BOLD™

System and Performance Considerations

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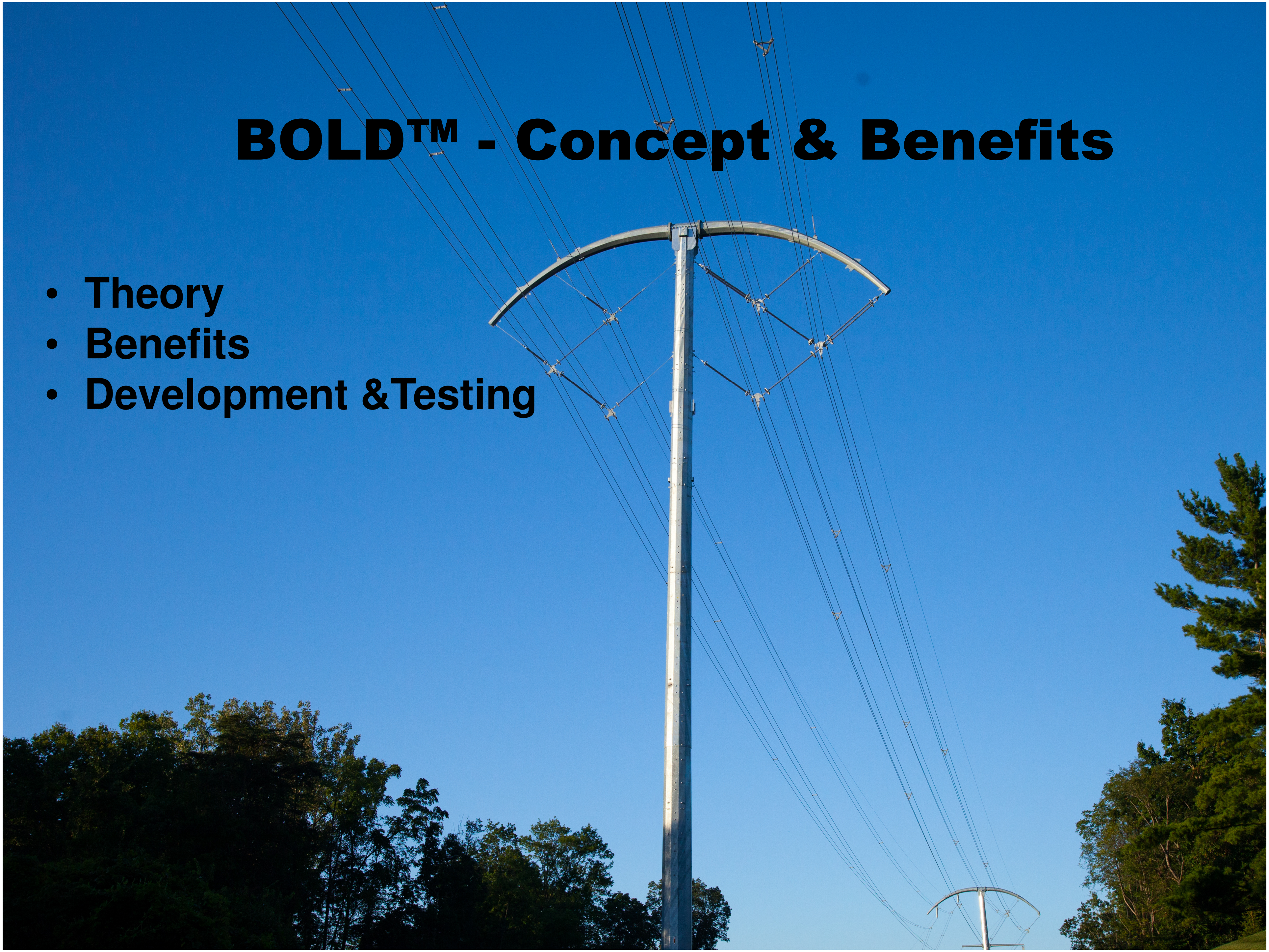
Breakthrough Overhead Line Design BOLD™

- **A new standard for compact overhead line designs**
  - Achieves greater capacity and efficiency at native voltages
  - Eliminates need for series compensation and other specialized equipment
  - Increases utilization of ROW
  - Reduces environmental and visual impacts

