HTS Value Propositions for Utility Applications

Navigant Consulting, Inc.

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The purpose of this presentation is to describe the HTS value proposition analysis undertaken by Navigant Consulting, Inc. (NCI).

- This work follows a prior market survey that indicated that HTS cable and HTS fault current limiters (FCL) are the most promising HTS value propositions for the near term.
- As a result, NCI was tasked by DOE OE to identify the best value propositions for HTS cable and HTS FCLs in electric utility applications.
- NCI developed an analytical framework to assess utility challenges and solutions to address these challenges.
- As part of this project, NCI interviewed 10 utilities to understand potential applications and potential barriers to adoption for HTS cable and HTS FCLs and to transfer knowledge to utilities regarding the current state of the HTS technology and activities of the DOE OE HTS program.
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1. Introduction
2. Analytical Framework
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Our “top down” approach started with the utilities’ strategic goals and ultimately identified appropriate HTS technologies.

HTS technologies and utility key business needs were analyzed to identify the best value proposition for utility applications.
The project approach included the following steps:

1. Identify utility goals, needs, & challenges
2. Identify solutions & technologies
3. Rate/Rank Challenges
4. Rate/Rank HTS Technologies
5. Analyze Challenges vs. HTS Technologies
6. Introductory Webinar
7. Conduct Site Visits
8. Incorporate Utility Input into Analysis
9. Conduct Telephone Interviews
10. Develop Best Value Propositions
Step 1: In the first step, four Strategic Goals were identified.

<table>
<thead>
<tr>
<th>Strategic Goals</th>
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<tbody>
<tr>
<td>1) Meet T&amp;D Capacity Demands</td>
</tr>
<tr>
<td>2) Meet Customer &amp; Regulatory Expectations for T&amp;D Reliability</td>
</tr>
<tr>
<td>3) Minimize Environmental Health and Safety (EHS) Impacts of T&amp;D</td>
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<tr>
<td>4) Ensure Security &amp; Minimize Vulnerability</td>
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</tbody>
</table>
Step 1: Key Business Needs and Challenges associated with these 4 Strategic Goals were identified.

<table>
<thead>
<tr>
<th>Strategic Goals</th>
<th>Key Business Needs</th>
<th>Challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Meet T&amp;D Capacity Demands</td>
<td>Ensure transmission infrastructure is sufficient to serve projected load.</td>
<td>Transmission is constrained by the capacity of the existing infrastructure (incl. load pockets).</td>
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<tr>
<td></td>
<td>Ensure distribution infrastructure is sufficient to serve projected load.</td>
<td>Contingency constraints limit utilization of the transmission system.</td>
</tr>
<tr>
<td></td>
<td>Ensure efficiently priced power is available.</td>
<td>New transmission corridors are difficult to obtain due to space and permitting issues.</td>
</tr>
<tr>
<td></td>
<td>Ensure distribution infrastructure is sufficient to serve projected load.</td>
<td>Adding new generation and/or transmission could cause fault current to exceed breaker ratings.</td>
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<tr>
<td></td>
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<td>Distribution is constrained by the capacity of the existing infrastructure.</td>
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<tr>
<td></td>
<td>Ensure efficiently priced power is available.</td>
<td>Substation capacity in constrained by the existing infrastructure.</td>
</tr>
<tr>
<td></td>
<td>Ensure efficiently priced power is available.</td>
<td>New distribution corridors are difficult to obtain due to space and permitting issues.</td>
</tr>
<tr>
<td></td>
<td>Ensure efficiently priced power is available.</td>
<td>Siting new or expanding existing substations is difficult.</td>
</tr>
<tr>
<td></td>
<td>Ensure efficiently priced power is available.</td>
<td>Adding new generation and/or distribution lines could cause fault current to exceed breaker ratings.</td>
</tr>
<tr>
<td></td>
<td>Ensure efficiently priced power is available.</td>
<td>Due to transmission congestion, there are inadequate transmission resources to access lower cost generation in load pockets.</td>
</tr>
<tr>
<td></td>
<td>Ensure efficiently priced power is available.</td>
<td>Accessing lower cost generation can cause voltage management difficulties.</td>
</tr>
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</table>
Step 1: Key Business Needs and Challenges associated with these 4 Strategic Goals were identified. (Continued)

