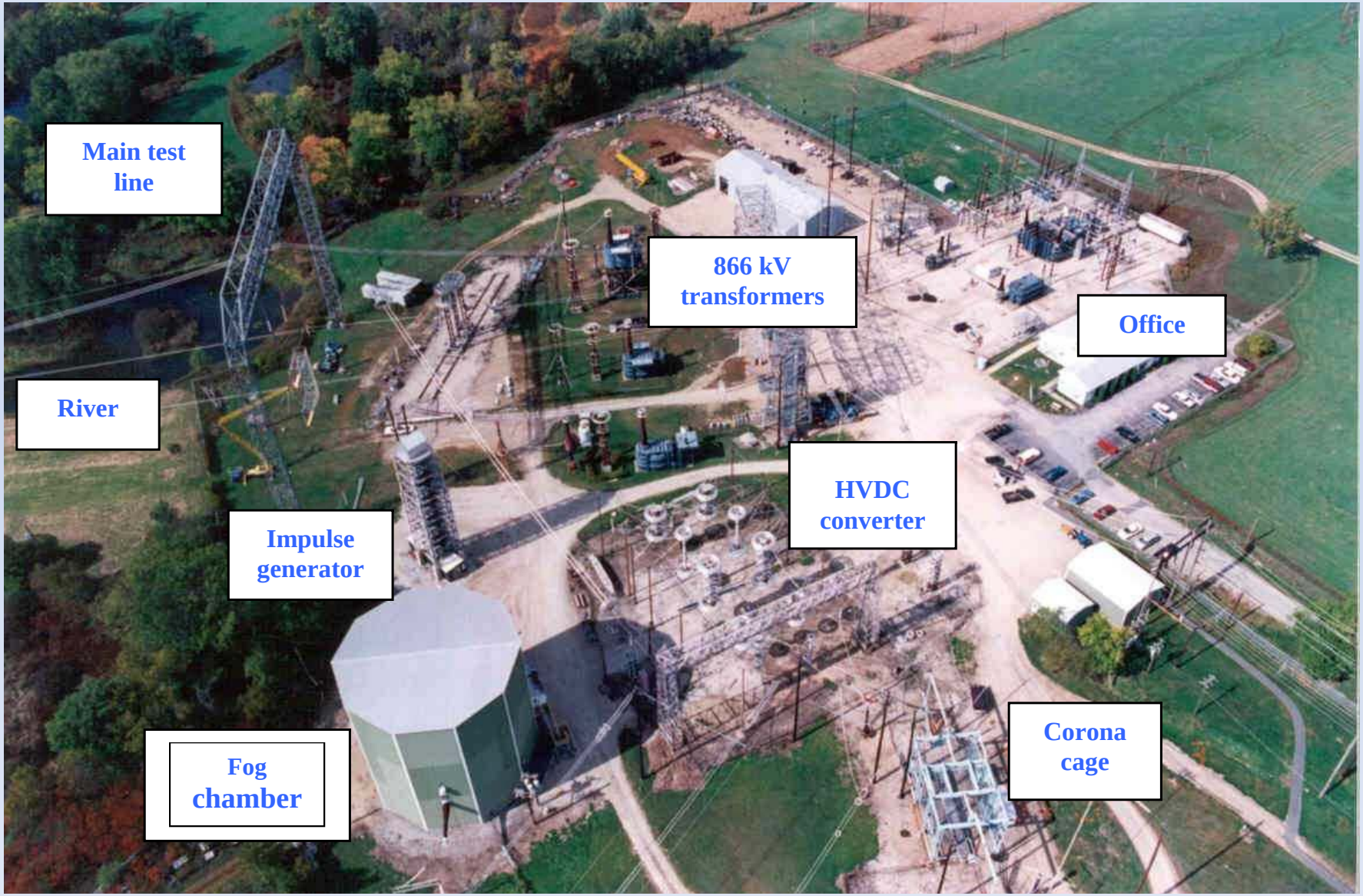
- The rapid increase in transmission voltages appeared to herald the introduction of even higher voltages, above 1000 kV.

  Lionel Barthold convinced EEI that it was prudent to research these voltages. In 1967, EEI sponsored the construction of Project UHV and a five-year research effort. GE assigned the direction of Project UHV to John Anderson.

- *Project UHV*, Ultra High Voltages, voltages of 1000 kV and above, is the name by which the EPRI Laboratory at Lenox was known around the world.

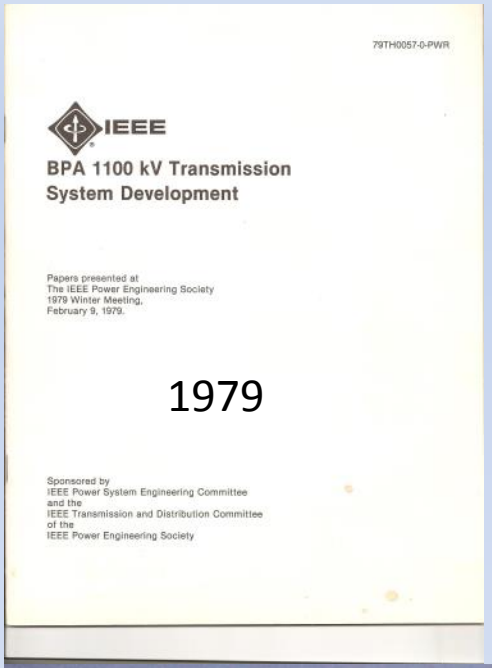
- Project UHV started with a single-phase test line that could be energized up to the phase-to-ground voltage of a 1500 kV three-phase line.

