Overhead v. Underground Transmission Lines: Factors & Analyses in Considering Placement

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Presentation to the:
EMERGING TECHNOLOGY ISSUES ADVISORY COMMITTEE
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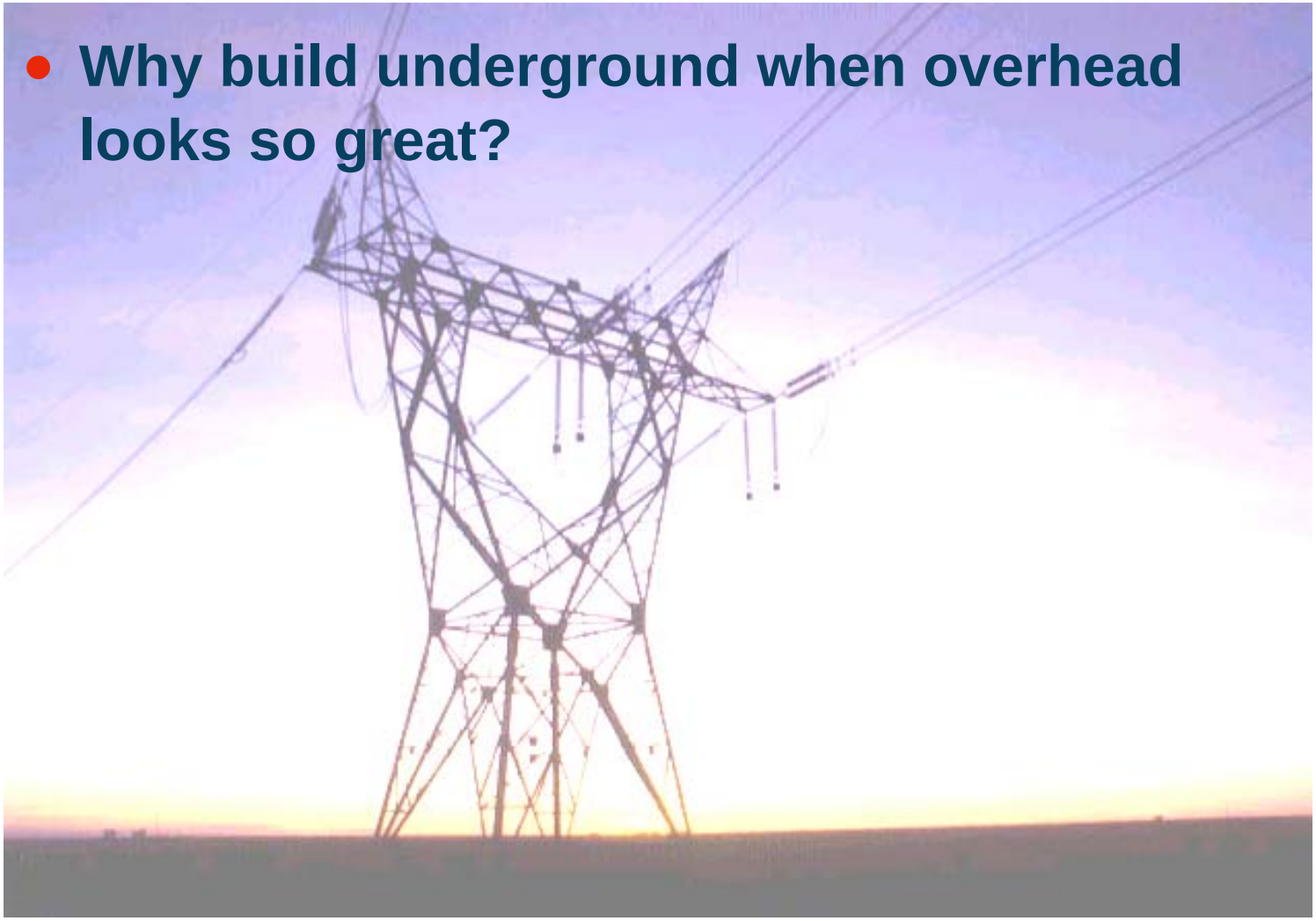
Engineer's Question



