Spacer Cable vs. Tree Wire: Pros and Cons of two Distinct Construction Options

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Hendrix®
AERIAL CABLE SYSTEMS

A Marmon Wire & Cable / Berkshire Hathaway Company

Spacer Cable vs. Tree Wire: Outline

- Definitions
- Similarities
- Differences
  - Mechanical configuration & support
  - Site prep & maintenance
  - Tree trimming considerations
  - Animal, weather & environmental performance
  - Construction challenges
  - Costing
  - Reliability & Quality of Service
- Summary

Spacer Cable vs. Tree Wire

Definitions:

- Tree Wire
- Spacer Cable

Definitions

Spacer Cable

3 heavily covered conductors supported by a messenger and separated and hung by spacers

Tree Wire

The same heavily covered conductors strung in an **open wire** configuration on cross-arms with polyethylene insulators.

Definition: Tree Wire Systems

- Heavily covered conductor
- Utilizes a three layer cable design
- Construction using standard (or shortened) cross-arms ***OR*** armless brackets
- Mounted on polyethylene pin type (or line post) insulators

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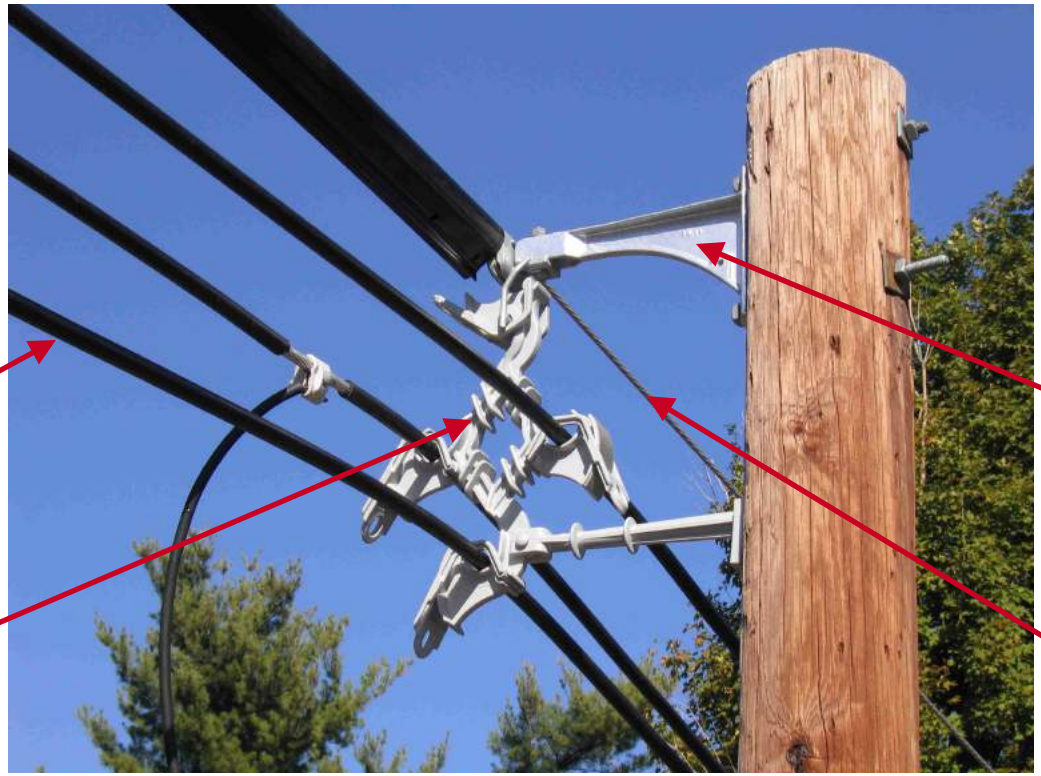
Tree Wire Systems

Definition: Spacer Cable Systems

Spacer Cable: Heavily covered non-shielded phase conductors held together and supported by a high strength messenger cable, and connected to diamond shaped spacers every 30 feet.



Spacer Cable: Single Phase

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Spacer Cable vs. Tree Wire: Similarities

What's the same?

- Tree Wire
- Spacer Cable

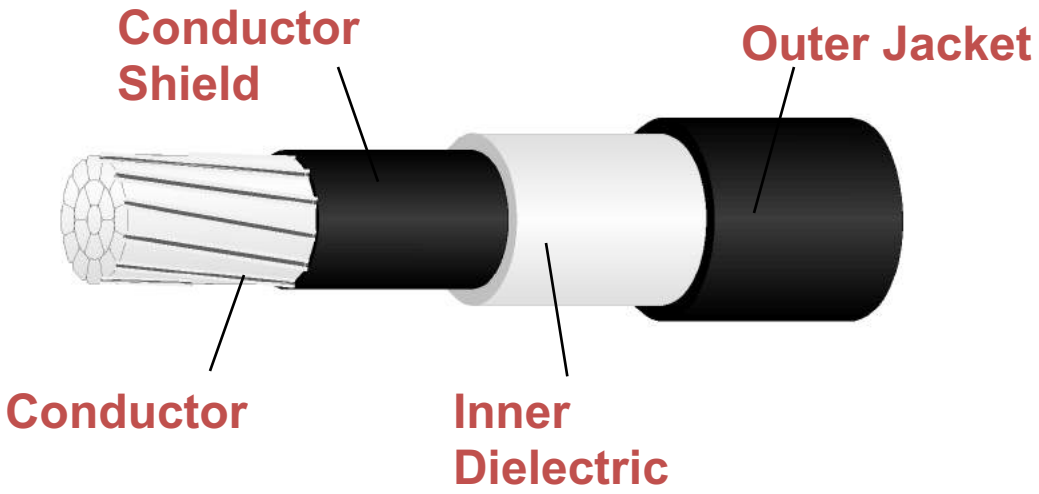
Similarities: NESC Compliance

National Electric Safety Code (NESC) Rule 230D:

Covered conductors shall be considered *bare* conductors for all clearance requirements except that spacing between conductors... may be reduced below the requirements for open conductors... when the conductor covering provides sufficient dielectric strength to limit the likelihood of short circuit ...

Similarities: Conductor design

System components: Conductor design (Identical)



Conductor Design Functionality (identical)

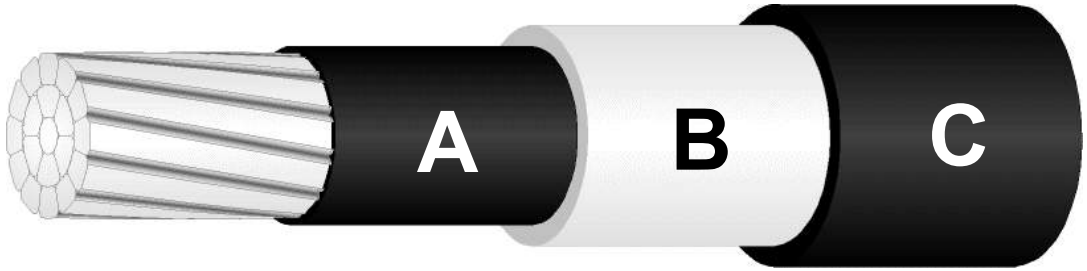
- Allows closer spacing of conductors
- Withstands temporary contact with tree branches and other ground points
- UV stable, tracking and abrasion resistant
- Low surface charging current and high impulse strength

Similarities: Insulation Layers

System components: Insulation layers (Identical)