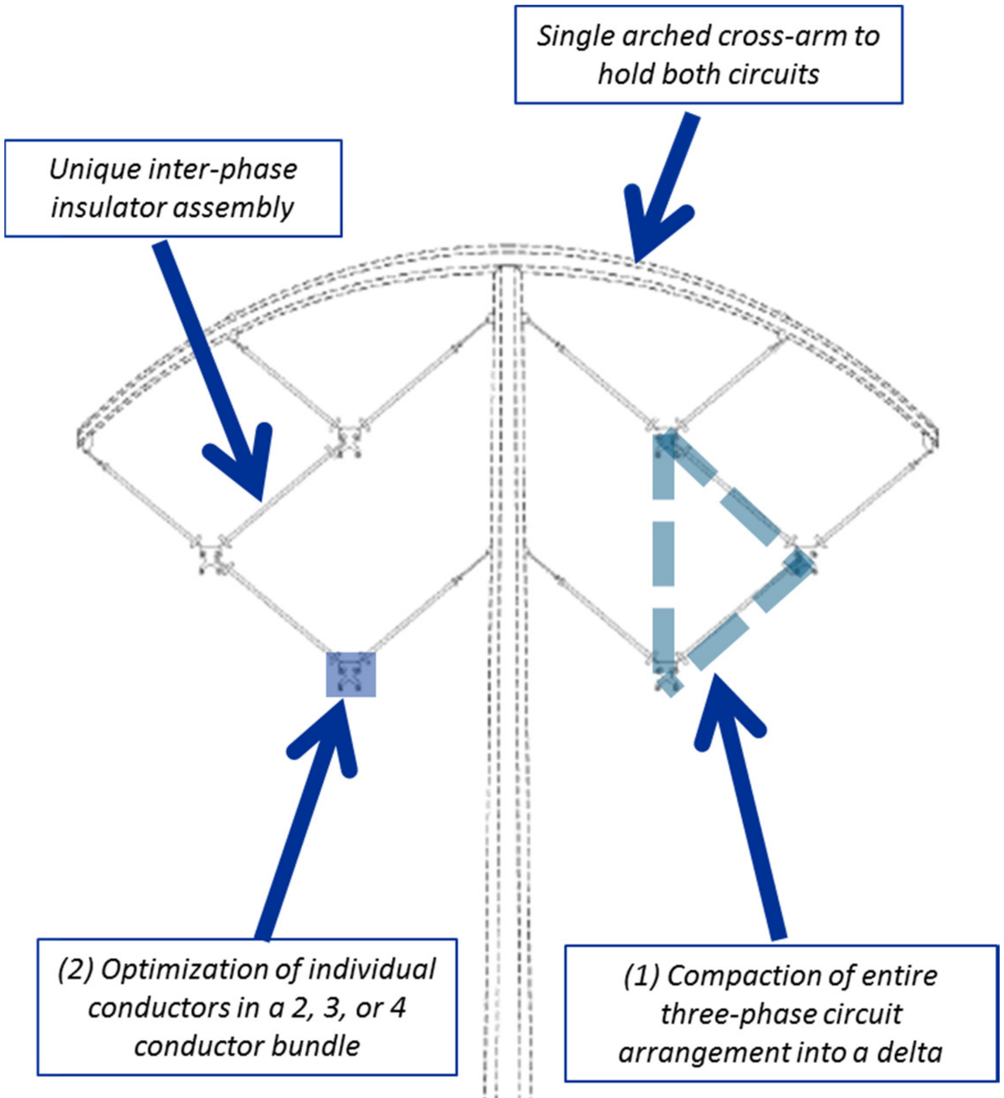
- **Extensive testing and optimization to ensure quality in both design and electrical performance**
- **BOLD to be constructed in two projects in Indiana by AEP**

