AC to DC Line Conversion

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HVDC Lines and Cables Course

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Industry Needs

- Need more transmission capacity to meet load demand
- Less incentives to build new lines - deregulation
- Difficult to get new rights-of-way

Solutions

- Maximize the use of existing AC transmission Corridors

- Many options
  - Dynamic Ratings
  - FACTS Controllers
  - HTLS Conductors
  - AC to DC line conversion

- Each option provides different benefits at different costs

What does AC to DC Conversion mean / Implications

- Structures – No change
- Conductors – No change
- Insulators – Re-insulation is required
- Terminal substations – DC converter stations have to be built
- Repermiting for DC

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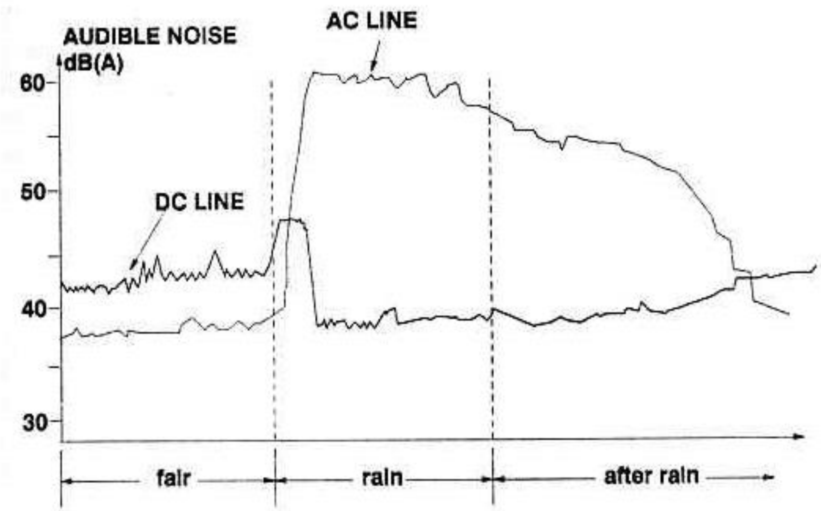
Options for Power Increase

Voltage

- Increases in voltage level above peak of AC wave is possible
- Certain limiting factors need consideration
  - Corona
  - Insulation
  - NESC
  - Ground level E-fields



Current

- Thermal limits only
- No Skin effect in conductors
  - Loss Reduction: Approx. 2/3 of AC
- Voltage constrained AC lines can be taken to thermal limits

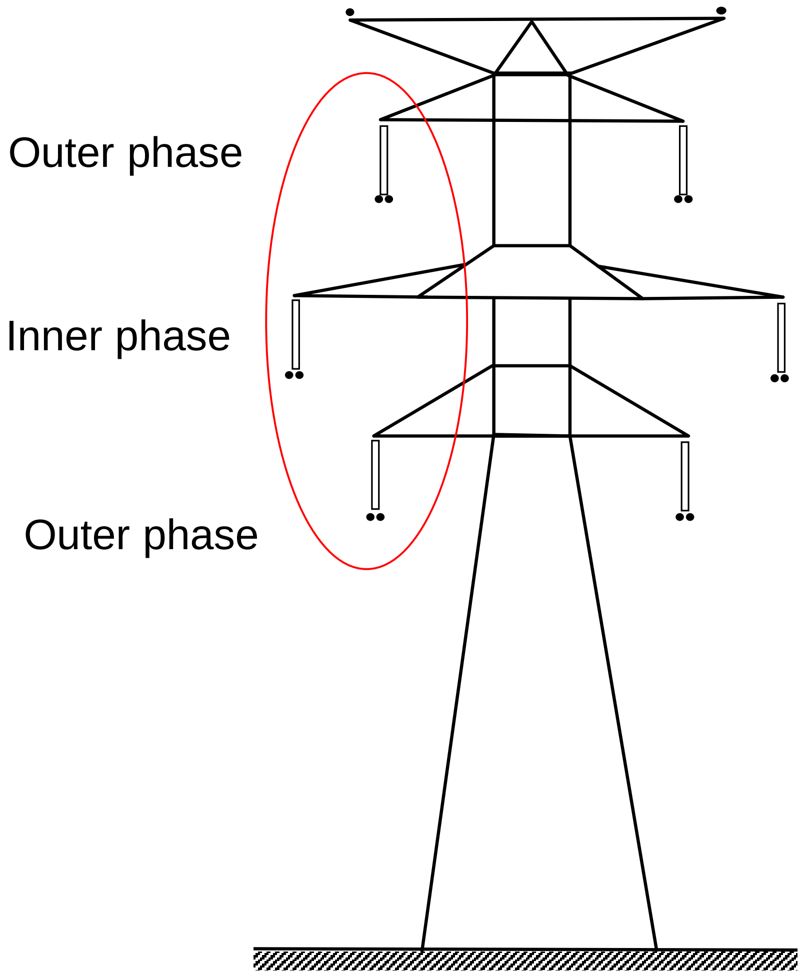
Configuration options

Single Circuit

- Outer phases used as a traditional Bipole – centre phase used as emergency metallic ground return
- Tripole configuration

