City Power & Singapore Power
Strategic Partnership to do Condition Monitoring
Patrick O’Halloran
September 2011
South Africa

Note:
1. Two major precinct: Ellis Park and Soccer City
2. Opening and Closing matches were to be played in JHB
3. Total of 14 matches
Our business model

National Energy Regulator of South Africa (NERSA)

We are in the business of buying electricity and selling it to customers.
City Power’s Vision

A World Class Electricity Distributor
How do Utilities achieve reliability and quality of supply to be world class?

1) Condition Monitoring of assets – don’t maintain if condition does not require

2) Network faults to be prevented – repeat faults not acceptable

3) Root cause of failure must be identified and managed to prevent repeated failures – once identified the problem should be contained in the business

4) N – 1 planning philosophy with no overload (unreliable equipment replaced)

5) Minimize technical losses ($I^2R = \text{heat}$)

6) First-Time-Right philosophy (Quality management systems)

7) Staff and contractor training and development (People teach people and people must enforce self quality checks)

8) Audit daily activities (Standards applied and improvements made)
System Average Interruption Duration Index, SAIDI

Condition monitoring introduced

0.31 min outage per customer per year
CONDITION MONITORING BENIFITS

- Ensure reliability and quality of supply
- Less faults to weaken network
- Rectification cost much cheaper than repair cost after failure
- Evidence of root cause not destroyed and preventative maintenance can be done before a failure occurs
- Time based maintenance is not always effective, so do effective maintenance only when the condition of equipment requires maintenance
EVOLUTION OF MAINTENANCE PRACTICES

CURRENT

- Post-Fault Repairs
- Preventive
- Predictive
- Condition-Based

NEW APPROACH
<table>
<thead>
<tr>
<th>Condition Monitoring Systems</th>
<th>What they detect</th>
<th>Applied to</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Scanning</td>
<td>Overheating</td>
<td>Equipment</td>
</tr>
<tr>
<td>Dissolved Gas Analysis</td>
<td>Abnormal oil contents</td>
<td>Equipment &amp; cables</td>
</tr>
<tr>
<td>Oil Pressure Monitoring</td>
<td>Low pressure</td>
<td>Cables</td>
</tr>
<tr>
<td>Distributed Temperature Sensing</td>
<td>Hot spots</td>
<td>Cables</td>
</tr>
<tr>
<td>Very Low Frequency Test</td>
<td>Low insulation</td>
<td>Cables</td>
</tr>
<tr>
<td>Partial Discharge Monitoring</td>
<td>Minute current leakage</td>
<td>Equipment &amp; cables</td>
</tr>
<tr>
<td>Operating Mechanism Monitoring</td>
<td>Abnormal operation</td>
<td>Equipment</td>
</tr>
</tbody>
</table>
Partial Discharge (PD) terminology vary, but once PD starts it will always worsen and finally lead to equipment failure.

PD understanding;
• What is PD?
• What causes PD?
• What are the effects of PD?

Videos from EA Technologies’ UK PD Academy
WHAT IS PARTIAL DISCHARGES (PD)
PARTIAL DISCHARGES (PD) CAUSES
CONDITION MONITORING TECHNIQUES BEING UTILIZED

1) Ultrasonic, TEV detectors and Infrared camera for substations and overhead lines
2) DGA and online gad and moisture monitors for transformers
3) Off line and on line PD diagnostic for cable systems
4) On line PD detection for GIS and AIS switchgear
5) Leakage current monitors for surge arresters
6) Quality of supply recorders (Blackbox)
BASIC SWITCHGEAR
PD TESTS

Thermal Scan

TEV test

Ultrasonic test
DGA for transformers (TX) is a very good indication to give us an idea of the condition of these critical network asset.

Additional electrical tests must still be done to verify findings as some TX designs have high pd.