<table>
<thead>
<tr>
<th>Strategic Goals</th>
<th>Key Business Needs</th>
<th>Challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td>2) Meet Customer &amp; Regulatory Expectations for T&amp;D Reliability</td>
<td>Minimize the frequency and duration of customer interruptions.</td>
<td>The infrastructure is aging. Weather and environmental conditions contribute to equipment failure. System components are subject to heavy loading on a consistent basis leading to component failure. System components are subject to high fault current leading to higher component failures.</td>
</tr>
<tr>
<td></td>
<td>Optimize dynamic performance of system.</td>
<td>Stability constraints limit ability to move power across the system.</td>
</tr>
<tr>
<td></td>
<td>Reduce the impact of using hazardous materials.</td>
<td>Transformers require the use of hazardous material.</td>
</tr>
<tr>
<td></td>
<td>Reduce emissions.</td>
<td>Load pockets are dependant on older local area generation. T&amp;D systems have inherent losses requiring more generation.</td>
</tr>
<tr>
<td>4) Ensure Security &amp; Minimize Vulnerability</td>
<td>Increase infrastructure security.</td>
<td>A large geographically-dispersed system is difficult to guard and it is therefore necessary to reduce the impact of the event.</td>
</tr>
</tbody>
</table>
Step 2: Thirty conventional technologies and 2 HTS technologies (i.e., cable and FCL) were identified to address the 21 Challenges.

<table>
<thead>
<tr>
<th>Strategic Goals</th>
<th>Key Decision Needs</th>
<th>Challenges</th>
<th>Potential Solutions</th>
<th>HTS &amp; RCS</th>
<th>HTS &amp; DC</th>
<th>ML &amp; DC</th>
<th>ML &amp; RCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meet T&amp;D Capacity Demands</td>
<td>Ensure transmission infrastructure is sufficient to serve projected load</td>
<td>Add generation at load center</td>
<td>ML</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reduce load factor</td>
<td>ML</td>
<td>ML</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reduce system losses</td>
<td>ML</td>
<td>ML</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Increase transmission capacity at existing right-of-way</td>
<td>ML</td>
<td>ML</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Add transmission infrastructure</td>
<td>ML</td>
<td>ML</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Contingency constraints limit utilization of the transmission system</td>
<td>Reduce load factor</td>
<td>ML</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Increase load factor</td>
<td>ML</td>
<td>ML</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Improve information available to more effectively manage the capacity</td>
<td>ML</td>
<td>ML</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>New transmission corridors are difficult to obtain due to space and permitting issues</td>
<td>Maximize use of existing right-of-way for transmission</td>
<td>ML</td>
<td>ML</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Facilitate the design of new network</td>
<td>ML</td>
<td>ML</td>
<td></td>
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</tr>
</tbody>
</table>

Examples of Conventional Technologies

- Conventional overhead lines
- Conventional underground cable
- Multi-circuit lines
- DC lines
- Reconfiguration with additional lines
- Higher voltage transmission
- Phase shifting or FACTS devices
- Power factor adjustment
- Static VAR compensators
- Breakers
- Substation
- Transformer
- Series reactors
Below is an example of how the approach was implemented to identify utility Challenges and Potential Solutions to address the Challenge.

<table>
<thead>
<tr>
<th>Strategic Goal</th>
<th>Meet T&amp;D Capacity Demands</th>
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<tbody>
<tr>
<td>Key Business Need</td>
<td>Ensure transmission infrastructure is sufficient to serve projected load.</td>
</tr>
<tr>
<td>Challenge</td>
<td>New transmission corridors are difficult to obtain due to space and permitting issues.</td>
</tr>
<tr>
<td>Potential Solution</td>
<td>Maximize use of existing right-of-ways for transmission.</td>
</tr>
</tbody>
</table>
| Conventional Technologies | **Best Comparison (BC):** new underground cables  
                           **Most Likely (ML):** multi-circuit lines  
                           **Other:** dynamic line rating, higher voltage transmission, reconductoring, enhanced cooling for underground lines, dynamic Volt/VAr control, phase shifting/FACTS devices |
Step 3: The 21 Challenges were rated on a scale of 1 to 5 for urban and rural utilities based on financial investment and extent among utilities.

