BOLD™, a new transmission technology for modernizing the grid and improving generating resource integration

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5.4M Customers over 200,000 sq. mi. in 11 States
40,000+ miles of transmission lines across 13 states
215,000+ miles of distribution lines
32 GW of Generation Owned

AEP Transmission, Transource Energy, and Joint Venture Projects provide service across the U.S.
Modernizing the Grid

- More Reliable New, Replaced and Upgraded Circuits – Example: over 100,000 miles in the US should be replaced in the coming years due to their age (see appendix)
- More Efficient Delivery of Electrons – Reduce line losses
- More Efficient Use of Rights-of-Way – More power with less land using new types of transmission structures, advanced conductors, etc.
- Addressing Political Issues – Reducing viewshed objections, concerns about EMF radiation, slowing rate increase pressures by cost-effectively increasing delivery of electricity
- Facilitating Generation in the Evolving Grid – Voltage management, impact on utility and regulatory planning accuracy
- Permitting Integration of Energy Storage and Future Technology – Flexibility to expand grid management solutions

NARUC’s February 17, 2016 regulatory policy resolution promotes cost effective advanced transmission technologies to address these issues (see appendix)
Breakthrough Overhead Line Design (BOLD)

- CREZ experience in Texas showed need for long high capacity lines, but also need to mitigate interference issues between series capacitors and wind farms.
- BOLD was envisioned to address these issues, but with additional focus on improving efficiency and environmental impact.
- Over 3 years spent in development:
  - Required significant electric simulation studies in collaboration with vendors.
  - Prototype testing included structural integrity/stress tests and electrical tests to validate studies.
- 14 worldwide patents (granted or pending).
- See October 26, 2015 article:
Comparison of BOLD vs. Conventional Designs

BOLD can be used for new or replacement transmission circuits up to 345 kV.

BOLD is a cost-effective design, and results in a net savings when benefits are considered.

<table>
<thead>
<tr>
<th>BENEFITS</th>
<th>BOLD 345 kV (3 Bundle)</th>
<th>BOLD 230 kV (2 Bundle)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased Capacity</td>
<td>42%</td>
<td>59%</td>
</tr>
<tr>
<td>Lower Tower Height</td>
<td>(32%)</td>
<td>(23%)</td>
</tr>
<tr>
<td>Lower Magnetic Field Levels</td>
<td>(50%)</td>
<td>(48%)</td>
</tr>
<tr>
<td>Lower Energy Losses</td>
<td>(33%)</td>
<td>(7%)</td>
</tr>
<tr>
<td>Lower Surge Impedance (Avoids Series Compensation)</td>
<td>(30%)</td>
<td>(37%)</td>
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- Costs for BOLD differ depending on design standards, but current estimates range from -10% to +25% compared with conventional designs.
  - The fabrication of the unique arched cross-arm is a new process that will become routine and less expensive as more lines are built.
  - Conventional 345 kV designs often use a 2-bundle conductor, whereas BOLD uses a 3-conductor bundle which adds cost. However a conventional structure using a 3-conductor bundle would be nearly equivalent in cost without the same benefits.
- BOLD is up to 33% less expensive than conventional on a cost per MW basis. This also means fewer lines are required to achieve the same level of capacity.
- Savings associated with reduced line losses further offset up-front material cost.
How BOLD Works

- Line Capacity = f(SIL, line length)
  - SIL = [(kV)^2/(Surge Impedance)]
  - If higher voltages can’t be applied; and
  - Fewer lines are desired; then
  - Lower Surge Impedance can boost line capacity

- Surge Impedance ~ √(L/C) (ohm)
  - L & C can be manipulated in various ways, such as:
    - Phase separation
    - Sub-conductors per bundle
    - Bundle size