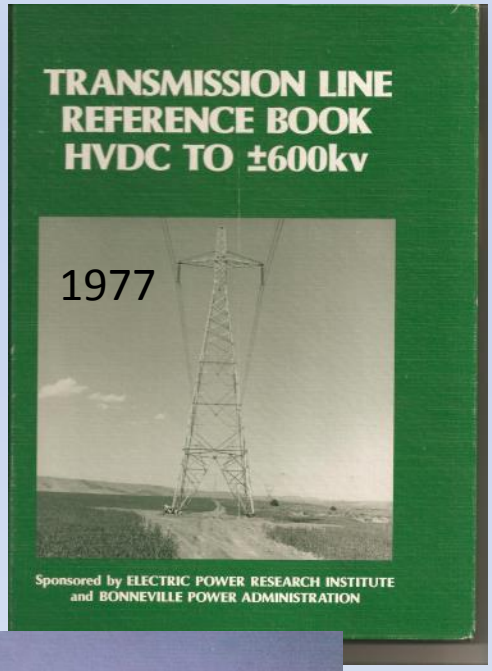
Laboratory Layout



Redbook Seminar – Lenox

Research at other labs





UHV lines

Hydro Quebec 735 kV - Canada

- First transmission line above 700 kV place in-service in 1965
- Designed to move large blocks of power 300 – 600 miles
  - 5300 MW from James Bay
- Experienced many socio-political forces
  - Energy needs not always in harmony with environmental goals
- Developed various tower designs

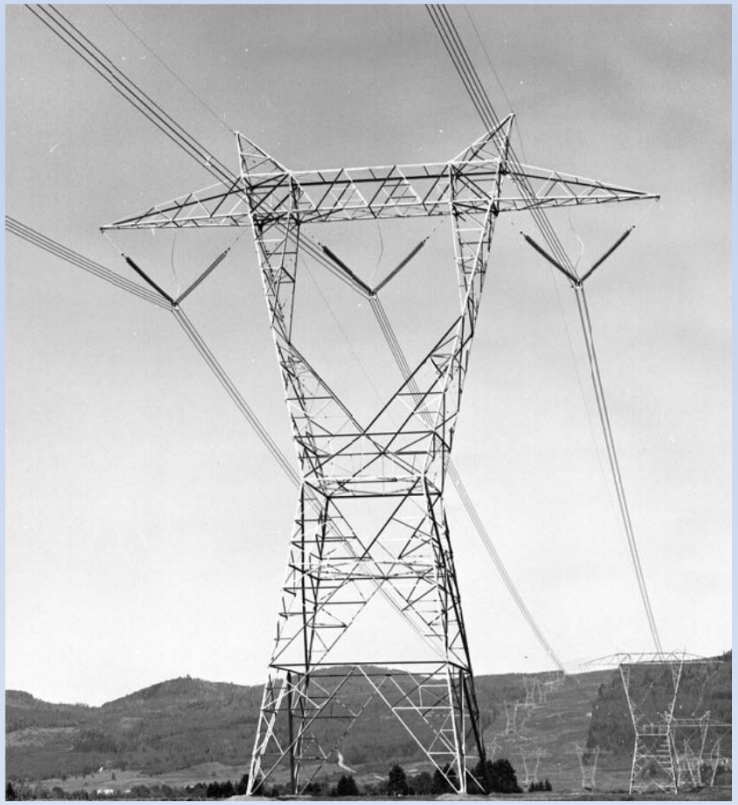


Figure 15.4-1 First-generation Hydro-Québec self supporting 735-kV tower.

Hydro Quebec 735 kV Grande

Figure 15.4-2 Hydro-Québec/TransÉnergie Chainette suspension tower.

Figure 15.4-3 Hydro-Québec/TransÉnergie tubular self supporting tower.

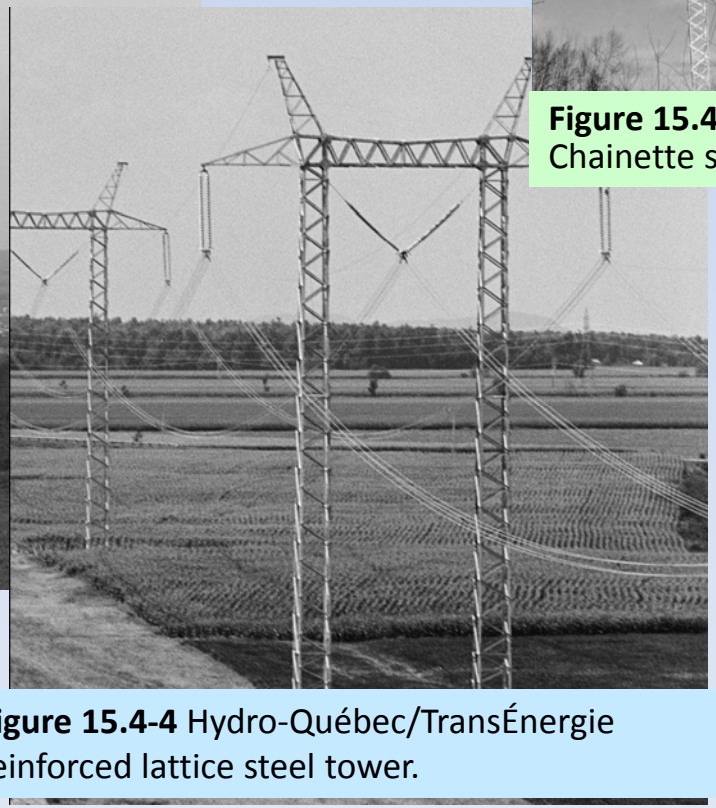


Figure 15.4-4 Hydro-Québec/TransÉnergie reinforced lattice steel tower.

AEP 765 kV

- Experienced many of the same socio-political forces as Hydro Quebec experienced in the deployment of Hydro Quebec's 735kV system
  - Energy needs not always in harmony with environmental goals
- Developed various tower designs

Figure 15.5-1 AEP 765-kV self-supporting suspension tower with four-conductor bundle.

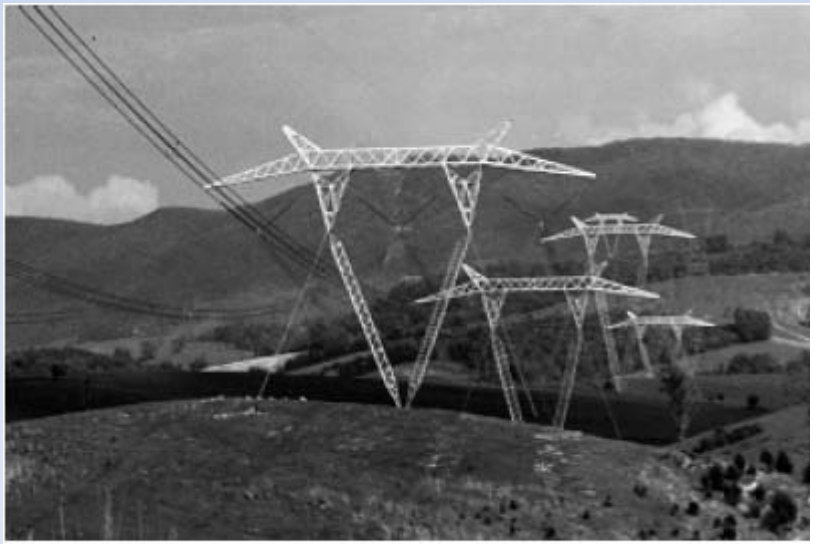


Figure 15.5-2 AEP 765-kV guyed-V suspension tower with four-conductor bundle.

