Installation of Advanced Composite Core Conductors: a growing part of capacity expansion and reliability at PLN

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PLN manages a transmission network spread across hundreds of islands with a population of almost 250 million people and over 50 million customers.
The toughest challenge faced by PLN is maintaining transmission capacity and meeting the rapid growth of demand and generation of new power.

- Growth on transmission lines (1,99%) and power transformer (11,91%) is still not covering the load growth (7,5%).
- Indonesian Electrification ratio: 78% → challenge and opportunity.
PLN require a growing solution used to upgrade the existing transmission lines and rapidly add capacity before new lines can be installed.

Only reconductoring existing assets with new tech. conductors can alternatively keep pace with PLN plans to add 5 – 10 GW per year.

Social problem: Public resistant to new OHTL
Composite core conductors were selected by PLN as HTLS conductors: (1) higher temp and (2) more Aluminum.

1. GAP 265mm²
2. ACSS “Hen” 242mm²
3a. Steel reinforced Various mm²
3b. ACCR 322mm²

Increase Operating Temperature = Increased Ampacity
Add more conductive material with lower conductivity, = net improvement over ACSR

ACSR “Lion” 238mm²
AAAC “Upas” 362mm²

Maximize Conductive Material for Lowest Losses
Composite Core 360 mm²
Al Equivalent 381 mm²
High Temperature with Low Sag

1. GAP
2. ACSS “Hen”
3. Steel reinforced
3a. Various mm²
3b. ACCR

Increase Operating Temperature = Increased Ampacity
Add more conductive material with lower conductivity, = net improvement over ACSR
After 30 projects and almost 6,000 kilometers of installations, PLN is now have more experiences on composite core conductor installation and performance.