<table>
<thead>
<tr>
<th>Challenges</th>
<th>Urban Utility</th>
<th>Rural Utility</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Financial Investment</td>
<td>Extent among Utilities</td>
<td>Rating</td>
</tr>
<tr>
<td>Weighting</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

**Financial Investment** – An estimate of the magnitude or significance of the challenge for a particular utility based on capital budget expenditures over a 5 year period. Challenges were rated relative to each other.

**Extent among Utilities** – An estimate of how many utilities across the United States struggle with this challenge.
Step 4: HTS technologies were compared to conventional technologies on a scale of −2 to +2, with 0 indicating relative equivalency.

<table>
<thead>
<tr>
<th>Challenges</th>
<th>Non-Recurring Installed Cost</th>
<th>Recurring Operating Cost</th>
<th>Permitting</th>
<th>Ease of Implementation</th>
<th>Public Benefits</th>
<th>Utility Benefits</th>
<th>Weighted Total Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weighting</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

**Non-Recurring Installed Cost** – This parameter represents the capital equipment and installation labor cost.

**Recurring Operating & Maintenance Cost** – This parameter accounts for O&M costs such as energy use, cryogenic system maintenance, and reduced line losses.

**Permitting** – A positive rating indicates fewer permits are required for the HTS technology.

**Ease of Implementation** – A positive rating indicates that HTS requires less effort due to changes in installation, procedures, or training.

**Public Benefits** – Credit is given if secondary public benefits are achieved such as: reduction in greenhouse gas and toxic air emissions; increased resource efficiency; reduction in the use of hazardous materials and the generation of hazardous waste; improved aesthetics; improved public safety; reduced EMF; minimized land use; and increased infrastructure security.

**Utility Benefits** – Credit is given if secondary utility benefits are achieved such as: increased power density; increased efficiency; improved controllability; improved worker safety; and reduced impacts of fault currents due to the inherent fault current limiting characteristic.
Step 5: The Challenges and associated HTS technologies were analyzed to identify 21 initial value propositions.

![HTS Technology Rating vs. Combined Challenge Rating](image-url)
NCI interfaced with utilities to transfer knowledge regarding the current state of the HTS technology and solicit input regarding value propositions and potential barriers to HTS technology adoption.

- Step 6: An Introductory Webinar was held on December 17, 2007 to:
  - Provide an overview of HTS technology and its application to the electric utility industry
  - Discuss the DOE OE funded R&D program for HTS technology
  - Inform utilities about the objective, scope, and approach for this project
Step 7: NCI conducted 4 interviews at utility sites.

- The purpose of the site visits was to:
  - Provide an overview of HTS technology and its application to the utility industry
  - Describe the objective, scope, and approach for this project
  - Review the utility strategic goals, key business needs, and challenges identified
  - Review the preliminary list of value propositions
- During the site visits, participants were asked to focus on providing input to the rating and prioritization of challenges.
- Participants were also asked to comment on the realism and applicability of preliminary value propositions to their system.
- Responses varied depending on the utility characteristics (urban vs. rural) and location.

**Site Visits**

- NSTAR – November 13, 2007
- First Energy – January 8, 2008
- Florida Power and Light – January 9, 2008
- Progress Energy – January 10, 2008

Step 8: Based on the site visit input, the initial analysis was revised and 9 value propositions were prioritized.
The 9 Value Propositions (VP) discussed during the telephone interviews addressed transmission capacity, substation capacity, and fault current.

### Increase Transmission Capacity with HTS Cable
- VP#1: Maximize the use of existing right-of-ways.
- VP#2: Reduce space and permitting requirements to facilitate the siting of a new corridor.
- VP#3: Install new infrastructure.

### Reduce Short Circuit Duty with HTS FCLs
- VP#8: Use HTS FCLs for transmission.
- VP#9: Use HTS FCLs for distribution.