Results obtained must be trended before decisions are made to maintain the TX.
FAILURES AVERTED DUE TO CONDITION MONITORING

POTENTIAL FAILURE FOUND

IN 88/11kV YARD ON TX

LOSE CONNECTION CAUSED EXCESSIVE HEAT TERMINATION REPLACED
FAILURES AVERTED DUE TO CONDITION MONITORING

POTENTIAL FAILURE FOUND

COMPOUND FILLED TERMINATION REPLACED WITH HEAT SHRINK AND INADEQUATE CLEARENCES AND CORE CROSSED
FAILURES AVERTED DUE TO CONDITION MONITORING

POTENTIAL FAILURE FOUND

PREVIOUS FAULT NOT PROPERLY REPAIRED AND CLEANED. INSULATION IN FAULTED PANEL SHOULD BE REPLACED AFTER A FAULT.
FAILURES AVERTED DUE TO CONDITION MONITORING

POTENTIAL FAILURE FOUND

LOOSE MV CONTACT CAUSED EXCESS HEAT AND HIGH DISCHARGE
REPLACED CONTACT AND TIGHTENED OTHER CONTACTS
FAILURES AVERTED DUE TO CONDITION MONITORING

POTENTIAL FAILURE FOUND

SMALL AIR GAP DISCHARGING – FILLED WITH GREACE TO REMOVE AIR
OEM DEFECT NORMALLY ONLY FOUND AFTER MANY YEARS
FAILURES AVERTED DUE TO CONDITION MONITORING

POTENTIAL FAILURE FOUND

MV CABLE BUSHING WITH PD ACTIVITY – BUSHINGS DESIGNED TO BE IN A COMPOUND CABLE BOX
FAILURES AVERTED DUE TO CONDITION MONITORING

POTENTIAL FAILURE FOUND

MV CABLE TERMINATION WITH HIGH PD ACTIVITY
TERMINATIONS SPACED AND CLEANED – NEED TO BE REPLACED
FAILURES AVERTED DUE TO CONDITION MONITORING

POTENTIAL FAILURE FOUND

MV CABLE BASEMENT FILL OF WATER AND CABLE BOXES OPEN
CABLE BOXES SEALED TO PREVENT VERMIN ENTRY
FAILURES AVERTED DUE TO CONDITION MONITORING

POTENTIAL FAILURE FOUND

MANY PREVIOUS FAULTS – MOSTLY FROM CABLE TERMINATION FAULTS
PANEL NOT BEEN CLEANED ADEQUATELY LEADING SECONDARY FAULTS
FAILURES AVERTED DUE TO CONDITION MONITORING

POTENTIAL FAILURE FOUND

OEM DESIGNED CHANGES WRT TO VERMIN PROOFING POSSIBLE ROOT CAUSE OF SOME FAILURES
FAILURES AVERTED DUE TO CONDITION MONITORING

POTENTIAL FAILURE FOUND

OEM DESIGNED CHANGES WRT TO SHUTTERS
POTENTIAL ROOT CAUSE OF SOME FAILURES
FAILURES AVERTED DUE TO CONDITION MONITORING

POTENTIAL FAILURE FOUND

MV CABLE TERMINATIONS WITH HIGH PD FROM REDUCED AIR CLEARENCES – ALL TERMINATIONS NEED TO BE REPLACED
FAILURES AVERTED DUE TO CONDITION MONITORING

POTENTIAL FAILURE FOUND

MANY PREVIOUS FAULTS – MOSTLY FROM CABLE TERMINATION FAULTS PANEL NOT BEEN CLEANED PROPERLY LEADING TO REPEATED FAULTS
FAILURES AVERTED DUE TO CONDITION MONITORING

POTENTIAL FAILURE FOUND

ALL DIRTY SHROUDS REMOVED - REPLACED TEMP WITH PUTTY & TAPE
OEM TO REPLACE ALL INSULAING MATERIAL AFTER ALL REPAIRS
FAILURES AVERTED DUE TO CONDITION MONITORING