BOLD™ - Concept & Benefits

- Theory
- Benefits
- Development &Testing

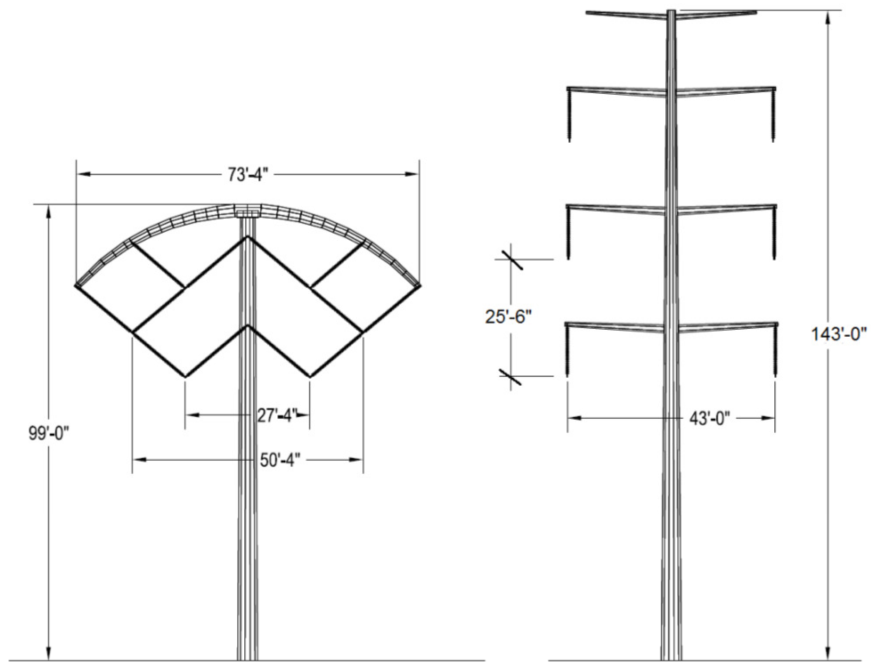


How BOLD Works



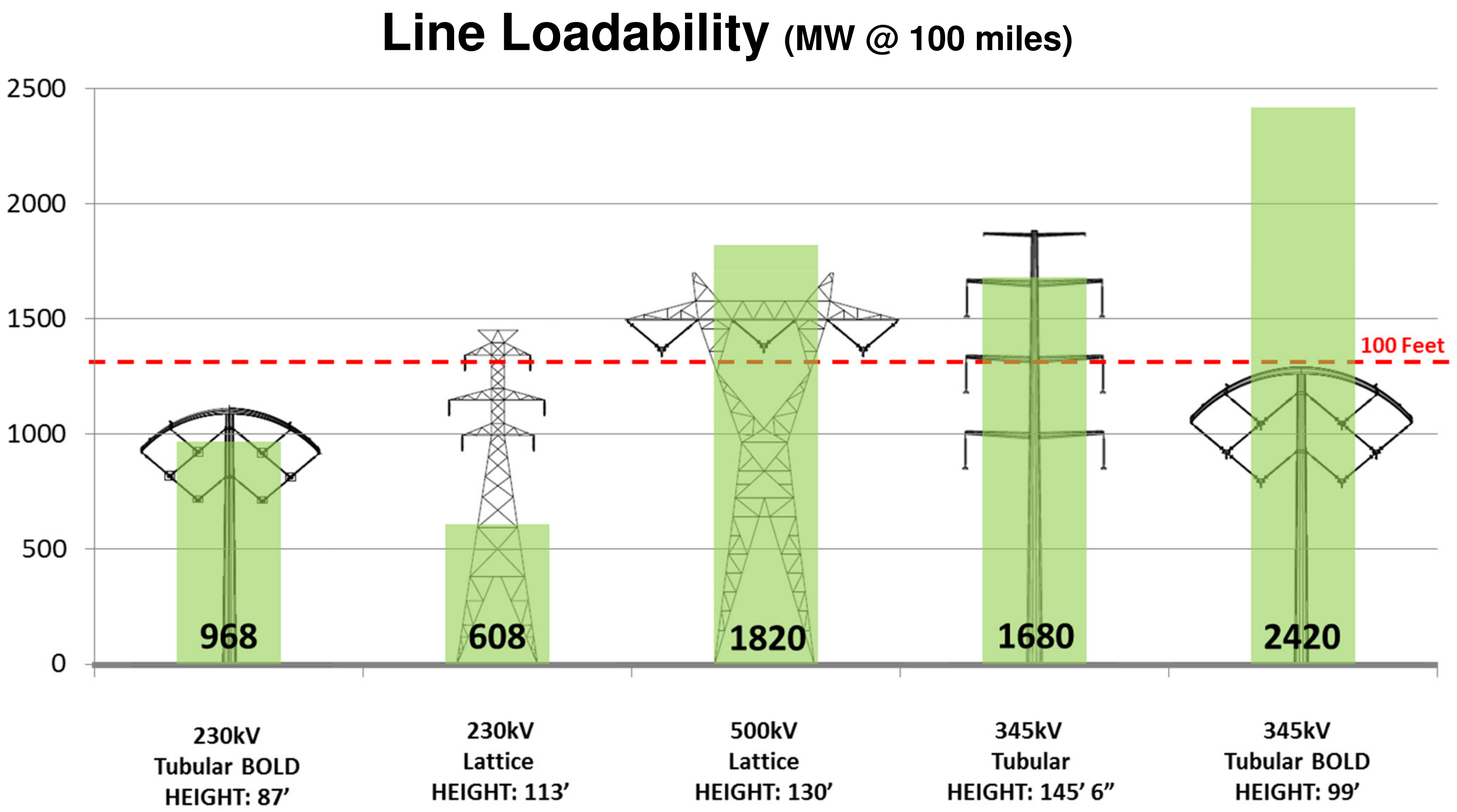
- Key design features:
  - Reduce phase separation into a compact "delta" configuration
  - Optimized bundle diameter
- Reduces line reactance (X) and increases charging (B), resulting in lower surge impedance ($\sqrt{X/B}$) which boosts surge impedance loading
- Higher degree of intrinsic "self-compensation"
- Arched cross arm and inter-phase insulators designed to hold conductors in exact locations