### Increase Substation Capacity with HTS Cable
- VP#4: Interconnect substations to avoid a new substation.
- VP#5: Interconnect substations to avoid a new transformer.
- VP#6: Interconnect substations with HTS cable instead of conventional cable.
- VP#7: Connect a substation located outside of a load center to minimize space and permitting limitations.
Step 9: NCI conducted 6 telephone interviews to discuss the prioritized value propositions.

- The purpose of these telephone interviews was to:
  - Review the revised list of value propositions
  - Discuss the role of HTS in Planning and Development such as:
    - Key milestones in the commercialization pathway
    - Barriers to technology adoption
- Responses varied depending on the characteristics (urban vs. rural) and location of the utilities.

<table>
<thead>
<tr>
<th>Telephone Interviews</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sacramento Municipal Utility District – March 13, 2008</td>
</tr>
<tr>
<td>Consolidated Edison – March 19, 2008</td>
</tr>
<tr>
<td>Exelon – March 21, 2008</td>
</tr>
<tr>
<td>Entergy – March 24, 2008</td>
</tr>
<tr>
<td>Southern California Edison – April 2, 2008</td>
</tr>
<tr>
<td>Long Island Power Authority – April 17, 2008</td>
</tr>
</tbody>
</table>

Step 10: Based on the utility input from the telephone interviews, the initial analysis was revised and 3 best value propositions for the electric utility industry were identified.
Compiling the initial analysis and the input from the utility interviews led to the identification of the 3 best value propositions.

1. **Initial Analysis** – Challenges and HTS Technologies were identified and rated to prioritize 21 potential value propositions.

2. **Utility Interface: Site Visits** – Based on the utility input on Challenge ratings, HTS Technology ratings, and 21 value propositions, the initial analysis was refined to prioritize 9 value propositions.

3. **Utility Interface: Telephone Interviews** – Based on the utility input on 9 value propositions, 3 were determined to be the best value propositions.

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HTS Value Propositions for Utility Applications
The best value propositions identified through the initial analysis and through utility input are:

1. VP#1: Use HTS cable to maximize the use of existing right-of-ways to increase transmission capacity.
   “Installing HTS cable in existing ducts is an opportunity to combat congestion without adding infrastructure.”
   “Where underground ducts already exist, HTS would absolutely be considered.”

2. VP#8: Use HTS fault current limiters (FCLs) to reduce short circuit duty on transmission systems.
   “The issue of fault current exceeding breaker duties is a rising concern for most utilities around the country.”
   “FCLs can offer significant advantages by avoiding breaker upgrades.”

3. VP#4: Interconnect substations with HTS cable to maximize substation capacity and avoid the need for new substations.
   “Connecting substations with HTS cable is an application the transmission planning group sees as a solution.”
   “The primary advantage of this application is avoiding the land requirements to build a new substation.”
Best Value Proposition #1: Use HTS fault current limiters (FCLs) to reduce short circuit duty on transmission systems.

**Strategic Goal**
Meet T&D Capacity Demands

**Key Business Need**
Ensure transmission infrastructure is sufficient to serve projected load

**Challenge**
New generation and/or transmission lines could cause fault current to exceed breaker ratings.

**Potential Solution**
Reduce short circuit duty

**Conventional Technologies**
BC: reconfigured network via additional lines; ML: breakers with higher ratings; Other: series reactor, DC lines, phase shifting or FACTS devices, solid state FCL

**Description:** In this analysis, an HTS FCL is compared to reconfiguring the network with additional lines in areas where fault current could exceed breaker ratings.

**Rationale:** As power systems become more highly networked and as more and more generation comes online, controlling fault current to within toleration levels of existing equipment is critical. HTS FCLs can control fault currents to levels that existing circuit breakers can operate. HTS FCLs can also minimize equipment damage from high through fault currents and improve worker safety.

**Utility Input:** All utilities interviewed indicated that dealing with fault current that exceeds breaker ratings is a growing challenge and that FCLs would add significant value.
Best Value Proposition #1: In this example, an HTS FCL reduces the short circuit duty from 65,000 A to 50,000 A.