- Semicon shield over aluminum
  - Smooths out E field
  - Reduces PD
  - Increases BIL
  - Lengthens useful service life
- Inner layer - Natural unfilled Polyethylene (HMWPE)
  - Excellent insulation – High BIL, 60hz withstand
  - Soft - easier to strip
- Outer layer - High Density Polyethylene (HDPE)
  - Track resistant
  - Abrasion and impact resistant
  - UV stability and weathering characteristics

Similarities : Insulation Thickness



Voltage Class (KV)	Thickness (inches)		
	A	B	C
15	.015	.075	.075
25	.015	.125	.125
35	.015	.175	.125
46	.020	.225	.175
69	.020	.250	.250

Spacer Cable vs. Tree Wire: Similarities

Benefits in common:

- Both require less foliage removal than bare wire
- Both eliminate temporary faults due to tree contact and incidental animal/bird contact
- Both promote environmental stewardship
  - More foliage, cleaner air
  - Birds, climbing animals protected
- Both are NESC compliant

Spacer Cable vs. Tree Wire: Differences

Differences:

- Mechanical Configuration and Support

Differences: Mechanical Configuration

Mechanical configuration

Tree Wire:

- Crossarms with Polyethylene Insulators
- Strip at deadends
- Full tension grips (can't use coated preformed grips)

  * Pre-formed grip at deadends not rec'd due to extreme tension req'd to grip conductor *over* the insulation (risk of fatigue failure insulation & circumferential cracking due to seasonal expansion/contraction)
- System has "bare" spots with attendant risk of temporary faults

Spacer Cable:

- Covered conductors hung from messenger with spacers
- Compact, Narrow ROW ➔ Low profile
- Completely covered system

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Differences: Conductor Type Used

Tree Wire: Self Supported – All Strength in *Phase Conductor*

- All Aluminum Alloy (AAAC)
- 6201 - T81 aluminum
- Aluminum Conductor Steel Reinforced (ACSR)

Spacer Cable: All Strength is in *Messenger*

- All Aluminum (AAC)
- 1350 – H19 aluminum
- Benefits:
  - Lower cost
  - Lighter weight
  - Higher ampacity
  - Able to compact – reduce diameter, PE used, mechanical profile, loading, poles, guys, etc.

Differences: Conductor Type Used

Notes:

- Possible to use AAC for tree wire
  - Function of conductor size
  - Span length
  - Tensile strength
  - Loading
- Possible to use AAAC or ACSR for spacer cable
  - Mechanically viable
  - Not economical
  - Not beneficial from ampacity standpoint
  - May be beneficial from stocking standpoint

Spacer Cable vs. Tree Wire: Differences

Differences:

- Tree Trimming, Site Preparation & Maintenance

Differences: Tree Triming

Conventional Bare Wire
or Tree Wire

Hendrix Spacer Cable

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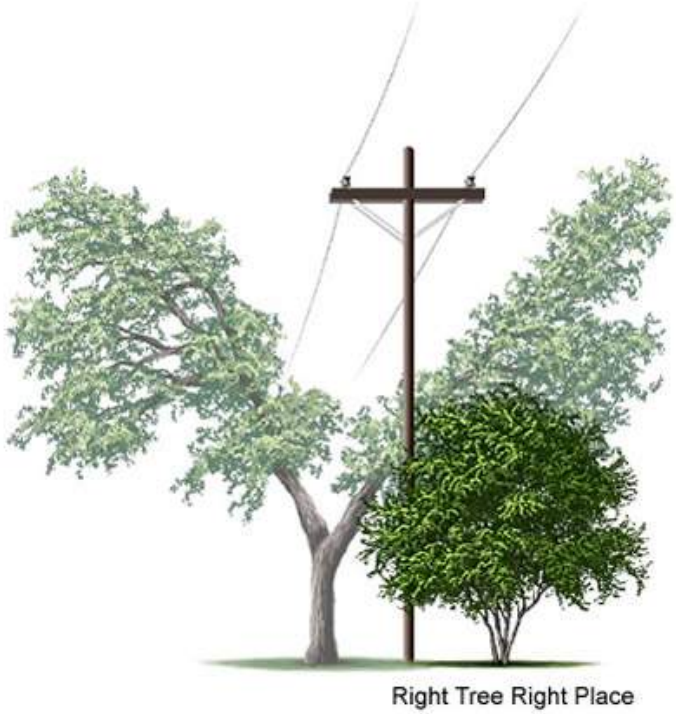
Differences: Tree Trimming



Conventional Bare Wire
Or Tree Wire

Hendrix Spacer Cable

Differences: Maintenance

	Tree Wire	Spacer Cable
Tree trimming	• Periodic • Clear large limbs • Keep foliage off phases	• Periodic • Clear large limbs • Keep foliage off phases
Spare parts	• Conductor Dead-End Grips & Splices • Cable • Polyethylene Insulators • Covered Tie Wire • Stripping tool	• Conductor Dead-End Grips & Splices • Cable • Polyethylene Insulators • Covered Tie Wire • Line-Duc • Messenger Dead-End Grips & Splices • Messenger

Difference – Tree Wire requires more patrolling since, while large limbs lying across phases won't cause outages, they will eventually cause abrasion and possibility of insulation damage

Differences: Costing

Costs: Materials, Installation, Site Preparation and Maintenance

	Cost Comparison to Bare Wire	
	Tree Wire	Spacer Cable
Material Cost	15% higher than bare wire	25% more than bare @ 15 kV & 10% more than tree wire @ 15 kV; Higher % increase for higher kV classes
Site Preparation	Same	Significantly less tree removal
Tree Trimming	Same	50-80% less foliage removal
Installation	Same	Same or less (depends on crew training)
Maintenance	Same/More	Less than either bare wire or tree wire

Spacer Cable vs. Tree Wire: Differences

Differences:

- Animal, weather, & environmental performance

Differences: Animal Contact Performance

Bird and Animal Contact

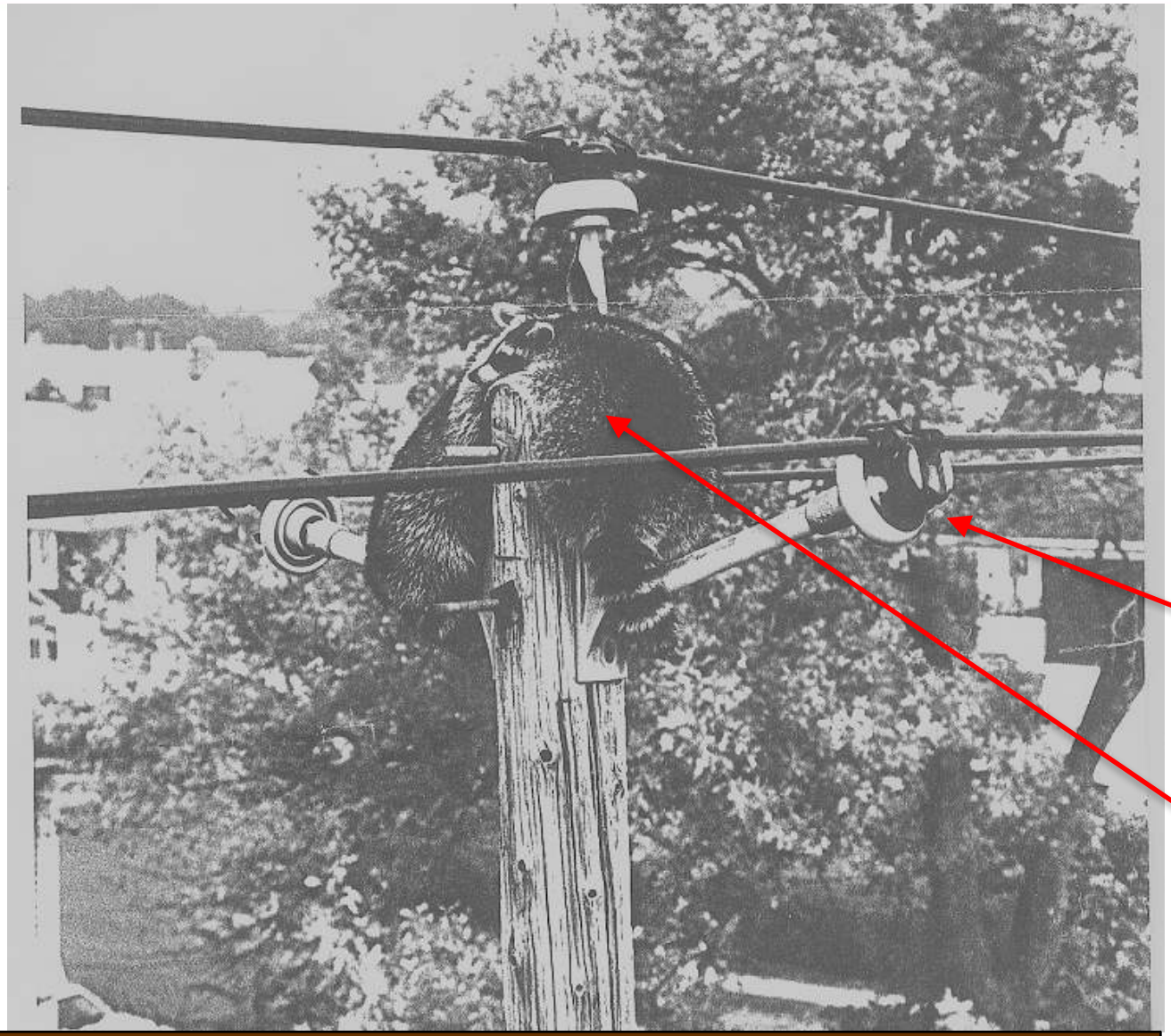
Tree Wire:

- Provides temporary fault protection
- Absence of covering at conductor ends poses safety hazard to birds and animals

Spacer Cable:

- Completely covered system eliminates safety hazard

Tree Wire: Bird and animal contact



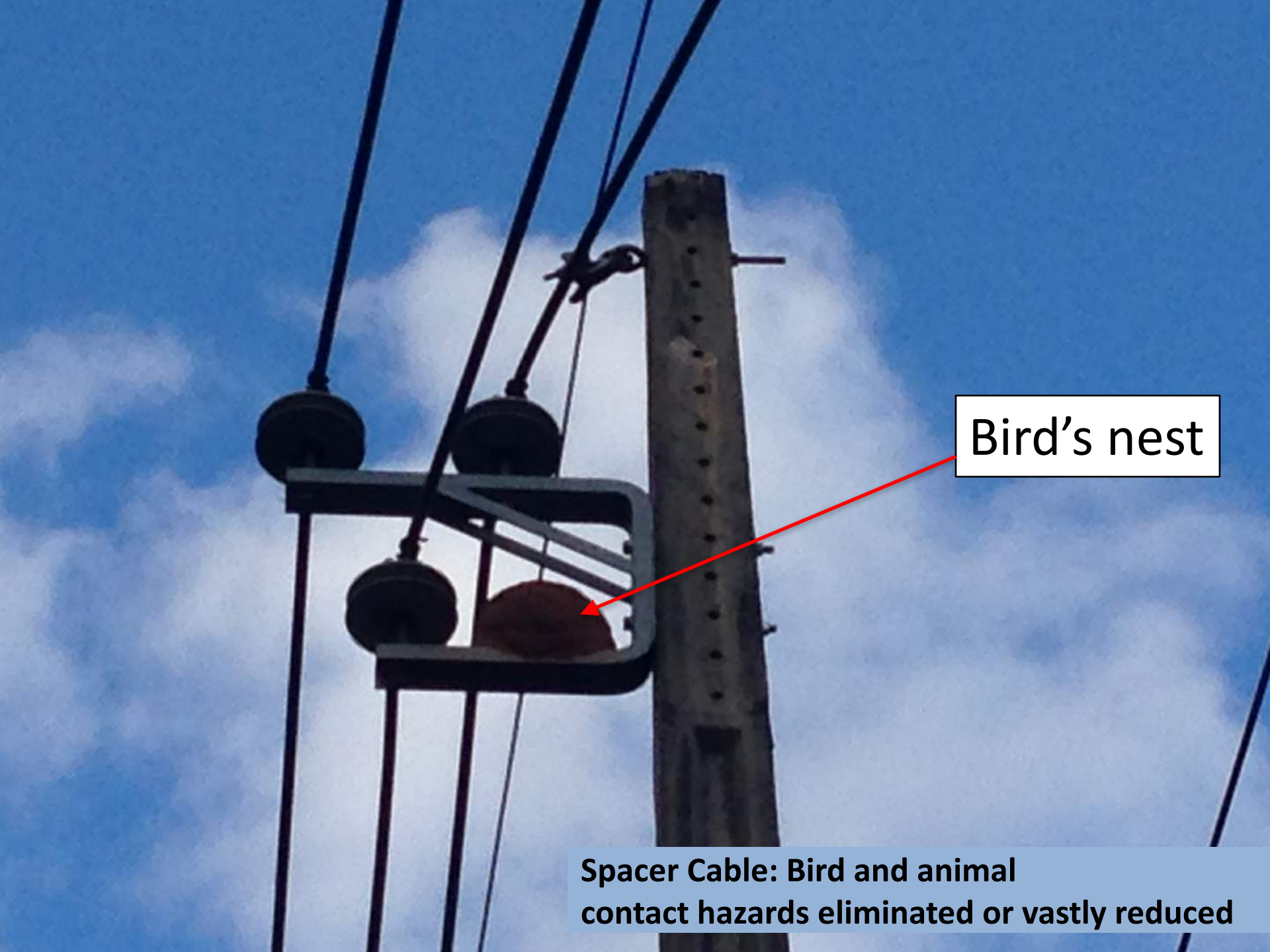
Tendency to use wrong components

- Porcelain Insulators
- Deadend shoes
- Stripping
- Etc.

