Live-line transmission lines upgrade projects

First-in-Africa project

Author & presenter: Patrick O'Halloran BTECH – Manager Technology Services at City Power Johannesburg

Abstract
This paper covers live-line (energized) techniques to upgrading and maintenance of high voltage transmission lines without any supply interruptions.

“Barehand” and “hotstick” energised techniques, coupled with patented robotic arm technology, eliminate power supply interruptions during overhead transmission and distribution line maintenance, refurbishment and upgrade work, which negates the cost of right of way acquisition, line switching, earthing (grounding) and outage scheduling. Until recently these techniques would only have been employed in the United States and Canada. Now these techniques are being utilized in South Africa for City Power.

1. Introduction
City Power Johannesburg has an internal 88kV transmission network which is now roughly 65 years old. The condition of this transmission network has become unreliable and based on the age should actually be replaced. Due to financial constraints this is not an option and other solutions had to be considered.

Frequent line faults were experienced due to either insulator flashovers or conductor failures. Johannesburg is exposed to some of the highest magnitude of lightning strikes, which over many years has stressed and weakened the transmission network even further.

Increased electricity demand within the City Power supply area had caused many of these old transmission lines to become overloaded. These transmission lines now had to be upgraded to cater for the current and future loading requirements. The Soccer World Cup 2010 also happened in the middle of winter and the expected load requirements for this period was also going to push networks to their extreme limits, if not upgraded in time.

The design capacity of the existing transmission lines varied from 60 to 100MVA. The old lattice tower designs 1930s and constructed in 1950s could only handle a maximum of 100MVA with conventional sized conductor. Current servitudes could also not cater for any new transmission lines and it was not possible to increase the current servitude sizes.

City Power’s master plan identified key network upgrade projects that had to be undertaken to avoid serious network overloading. Increased power had to be made available at substation deep within the City Power network and this meant that transmission lines capacities had to be increased.

2. Transmission line upgrade options considered
The highest priority of the 88kV circuits were the Kelvin Cydna circuits one to four from the Kelvin Power Station to the Cydna Substation that had to be refurbished and upgraded from 100 MVA to 200 MVA while reducing thermal sag. These transmission lines supply power to the Alexandra, Cydna and Rosebank substations areas.
It was also agreed to then in the future standardize on 200MVA capacity lines for all other existing lines to ensure adequately capacity throughout City Power’s transmission network as the demand increases throughout the area of supply. This means that the current transmission network capacity would be doubled eventually throughout City Power’s network.

To achieve this doubled capacity on the existing transmission network the following upgrade options were considered;

1) Increase the tension of the conductor on the existing transmission lines,
2) Increase the size of the conductor on the existing transmission lines,
3) Install new tower with bigger conductor to replace the existing transmission lines,
4) Increase the system voltage from 88kV to 132kV to increase the system MVA,
5) Install new high temperature conductor on existing old towers the conventional way,
6) Install new high temperature conductor on existing old towers live-line, and lastly
7) Install new HV cable systems.

Table No. 1 below summarises the above options vs. requirements of the options.

<table>
<thead>
<tr>
<th>Summary of options</th>
<th>Requirements of options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reconductoring with larger diameter conductors or increase the tension on existing conductors.</td>
<td>Towers designed in 1930s. Considering current tower condition they would not able to handle additional loading with existing span lengths.</td>
</tr>
<tr>
<td>Reconductoring existing towers with high temperature conductors the conventional way (off line).</td>
<td>Extended outages required. Not possible due to network loading.</td>
</tr>
<tr>
<td>Reconductoring existing towers with high temperature conductors live-line</td>
<td>Never been done in Africa. Expensive compared to the conventional way of reconductoring.</td>
</tr>
<tr>
<td>Rebuild lines and install new towers with larger conventional diameter conductor</td>
<td>Extended outages required. Not possible due to network loading. Towers to be changed.</td>
</tr>
<tr>
<td>Increase the system voltage from 88kV to 132kV</td>
<td>Towers, power transformers and related switchgear to be changed. Very expensive.</td>
</tr>
<tr>
<td>Install HV cables</td>
<td>Very expensive option compared to all of the above options.</td>
</tr>
</tbody>
</table>

Table No. 1: Summary of the options consider to upgrade the existing HV transmission lines

3. Option chosen to resolve the technical and commercial challenges

Based on all the options above, it was agreed that the most technically and financially viable solution would be to reconductor the existing lines with high temperature conductor under live-line conditions.
The four double-circuit 88 kV transmission lines had to be refurbished and upgraded under live-line (energized) conditions while retaining the existing towers. City Power Johannesburg contracted the Edison Jehamo Power (EJP) with Quanta Services / Alteck Line Contractors (NYSE: PWR) which is a First-in-Africa project completed energized.

**Picture No. 1: Kelvin to Cydna 88kV transmission lines**

Mott MacDonald (Merz and McLellan) consultants where appointed by EJP to conduct line survey, conductor assessments, tower load calculations, refurbishment requirements, specialised hardware and fittings requirements, and live-line approach distances calculated to IEEE standards.

Various high-temperature conductors were reviewed before CTC Cables' ACCC Lisbon aluminum conductor carbon composite core, able to run at up to 180°C under peak loading conditions without clearance infringements, was selected.

**Picture No. 2: CTC Cables' aluminum conductors carbon composite (ACCC) conductor**

The old porcelain and glass insulators were replaced with new composite silicon insulators which have increased creepage requirements for the same length of insulator.

**Picture No. 3 & 4: Old porcelain insulators that were replaced with composite silicon insulators**
4. Live-live work undertaken by EJP and Quanta Services / Allteck

The conductor, insulators and all line hardware and accessories would be installed under live conditions to prevent service interruption or rerouting of the load. This process had only been undertaken previously extensively in the United States.

