UHV Transmission lines worldwide
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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?

• 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!!!
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
Recognize anyone?

- 1959 - today
History of the R&D at Lenox, and Evolution of the Redbook

Recognize anyone?

1960
The GE Transformer Plant: 1950
Looks familiar?
1883 – Pittsfield Electric Light Company formed

1886 – William Stanley invents the transformer. Great Barrington becomes first town to have electricity

1912 – GE opens Power Systems Div. In Schenectady, NY

1958 – GE builds lab in Lenox to study EHV / UHV systems

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

- Main test line
- River
- Impulse generator
- Fog chamber
- 866 kV transformers
- HVDC converter
- Office
- Corona cage
Redbook Seminar – Lenox
Research at other labs

- 1979
- South Korea
- Japan 1000 kV sub
- China
- China
- 1977
- Transmission Line Reference Book HVDC TO ±600 kV

Books and references related to power transmission systems.
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, Canada

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
- 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 technical considerations
  – Land cost minimal
  – Environment given limited attention (compared to the West)
• First 750 kV line
  – 1967, 55 miles long
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
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 contamination areas at high elevations
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
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
Thank you!