Porcelain Insulators Incorrect

Safety hazard to birds and climbing animals

Vulnerability to Component Selection Errors



Spacer Cable: Bird and animal contact hazards eliminated or vastly reduced

Spacer Cable: Bird and Animal Contact

Wildlife protection

Tule Lake National Wildlife Refuge, California

Differences: Environmental Resilience

Spacer Cable:
Resilience to seacoast contamination
Massachusetts 15kV

Differences: Harsh Weather Performance

Tree Wire:

- Provides temporary fault protection
- Resilient to small tree limbs; however, branches may lie across the conductor, eventually causing abrasion leading to insulation damage, future outages
- Fallen trees or large branches may knock system to ground, resulting in outage
- Conductor breaks before pole

Spacer Cable:

- Considered more robust in extreme weather due to mechanics of design
- Overhead messenger protects the phase conductors from trees/branches
  - Protects line from fallen trees
  - Keeps trees/branches from causing outages
- Usually fallen tree supported by messenger
- Large impact may cause poles to break
- Line stays energized ➔ no outage

Differences: Harsh Weather Performance

69 kV Spacer Cable PEPCo - Washington, DC

Spacer Cable: Banff National Park, Alberta, CANADA


Spacer Cable: ENSA, PANAMA

Differences: Harsh Weather Performance

Spacer Cable: Large tree down, line stayed energized

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Differences: Harsh Weather Performance

Spacer Cable: Large tree down, line stayed energized

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Differences: Harsh Weather Performance

Spacer Cable: McMurdo Bay, Antarctica

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Differences: Harsh Weather Performance

Empirical Data:
Field Study

Differences: Harsh Weather Performance

European Field Study:
Spacer Cable vs. Tree Wire vs. Bare Wire
in Harsh Weather Conditions—
Deadwater Fells Test Site, England/Scotland border

Test Conditions

- 2,000 ft. above sea level
- 330 ft. spans
- Harsh weather conditions
- Sustained wind speeds 50-70 mph
- Wind gusts to 75 mph
- Temperature dropped to –8 C (19 F)

Field Test Data

- Study duration: 6 months
- Hazel (60 mm2) AAAC bare
- 50 mm2 Tree Wire 15 kV
- 50 mm2 Spacer Cable 15 kV

Deadwater Fells Outdoor Test Site - UK

Deadwater Fells Outdoor Test Site - UK

Data Collection:

Load cells

Load cells monitor tension levels in the conductors. Each conductor is also mounted with a turn-buckle arrangement to enable tensions to be altered easily. This process is carried out from a platform built specifically for the purpose of accessing all the conductor monitors.

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Deadwater Fells Outdoor Test Site - UK

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Deadwater Fells Outdoor Test Site - UK

Field Study: Tension Data (Blizzard Conditions)

Conductor	Tension on 26 February (kN/lbf)	Tension on 25 February (kN/lbf)	% change
Bare Hazel 60 mm2	3.23 (725)	6.02 (1353)	86%
Tree Wire 50mm2	1.54 (346)	4.90 (1101)	218%
Spacer Cable 50mm2	11.08 (2490)	19.96 (4485)	80%

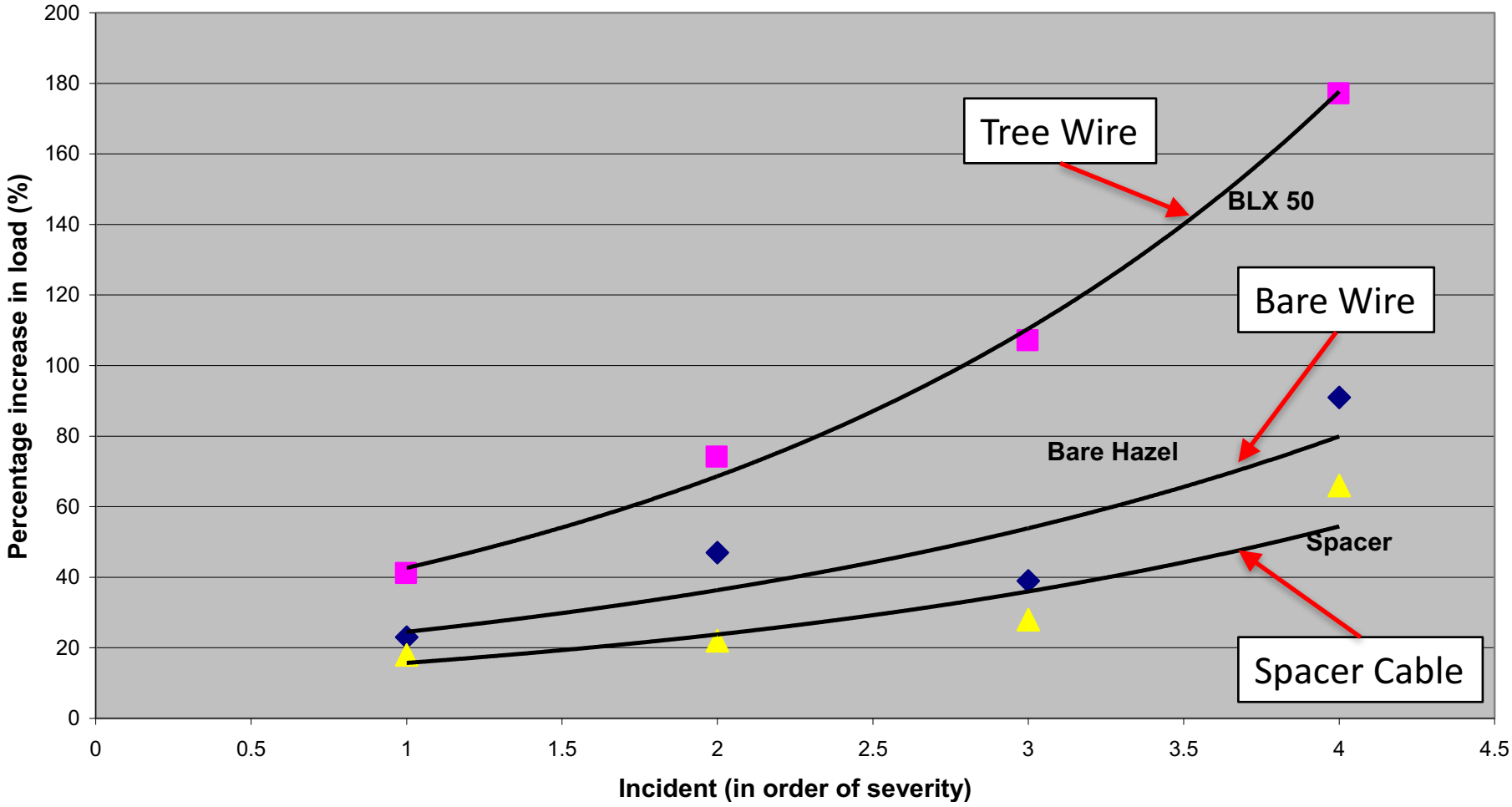
Change in tensions during the ice/blizzard conditions in Weeks 8/9, 2002

Conductor	Tension on 26 February (kN/lbf)	Tension on 27 February (kN/lbf)	% change
Bare Hazel 60 mm2	3.23 (725)	6.76 (1519)	110%
Tree Wire 50mm2	1.54 (346)	5.37 (1207)	249%
Spacer Cable 50mm2	11.08 (2490)	22.93 (5153)	107%

Change in tensions during the blizzard conditions in Week 9, 2002

Deadwater Test Results: Wind Only

Effect of increasing wind severity against percentage load change.