Double Circuit

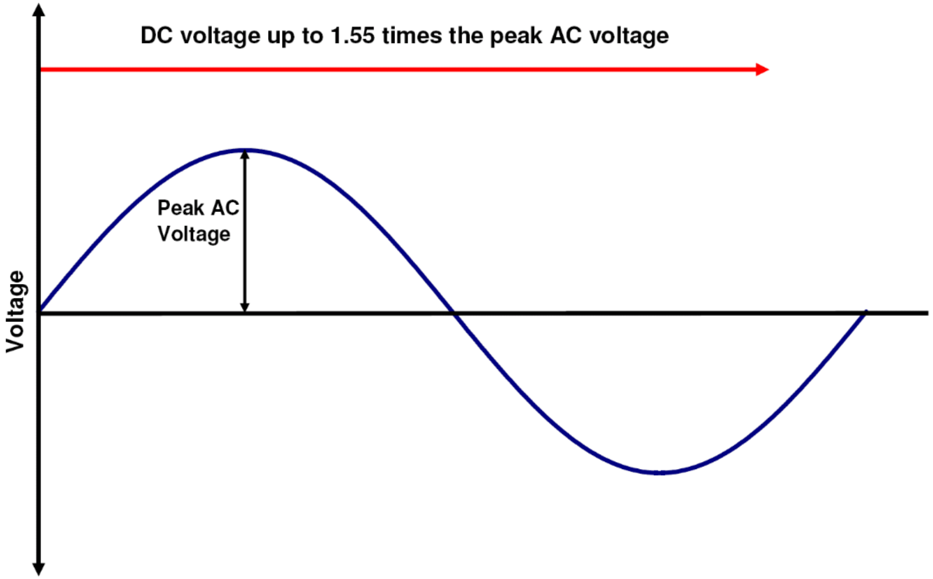
- One circuit converted – as above
- Three conventional Bipoles
- A single Bipole (3 bundles making up a single pole)
- Two Tripoles



DC Voltage Limiting Factors

- Conductor gradient
- Ground-level electric field
- Clearance for insulators at the structure
- NESC clearance to ground
- Live Working Clearances

A DC voltage of up to 1.55 times the AC l-g peak voltage can often be achieved.



DC Power also depends on Max DC Current

While AC Current is limited by:

1. **Surge Impedance of Line**
2. **Voltage Drop limits**
3. **Steady State Stability limits**
4. **Thermal Limits**

…DC Current is limited only by Thermal Limits

Power Gain Summary Table

	Single Circuit - Bipole	Single Circuit - Tripole	Double Circuit – 3 Bipoles
DC Voltage = 1.5 * Peak AC l-g voltage DC Current = AC Current	155%	213%	235%
DC Voltage = 1.5 * Peak AC l-g Voltage DC Current = 1.5 * AC Current	233%	320%	353%