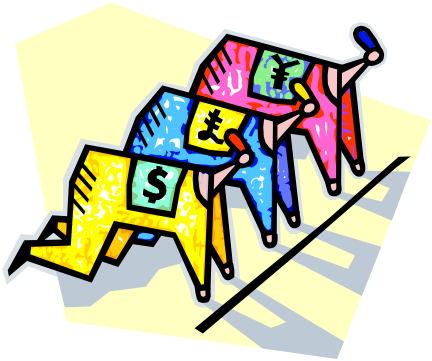
- **Why build underground when overhead looks so great?**

Note: Until it's in my backyard!

Starting Point

- Let's agree that a line is needed from Point A to Point B.

- Then consider:
  - Routing alternatives
  - Design alternatives



Routing Alternatives

- Use existing ROWs
- Identify new ROWs
  - Public lands
  - Private lands
- Special considerations
  - Bodies of water (bridges)
  - Highways
  - Parks
  - Schools

Transmission Design Alternatives

- Voltage level
- Single versus double circuit
- **Overhead versus Underground**
- AC/DC

Basic Factors in Comparing Overhead versus Underground

- Overhead is less costly but much more visible
- Underground is “out of sight” but much more expensive
- Both line types produce EMF but exposures differ
- Sometimes there is no choice
  - Urban areas
  - Wetlands
  - Mountainous terrain

Key Considerations in Choosing the Underground Alternative

- Is it technologically feasible?
- Is the cost acceptable?
- What other costs will be incurred?

Elements of Technological Feasibility

- Effects on local system
- Effects on regional system
- Risks of implementation
  - Failure potential
  - Industry experience to date

Key Challenge – Transmission Line Capacitance

- Capacitance
  - Gives a gross measure of the electric field between two conductors.
  - Present whenever two (or more) conductors carrying varying currents at different voltages are close to one another.
  - Occurs in transmission lines and fixed capacitors (used to control voltage)

- Underground cables have much more capacitance than overhead lines

Choice of Cable Type Affects Feasibility

	High Pressure Fluid Filled (HPFF)	Cross-Linked Polyethylene (XLPE)
Design/ Manufacturing	▪Proven Reliable – Over 30 years experience at these voltage levels ▪Fewer Manufacturers as Industry moves toward XLPE	▪Improving design/manufacturing techniques ▪Direction the Industry heading ▪Limited in-service experience at 345 kV
Installation	▪Mature installation techniques ▪Greater availability of experienced personnel ▪Continuous piping system between terminals	▪Duct or direct burial ▪Limited experience with splicing at higher voltages of 345 kV ▪Availability of skilled craftsmen ▪Best practice – installation of partial discharge monitors for each splice
Operation & Maintenance	▪Higher capacitance – more reactive compensation required ▪Lower operating temperature, reduces current carrying capability ▪More auxiliary equipment (cable fluid/pressurization system, piping cathodic protection)	▪Lower capacitance ▪Higher operating temperature – may eliminate 345 kV series reactor required for line out conditions ▪Cautiously optimistic about going forward reliability ▪Operating temperature can be continuously monitored by sensors
Environmental Impact	▪Fluid filled ▪Usually installed as 3-phases in one pipe, which cancels out the EMF	▪Solid core ▪Usually installed as a single-phase in each conduit creating the potential for EMF problems

Source: ISO New England, Discussion of Cable Technologies Under Evaluation for use in the Southwest Connecticut 345 kV Transmission Project, Peter T. Brandien, March 14, 2005