- Spacer cable (triangles) always exhibits the lowest % increase in load
- Bare wire (diamonds) tends to be worsen as winds increase
- Tree Wire (squares) is the most greatly affected by the wind

This may be expected as the tree wire has the largest size/weight ratio

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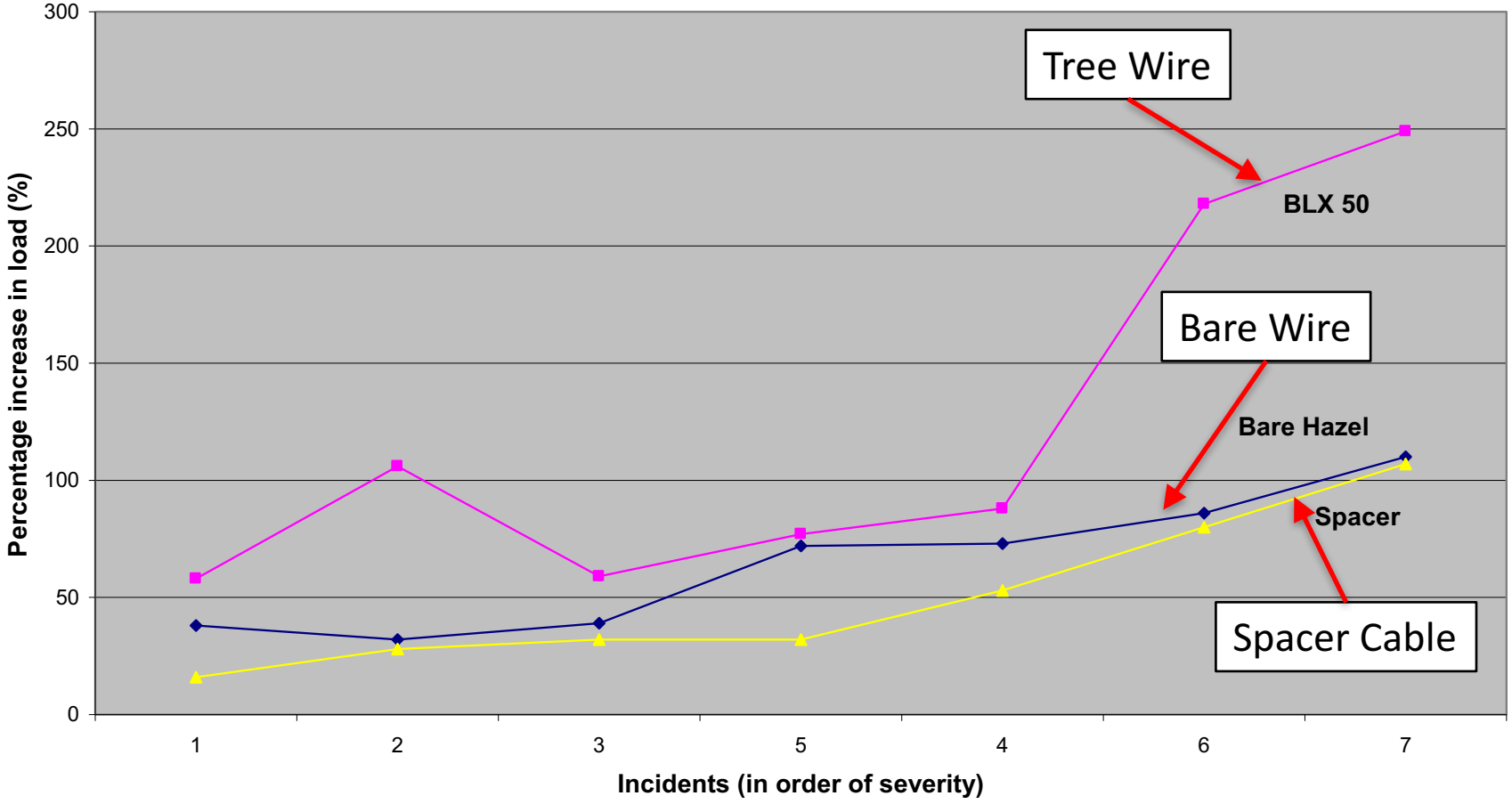
Deadwater Test Results: Effect of snow/ice against percentage load change

Figure 4.2 Snow/ice effects on conductor loads



- Spacer Cable (lower yellow line) is always the best performer
- In most cases it is only slightly better than the bare wire (middle blue line)
- Tree Wire (top line) is always worst, and is substantially the worst performer under the most severe conditions.

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Deadwater Fells UK Test - Conclusions

These graphs have tried to summarise the data in a simple graphical form. However, looking at the data generally some conclusions can be drawn:

- The Hendrix Spacer Cable has performed extremely well in very severe conditions. It has had to withstand wind gusts of hurricane force as well as severe snow and ice incidents.

- In comparison with Tree Wire System, the Hendrix Spacer Cable has accreted less snow/ice and suffered less from wind loads, especially as the weather conditions got worse.

- In comparison with bare Hazel conductor, the Hendrix Spacer Cable has generally performed better under all scenarios.

Differences: Performance

Animal Contact, Weather & Environmental Performance

	Tree Wire	Spacer Cable
Animal contact	Vulnerable at stripped points	Eliminates or vastly reduces hazard
High winds	✓	✓
Snow/Ice		✓

Spacer Cable vs. Tree Wire: Differences

Differences:

- Construction Challenges

Differences: Construction Challenges

Reduced Right-of-Way (ROW) Construction

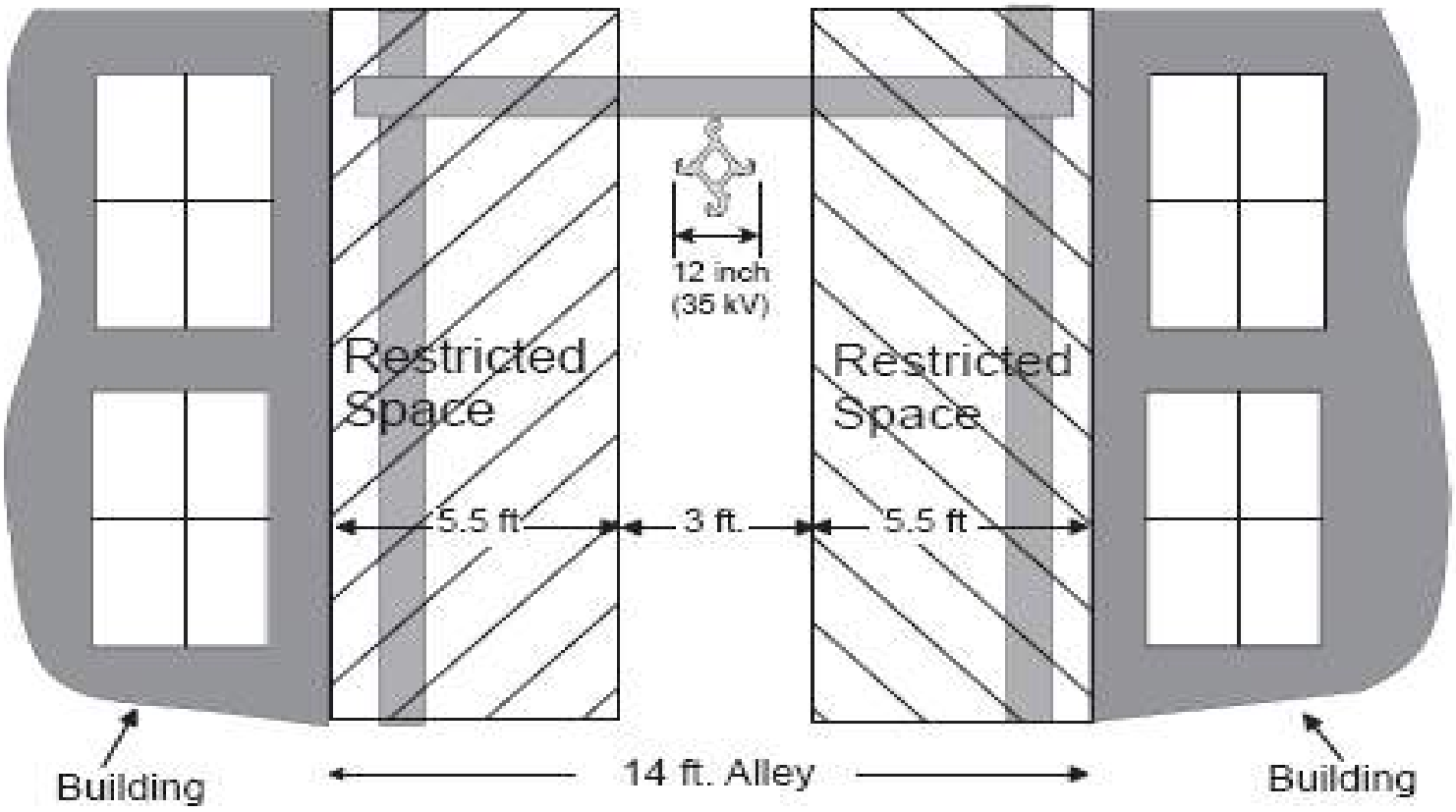
Tree Wire:

- Only ***Bare Wire*** alternative is to build the line above the roofline
- Requires 12.5’ clearance above the roofline
- Unreasonable pole heights
- Maintenance Issues
- Safety issues
- Impossible with tall buildings

Spacer Cable:

- Revision to NESC; IEEE C2-1997, footnote to Table 234-1: ***clearance may be reduced by 2 ft.*** provided the wires, conductors, or cables, including splices and taps, and unguarded rigid live parts have a covering that provides sufficient dielectric strength to limit the likelihood of a short circuit in case of momentary contact with a structure or building.

Spacer Cable: Reduced ROW



- 5.5’ required for covered conductor allows 3’ width
- Sufficient for 5kV – 35kV construction with spacer cable

Spacer Cable: Reduced ROW

5kV to 15kV Conversion: Costly with UG;
Bare Wire requires prohibitively tall poles

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Spacer Cable: Reduced ROW

Spacer Cable provides a clean and economical solution (and satisfies NESC)

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Tree Wire: Reduced ROW

Differences: Reduced Right of Way

Spacer Cable
Substation Exit
in a reduced
residential ROW

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Differences: Long Spans

Long Spans

Tree Wire:

- Long crossings have weight issue
- Requires heavier poles
- Benefits compared to bare wire since conductor clashing is no longer an issue

Spacer Cable:

- All strength is in messenger
- No limit to crossing length
- The longer the crossing, the greater the benefit of spacer cable compared with tree wire (or bare wire)

Differences: Long Spans

Spacer Cable: Long Span
Massachusetts – 200m crossing
Seacoast application

Spacer Cable: River Crossings

- 520m River Crossing – White River Indiana
- Option 1 – submarine cable – cost $1MM
- Option 2 – build around shoreline – cost $800k
- Option 3 – Spacer cable – cost $75k


Spacer Cable especially viable for river crossings with multiple circuits
Edmunston, NB River Crossing

Differences: Multiple Circuits

Multiple Circuit Configurations

Tree Wire:

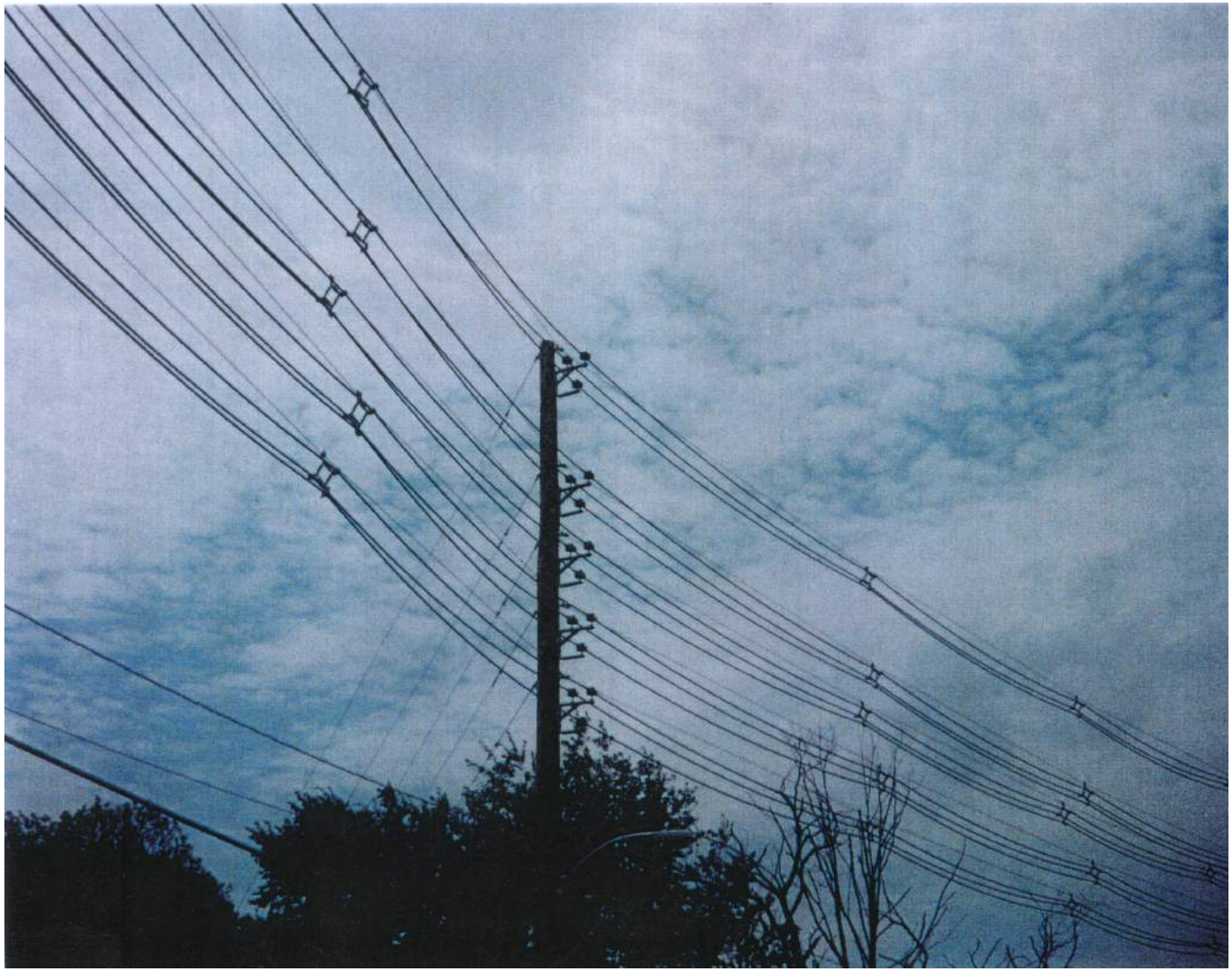
- 2 circuits/pole

Spacer Cable:

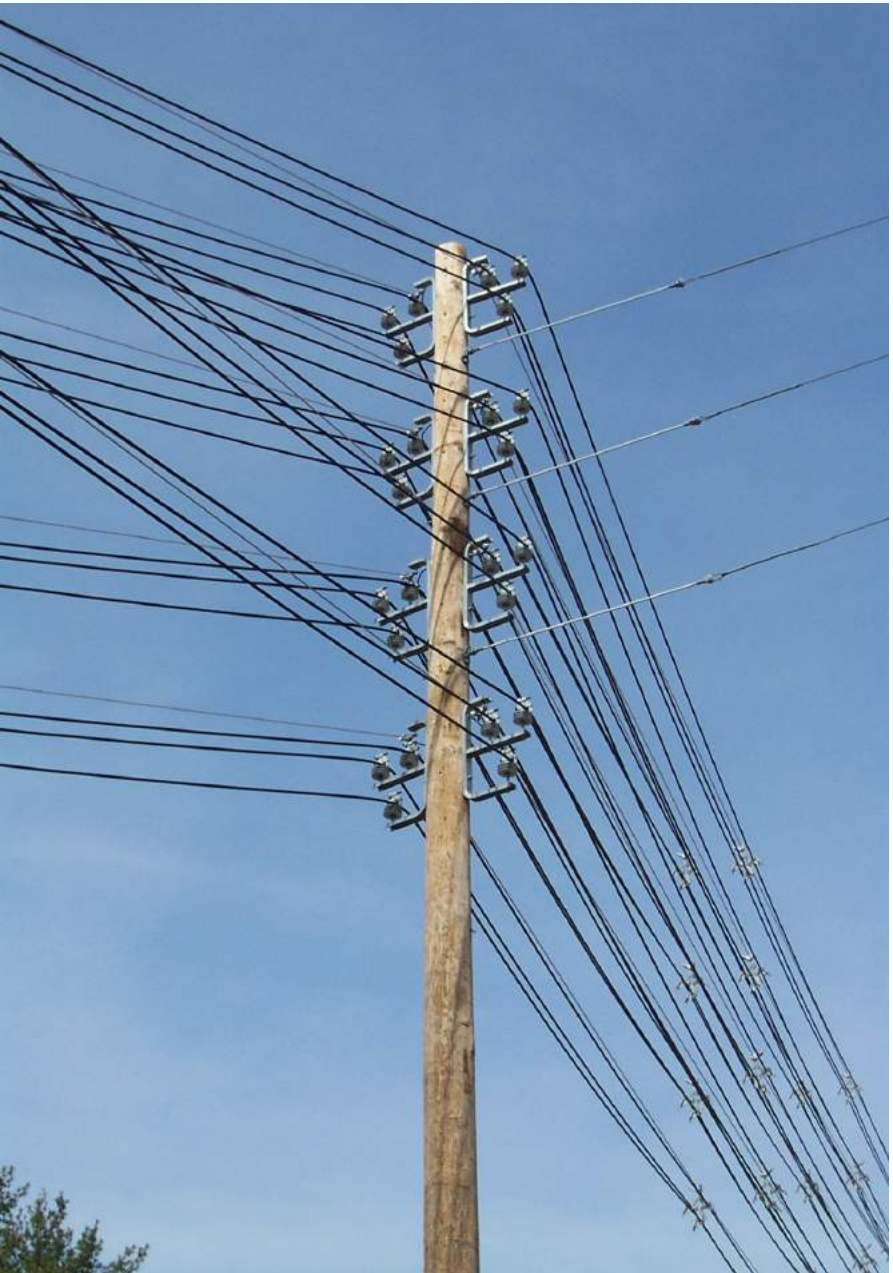
- No limit to # circuits on a single pole
- Transmission line underbuild
- Distribution line overbuild
- Substation getaway

Tree Wire: Multiple Circuit Limitations

Spacer Cable: Multiple Circuits



Spacer Cable: Multiple Circuits



Spacer Cable: Multiple Circuits

Solar Ranch - 550 MW

Spacer Cable: Multiple Circuits

69kV with 25kV underbuild
National Forest
CHILE, S. America

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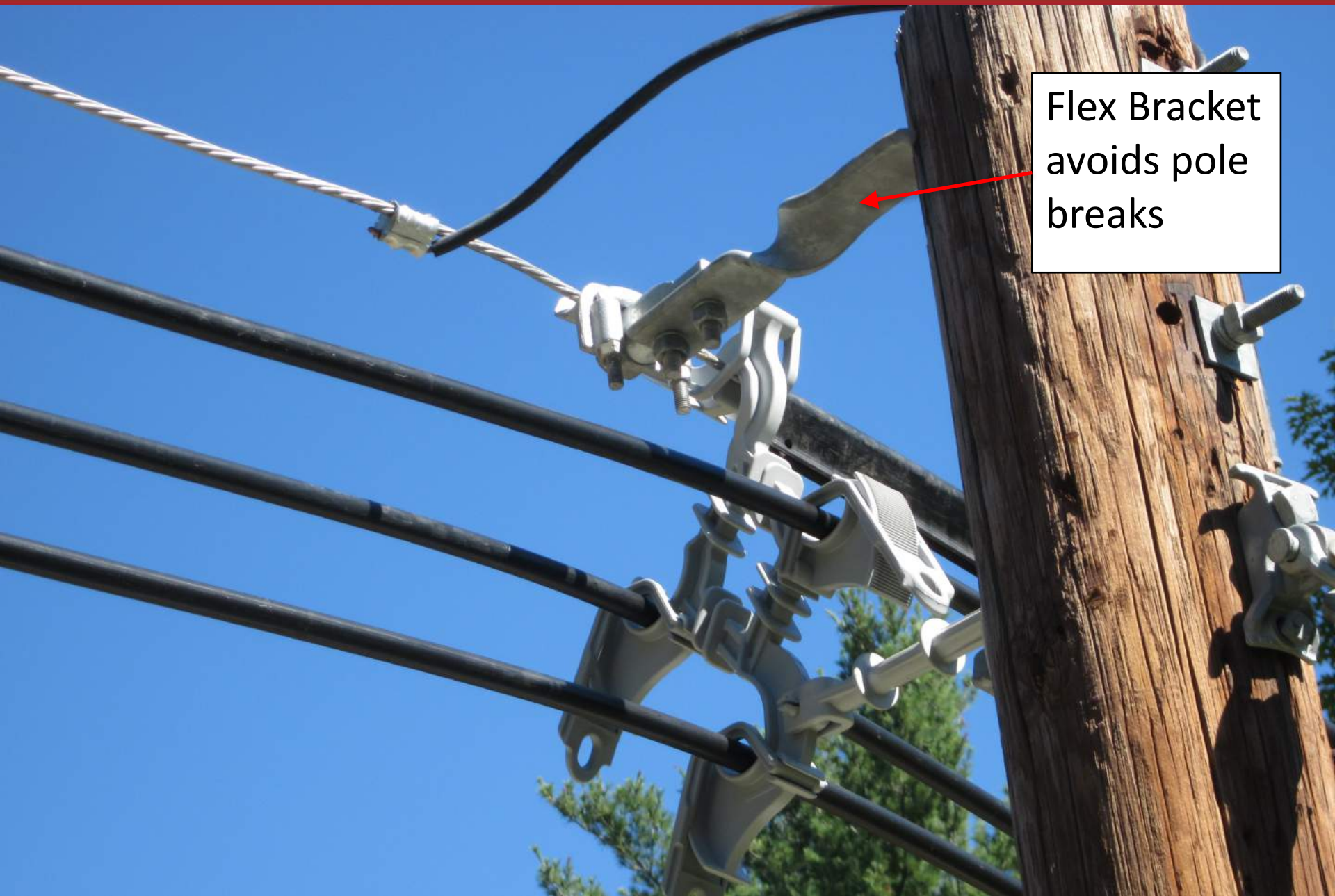
Spacer Cable: Storm Hardening