AEP 765 kV - USA

- AEP's first generation 4-cond. bundle uses with 954 kcm Rail conductor
- AEP's second generation 4-conductor bundle uses with 1351 kcm Dipper conductor

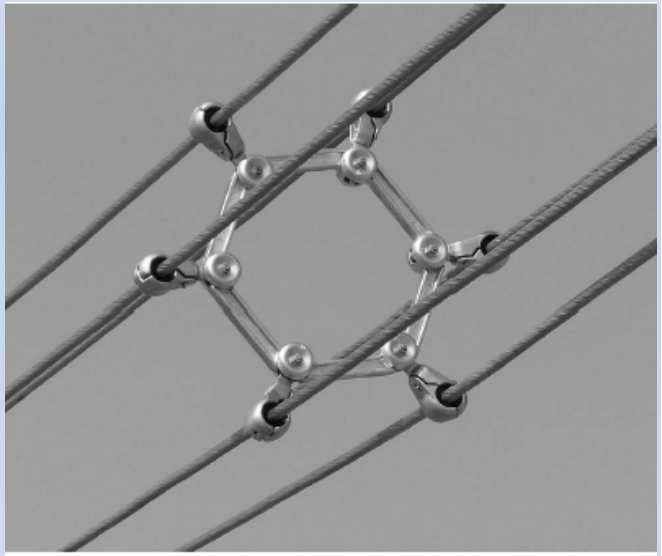


Figure 15.5-3 Six-conductor-bundle spacer damper.

- The new 765 kV line uses 6-conductor bundle with Tern conductor
- AEP installs 30 or 32 porcelain disc insulators in a string, depending upon conductor to tower clearances

USSR 700 kV and 1150 kV - Russia

- The USSR EHV system was developed to address the vast expanse of the original USSR system and generation located remotely from population centers
  - 4400 miles across the USSR grid
- Voltage selected by technica
  - Land cost minimal
  - Environment given limited attention (compared to the West)
- First 750 kV line
  - 1967, 55 miles long

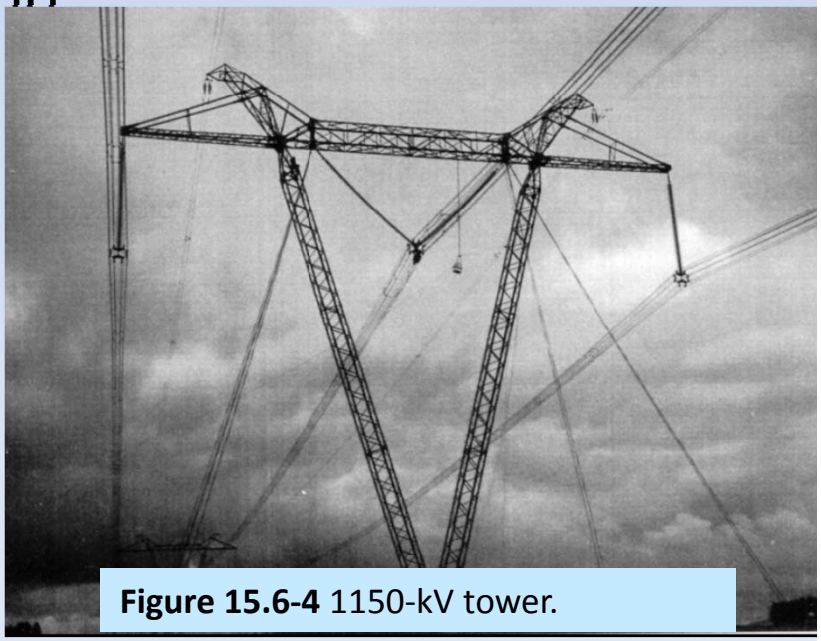


Figure 15.6-4 1150-kV tower.

USSR 700 kV and 1150 kV - Russia

- Eventually, USSR EHV grid contained 5000 miles of 750 kV
  - 1900 miles in present-day Russia
- 1150 kV test station and line established in 1973
- USSR planned for 6200 miles of 1150 kV
  - 1500 miles constructed
  - Only 550 miles ever operated at 1150 kV
    - Initial 1150 kV operation in 1985. Since 1995 all 1150 kV lines have operated at 500 kV

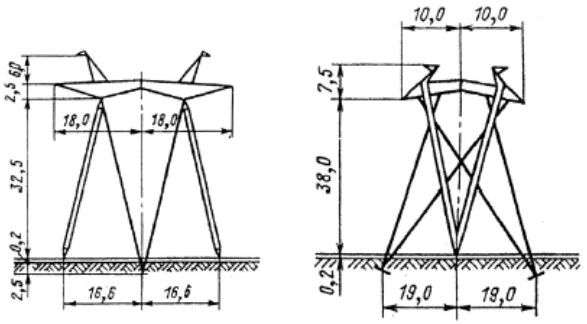


Figure 15.6-2 Typical 750-kV guyed V towers.