<table>
<thead>
<tr>
<th>Contribution</th>
<th>Fault Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generator</td>
<td>15,000 A</td>
</tr>
<tr>
<td>Trans Ckt #1</td>
<td>18,000 A</td>
</tr>
<tr>
<td>Trans Ckt #2</td>
<td>16,000 A</td>
</tr>
<tr>
<td>Trans Ckt #4</td>
<td>16,000 A</td>
</tr>
<tr>
<td>Total</td>
<td>65,000 A</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Contribution</th>
<th>Fault Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generator</td>
<td>0 A</td>
</tr>
<tr>
<td>Trans Ckt #1</td>
<td>18,000 A</td>
</tr>
<tr>
<td>Trans Ckt #2</td>
<td>16,000 A</td>
</tr>
<tr>
<td>Trans Ckt #4</td>
<td>16,000 A</td>
</tr>
<tr>
<td>Total</td>
<td>50,000 A</td>
</tr>
</tbody>
</table>
Best Value Proposition #2: Use HTS cable to maximize the use of existing right-of-ways to increase transmission capacity.

<table>
<thead>
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<th>Strategic Goal</th>
<th>Meet T&amp;D Capacity Demands</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key Business Need</td>
<td>Ensure transmission infrastructure is sufficient to serve projected load.</td>
</tr>
<tr>
<td>Challenge</td>
<td>New transmission corridors are difficult to obtain due to space and permitting issues.</td>
</tr>
<tr>
<td>Potential Solution</td>
<td>Maximize use of existing right-of-ways for transmission.</td>
</tr>
<tr>
<td>Conventional Technologies</td>
<td>BC: new underground cables; ML: multi-circuit lines; Other: dynamic line rating, higher voltage transmission, reconductoring, enhanced cooling for underground lines, dynamic Volt/VAr control, phase shifting/FACTS devices</td>
</tr>
</tbody>
</table>

**Description:** In this analysis, HTS cables are compared to adding new underground conventional cables. This assumes that new transmission corridors are difficult to obtain due to space and permitting issues and no new overhead lines can be constructed. This application is especially valuable where HTS cables can be installed in existing underground ducts.

**Rationale:** HTS can provide greater capacity in the same size or smaller footprint.

**Utility Input:** HTS cables would be very attractive if they could fit into existing underground ducts. This would reduce the cost and effort significantly. However, most utilities do not have significant lengths of conventional underground cable. So, the application of this value proposition would be limited.
Best Value Proposition #2: HTS cables can be added to an existing duct bank to increase transmission capacity by filling empty ducts or replacing conventional cable.

**BEFORE**

1350 A, 138 kV
323 MVA

**AFTER: TRADITIONAL SOLUTION**

1800 A, 138 kV,
430 MVA

The traditional solution would require a larger duct bank to transmit an equivalent amount of capacity carried by HTS cables.

**AFTER: HTS BASED SOLUTION**

2700 A, 138 kV,
645 MVA

The HTS solution would not require the addition of a new duct bank to transmit the required capacity.
Best Value Proposition #3: Interconnect substations with HTS cable to maximize substation capacity and avoid the need for new substations.

**Strategic Goal** | Meet T&D Capacity Demands
---|---
**Key Business Need** | Ensure distribution infrastructure is sufficient to serve projected load
**Challenge** | Substation capacity is constrained by the existing infrastructure
**Potential Solution** | Increase substation capacity
**Conventional Technologies** | BC: new substation; ML: new transformers

**Description:** In this analysis, interconnecting substations to enable the use of unused transformer capacity is compared with adding a new substation to increase substation capacity. For example, if 3 substations each have 2 transformers utilized at 60% capacity in normal operations, a transformer may have to support 120% capacity if one transformer fails. However, if the substations are connected, each transformer could be operated at 100% under normal conditions and would rely on transformers at two adjacent stations if one transformer fails.

**Rationale:** Maximizing the use of transformers at existing substations may eliminate the need for new substations or transformers.