- L, Z decrease; C increases with:
  - Closer phase spacing
  - More sub-conductors
  - Larger bundle diameter
  - Larger conductor diameter
Actual modeling results of a BOLD line in place of a line in New York state showing a 42% (400 MW) increase in power carrying capability versus a traditional design, while maintaining stable voltage.
Typical Structure Comparison
Profile vs. Power Delivery Capability

Surge Impedance Loading (MW @ 100 miles)

- 230kV Tubular BOLD HEIGHT: 87’ - 968 MW
- 230kV Lattice HEIGHT: 113’ - 608 MW
- 500kV Lattice HEIGHT: 130’ - 1820 MW
- 345kV Tubular HEIGHT: 145’ 6” - 1680 MW
- 345kV Tubular BOLD HEIGHT: 99’ - 2420 MW

100 Feet
BOLD can provide 40-60% more capacity in the same right-of-way
Mitigating EMF Concerns

BOLD reduces magnetic field levels by approximately 50%, assuming the same current flowing through the line.

BOLD also reduces audible noise.
Excerpt from NYPSC Policy for Expedited Transmission Line Siting

B. **Eligibility.** Applicants proposing a major electric transmission facility as defined by PSL Section 120 may request that that application be reviewed on an expedited schedule provided: (1) the facility is proposed to be located wholly within existing transmission rights-of-way and/or buried within existing state-owned rights-of-way except for any de minimus deviations; (2) the facility would not result in structures taller than those presently located on the existing rights-of-way or the change in height is de minimus; (3) the facility would not require expanding the width of the existing rights-of-way or the change in width is de minimus; and, (4) the applicant is not requesting waiver of any application filing requirements described in the Commission’s rules or has already received such waivers in advance of submitting the application.
Reducing Line Losses

- Higher voltage lines experience lower energy losses, particularly over long distances or when lines are heavily loaded.

- BOLD utilizes low-impedance bundle designs, offering up to 40% less energy loss compared with existing lines of the same voltage.

- For a 50-mile 345 kV line, using the BOLD design could save enough energy to power around 7,000 US homes each year.

- Energy losses, while not often valued, can help offset costs of new technology.
Wind resources are often require long transmission lines for delivery.

Series compensation has been utilized to increase transfer capability for performance needs.

Series capacitors can create harmonic interference know as Sub-Synchronous Resonance (SSR) which can interfere with and even damage turbine generation facilities.

BOLD’s compact line design, not requiring series compensation, is able to perform equal to or better than a traditional line with series compensation and avoid this potential complication.
BOLD Applications – First AEP Projects

AEP’s Robison Park-Sorenson rebuild - Fort Wayne, IN
Building 345 kV and 138 kV BOLD on existing 138 kV right-of-way
Approved by PJM regional regulator
Construction began April 2014
Line scheduled in service June 2016
Why BOLD?

- **Performance** – high capacity, low impedance of BOLD enabled use of single 345 kV line
  - Achieves 5X capacity in same corridor
  - Self-compensating nature of BOLD design boosts system voltages
- **Right-of-way Considerations** – development and encroachments limited corridor expansion and new line route options
- **Community/Public Impacts** – feedback from public open houses positive toward tower design and profile
- **Other Factors Considered**:
  - Line Losses – 3-conductor bundle will reduce losses by approximately 33%
  - Aging Infrastructure – need to rebuild existing 1940’s vintage line would be required in near future
BOLD Applications – First AEP Projects

Lafayette, Indiana (20 miles)
First double-circuit 345 kV application with lattice towers
Rebuild of initial segments of longer corridor
Line scheduled in service June 2018
Lower Rio Grande Valley Proposal (Southeast Texas)

- 130-mile 345 kV proposal
  - Combines BOLD advantages with Static Var Compensators (SVCs) to provide voltage regulation

- Addresses reliability and supply concerns without series compensation
  - Mitigates potential interference with nearby wind farm developments

- 20-mile segment approved by ERCOT regional regulator Q4 2015

- Full project pending ERCOT review Q2 2016
BOLD Next Steps

- BOLD is one example that shows that the electric industry can build a better, more flexible grid