<table>
<thead>
<tr>
<th>No</th>
<th>Project Name</th>
<th>Total CCTs</th>
<th>Line Length</th>
<th>Ex</th>
<th>Upgraded New Conductor</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bukit Asam - Lahat (Sumatera)</td>
<td>2</td>
<td>44.7</td>
<td>ACSR Hawk</td>
<td>Comp/Core 310 Lisbon</td>
<td>Energized on October 2010</td>
</tr>
<tr>
<td>2</td>
<td>New Tangerang – Cengkareng</td>
<td>2</td>
<td>6.2</td>
<td>2 x ACSR Zebra</td>
<td>2 x Comp/Core 520 Dublin</td>
<td>Energized on April 2011</td>
</tr>
<tr>
<td>3</td>
<td>Angke – Ancol</td>
<td>2</td>
<td>4.7</td>
<td>ACSR Drake</td>
<td>Comp/Core 510 Warsaw</td>
<td>Energized June 2011</td>
</tr>
<tr>
<td>4</td>
<td>Kota Bumi - Bukit Kemuning (Sumatera)</td>
<td>2</td>
<td>34.3</td>
<td>ACSR Hawk</td>
<td>Comp/Core 310 Lisbon</td>
<td>Energized June 2011</td>
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<tr>
<td>5</td>
<td>Bandung Selatan - Cigereifeng</td>
<td>2</td>
<td>13.26</td>
<td>2 x ACSR Dove</td>
<td>2 x Comp/Core 310 Lisbon</td>
<td>Energized on October 2011</td>
</tr>
<tr>
<td>6</td>
<td>Cibinong - Sentul - Bogor Baru</td>
<td>2</td>
<td>23</td>
<td>ACSR Dove</td>
<td>Comp/Core 360 Amsterdam</td>
<td>Energized Feb 2012</td>
</tr>
<tr>
<td>7</td>
<td>Menanggir - Incomer</td>
<td>2</td>
<td>4.3</td>
<td>2 x ACSR Hawk</td>
<td>2 x Comp/Core 310 Amsterdam</td>
<td>Energized 2012</td>
</tr>
<tr>
<td>8</td>
<td>Pedan - Klaten</td>
<td>2</td>
<td>12.7</td>
<td>1 x ACSR Hawk</td>
<td>Comp/Core 310 Lisbon</td>
<td>Energized on April 2012</td>
</tr>
<tr>
<td>9</td>
<td>Langsa – Pangkalan Brandan (Sumatera)</td>
<td>2</td>
<td>127</td>
<td>ACSR Hawk</td>
<td>Comp/Core 310 Lisbon</td>
<td>1cct energized Sept 2012</td>
</tr>
<tr>
<td>10</td>
<td>Langsa – Pangkalan Brandan (Sumatera)</td>
<td>2</td>
<td>39.5</td>
<td>ACSR 150/50</td>
<td>Comp/Core 150 Helsinki</td>
<td>Energized on Sept 2012</td>
</tr>
<tr>
<td>11</td>
<td>Pagelaran – Tegineneng (Sumatera)</td>
<td>2</td>
<td>127</td>
<td>ACSR Hawk</td>
<td>Comp/Core 520 Dublin</td>
<td>Energized Oct 2012</td>
</tr>
<tr>
<td>12</td>
<td>Mandai-Pangkep (Makassar)</td>
<td>2</td>
<td>127</td>
<td>ACSR Hawk</td>
<td>Comp/Core 310 Lisbon</td>
<td>Energized on Sept 2012</td>
</tr>
<tr>
<td>13</td>
<td>Kediri-Kediri Baru</td>
<td>2</td>
<td>127</td>
<td>ACSR Hawk</td>
<td>Comp/Core 310 Lisbon</td>
<td>Energized Sept 2012</td>
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<td>14</td>
<td>Gilimanuk – Celukan Bawang (Bali)</td>
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<td>15</td>
<td>Kapal - Padang Sambian - Pesanggaran (Bali)</td>
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<td>ACSR Hawk</td>
<td>Comp/Core 310 Lisbon</td>
<td>Energized Jan 2013</td>
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<tr>
<td>16</td>
<td>Probolinggo - Lumajang</td>
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<td>127</td>
<td>ACSR Hawk</td>
<td>Comp/Core 310 Lisbon</td>
<td>Energized on Jan 2013</td>
</tr>
<tr>
<td>17</td>
<td>Natar-Sutami</td>
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<td>127</td>
<td>ACSR Hawk</td>
<td>Comp/Core 310 Lisbon</td>
<td>Energized on May 2013</td>
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<tr>
<td>18</td>
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<td>39.5</td>
<td>ACSR 150/50</td>
<td>Comp/Core 150 Helsinki</td>
<td>Energized June 2013</td>
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<tr>
<td>19</td>
<td>Cibinong – ITP</td>
<td>2</td>
<td>8.5</td>
<td>ACSR Hawk</td>
<td>Comp/Core 310 Lisbon</td>
<td>1cct energized Oct 2013</td>
</tr>
<tr>
<td>20</td>
<td>PLTGU Duri – Garuda Sakti</td>
<td>2</td>
<td>80.3</td>
<td>ACSR HAWK</td>
<td>Comp/Core 360 Amsterdam</td>
<td>Energized on Dec 2013</td>
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<tr>
<td>21</td>
<td>Surabaya Barat – Babatan</td>
<td>2</td>
<td>15.6</td>
<td>ACSR Hawk</td>
<td>Comp/Core 310 Lisbon</td>
<td>Energized on January 2014</td>
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<tr>
<td>22</td>
<td>PLTGU Duri – Duri</td>
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<td>42</td>
<td>ACSR Hawk</td>
<td>Comp/Core 310 Lisbon</td>
<td>Energized on April 2014</td>
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<td>23</td>
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<td>98.5</td>
<td>ACSR Hawk</td>
<td>Comp/Core 310 Lisbon</td>
<td>Energized on July 2014</td>
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<tr>
<td>24</td>
<td>GI Sei Harapan - GI Baloi - GI Batu Besar (Batam)</td>
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<td>16.72</td>
<td>1 x ACSR Hawk</td>
<td>Comp/Core 310 Lisbon</td>
<td>Energized October 2014</td>
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<td>25</td>
<td>Borang - Seduduk Putih</td>
<td>2</td>
<td>13</td>
<td>ACSR 120/25</td>
<td>Comp/Core 150 Helsinki</td>
<td>1 cct energized Oct 2014</td>
</tr>
<tr>
<td>26</td>
<td>Cilegon Baru – Serang</td>
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<td>22.7</td>
<td>ACSR Zebra</td>
<td>Comp/Core 550 Hamburg</td>
<td>Under Construction</td>
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<tr>
<td>27</td>
<td>Dumai – Duri</td>
<td>2</td>
<td>55.8</td>
<td>ACSR Hawk</td>
<td>Comp/Core 310 Lisbon</td>
<td>Under Construction</td>
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<td>28</td>
<td>Baturaja – Bukit Asam</td>
<td>2</td>
<td>72.74</td>
<td>ACSR Hawk</td>
<td>Comp/Core 310 Lisbon</td>
<td>Under Construction</td>
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<td>29</td>
<td>Binjai - Paya geli</td>
<td>2</td>
<td>13.7</td>
<td>2x ACSR Hawk</td>
<td>2 x Comp/Core 310 Lisbon</td>
<td>Under Construction</td>
</tr>
<tr>
<td>30</td>
<td>Padalarang - Cibabat</td>
<td>2</td>
<td>9.2</td>
<td>2x ACSR Hawk</td>
<td>2 x Comp/Core 310 Lisbon</td>
<td>Under Construction</td>
</tr>
</tbody>
</table>

Almost doubled ampacity (726 amp to 1350 amp) Without any changes to tower constructions
Composite core have delivered on the promise of higher capacity, low $I^2R$ losses and maintaining sag clearance without tower modifications.