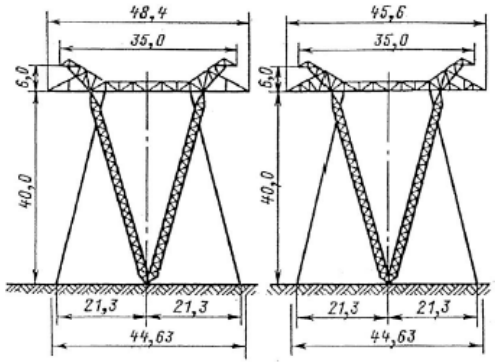
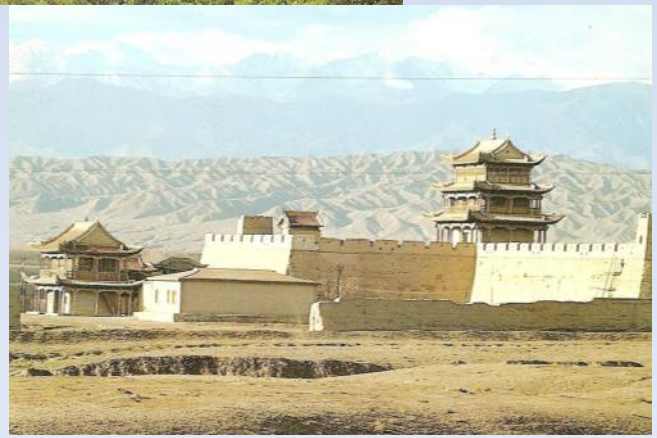
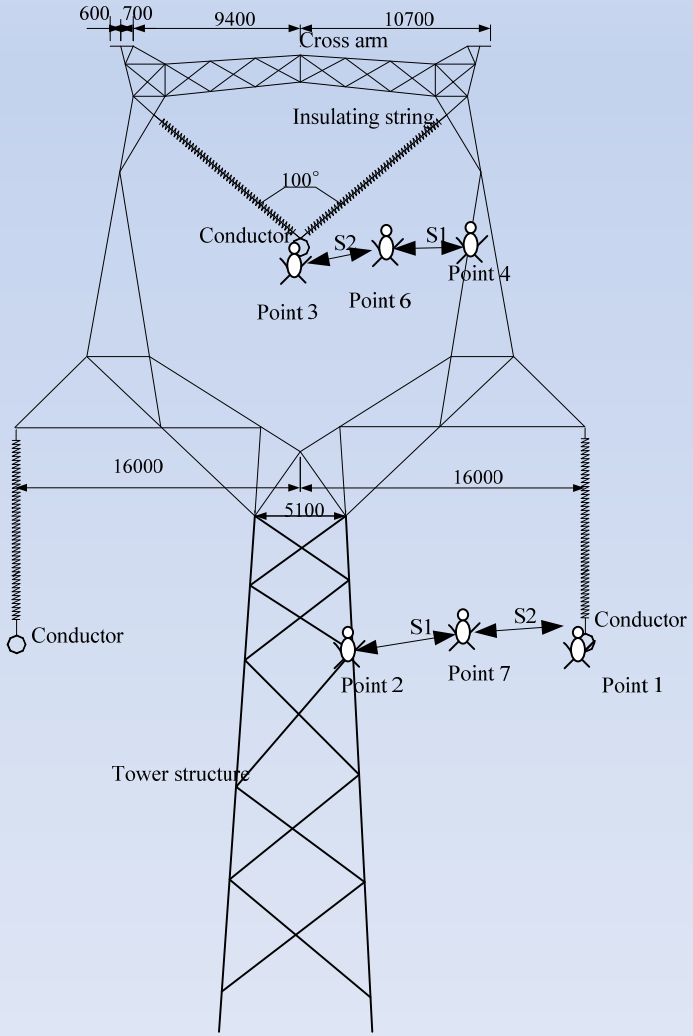


Figure 15.6-3 Typical 1150-kV guyed V towers.

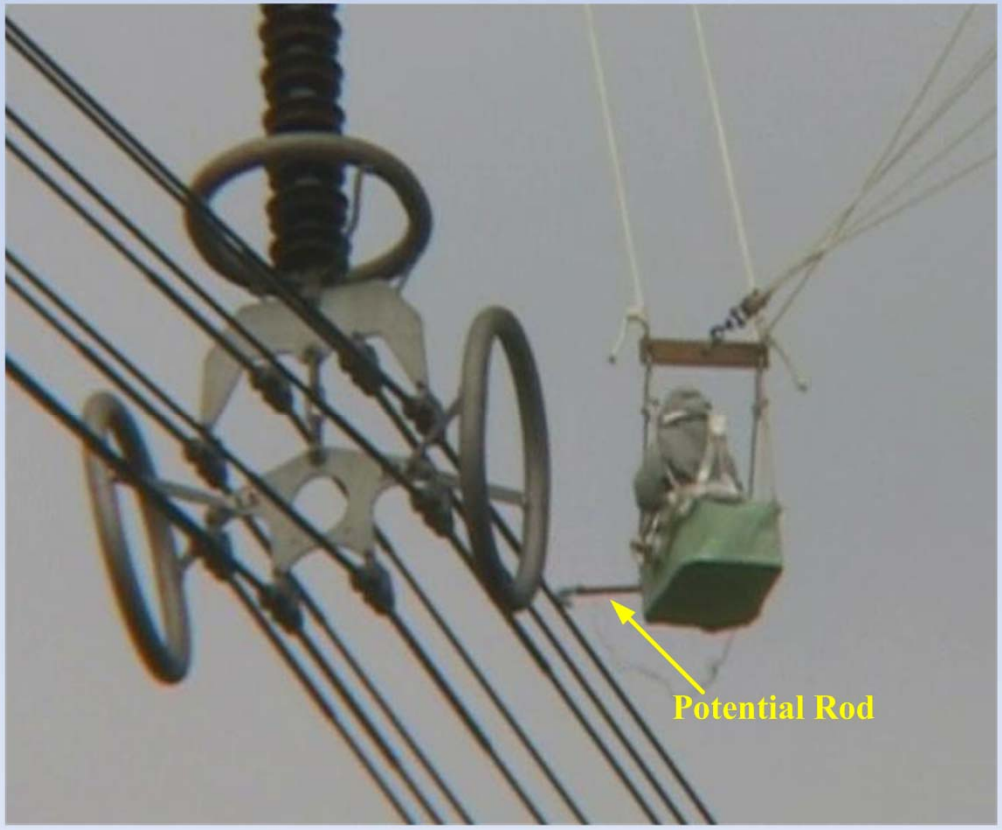
1000 kV line, China, long, varied terrain