BOLD vs. Conventional

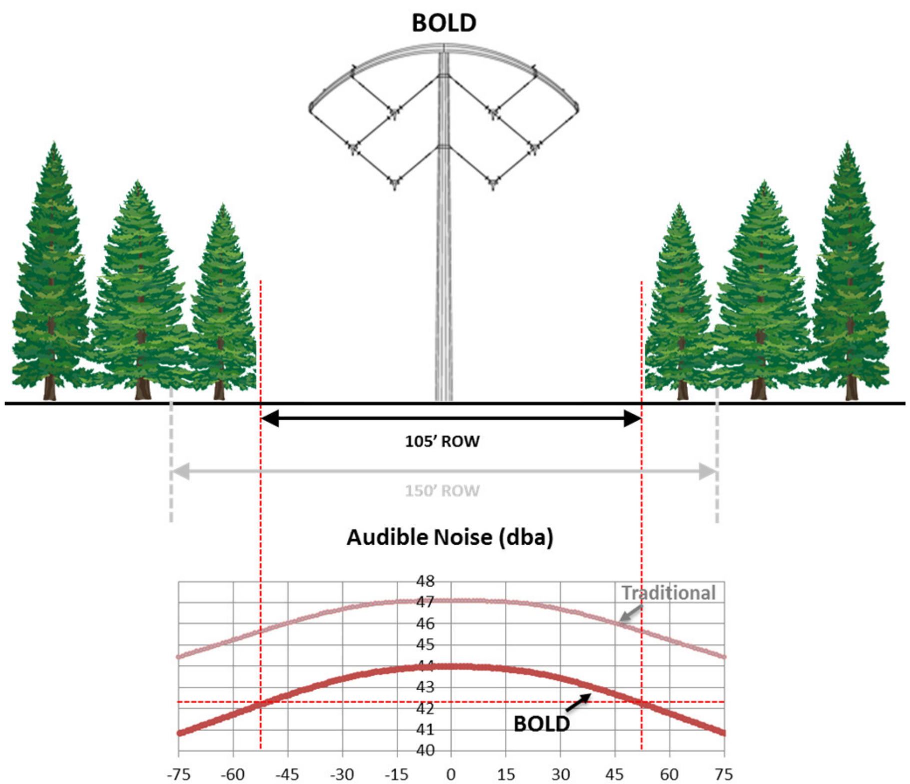


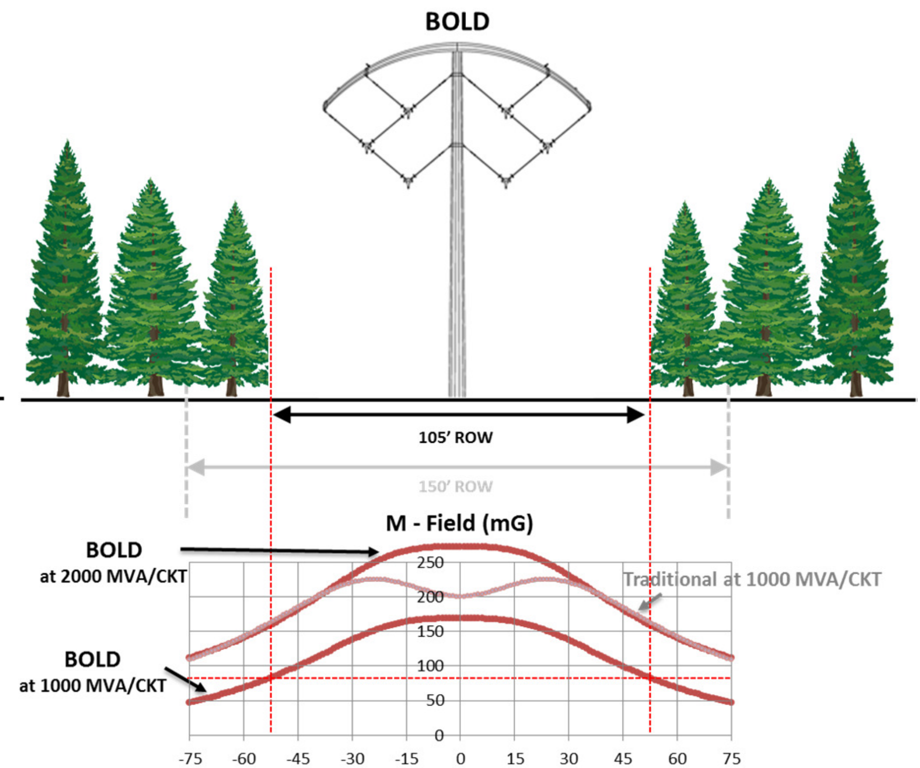
Span Length:	**850 feet**	
Phase Configuration:	**3-954 kCM ACSR Cardinal**	**2-954 kCM ACSR Cardinal**
Overall Structure Height:	**99'-0" (-31%)**	**143'-0"**
Groundline Moment:	**4,700 ft-kips (+2.2%)**	**4,600 ft-kips**
Structure Weights:	**43,000 lbs. (+2.4%)**	**42,000 lbs.**

Power Delivery vs. Profile



Noise & EMF Consideration





- *Design allows for installation in constrained right-of-way*
- *Audible noise 3db lower than conventional*
- *Magnetic field 50% lower at same loading level*