The live-line work entailed installing an additional bypass circuit (including new fittings, insulators and assemblies) to the tower and using transposition/temporary structure points to switch between circuits. This allows all four circuits to be kept alive while the fifth bypass circuit is used to do the refurbishment.

**Drawing No. 1: Typical arrangement with bypass circuit and structures in place**

The one circuit is now into the new temporary position. The new ACCC conductor is pulled into place with an insulated guide rope and secured in position.

**Picture No. 5: Bypass conductor in position to allow load transfer from conductor to be replaced**

Once the load has been transferred to the bypass conductor/circuit, the new ACCC conductor is pulled safely into place with the old de-energized conductor.
The two types of live-line work entailed in the process were “hotstick” and “barehand.”. The hotstick techniques are traditionally used for tasks such as moving conductors, installing fuses and opening and closing switches.

Barehand work, involving more intricate repairs, entails the use of specially designed protective gear enabling live-line workers to work at the same electrical potential as the line. Workers can handle and repair live-lines up to 765 kV. In the past, this method has enabled Quanta Services to repair a U.S. nuclear plant’s 500 kV substation switches in one day without shutting down the reactor, saving the utility an estimated $10 million.
The suit consists of a hooded jacket, overalls-style pants, socks and gloves. It is made out of Nomex, a fire-retardant material, and stainless steel fibres. This metallic mesh serves as a Faraday Cage, which puts the line worker at the same potential as that of the conductor on which he is working. With the metallic mesh clothing bonded to the conductor, the lineman can work protected inside the electrical field.

The live-line bucket is elevated and leakage current is tested by touching a wand to the conductor. Linemen are then hoisted to the level of the conductors and Quanta Services’ patented LineMasterTM robotic arm, remotely controlled by an operator on the ground, approaches the conductor, which is
trapped by means of a hotstick. Once all the lines are captured and the robotic arm has taken their weight, the insulation assemblies are detached. The robotic arm moves the conductors away from the tower, and redundant fittings are replaced with new suspension assemblies bare-handed. The linemen then bond on to the conductor and install the new assembly.

Picture No. 10: LineMaster robotic arm being utilized to hold and manoeuvre live conductors

Special wedge crimp dead ends and ferrules are installed on the ACCC conductor. The carbon composite core provides the support for the aluminum conductors when the temperature increases, therefore it is essential to secure the composite core in the wedge and then crimp over the entire assembly.

Picture No. 11: Dead end wedge crimp connectors
Table No. 2 below summarises all the HV 88kV transmission lines that have been installed. To date almost 400km of CTC Lisbon high temperature conductor has been installed in a 2 year period.

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>DISTANCE CIRCUIT LENGTH (km)</th>
<th>NO. OF CIRCUITS</th>
<th>YEAR COMPLETED</th>
<th>CONDUCTOR TYPE</th>
<th>TOTAL LENGTH OF ACCC INSTALLED LIVE-LINE (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kelvin to Cydna Circuit 1, 2, 3 &amp; 4</td>
<td>16.8</td>
<td>4</td>
<td>2010</td>
<td>Lisbon</td>
<td>201.6</td>
</tr>
<tr>
<td>Delta/Westfield/Kelvin Circuit 1</td>
<td>12</td>
<td>1</td>
<td>2010 (Emergency repair before SWC 2010)</td>
<td>Lisbon</td>
<td>36</td>
</tr>
<tr>
<td>Delta to Delbank Circuit 1 &amp; 2</td>
<td>1.26</td>
<td>2</td>
<td>2011</td>
<td>Lisbon</td>
<td>7.56</td>
</tr>
<tr>
<td>Orlando to Hursthill Circuit 1 &amp; 2</td>
<td>10.8</td>
<td>2</td>
<td>2011</td>
<td>Lisbon</td>
<td>64.8</td>
</tr>
<tr>
<td>Kelvin to Gresswold Circuit 1 &amp; 2</td>
<td>11.35</td>
<td>2</td>
<td>Installing (Completion early 2012)</td>
<td>Lisbon</td>
<td>68.1</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>378.06</strong></td>
</tr>
</tbody>
</table>

**Table No. 2: Summary of HV 88kV transmission lines that have been installed**

**5. Special project that was undertaken after a car accident**

During the Soccer World Cup 2010 Tournament, a freak accident occurred when a vehicle travelling on a highway off ramp crashed through the Armco barrier and caused extensive damage to an 88kV transmission line lattice tower. The tower was held in place by the weight of the conductors only.

This tower had to be replaced urgently and because of the network loading conditions it could only be replaced under live-line conditions.

The below pictures show the critical stages of this urgent tower replacement project.

![Picture No. 12, 13 & 14: Damaged tower being removed while conductors are still energized](image-url)
Picture No. 12, 13 & 14: New tower being installed while conductors are still energized

Note: The weather during this 4 hour tower replacement project changed drastically, but the project was completed successfully as all possible contingencies where identified and mitigated.

Picture No. 15: New tower in position with no supply interruptions experienced

6. Conclusion

The use of new live-line techniques and equipment is critical to ensure the improved performance of overhead line transmission networks.

These projects would not have been so successful if live-line work methods where not utilized.
The new ACCC high temperature conductors allow utilities a viable solution to upgrade existing overload overhead transmission lines.

Although the project is done all live-line it is actually safer than de-energized work, as all the safety requirements are in place to withstand an accidently flashover.

Lastly, it is essential for projects of this critical nature that strategic partnerships be formed with companies who have a proven track record to perform this live-line project without any incidents.