

Engineering Overhead Electric Lines for Ice, Wind and Freezing Rain



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Storm damage can interrupt access and transmission supply while leaving recoverable distribution assets in place.

Abstract

Freezing rain and wind expose the complete overhead distribution line to concurrent mechanical and electrical risks. Radial ice increases vertical load. Wind acting on an ice-altered profile increases transverse load and may initiate conductor motion. Ice-laden vegetation adds impact, sustained contact and uneven loading. This paper examines how Hendrix® Aerial Cable Systems (ACS), a messenger-supported spacer cable configuration, change that risk profile. It reviews a monitored severe-weather comparison conducted at EA Technology's Deadwater Fell test site during the 2001-2002 winter and field observations from Littleton, Templeton, West Boylston and National Grid during the catastrophic December 2008 Northeast ice storm. The evidence shows that the tested Hendrix Spacer Cable system generally experienced lower percentage load increases than bare Hazel and single covered BLX 50 conductors under wind, snow and ice. Utility reports also show that intact Hendrix ACS circuits supported rapid re-energization after transmission, pole and hardware damage. These results support the use of messenger-supported aerial cable as a targeted resilience option where ice, wind, vegetation and restoration access create material risk. The design must evaluate the complete load path, including messenger, brackets, attachments, poles, foundations and guying. Covered conductors must remain subject to energized-line safety practices.

Index Terms aerial cable systems, covered conductor, freezing rain, ice loading, overhead distribution, spacer cable, storm hardening, wind loading

1. Introduction



Ice and snow loading on a tree overhead corridor.

Ice storms cause extended outages because several exposures occur at the same time. Ice accumulates on conductors, messengers, hardware and structures. Wind acts on the increased projected area. Conductors may move or gallop. Trees and limbs may bend or fall into the line. Damage can occur at the conductor, bracket, crossarm, pole, guy or foundation. A useful resilience assessment must therefore address the complete line rather than a single component.

For utility engineers, the practical question is how a line will behave when those exposures occur together. A conductor system may perform acceptably under normal loading yet respond differently when ice changes its weight and aerodynamic profile, wind increases structural demand, and vegetation adds impact or sustained contact. Design decisions made years before a storm influence whether damage remains localized or expands into circuit reconstruction.

This system view is particularly important on long rural feeders and heavily treed corridors. Access may be limited during the storm, damage may be dispersed across many miles, and restoration resources may be constrained. The design objective is not only to prevent failure. It is also to limit electrical faults, control mechanical failure modes and preserve safe restoration options.

Hendrix® Aerial Cable Systems (ACS), also described as spacer cable, use three covered phase conductors held in a compact arrangement by polymer spacers and supported by a high-strength messenger. The messenger provides the primary mechanical support. This arrangement separates the phase conductors' electrical function from the system's principal mechanical load path.

2. Ice, Wind and Vegetation Exposure

2.1 Radial Ice and Wind on Ice

Ice accretion increases conductor weight and changes its aerodynamic profile. Wind then adds transverse force to the increased projected area. The combined load is transferred through conductors, support hardware, poles and foundations. The governing condition may be a moderate wind acting on a heavily iced system rather than the maximum recorded wind speed alone.

Freezing rain, rime ice and wet snow do not produce identical deposits. Accretion depends on air temperature, liquid water content, wind speed and direction, exposure, conductor diameter, surface condition and the ability of the conductor to rotate or shed material. Local weather history and utility experience should supplement the applicable loading district.

2.2 Conductor Motion

An ice-altered conductor can develop aerodynamic lift and oscillate. Galloping produces low-frequency, high-amplitude motion that may increase attachment loads, reduce electrical clearances and create conductor contact. Aeolian vibration and galloping are different phenomena and require different design responses. Conductor tension, span length, support geometry and damping must be evaluated for the selected system.

2.3 Vegetation Loading

Vegetation often creates the dominant outage mechanism. Ice-laden trees and limbs may apply impact, sustained vertical load or lateral load. Bare conductors can fault when vegetation bridges phases or establishes a path to ground. Covered conductors are not insulated and are not safe to touch, but their covering can reduce faults from temporary incidental contact when the system is properly designed and maintained.