Differences: Construction Challenges

	Tree Wire	Spacer Cable
Reduced Right-Of-Way	More compact & allow closer clearances than bare wire	Still more compact than tree wire
Long spans	Better than bare wire (no clashing)	More compact (1 pole) and more reliable (no clashing)
Multiple circuits	2/pole limit	No limit # circuits/pole
Storm Hardening	Difficult – weak link is conductor, insulator, pole	Options – Flex Bracket (avoid pole breaks), heavy messenger, heavy pole, or combination

Spacer Cable vs. Tree Wire: Differences

Differences:

- Quality of Service

Differences: Quality of Service

Voltage Regulation

Tree Wire:

- Same as bare wire

Spacer Cable:

- Closeness of phases reduces mutual inductance
- Total inductance is reduced
- Total impedance reduced by 15-20%
- Reduced voltage drop by 15-20% compared to bare or tree wire
- Reduced need for switched capacitors, voltage regulators
- Better end-of-line voltage on voltage-limited long feeders
- Higher power factor

Differences: Quality of Service

Restoration Time

Tree Wire:

- Faster restoration time for faults involving pole failures
- Safety/Reliability concerns when conductor is exposed to long term abrasion (e.g. fallen tree limb in contact with phase conductors)

Spacer Cable:

- Increased reliability reduces maintenance demands
- For extremely large/heavy tree, result may be pole break

Differences: Quality of Service

Reliability and associated costs

Tree Wire:

- Reliability indices (SAIDI, SAIFI, CAIDI, etc.) favorable

Spacer Cable:

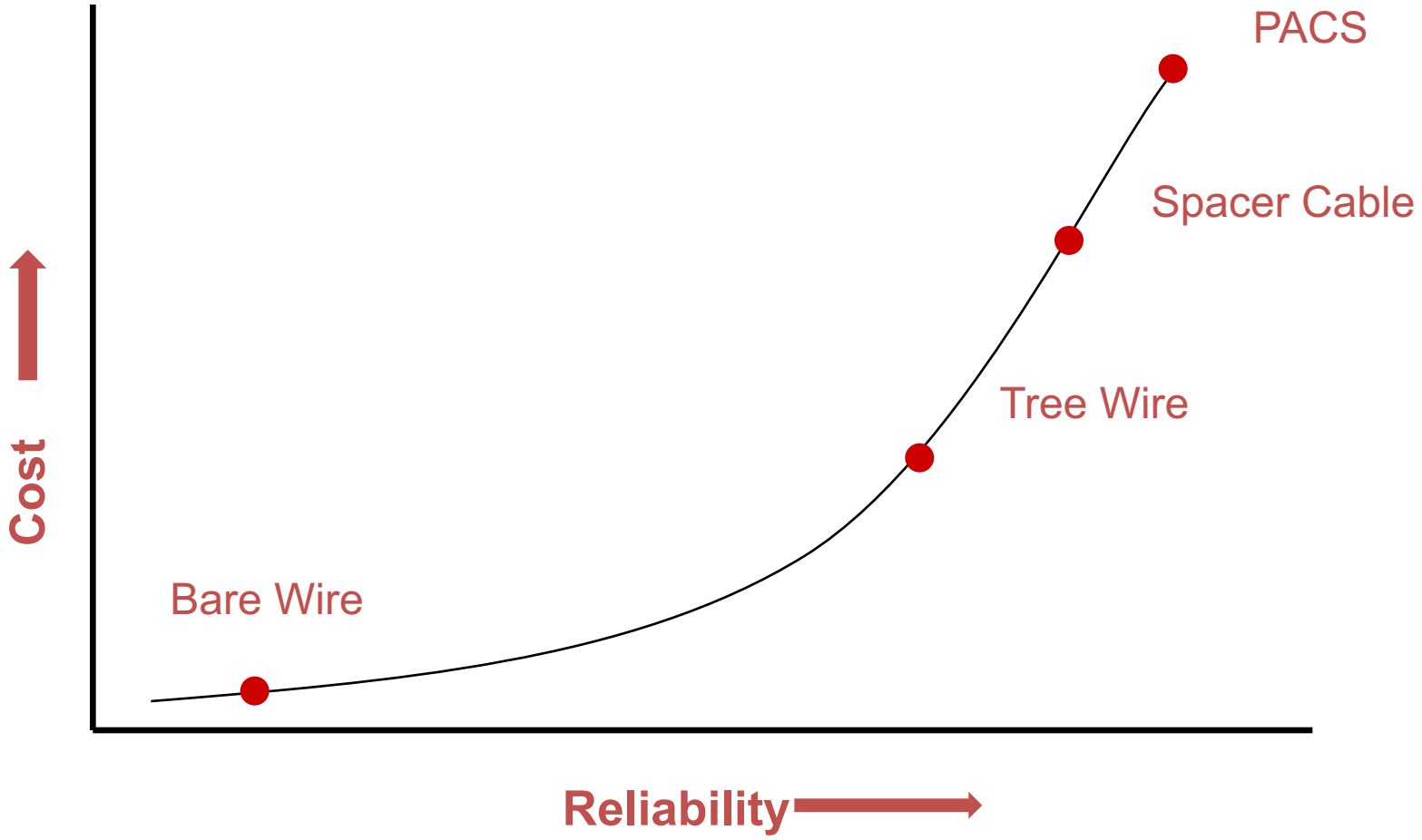
- Reliability indices (SAIDI, SAIFI, CAIDI, etc.) superior
- Reduced outages
- Reduced loss of revenue for outages
- Reduced trouble crews and Operations & Maintenance costs
- Greater regulatory compliance and penalty avoidance

Quality of Service: Cost vs. Reliability

What is Cost of Reliability?

- Sending crews to find faults
- Lost revenue
- Public relations
- PUC SAIDI/SAIFI/CAIDI financial penalties
- Loss of industrial load
- Inability to attract industry
- Loss of critical loads (Hospital, Data Center, etc.)

Quality of Service: Cost vs. Reliability



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Differences: Quality of Service

Quality of Service

	Tree Wire	Spacer Cable
Voltage regulation	Same as bare wire	15-20 % improvement
Surge protection	Worse than bare wire (open at deadends)	Improved over bare wire or tree wire (closed system, high BIL)
Restoration time	Same as bare wire	Takes longer if pole broken
Reliability and associated costs	Better than bare wire	Better than both bare wire and tree wire

Spacer Cable vs. Tree Wire

Summary

Spacer Cable vs. Tree Wire: Summary

- Both Spacer Cable and Tree Wire are adaptable and suitable to a wide range of application areas
- Selection between the two options must weigh multiple considerations
- Table which follows highlights the choice that will, in general, give optimal results per criterion

Spacer Cable vs. Tree Wire: Suitability

Considerations	Tree Wire	Spacer Cable
Minimal install time/cost	✓	✓
Inaccessible terrain	✓	✓
Heavily treed		✓
Animal contact		✓
Environmental contamination	✓	✓
Harsh weather		✓
Restricted Right-of-Way	✓	✓
Long spans		✓
Multiple circuits		✓
Storm restoration time	✓	
Storm Hardening		✓
Voltage Regulation		✓
Overall Quality of Service		✓

Q & A

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