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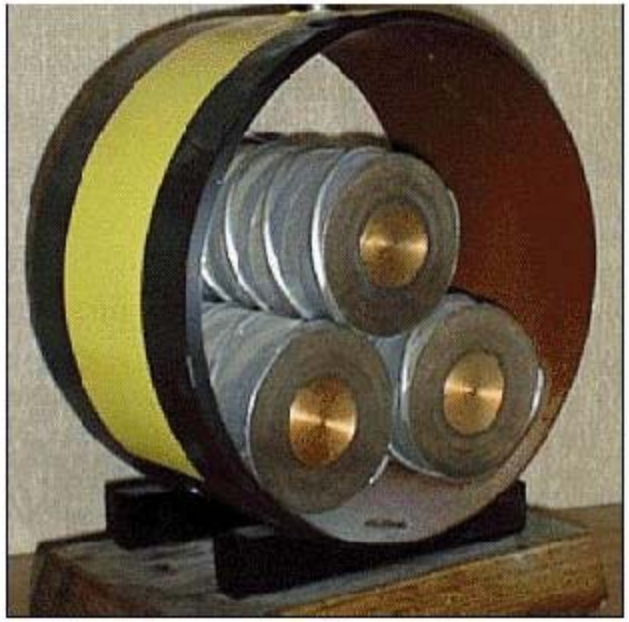
Two Types of Underground Cables



Three-Phase High Pressure Fluid Filled, (HPFF)

Single Phase Cross-Linked Polyethylene, (XLPE)

Source: ISO New England, Discussion of Cable Technologies Under Evaluation for use in the Southwest Connecticut 345 kV Transmission Project, Peter T. Brandien, March 14, 2005