3. Hendrix Aerial Cable System Architecture

A spacer cable system consists of covered phase conductors, polymer spacers, a messenger, supporting brackets and coordinated transition, dead-end and protection components. The messenger supports the phase conductors and allows the installed system to use a compact cross section with controlled sag. Phase-conductor size can be selected for electrical requirements while the messenger and supporting assembly are selected for mechanical duty.

The design advantage is architectural rather than material. The system establishes a dedicated mechanical load path and keeps the three phases in a consistent geometry. The covering adds tolerance to incidental contact. The compact arrangement reduces the space required for the circuit. These attributes can reduce exposure and support recovery, but they do not eliminate the loads imposed on poles and foundations.

4. Deadwater Fell Severe Weather Evaluation

4.1 Test Site and Monitoring

Field observations after a major storm can show which circuits remained available and how crews restored them. A monitored comparison adds another layer of evidence by recording how different conductor systems respond to the same weather. The Deadwater Fell evaluation provides that controlled context.

EA Technology installed a 15 kV Hendrix Spacer Cable system at the Deadwater Fell severe-weather site on the English-Scottish border in August 2001. The site is located at approximately 600 m elevation on an exposed fell. Two 100 m spans were monitored through the 2001-2002 winter. The site recorded conductor tension, ambient temperature, wind speed and wind direction. Time-lapse and digital video documented conductor behavior. Load cells and turnbuckles allowed the research team to monitor and adjust conductor tension.

The spacer cable was installed on the upper crossarm, approximately 2 m above the Hazel and BLX conductors. The report estimated that the spacer cable may therefore have experienced wind speeds at least 15% higher than the wind measurement at the lower-crossarm elevation. No correction was applied.

Test Element	Reported Configuration
Hendrix Spacer Cable	Three 50 mm ² covered aluminum phase conductors on polyethylene spacers and an Alumoweld messenger
Bare Comparison	60 mm ² AAAC Hazel conductor
Covered Comparison	50 mm ² single covered BLX conductor
Span Arrangement	Two 100 m spans with an intermediate pole
Installed Spacer Tension	6.5 kN at 20 mph wind and 7.5°C; approximately 7 kN during service
Phase Conductor Tension	Approximately 1 kN per covered phase conductor

4.2 Comparison Method

The report compared changes in measured tension from lower-load reference conditions to defined wind, snow and ice events. For the single-conductor Hazel and BLX measurements, the tension increase was multiplied by three to estimate the change for a three-phase line. The spacer result represented the complete supported system. Both percentage change and estimated actual change are relevant. Percentage change indicates sensitivity to the event; actual change indicates the additional load transferred to supporting structures.

5. Test Results

The results are most useful when percentage change and actual load change are considered together. Percentage change shows how strongly each configuration responded to an event. Actual change more directly informs the demand transferred to supporting structures. Neither measure should be read in isolation.

5.1 Wind Without Ice

The spacer cable produced the lowest percentage tension increase in each summarized wind event. At 40 mph in week 36, its tension increased 22%, compared with 47% for Hazel and 74% for BLX 50. At 50 mph in week 3, the increases were 28%, 39% and 107%, respectively. The estimated increase for a three-phase line was also lowest for the spacer system in these events.

Event	Hazel %	BLX 50 %	Spacer %	Hazel Δ kN	BLX 50 Δ kN	Spacer Δ kN
40 mph Week 36	47	74	22	2.01	2.22	1.63
34 mph Week 43	23	41	18	1.92	1.92	1.46
50 mph Week 3	39	107	28	3.48	3.48	2.88
50 mph Week 5	91	177	66	8.19	8.19	6.81

Table 2 Reported tension increase during selected wind-only events. Actual changes for Hazel and BLX 50 were multiplied by three in the source report to represent a three-phase line. Δ indicates estimated increase in total line tension.

5.2 Snow and Ice

The spacer cable also produced the lowest percentage increase across the major snow and ice events summarized by the researchers. During a gradual ice event in week 2, spacer-cable tension increased 16%, compared with 38% for Hazel and 58% for BLX 50. The estimated actual increases were 1.64 kN, 3.45 kN and 2.61 kN, respectively.