- Suspension and deadend towers





1000 kV lines, China
Jindongnan-Nanyan-Jingmen project

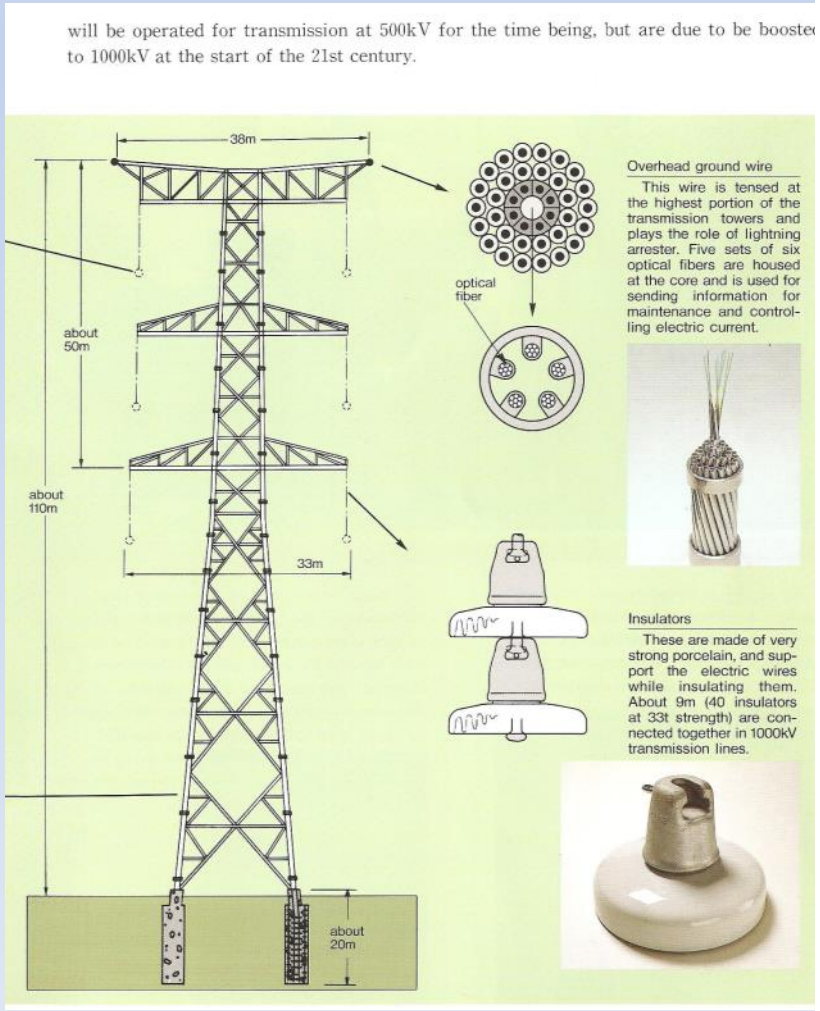


1000 kV conductive suits, China

- For live work on 1000 kV line

Tokyo Electric Power Company (TEPCO) 1000-kV Lines - Japan

- Continuing growth exceeds the capacity of 500 kV system
- Difficult to obtain ROW
- Decided to construct 1000 kV lines
- One line was energized in 1992 at 500 kV, still operating at 500 kV
- Another line branch has been constructed
- Once the entire system is completed, it will be energized at 1000 kV



1000 kV line, Japan

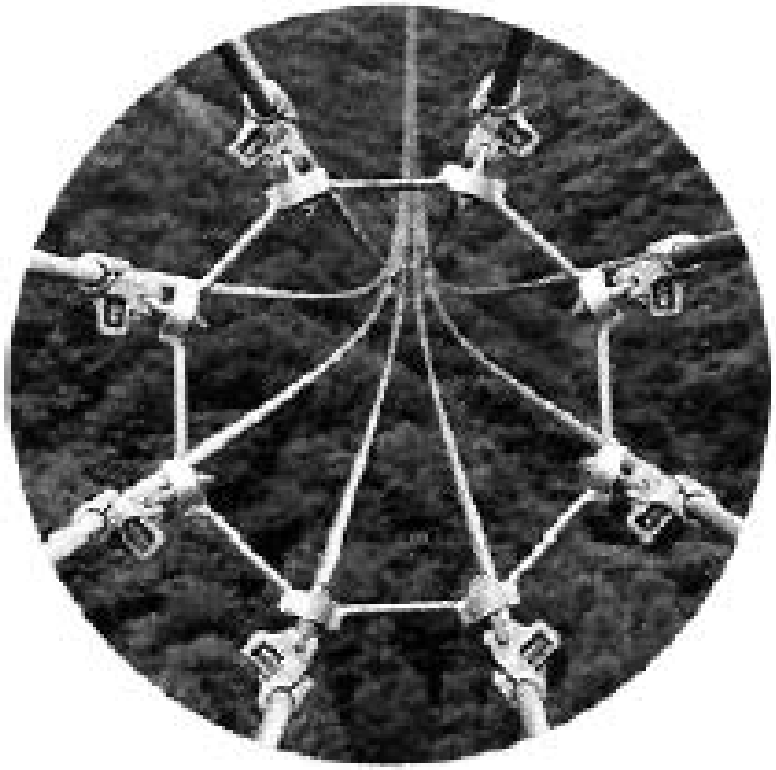
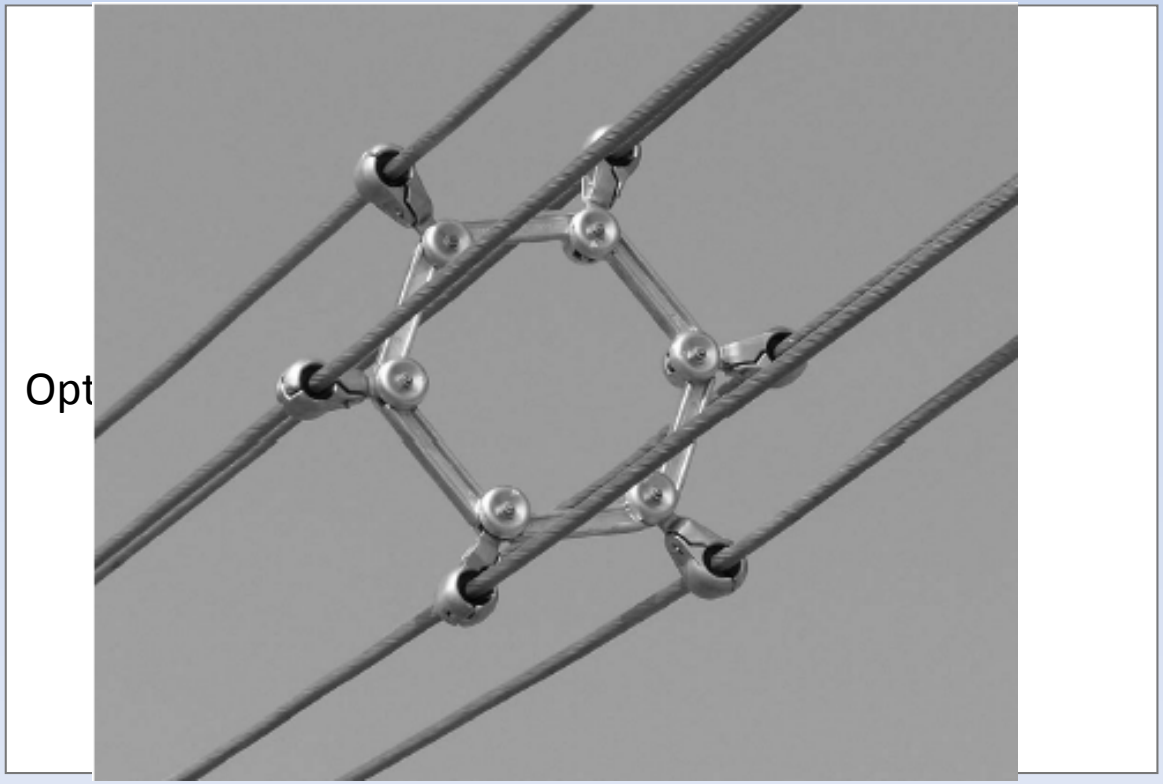