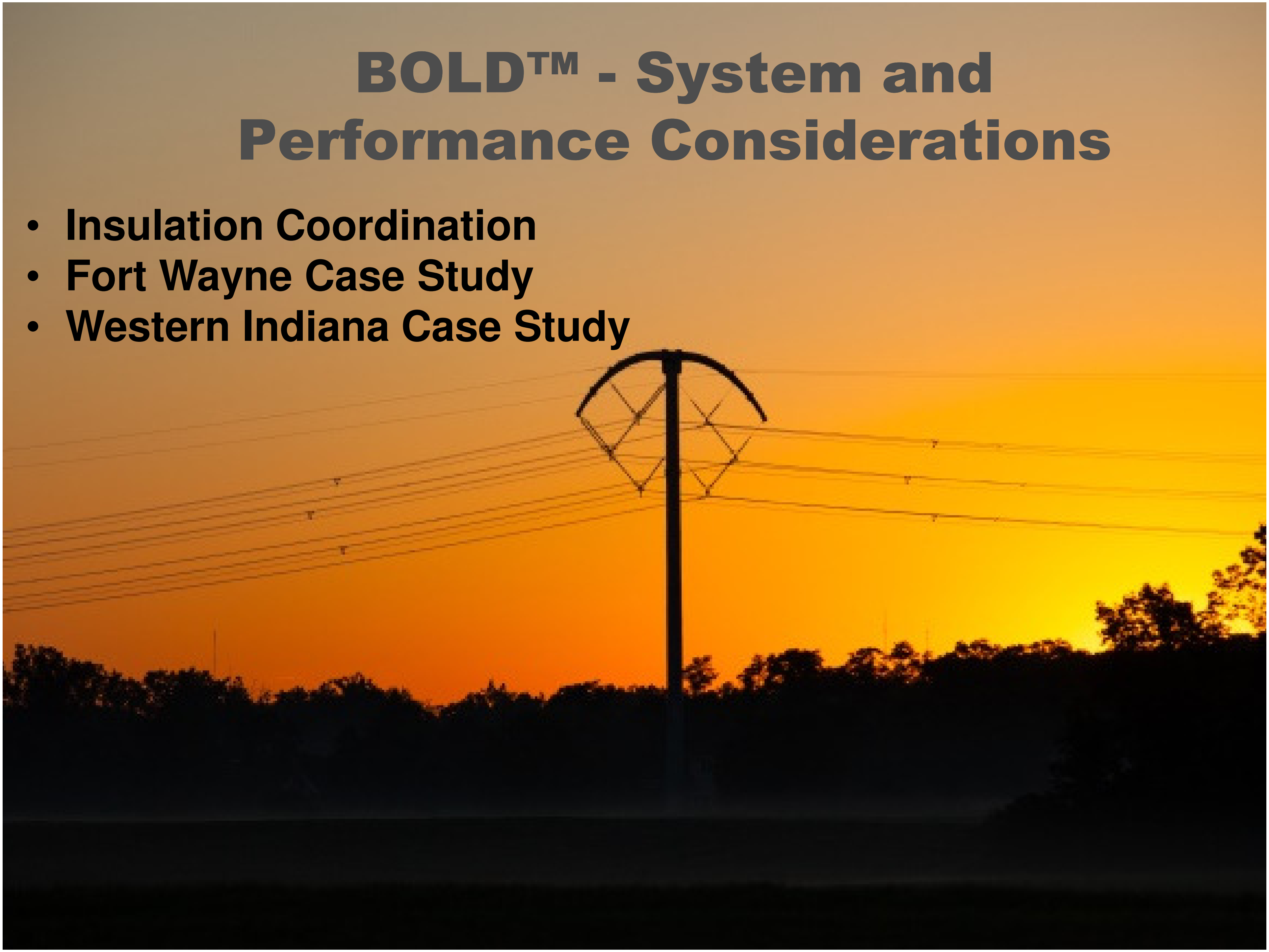
Full-Scale Testing

Electrical Testing

- Corona Inception
- Audible Noise
- Air Gap Electrical Strength
  - Switching Over-Voltage
  - Lightning Over-Voltage

Structure Testing

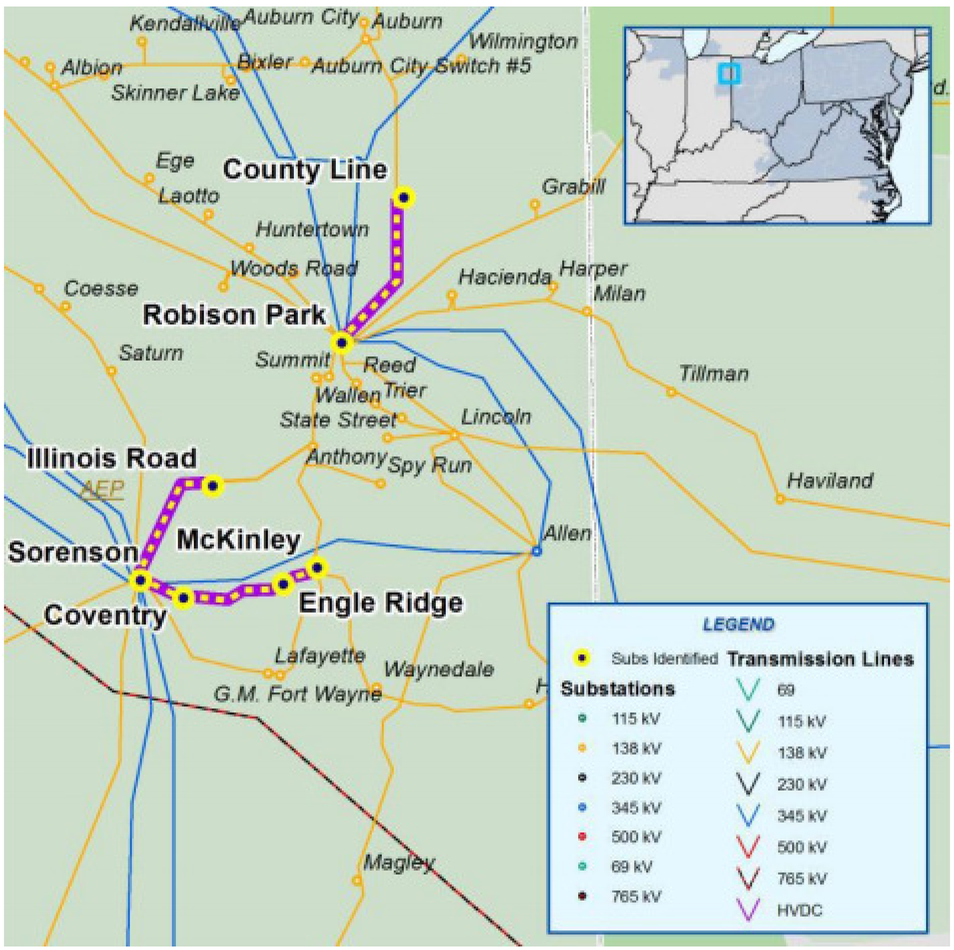
- Validate Design Assumptions
- Validate Selection of Material Properties
- Validate Arm Post-Bending Strength