POTENTIAL FAILURE FOUND

PD DETECTED AROUND CLUSTERS AND THE SMALL AIR GAP IS DISCHARGING – FILLED WITH GREASE – OEM DESIGN CONCERN
FAILURES AVERTED DUE TO CONDITION MONITORING

POTENTIAL FAILURE FOUND

PD DETECTED ON VT AND REPLACEMENT CTS NOT INSTALLED CORRECTLY OEM DESIGN PROBLEM AND POOR WORKMANSHIP
FAILURES AVERTED DUE TO CONDITION MONITORING

POTENTIAL FAILURE FOUND

PREVIOUS CABLE TERMINATION FAILURE WHICH WAS NOT REPAIRED
OEM TO REPLACE ALL INSULATED PARTS AFTER A FAILURE
FAILURES AVERTED DUE TO CONDITION MONITORING

MV SF6 RMU – WRONG TERMINATION USED
Currently people only require pressure tests on new and aged cable networks

“Go” or “No Go” testing – i.e. Voltage and time only

Many times the cable fails again in service after a few days or weeks?

Rather combine pressure tests with diagnostic tests, to achieve a clear picture and a base line to work from in the future for a condition monitoring analysis

If PD is present then the cable or cable accessory must be removed prior to re-energizing – this will prevent fails
PD TEST ON AGED PILC CABLE (NO CONCENTRATED PD)
PD IN CABLE JOINT LOCATED AND THEN JOINT WAS REMOVED AND PD HAS DECREASED TO ACCEPTABLE PREDEFINED LIMITS
The recommended repairing PD limits (the maximum PD between $1.0 \, U_0$ and $1.7U_0$) by OWTS

<table>
<thead>
<tr>
<th>XLPE cable</th>
<th>Cable part</th>
<th>Termination</th>
<th>Joint</th>
</tr>
</thead>
<tbody>
<tr>
<td>PD limitation (pC)</td>
<td>&gt;300</td>
<td>&gt;1000</td>
<td>&gt;500</td>
</tr>
<tr>
<td>XLPE and PILC mixed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cable part</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PD limitation (pC)</td>
<td>300 for XLPE</td>
<td>&gt;1000</td>
<td>&gt;1000</td>
</tr>
<tr>
<td></td>
<td>1000 for PILC</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
City Power has now changed to XLPE MV cables to implement PD testing of newly installed cable systems to ensure MV joints and terminations have been done correctly.

The new 3\textsuperscript{rd} generation XLPE is now designed and manufacture to international standards and the problems in the first generation XLPE have been resolved.

Longitudinally block design as per SANS 1339 have been specified – stop the water if it successfully enters the cable.

All new HV cables installed are XLPE insulated.

XLPE cable is PD free when manufactured.
TEST VEHICLE EQUIPPED WITH CABLE PD TESTERS
150KV CABLE PD TESTER
• DATA is the key to doing condition monitoring successfully
• On line data acquisition is the safest way to protect important assets
• Trended data shows us when changes in asset condition occur
• Reduce the temperature by 10 Degrees Celsius and the life expectancy of the asset is double
1) HV and MV system faults averted - cost saving of faults averted (R500k – R30mil/fault depending what damage is caused by the fault)

2) Reduction of OPEX cost required to repair failures

3) Improved network performance results (NRS 048, SAIDI, CAIFI etc.)

4) Less risk of explosions which could injure or kill staff and public
At the last ESLC meeting it has been agreed to form a PD users group for end users via the ESLC network (AMEU, PIESA & NRS)

This will be an open working group and all end users are welcome to get involved

Industry PD findings will be discussed and possible solutions will be documented and published – The respective OEM will be involved to explain the PD findings to ensure the problem can be resolved

This initiative will ensure reliability and quality of supply by reducing equipment failures (Workmanship, design, wrong application etc.)
Thank you