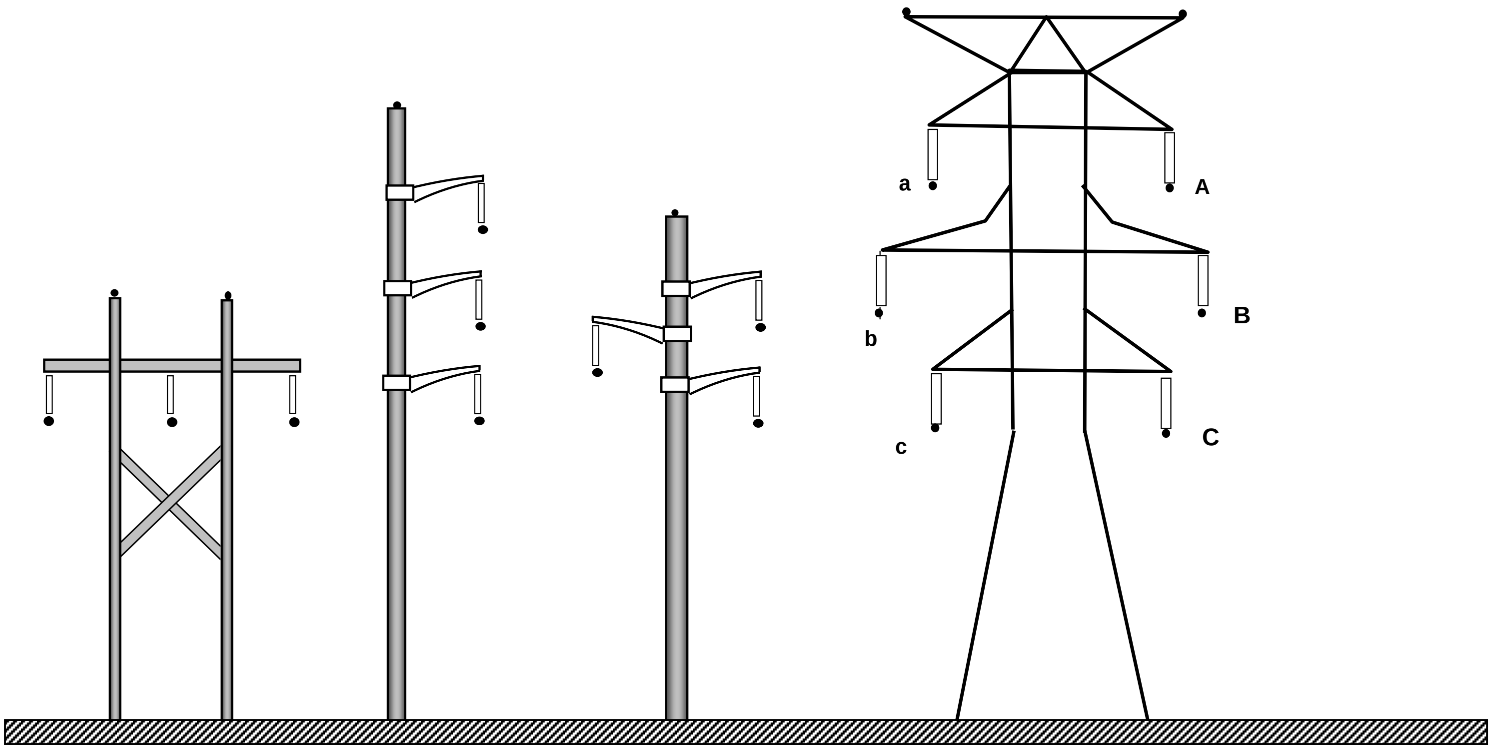
Advantages of AC-DC Conversion

- Increased power flow
- Lower % losses
- Power flow controllability
- Limitation of short circuit currents
- Line investment costs
- Asynchronous connections
- ROW – cost and environmental

Challenges

- Acceptance
- Less institutional knowledge / utility experience in DC
- Terminal station costs / justification