BOLD™ - System and Performance Considerations
• Insulation Coordination
• Fort Wayne Case Study
• Western Indiana Case Study

Insulation Coordination (IC)

- Appropriate line insulators, tower clearances, hardware, tower grounding, and terminal equipment
- Lightning (IC) assesses overvoltage stresses from shielding failures or lightning strikes to the tower or shield wire system relative to a transmission line's insulation strength
  - Lower height results in fewer lightning flashes
  - Improved backflashover rate due to greater phase-to-ground strike distances
  - Virtually eliminates shielding failure flashovers in flat terrain.
  - Estimated lightning performance of BOLD is as good as or better than that of conventional line designs.
- Switching (IC) assesses overvoltage stresses from various switching events relative to a transmission line's insulation strength
  - Without shunt reactors Ph-G and Ph-Ph flashover probabilities are high. Shunt reactor at the receiving end of the line reduced the flashover probabilities essentially to zero.
  - Pre-insertion resistors in 345 kV CB's of BOLD can help reduce Ph-G and Ph-Ph switching over voltages. For BOLD 230 kV, line-end surge arresters can be used to reduce the risk of switching surge flashovers.
  - System strength has a marginal impact on the switching overvoltage level and hence the switching surge flashover rate.

Fort Wayne, Indiana Case Study

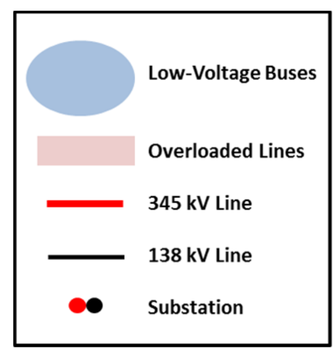


Reliability Concerns:

- Reactive power deficiency
- Widespread low-voltage conditions
- Multiple 138 kV line overloads

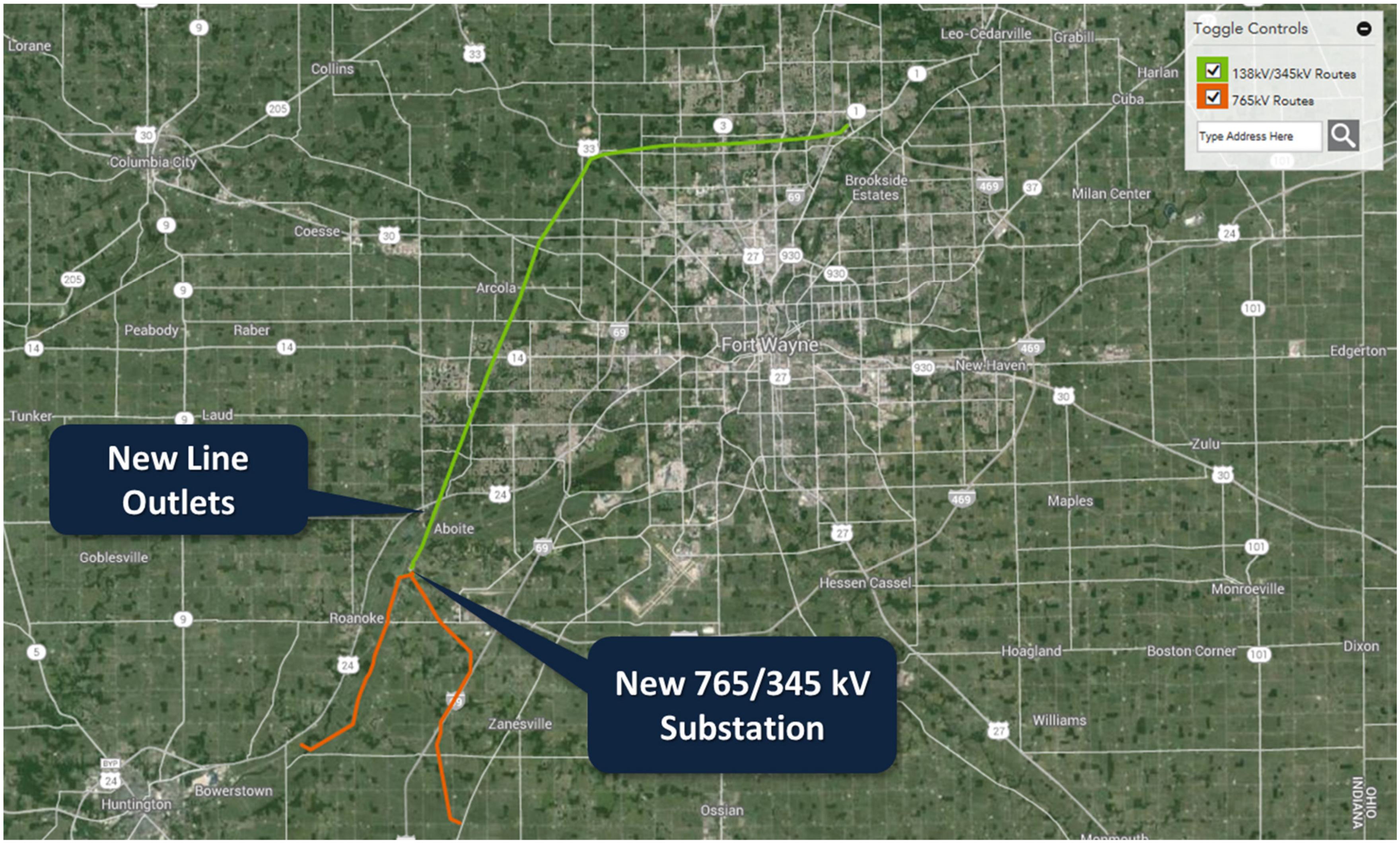
Contributing Factors:

- Limited local generation
- Fossil unit retirements
- New generation primarily wind
- Heavy power flows into Michigan



http://www.pjm.com/~/media/planning/rtep-dev/baseline-reports/2012-rtep-baseline-assessment.ashx

Sorenson Substation Solution



Line Alternatives Considered

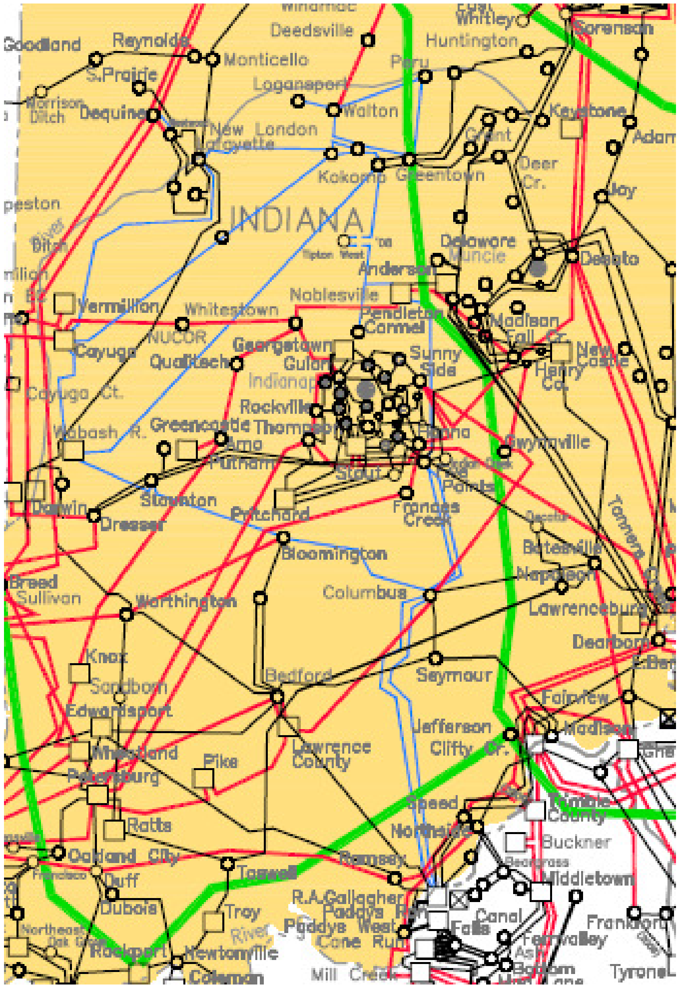
- **Rebuild/Reconductor Existing 138 kV Lines**
  - **Pros:** Avoids issues associated with use of higher voltage; low ROW costs
  - **Cons:** Cost to rebuild of nine total lines; requires additional reactive compensation to meet system needs; significant construction outage requirements; age/condition of existing towers questionable for reconductor
- **New Greenfield Conventional 345 kV Double-Circuit Line**
  - **Pros:** No construction outages required; full double-circuit capacity; no need to convert existing substations
  - **Cons:** Length of routes and ROW add cost; significant landowner impacts
- **Rebuild Existing 138 kV Corridor with Conventional Double-Circuit 345 kV Line**
  - **Pros:** Less ROW cost
  - **Cons:** Requires conversion of 138 kV substations to 345 kV; landowner impacts due to new structures and ROW expansion
- **Rebuild Existing 138 kV Corridor with BOLD 345 kV/138 kV Hybrid Line**
  - **Pros:** Less ROW cost; fewer anticipated landowner impacts; no substation conversions; voltage support from line capacitance
  - **Cons:** First use of technology; cost premium compared with conventional designs