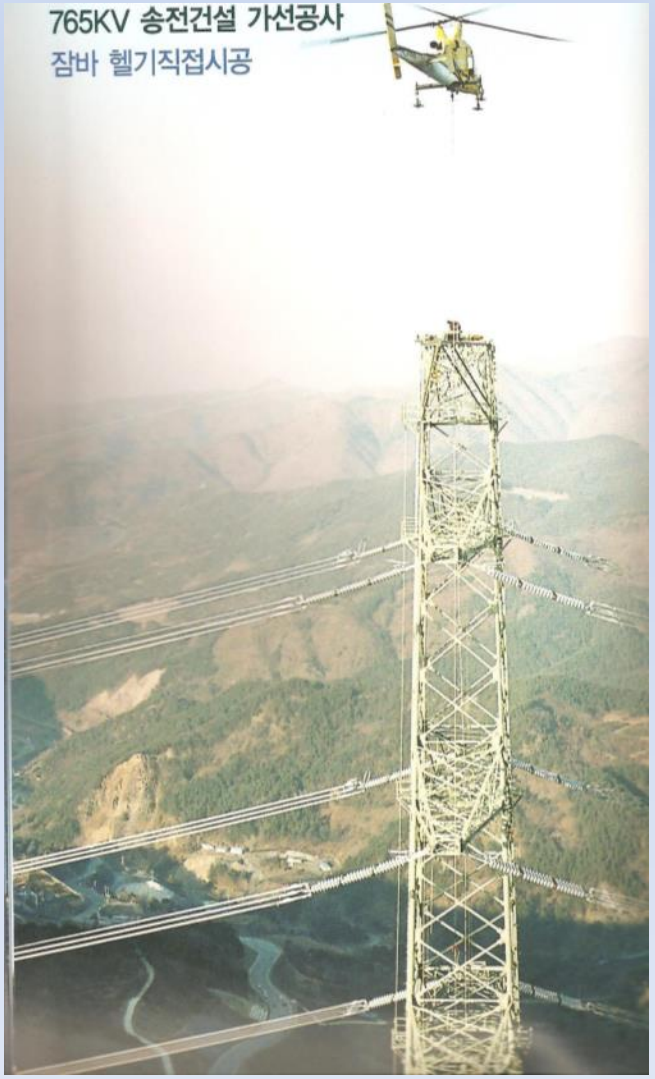
Figure 15.13-6 Spacer used for eight-conductor bundle (Tokyo Electric Power Company 1994).

Double-circuit vertical 765 kV line, South Korea



Korea Electric Power Corporation – South Korea

- Committed to expanding their grid with 765 kV in the early 1980's to support the country's economic growth
  - Rapid growth
  - Larger generating stations
  - 345 kV was not adequate to transmit the required large blocks of power
- First double circuit 765 kV line



Korea Electric Power Corporation – South Korea

- Insulation varied with contamination levels and elevation
  - 28 discs in clean areas at low elevations
  - 58 discs in heavy contaminati areas at high elevations

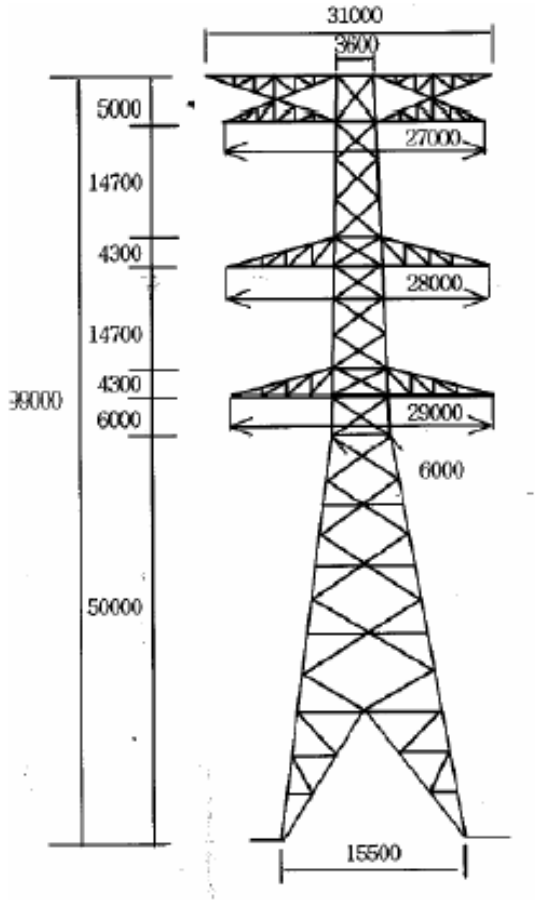


Figure 15.12-1 KEPCO 765-kV suspension tower.

Korea Electric Power Corporation – South Korea

- A 6 conductor bundle was used
  - LN-Grackle conductor
  - Raised strands used to increase drag and limits the possibility of Aeolian noise

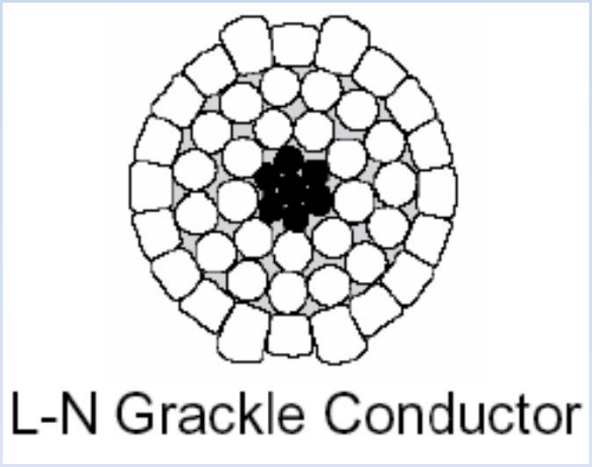


Figure 15.12-5 Cross-section view of a LN-Grackle conductor.