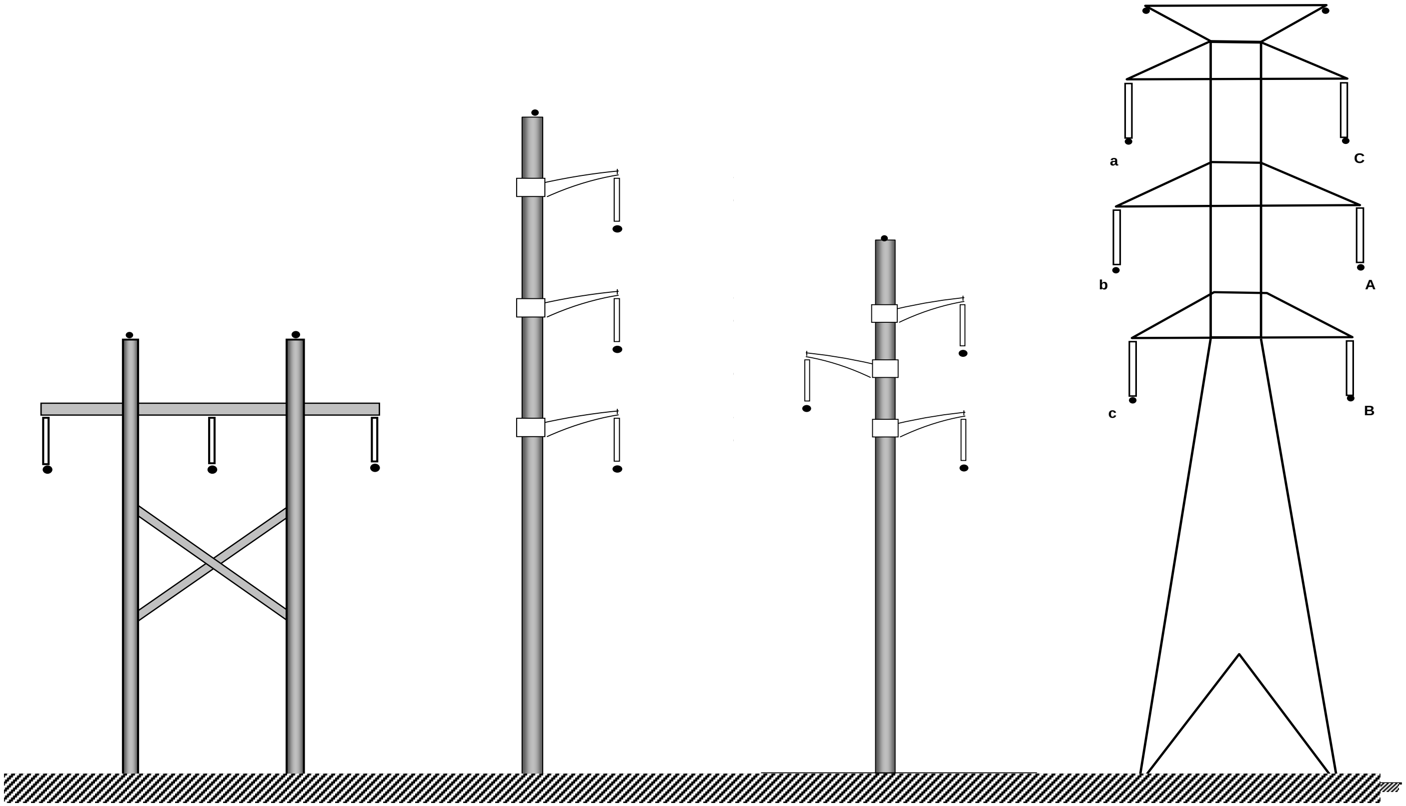
Structures Reviewed: 138 kV



ACSR:	795 kcmil
Diameter	1.106"
Insulators	8

ACSR:	2,156 kcmil
Diameter	1.735
Insulators	9

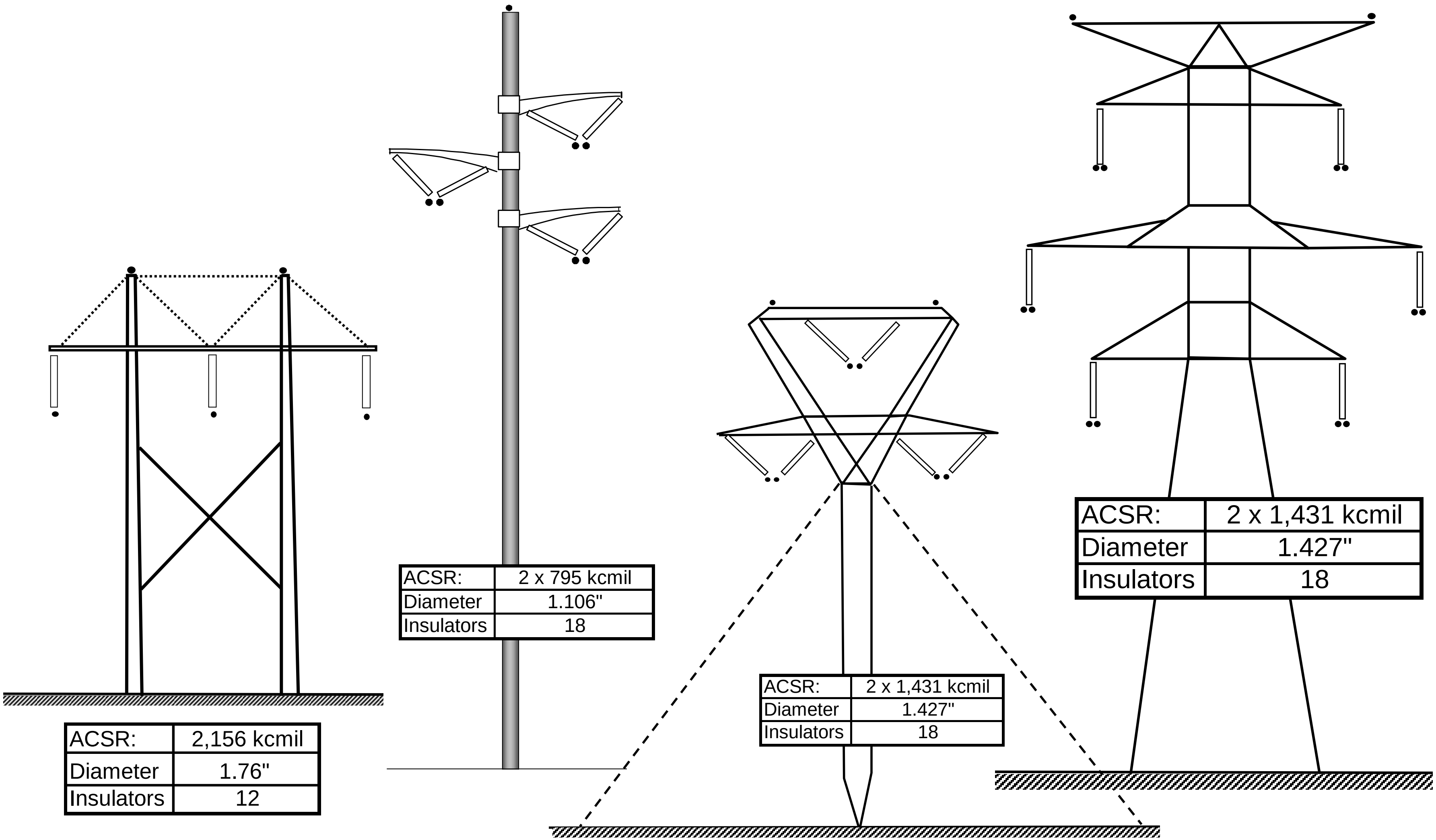
Structures Reviewed: 230 kV



ACSR:	954 kcmil
Diameter	1.196"
Insulators	12

ACSR:	1,590 kcmil