Decision Factors

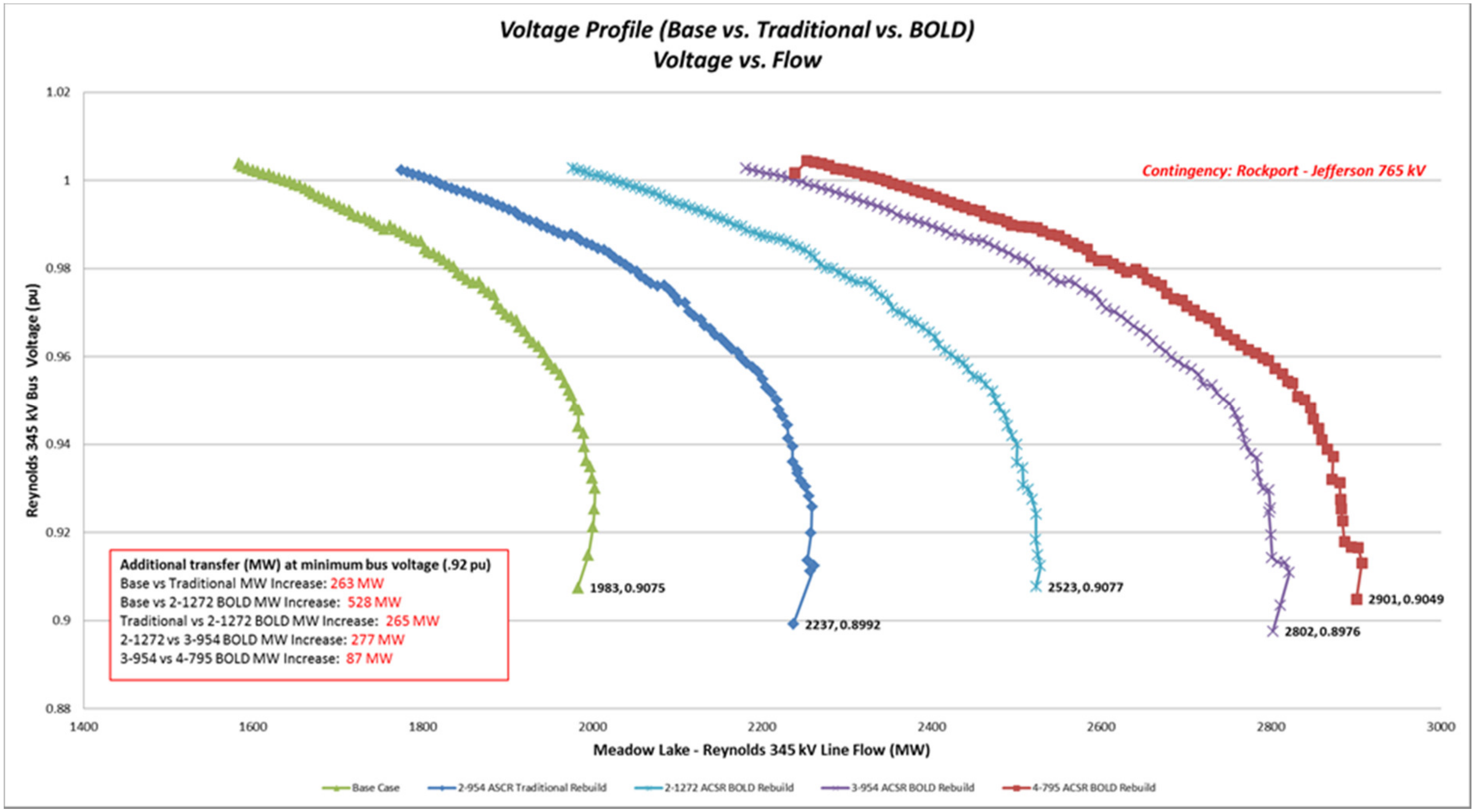
- **Performance** – high capacity, low impedance of BOLD enabled use of single 345 kV line
  - Achieves 5X capacity in same corridor
  - Self-compensating nature of BOLD design boosts system voltages
- **Right-of-way Considerations** – development and encroachments limited corridor expansion and new 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

Western Indiana Study

- Meadow Lake – Reynolds 345 kV line is approved for BOLD rebuild
- Part of a long 345kV double circuit corridor: Sullivan – Reynolds (~120 miles)
  - Meadow Lake Wind Farm (600 MW nameplate and 200 MW in the PJM queue)
  - Fowler Ridge Wind Farm (750 MW nameplate) connected at Dequine 345 kV station
  - Reynolds – Greentown 765 kV line
- PV analysis shows additional benefits of BOLD



Transfer Analysis



Questions