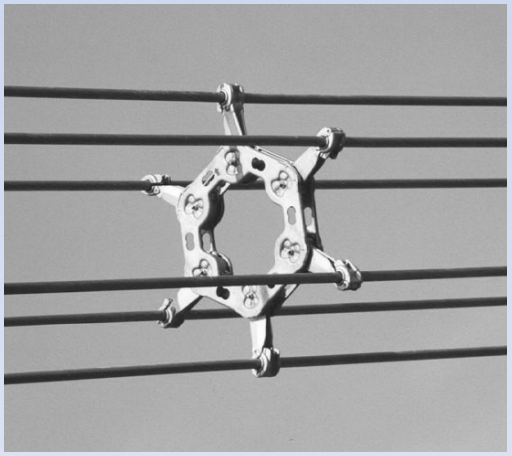


Figure 15.12-6 Six-conductor bundle spacer damper.

Korea Electric Power Corporation – South Korea

- Tower main members are steel tubular pipes
  - Work staging platforms were installed at hillside tower locations to minimize environmental impact of construction
- Typical tangent tower is 300' tall
  - Each tower can accommodate a gas-powered car as an elevator

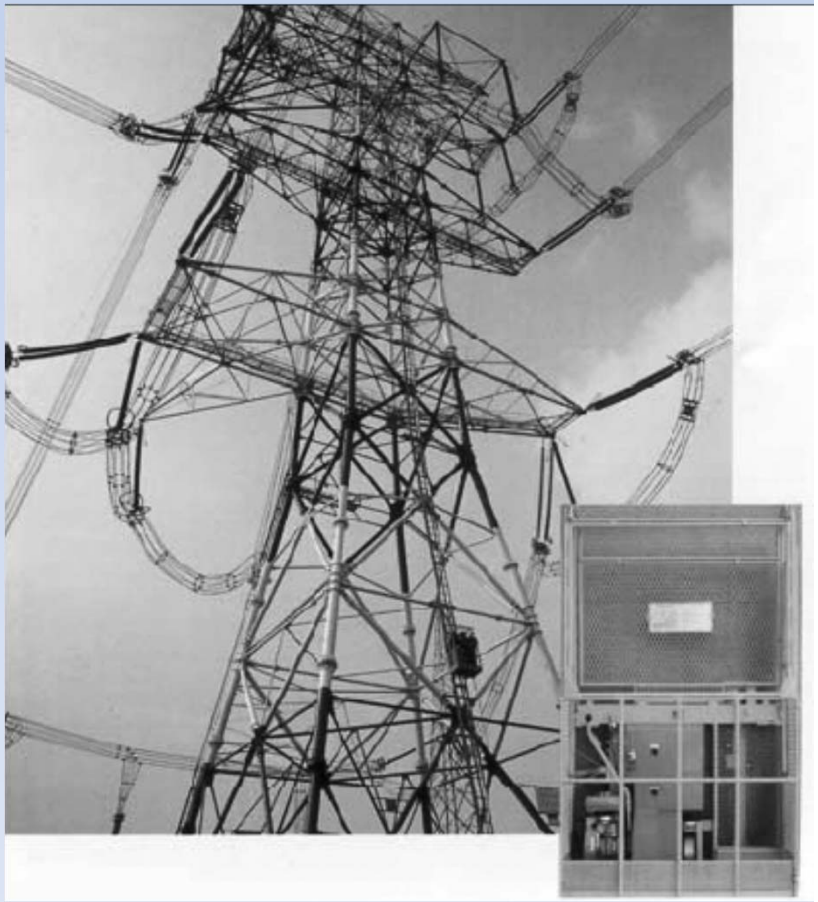


Figure 15.12-3 765-kV tower showing elevator and its rail.