Diameter	1.502"
Insulators	12

Structures Reviewed 345 kV



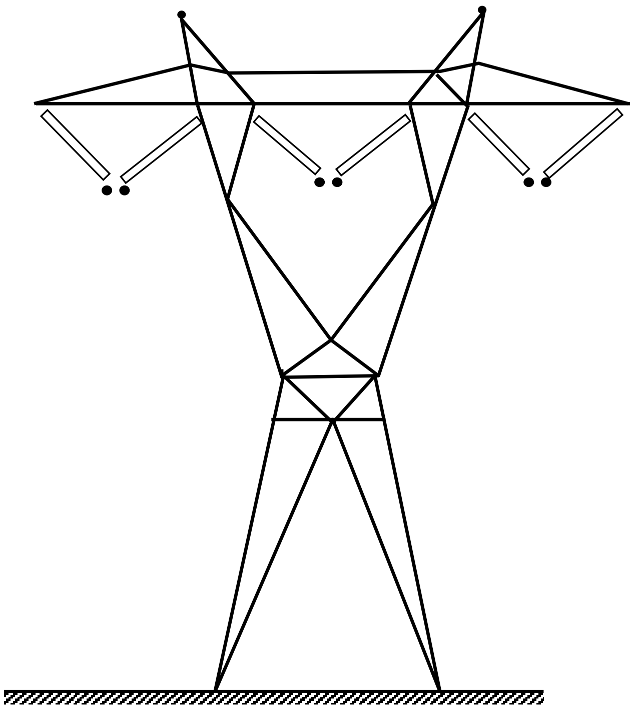
ACSR:	2,156 kcmil
Diameter	1.76"
Insulators	12

ACSR:	2 x 795 kcmil
Diameter	1.106"
Insulators	18

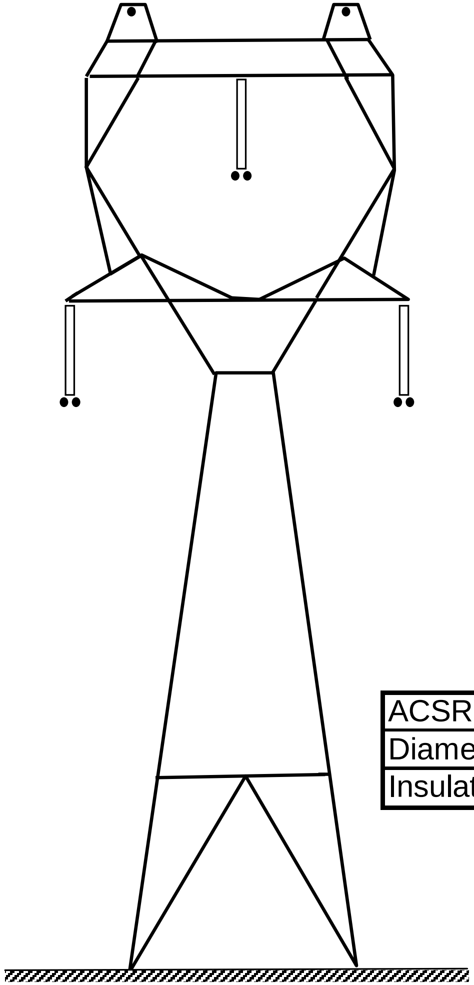
ACSR:	2 x 1,431 kcmil
Diameter	1.427"
Insulators	18