Comparative Failure Rates

Cable Type	Actual (per 100 miles of cable per year)
HPFF in steel pipe	0.5
XLPE in Duct – Optimistic	0.64
XLPE in Duct – Realistic	2.02
XLPE in Duct – Pessimistic	9.93

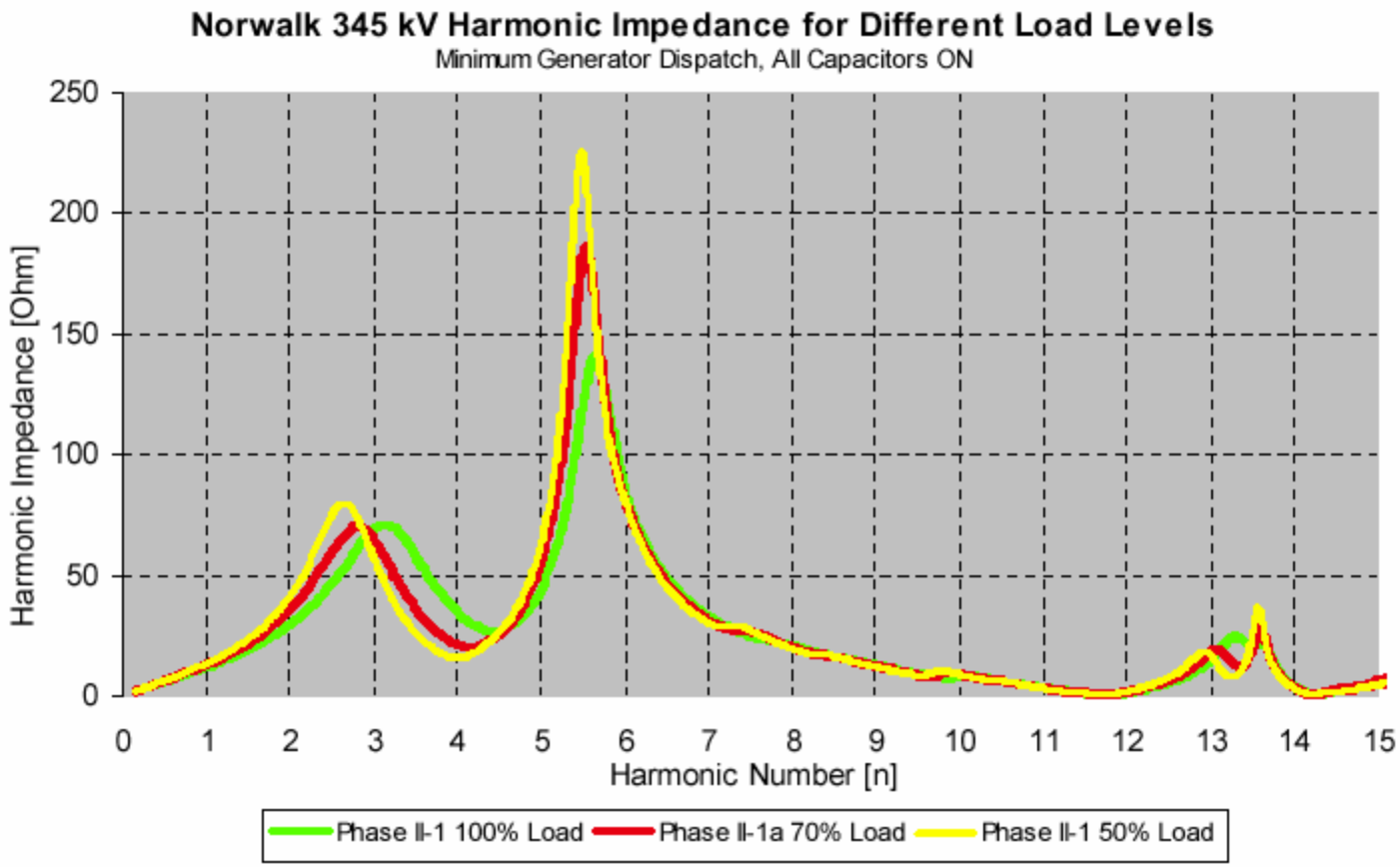
Source: ISO New England, Discussion of Cable Technologies Under Evaluation for use in the Southwest Connecticut 345 kV Transmission Project, Peter T. Brandien, March 14, 2005