Event	Hazel %	BLX 50 %	Spacer %	Hazel Δ kN	BLX 50 Δ kN	Spacer Δ kN
Snow blizzard Week 48	73	88	53	5.67	4.71	4.76
Snow blizzard Week 49	72	77	32	6.24	3.39	2.82
Ice and Snow Week 51	39	59	32	3.67	2.73	3.20
Ice Week 1	32	106	28	3.57	4.80	2.94
Ice Week 2	38	58	16	3.45	2.61	1.64
Peak combined event	110	249	107	10.59	11.49	11.85

Table 3 Reported tension increase during selected snow and ice events. Values follow the comparison method used in the source report.

The peak combined wind, ice and snow event is an important boundary condition. Percentage increase remained lower for spacer cable than for BLX 50 and slightly lower than for Hazel. Actual load increases were similar across the systems, and the spacer system recorded the highest actual increase by a small margin. The report attributed this result to the iced surface area of the messenger, three conductors and spacers under high wind. This finding reinforces the need to calculate the complete structural load rather than infer pole performance from conductor behavior alone.

5.3 Interpretation and Limitations

The researchers concluded that the tested spacer cable performed well under severe wind, snow and ice. It accumulated less snow and ice and experienced less wind-related load than the single covered conductor, especially as conditions worsened. It generally performed better than the bare Hazel conductor. These conclusions apply to the tested configurations, tensions, spans and site. They should not be treated as universal ratios for other conductor sizes, voltage classes or structures.

The report did not calculate pole or foundation stresses and did not provide a controlled reliability comparison based on customer interruptions or circuit miles. The tests establish comparative mechanical behavior at the monitored site. They do not, by themselves, establish an outage-reduction percentage.

6. Utility Performance During the 2008 Northeast Ice Storm



Ice accumulation along a Templeton, Massachusetts corridor during the December 2008 event.

The December 11-12, 2008 Northeast ice storm produced widespread freezing rain across New York and New England, with reported radial ice accumulation ranging from approximately 0.5 inch to more than 1.25 inches. At its peak, the storm left 1.7 million electric customers without service. The utility observations that follow—Littleton, Templeton, West Boylston and National Grid—document system performance, circuit availability and restoration work across several New England systems.

The accounts were not normalized for circuit exposure and do not constitute a controlled reliability study. Their value is operational. They document whether primary circuits remained intact, which components failed, how quickly viable circuits could be re-energized and how much reconstruction was required before service returned.

6.1 Cross Utility Observations

Utility	Reported System Context	Reported 2008 Storm Outcome
Littleton Electric Light and Water Departments	Littleton was approximately 80% spacer cable; Boxborough was approximately 10%.	Primary feeder outages affected 75% of Littleton and 100% of Boxborough. Primary restoration took about one day in Littleton and four days in Boxborough. Approximately 90% of Littleton customers were restored within 24 hours; Boxborough lateral and service restoration extended to about seven days.
Templeton Light and Water	Four main Hendrix circuits served as the distribution backbone.	The circuits remained intact while the transmission supply was unavailable. After transmission returned, approximately 70% of customers were restored quickly. Crews reported removing trees two to three feet in diameter and temporarily reinstalling brackets to return intact cable to service.
West Boylston Municipal Light Department	Approximately 70% of town wiring used spacer cable.	Main spacer-cable circuits were restored quickly, and full restoration was completed in about one week.
National Grid	Spacer cable was installed across parts of the regional distribution system.	Observed damage more often involved poles or pole-top brackets than failure of the cable assembly. Broken brackets were comparatively direct to restore when the cable remained viable.

6.2 Common Engineering Pattern

The utility accounts describe a consistent pattern. Covered phases reduced the likelihood that temporary vegetation contact would become an electrical fault. The messenger-supported assembly often remained intact even when trees, poles or brackets were damaged. When the primary cable assembly remained viable, crews could focus on localized structural repairs and re-energize circuits without rebuilding the complete line.