ACSR:	2 x 1,431 kcmil
Diameter	1.427"
Insulators	18

Structures Reviewed: 500 kV



ACSR:	2 x 2,048 kcmil
Diameter	1.65"
Insulators	25



ACSR:	2 x 1,780 kcmil
Diameter	1.602"
Insulators	25

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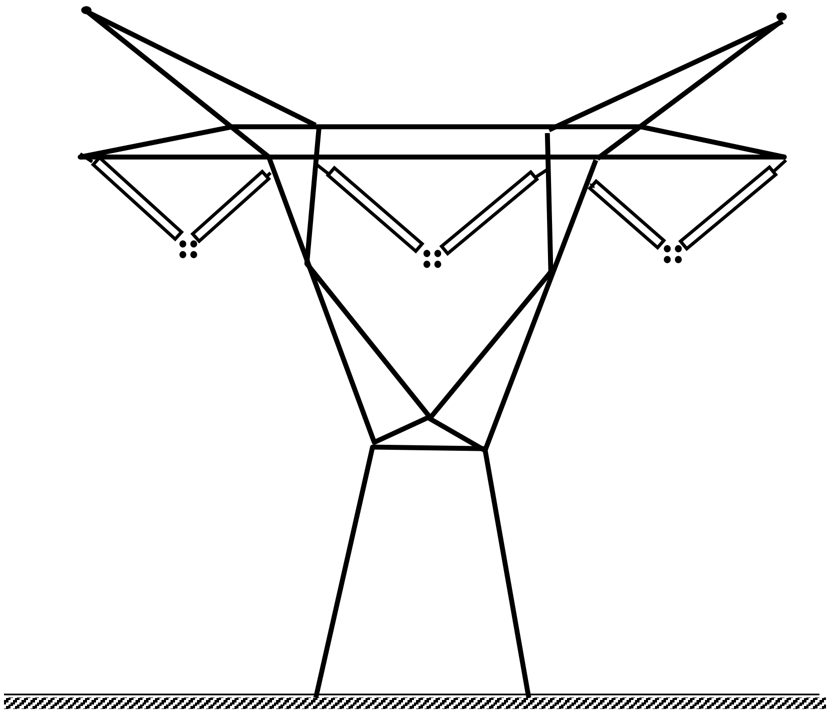
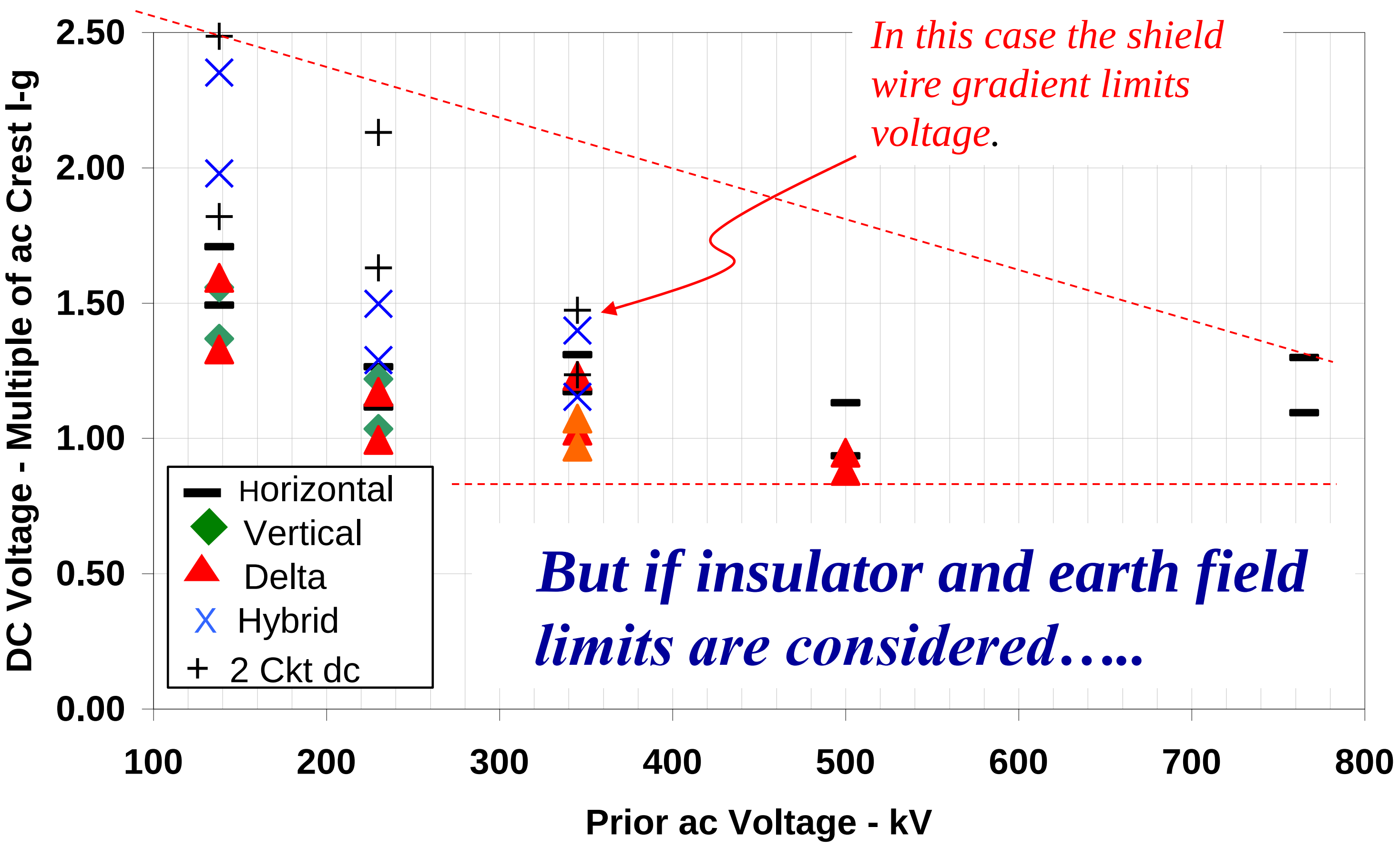
Structures Reviewed: 765 kV