**Utility Input:** If substations in a radial network are located within a few miles of each other, sharing capacity would provide significant value, especially if a new substation can be avoided. However, this may be a niche application.
Best Value Proposition #3: Under normal conditions, two new substations would be required to equal the capacity of interconnecting existing substations with HTS cables.

**TRADITIONAL SOLUTION**

Two new stations are added where each station relies on a parallel transformer during an outage limiting normal station load to 60% of its nameplate rating.

- Total nameplate capacity = $10 \times 50$ MVA = 500 MVA
- Maximum normal load = $10 \times 60\% \times 50$ MVA = 300 MVA
- Unused capacity = 200 MVA
- Emergency load = $((8 \times 60\%) + (1 \times 120\%)) \times 50$ MVA = 300 MVA

**HTS BASED SOLUTION**

Ties to adjacent stations allow each transformer to be loaded to 100% of nameplate rating when all units are in service.

- Total nameplate capacity = $6 \times 50$ MVA = 300 MVA
- Maximum normal load = $6 \times 100\% \times 50$ MVA = 300 MVA
- Unused capacity = 0 MVA
- Emergency load = $5 \times 120\% \times 50$ MVA = 300 MVA
In addition to the best value propositions identified, the following issues were raised based on utility input:

- **HTS Cable Diameter**
  A significant near-term opportunity may exist if HTS cable could fit into existing underground transmission ducts.

- **Auxiliary Equipment Footprint**
  The footprint of the cryogenic system equipment must be taken into consideration to ensure that the benefits of higher power density through the HTS cable are not negated.

- **Overall Cost**
  Utilities perceive the cost of HTS cable to be too high to be competitive with conventional technologies.

- **Reliability**
  Replacing several conventional cables with a single HTS cable creates a single point of failure and leads to concerns regarding reliability and redundancy. Utilities also voiced concern regarding the reliability of a new, unproven technology.
To achieve the objective of the next phase, NCI will engage three key stakeholders: utilities, regulators, and the HTS industry.

Increase awareness and foster acceptance of HTS technology within the electric utility industry

**Utilities**
- Provide utilities with the information and framework necessary to evaluate HTS solutions as compared to conventional solutions.

**Regulators**
- Understand regulatory requirements for approval of HTS investments by engaging regulatory commission staff in discussions and review of analysis approaches.

**HTS Industry**
- Collaborate with the HTS industry by providing project status updates and soliciting input.
The proposed approach includes the following steps:

1. **Conduct a Literature Review**
   - Survey existing frameworks used to compare alternative T&D investment options.
   - Characterize how utilities currently compare alternative solutions.
   - Understand what costs and benefits are considered by regulators.

2. **Interview Regulators**
   - Identify variations in requirements for approval by jurisdiction.
   - Identify variations in requirements for approval for new technologies versus established technologies.

3. **Interface with the HTS Community**
   - Collaborate with utilities to identify parameters necessary to develop the analysis framework.
   - Update the HTS industry on the status of the project.

4. **Develop an Analysis Framework**
   - Develop an analysis framework by identifying and quantifying the categories of costs and benefits of conventional solutions and HTS solutions.
   - Use sensitivity analyses to understand key value drivers.

5. **Interface with the HTS Community**
   - Interface with utilities to review the developed alternative analysis framework.
   - Update the HTS industry on the status of the project.

6. **Apply the Analysis Framework to Case Studies**
   - Use case studies with real world examples, based on actual or planned utility projects or reasonable prototypical projects.
   - Collaborate with utilities to provide input for the case studies and refine the analysis framework.
<table>
<thead>
<tr>
<th>Name</th>
<th>Title</th>
<th>Phone</th>
<th>Email</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>David Walls</td>
<td>Director</td>
<td>781.270.8436</td>
<td><a href="mailto:DWalls@navigantconsulting.com">DWalls@navigantconsulting.com</a></td>
<td>77 South Bedford St, Ste 400</td>
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<tr>
<td>Colette Lamontagne</td>
<td>Managing Consultant</td>
<td>781.270.8340</td>
<td><a href="mailto:Colette.Lamontagne@navigantconsulting.com">Colette.Lamontagne@navigantconsulting.com</a></td>
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