Analyses Used to Evaluate Feasibility

- Thermal & voltage
- Stability
- Short circuit
- Harmonic performance
- Transient

Harmonic Resonance – Plot 1

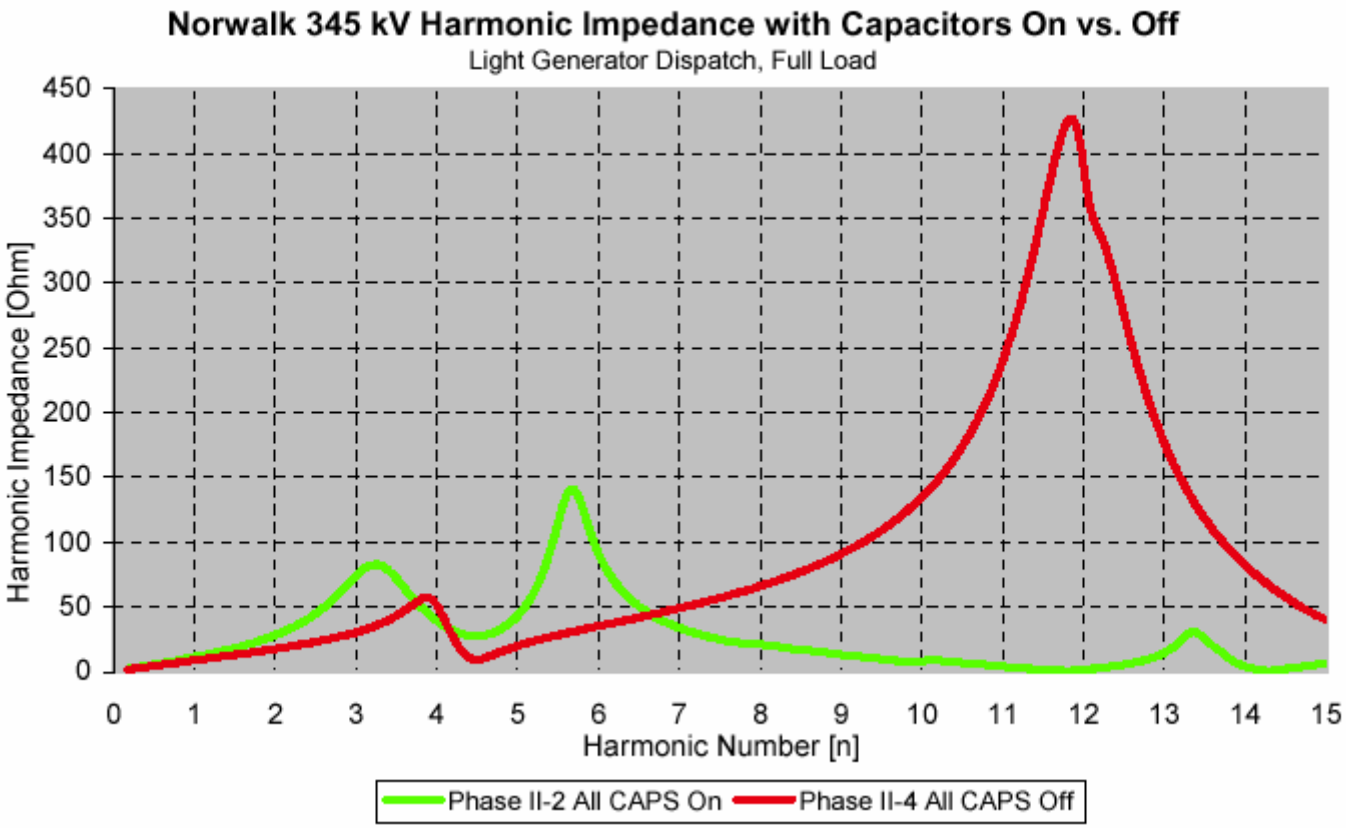
Effect of Load Variation on Harmonic Impedance of Phase II Base Case