ACSR:	4 x 1,585 kcmil
Diameter	1.602"
Insulators	32

Sustainable dc Voltage

Voltage constrained only by conductor gradient:



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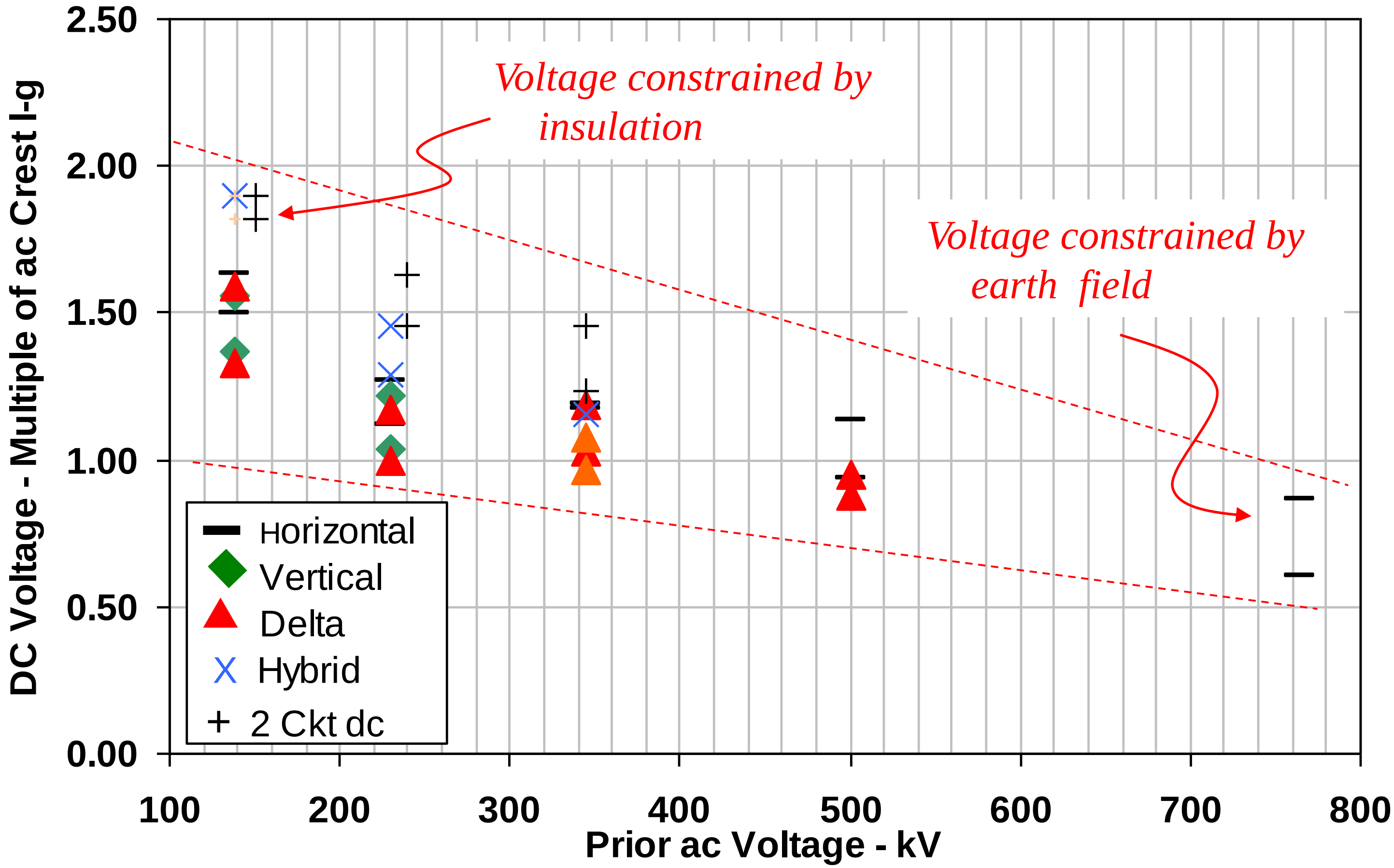
Sustainable dc Voltage