- Because BOLD has different modeling and design parameters, it is important for policymakers, regulators and project developers to understand the technology
  - Webinars and/or workshops can be arranged to introduce BOLD to interested stakeholders

- BOLD Transmission, LLC is a subsidiary of AEP Transmission established to work with transmission owners/developers to build BOLD through business partnerships
  - BOLD will work to evaluate and tailor the technology to each project’s needs
Q&A – Thank You

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APPENDIX

• US Infrastructure Investment Needs
• National Association of Regulatory Utility Commissioners (NARUC) Resolution Supporting Advanced Electric Transmission Technology
US Infrastructure Investment Needs

230 kV originated in late 1920’s and early 1930’s with a large portion built before 1950.

345 kV originated in the mid-1950’s with the bulk of lines built between 1960 and 1970.

Data shows a significant increase in line miles to be replaced or upgraded as these facilities already exceed 50 years of age and many approach 70-100 years of age.

Source: The Brattle Group, December 2014, “Dynamics and Opportunities in Transmission Development”
WHEREAS, A secure, reliable, and resilient power grid integrating generation resources serves as a foundation of a growing economy and is critical to our national security; and

WHEREAS, Regulators, policymakers, and consumers expect generating resources and the grid to perform extremely reliably; and

WHEREAS, A significant portion of the nation’s transmission facilities are aged and will require a replacement strategy; and

WHEREAS, Environmental regulations, State renewable energy portfolio standards, State and federal tax policies, other economic factors, and technology developments are causing some electric generation resources to retire, while replacement generation, some of it fueled by intermittent resources, is being sited at other locations on the electric grid; and

WHEREAS, New innovative cost-effective transmission technologies (including, but not limited to, high-capacity/high-efficiency conductors, compact transmission towers, and variable frequency transformers) are commercially available that can increase grid capacity, improve energy transfers, promote greater stability and resiliency, make more efficient use of rights-of-way, reduce transmission line losses, and help to streamline siting and construction activities; and

WHEREAS, New and advanced replacement transmission facilities can be designed to enable a wide variety of new generating resources and can address technical, environmental, and aesthetic issues that might impede or limit the development and operation of these resources; and

WHEREAS, Crowded utility corridors often allow little room for expansion; and

WHEREAS, Some States have established policies that encourage the use of advanced transmission line technologies; now, therefore be it

RESOLVED, That the Board of Directors of the National Association of Regulatory Utility Commissioners (NARUC), convened at its 2016 Winter Committee Meetings in Washington, D.C., encourages utility efforts to: 1) investigate and consider new advanced transmission technologies when replacing aged transmission infrastructure; 2) evaluate new transmission technologies to determine whether they can cost-effectively ensure the continued reliable delivery of electricity while providing greater capacity and enhanced efficiency; 3) consult with the Department of Energy and its National Laboratories to understand advancing transmission technologies; and 4) consider the ability of these technologies to reduce environmental and visual impacts to communities; and be it further

RESOLVED, That NARUC encourages Regional Transmission Organizations/Independent System Operators and other planning authorities to support and consider cost-effective advanced electric transmission infrastructure options that can increase grid capacity, reduce transmission line losses, improve energy transfers, make efficient use of rights-of-way, improve energy efficiency, and help to streamline siting and construction activities in their planning, evaluation and oversight of transmission grid development; and be it further

RESOLVED, That NARUC encourages State public service commissions to include in their oversight of transmission facilities the consideration of cost-effective use of advanced electric transmission technologies in support of the continued provision of affordable, reliable electricity to consumers.

Sponsored by the Committee on Electricity
Adopted by the National Association of Regulatory Utility Commissioners Board of Directors on February 17, 2016
http://pubs.naruc.org/pub/66436AF7-DFB2-C21E-43B2-1AE83A02D8F5