Source: KEMA Harmonic Impedance Study for Southwest CT Phase II Alternatives

Harmonic Resonance – Plot 2

Effect of Capacitor Allocation on Harmonic Impedance of Phase II Base Case



Source: KEMA Harmonic Impedance Study for Southwest CT Phase II Alternatives

Transient Network Analysis – Why?

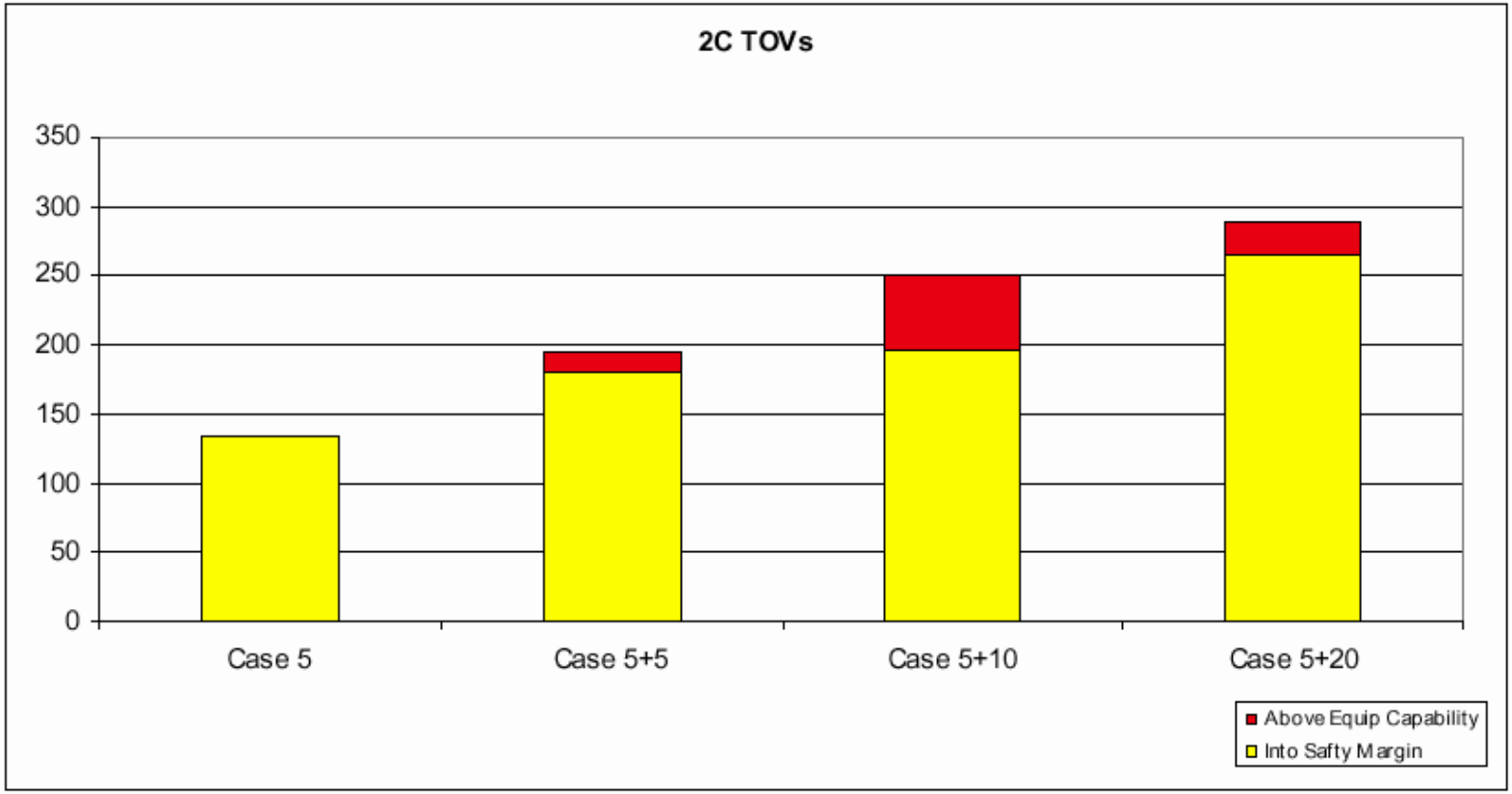
- Transient switching events cause higher frequency currents.
- These currents are amplified by harmonic resonances.
- Temporary overvoltages (TOVs) occur with potential to damage equipment and cause outages.

Temporary Overvoltages (TOVs)