Littleton provides the most quantified comparison within the event because Littleton and Boxborough entered the storm with markedly different system mixes. LELWD used that experience to guide a sustained hardening program. By 2026, the reported spacer-cable share had increased to approximately 99% in Littleton and 95% in Boxborough, supported by vegetation management and annual capital investment. General Manager Nick Lawler and Assistant General Manager David (Dave) Ketchen have shared that broader reliability journey through APPA presentations and media discussions with T&D World and Factor This. Their experience reinforces the central engineering lesson from the storm: line design matters, but durable improvement depends on coordinated planning, maintenance and continued investment.

7. Engineering Application

The test and field evidence support messenger-supported ACS as a targeted overhead resilience option. The decision begins with the circuit problem, not the conductor system. Engineers must identify the dominant outage mechanisms, the customers and loads affected, access constraints, available right-of-way and the restoration consequences of failure. Only then can the alternatives be compared on a consistent basis.

Application requires a coordinated line design. The larger installed weight and projected area of covered phases, spacers and messenger must be included in the loading model. The design should use the applicable code requirements as a minimum and evaluate local extreme-weather history,

terrain, span exposure, vegetation and service consequence.

7.1 Corridor Selection

Design Area	Required Elevation
Environmental loading	Radial ice, wind on ice, temperature, unbalanced loading, wind direction, terrain and exposure
Mechanical system	Messenger strength, sag-tension, span length, line angle, spacers, brackets, attachments, dead ends and transitions
Structures	Pole class, crossarm or bracket location, guying, foundations and controlled failure modes
Electrical system	Ampacity, voltage class, clearances, insulation coordination, grounding, lightning performance and protection settings
Construction	Pulling and tensioning practices, manufacturer design support, crew training, inspection and documentation
Storm readiness	Damage assessment, temporary support methods, spare brackets and spacers, grounding procedures and restoration sequencing

ACS provides the greatest value where several risks converge: recurring freezing rain or wet snow, dense vegetation, constrained rights-of-way, difficult access, long restoration distances, multi-circuit congestion or high-consequence loads. Substation exits, treed road corridors and feeders serving critical or remote loads are common candidates.

The decision should be made at the corridor level. Compare conventional open wire, messenger-supported ACS, selective undergrounding, stronger structures, vegetation measures and automation using lifecycle cost, expected interruption exposure, constructability and restoration logistics. These measures are complementary. ACS should not be positioned as a substitute for protection coordination, vegetation management or structural design.

7.2 Restoration and Safety

An intact cable assembly can provide restoration flexibility after localized pole or hardware damage. A utility may be able to support or reposition the cable temporarily while permanent structural repairs are scheduled. Any such method must be engineered, included in utility procedures and performed by qualified personnel.

The same electrical integrity that supports restoration creates a safety requirement. A downed or contacted covered conductor may remain energized. Covered conductor is not touch-safe. Crews and the public must treat the system as energized until it is isolated, tested and grounded according to utility rules. Public communication, dispatch protocols and field training must reflect this condition.

8. Conclusion

Freezing rain resilience depends on the behavior of the complete overhead line and on the utility program surrounding it. Ice, wind and vegetation create combined loads that act through conductors, hardware, poles and foundations. Capital planning, vegetation management, installation quality and restoration procedures determine how the physical design performs over time. A messenger-supported aerial cable system changes the line architecture by assigning primary mechanical support to a dedicated messenger, maintaining compact phase geometry and adding tolerance to temporary vegetation contact.

The Deadwater Fell evaluation provides measured evidence. Under the tested conditions, spacer cable consistently produced the lowest percentage load increases in wind-only events and generally produced the lowest percentage increases in snow and ice. The most severe combined event also showed why the complete structure must be calculated: actual load increases were comparable, and the spacer system carried a slightly higher increase than the alternatives.

The 2008 New England field accounts add operational evidence. Intact Hendrix ACS circuits supported rapid re-energization, while localized pole and bracket damage could be addressed without reconstructing the cable assembly. Together, the test and field evidence support messenger-supported aerial cable as a technically credible resilience option for ice-prone, vegetation-exposed corridors. The benefit depends on coordinated system design, installation quality, protection and disciplined restoration practices.



References

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