<table>
<thead>
<tr>
<th>Expectation</th>
<th>Performance Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity Increase</td>
<td>Double capacity versus installed ACSR conductor of the same diameter.</td>
</tr>
<tr>
<td></td>
<td>Meets expectations. Composite core conductors that use trapezoidal strands of pure aluminum have matched performance models for capacity.</td>
</tr>
<tr>
<td>Low Losses</td>
<td>40% reduction lower $I^2R$ losses versus ACSR of same diameter. (~50% capacity increase with the same $I^2R$ losses.)</td>
</tr>
<tr>
<td></td>
<td>Meets expectations. Composite core conductors that use trapezoidal strands of pure aluminum meet resistance target.</td>
</tr>
<tr>
<td>Low Sag</td>
<td>Provide up to two times capacity while matching the clearance of the initial ACSR conductor.</td>
</tr>
<tr>
<td></td>
<td>Meets expectations. Low thermal expansion of composite core conductors has been proven in the field.</td>
</tr>
<tr>
<td>Ease and Speed of Installation</td>
<td>Install at least 10km circuit in 2 weeks with standard equipment/techniques to allow for open bid with multiple bidders.</td>
</tr>
<tr>
<td></td>
<td>Exceeds expectations. After three years of experience, local contactors can beat this target of installation speed.</td>
</tr>
<tr>
<td>Cost of Project</td>
<td>Less than ACSR conductor size increase (or twin conductor) and tower expansion.</td>
</tr>
<tr>
<td></td>
<td>Meets expectations. The cost of conductor is offset by the speed and elimination of tower improvements.</td>
</tr>
</tbody>
</table>

Metal core HTLS conductors struggle to meet project capacity increases while maintaining sag without significant tower modifications increasing time/costs.
Composite core conductors have had installation issues, but on whole it has been identified and solved to be reliable and consistent as any conductor.

<table>
<thead>
<tr>
<th></th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td># of Projects</td>
<td>1</td>
<td>4</td>
<td>8</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>KM of HTLS</td>
<td>268</td>
<td>468</td>
<td>1,092</td>
<td>1,732</td>
<td>2,297</td>
</tr>
<tr>
<td># of DE/MSJ</td>
<td>126 / 60</td>
<td>912 / 112</td>
<td>1398 / 219</td>
<td>3042 / 291</td>
<td>3762 / 645</td>
</tr>
<tr>
<td>Small Issues</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Large Issues</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

**Case 1**
Unreported installation error while deadending.

**Case 2**
Puller location during stringing led to bad installation technique during deadending.

**Case 3**
Poorly manufactured conductor was delivered to the field and decided by all parties (including core manufacturer) to be installed with techniques that deviated from standard.

**Case 4**
Unreported installation issue during mid span joint completion.
2010: Issue #1
Installation crew did not report conductor drop during deadending process.

The Facts:
• During the deadend process, the conductor was not properly secured and dropped causing damage to the core at the grip.
• The crew did not report the incident to the supervisor and the damage was not repaired until after initial energization.

Lessons Learned
• No matter how good the procedures and training are, communication is the key to identifying damage and making repairs in the field.
• Training was changed to emphasize that reporting mistakes is not an issue.
Unnoticed bad angle on tensioned conductor during deadending process.

The Facts:

- Excellent control of angles were used by the contractor on a difficult puller placement.
- Damage was caused pulling the grip to deadend.
- A repair was made and the line has operated as expected.

Lessons Learned

- Pre-planning is important to identify areas that require non-standard techniques.
- Supervisors and Master Installers should be involved early in the project planning in order to focus on the exceptions during a project.
2013: Issue #3
Tensioned control line during mid-span joint installation.

The Facts:

• A control line was not released in a timely fashion after installing a mid-span joint.

• The damage was repaired and the line is operating as expected.

Lessons Learned

• Trained crews and supervisors can still make mistakes during installation, but following techniques and reporting errors can fix problems before installation.
2012: Issue #4

“Keystoned” conductor was not rejected at the factory and led to field issues.

Well made composite core conductor has good contact between all layers of aluminum strands and composite core.

Three examples of extreme keystoning during installation illustrate the extent and variability of the issue. Resulting in the need to adjust the sagging technique.
Systematic use of core crushing clamp to adjust for poorly made conductor.

The Facts:

- Poorly stranded conductor resulted in grips not being able to hold during deadending, to avoid slippage a non-standard technique using a wavy clamp (deadend shoe) was employed.

- Details of the damage and repairs to follow.
Extensive laboratory testing confirmed the cause of damage.