- Key Concerns
  - Maximum Level
  - Duration

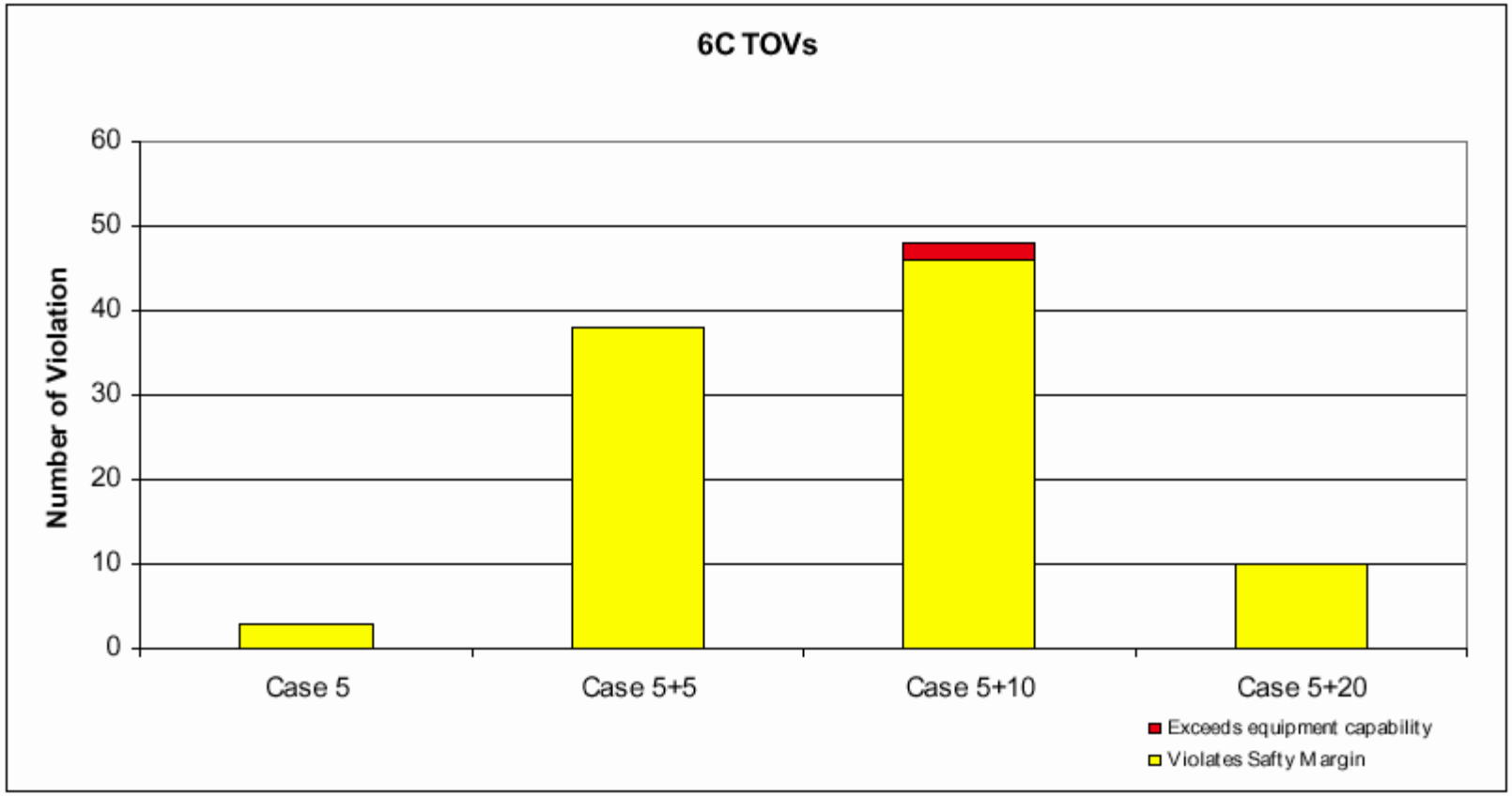
- Must be measured for:
  - Various conditions
  - Various locations

Results for Connecticut – 2 Cycle TOVs



Source: Enerex

Results for Connecticut – 6 Cycle TOVs

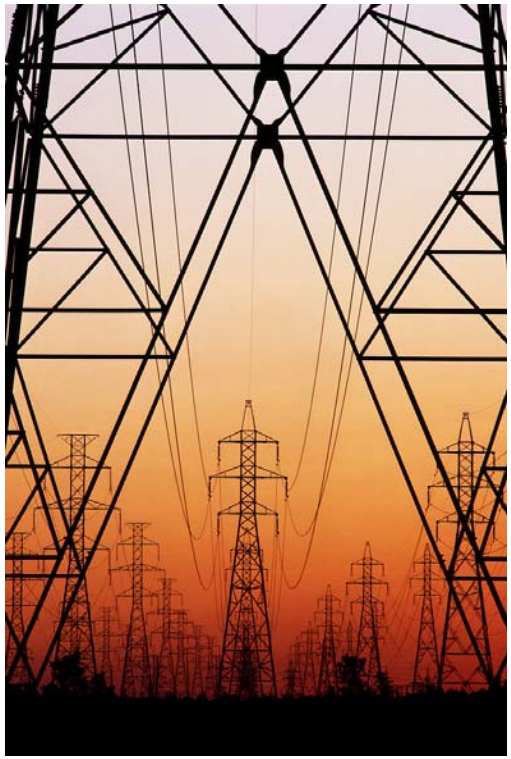


Source: Enerex

Mitigation Possibilities

- STATCOMS
  - Operational complexity unacceptable

- Filtering
  - C-Type Filters appear promising
  - Little or no industry experience for this application
  - Risk unacceptable for TOVs anticipated

Thank you.

Questions?