Voltage constrained by insulation and/or earth gradient:



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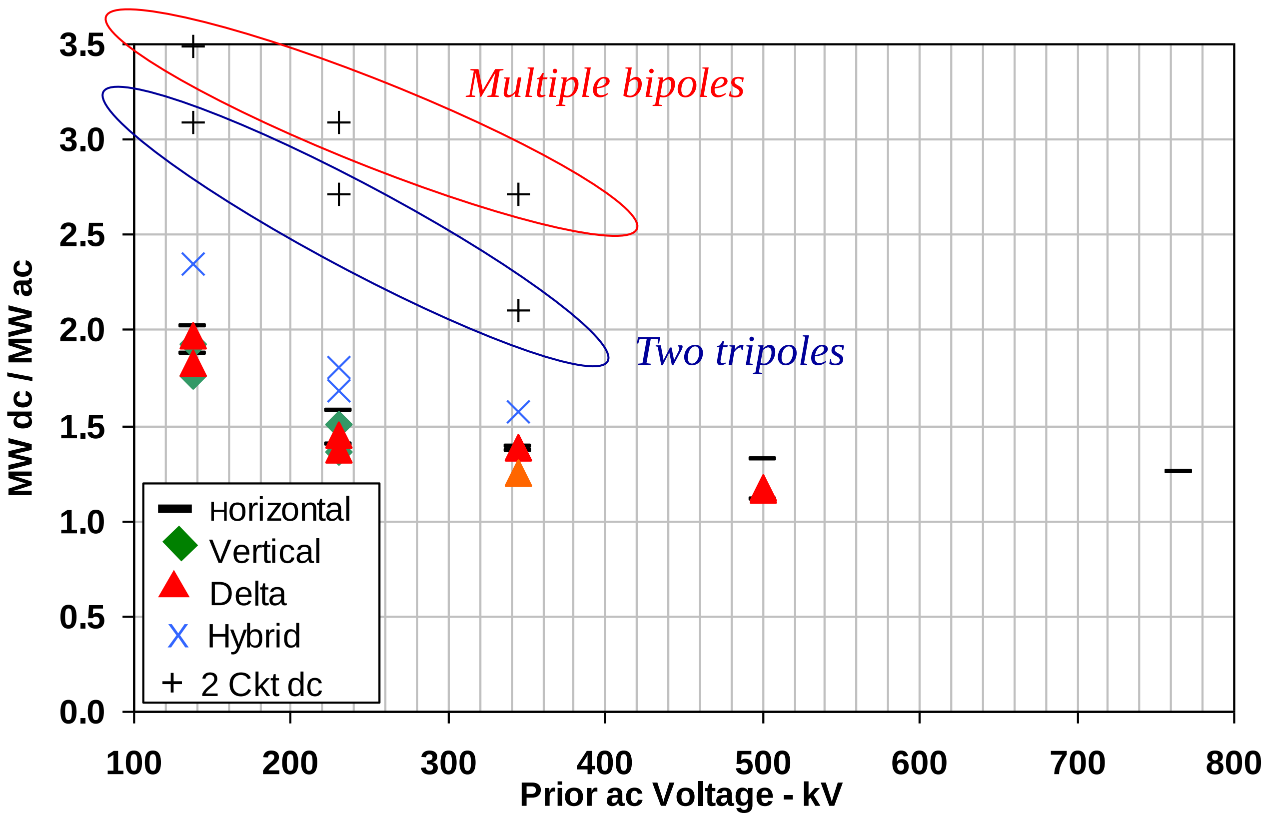
Post-Conversion DC/AC MW Ratio



DC at Max Continuous conductor rating, AC at 80% of maximum rating, pf = 0.95 (Voltage respects all constraints)

HVAC to DC Testing @ Lenox, MA
Eskom

- **Opportunity**
  - 275kV AC → ±400kV DC
  - Potential Power Flow Increase:
    - 1.5 → 1.7
- **Issues**
  - Fair Weather Noise
  - E-field on Ground
  - Insulation
  - Pole to Pole Spacing
- **Approach**
  - Testing @ Lenox, MA
    - E-Field
    - Noise: AN / RI
  - Insulation Under Consideration

Conclusions: AC/DC Line Conversion

- Conversion allows major increase in voltage at low or intermediate voltages.
- Conductor gradient usually limits V_{dc} up to 500 kV, Earth field for 765 kV.
- Where insulation is limiting, there are work-arounds
- Conversion can increase a circuit's contribution to path flow by 2:1 or more… largest gains at lowest transmission voltages.
- Conversion may increase path flow more than an additional ac circuit of like rating.
- Reconductoring along conversion can double ampacity gain

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Together…Shaping the Future of Electricity