1200 kV, India

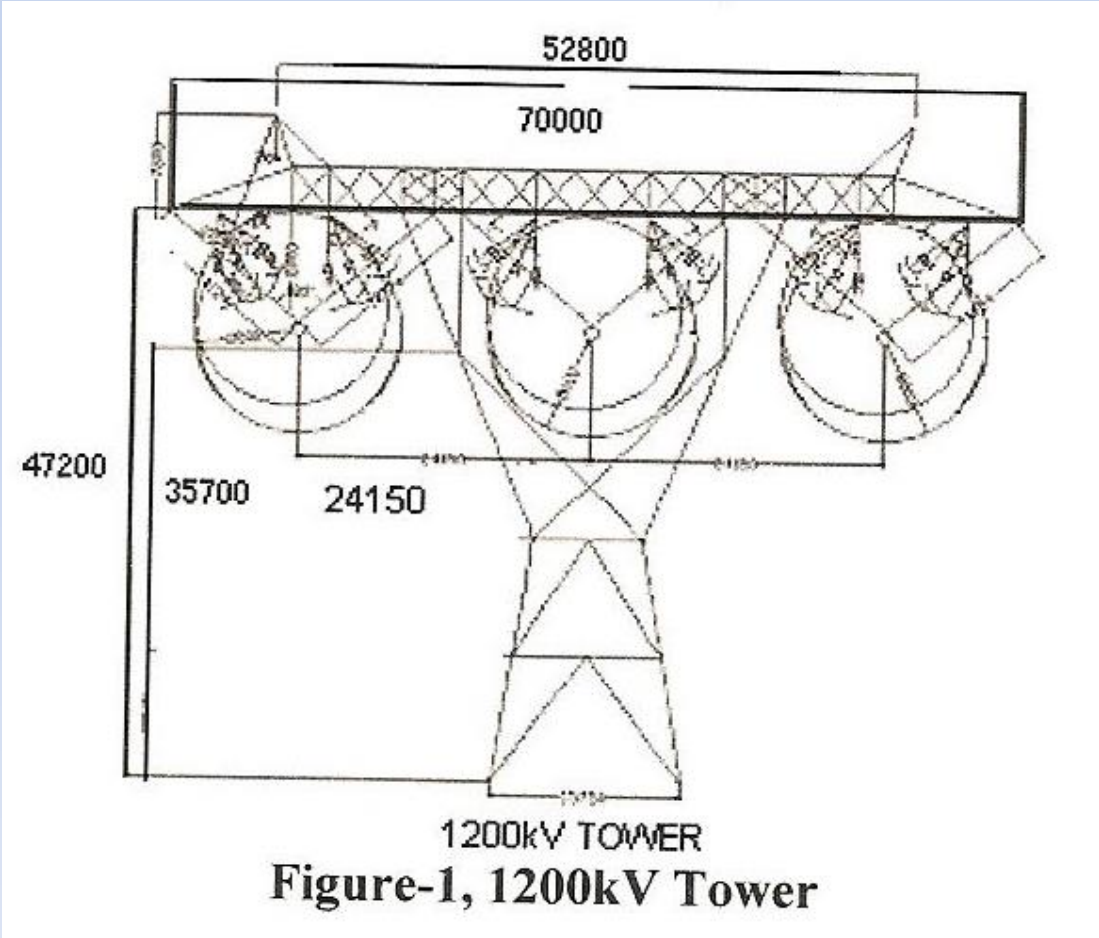


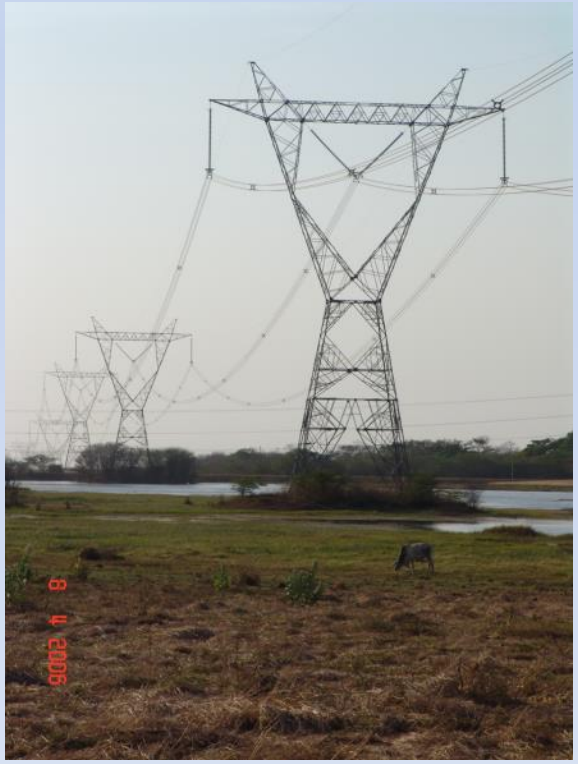
Figure-1, 1200kV Tower

Towers support conductors

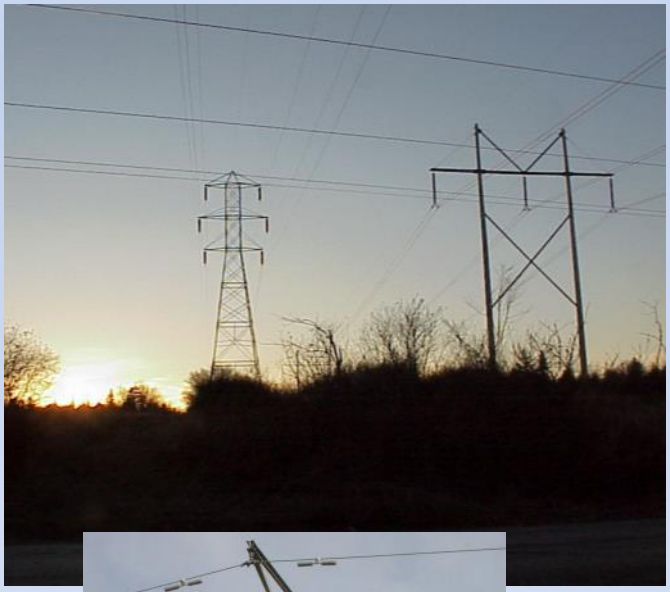
- Some towers are small, some are very massive, some are very pretty
- Made of wood, steel, concrete

사진내용 : 765kV 송전철탑 헬기이용 내장애자련 취부

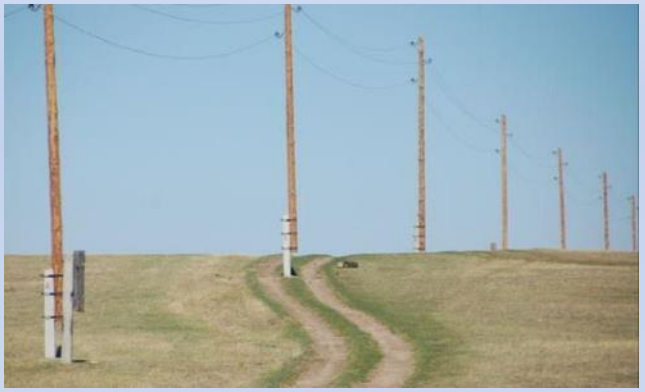
More towers

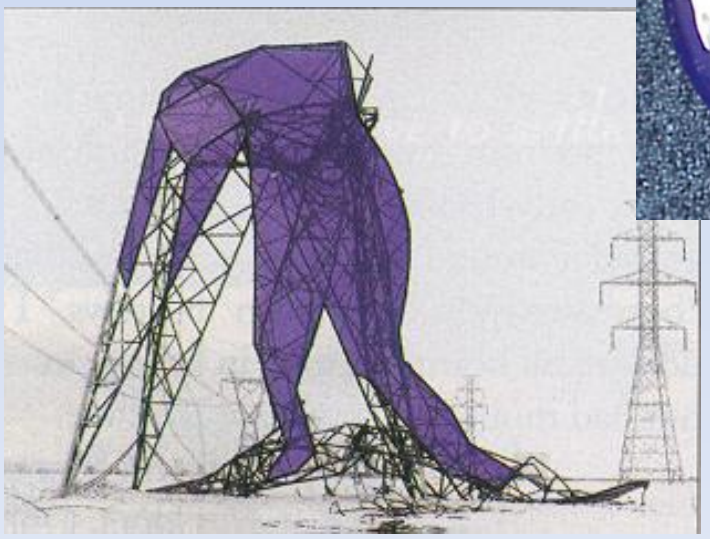


Some tower carry one line, some two or more

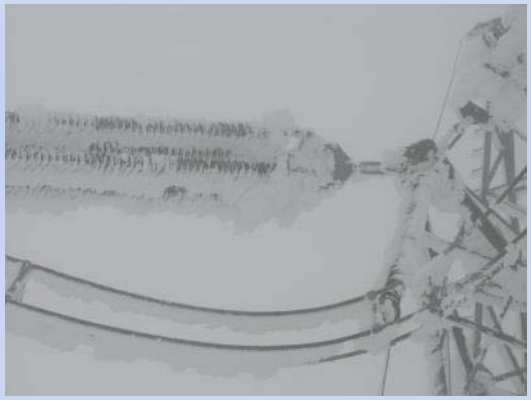


Some towers and lines fail





Some towers and lines have problems



Work has to be done on tower and lines

BETC

Thank you!

text