- On all samples examined in the lab, there was an exact correlation of the damaged areas and the waves of the deadend shoe.
- The exact amount of damaged varied by the "heaviness" of the crimp, and perhaps by the amount of keystoning, but the sample size was too small to confirm an exact correlation.
2012: Issue #4
Repairs were made with the support of the core and conductor supplier.

The line is now operating at ±80% of maximum capacity (±150% ACSR).
In 2010, before the first installation in Indonesia, PLN and the core and conductor suppliers met to establish training and supervision procedures for projects.

1. Submit core and conductor information to allow PLN to create specifications.
2. Submit samples and qualify to the PLN specification.
3. Supply core to manufacturer.
4. Supply conductor to contractor.
5. Training of contractor in a classroom environment prior to job.
6. Field training of the installation crew and introduction of supervisors.
7. Supervise in the field to ensure good technique, make recommendations, and troubleshoot as needed.
In 2014, after four years and 30 projects, PLN and the core and conductor suppliers met to recommend improvements to training and supervision.

1. The core supplier or designated company will sign off on conductor quality before delivery to the jobsite.

2. PLN is taking a more active role in the training and certification of contractors to the guidelines and techniques of all suppliers.

3. The core supplier or designated company will sign off on the installation, indicating that best practices were followed and the conductor is properly installed.
Example of installation training slides using pictures as well as words.

- Store the reels with flanges upright.
- Never lay or transport the reels on their side. Only exception is when the reels are transported by air freight.
- Lift reels with spreader bar/cradle sling.
- Lift reels using ‘fork truck’ approaching from side of reel so the weight is lifted on reel flanges.
- Never lift reels with short slings that cave in the sides of the reel.
Example of installation training slides using pictures as well as words.

Lifting the Conductor

- Do not lift the conductor with the hook of a strap hoist or chain hoist. Lifting in this way could damage the conductor/core.
- Use a wide nylon strap or other lifting device that doesn’t put a sharp angle on the conductor/core.
- Lift on the armor rod wires to distribute the force being applied on the conductor.
Example of installation training slides using pictures as well as words.

By dropping down the insulator and hooking the deadend to the insulator, there is very little chance of damaging the conductor. For higher voltages the insulators are heavy. Use an alternate method for lifting the conductor. Acceptable but not preferred. Birdcages are possible and the conductor is more likely to be damaged.
Example of installation training slides using pictures as well as words.

**Sagging the conductor**

Control the conductor at all times from the grip back to the structure. Protect the conductor from being damaged near the hoist hook at the grip. (See orange hose below). If the conductor were to fall from the grip, the core could likely be damaged.
Good people and good training are the keys to all success. PLN has incorporated composite core installation and maintenance training into standard practice.

Since 2010 there are:

- 4 Master Installers
- 11 Contractors
- 48 Supervisor
- 155 Trained linesmen

An increased focus on training began in 2014, and will continue with PLN Corporate Univ.

PLN demonstrates high commitment in improving the human resources competence and integrity to support the transformation into a world class electricity company. PLN has realized competence and integrity improvement training programs, comprising:

- Conducting training programs.
- Declaration of training - education facility becoming the PLN - Corporate University
- Organizing the 4th Knowledge, Norm, Innovation, Festival and Exhibition (KNIFE) innovation week in 2013.
- Declaration of compliance with Code of Conduct.
Composite core conductors have proven themselves a valuable part of the PLN solution to rapidly add transmission capacity and maintain efficiency.

1. PLN General Managers, engineers, project and asset managers, and maintenance managers have developed confidence in composite core conductors.

2. Multiple suppliers of composite core conductor provide high quality and pricing competition.

3. To meet PLN and Government plans for 5-10 GW per year, composite core conductors are expected to be a much larger part of transmission grid expansion in the next 5 years.

4. No other HTLS conductor can be used as effectively and quickly to add capacity and maintain system efficiency as composite core conductors.

Expanded use of composite core conductors on 275kv and 500kv transmission will reduce the need for new lines to move power to critical load centers.
Composite core conductors have become an alternative solution for transmission line congestion in Indonesia with 4 years and 30 projects of proven reliability.

1. Any experienced contractor can successfully install composite core conductors if the guidelines provided by suppliers are followed.

2. To minimize the learning curve for contractors, PLN has focused on reinforcing the three steps of (1) planning, (2) training and (3) supervision for each project.

3. PLN support for “Master Installers” to have authority in the field during installation has created a positive avenue to communicate questions or incidents and continue training and troubleshooting during the job.

4. After four years of installation, composite core conductors have become an alternative product option for PLN with multiple experienced contractors bidding on every project.

5. Composite core conductors have proven safe and reliable on thirty projects since 2010, and PLN is considering to use composite core conductors on higher voltage transmission lines up to 500kv in the future.
Thank You