Holyrood Unit One Assessment and Repairs
April 3, 2013
Review of Loss to Holyrood Unit One

- Hydro completed a comprehensive system analysis
  - expert independent analysis undertaken by Alstom, AMEC and System Improvements, Inc.
  - three-phased work
  - undertook a root cause analysis using TapRooT®
  - work was overseen by Hydro

- Hydro has filed a capital plan with the Board
Holyrood Thermal Generating Station

• Three generating units with total capacity of 490MW
• Plays a critical role in the island’s power system
• Approx. 1/3 of Hydro’s total island capacity
• Oct-April, at least one unit and most often two-three are required to reliably meet the system demand
• Operating reliably with strong availability performance during winter months
• Provides energy security to island grid during low water years
Overview of January 11 System Event

• Major winter storm caused damage and wide-spread power interruptions to island grid
• Damage to the Holyrood terminal station
• Electrical fault experienced in Holyrood switchyard
• Unit One was generating at the time
• Protection systems removed it from service in response to this fault condition
Loss of Holyrood Unit One

• Root cause analysis identified that the DC lubricating oil pump did not provide the required lubricating oil to the bearings during the unit shut down.
Loss of Holyrood Unit One

- The reason the pump set didn’t deliver the required pressure is still being finalized. The following is known at this time:
  - All routine maintenance and inspection/testing has been performed regularly as per the manufacturer’s recommended program established when the plant went into service.
  - Unit Two system, which is identical to Unit One, didn’t experience the same problem, and delivered pressure as expected.
  - A pump set investigation is being performed by external experts for further information.
Additional Factors on Unit One

- The primary and stand-by lube oil pumps are powered by AC (alternating current) power.
- Weather events of Jan. 11\textsuperscript{th} removed the unit service AC pump from service and a sustained under voltage condition prevented the restart of the stand-by AC pump.
Additional Factors on Unit One

- In the absence of both AC pumps, the lubricating oil system was dependent on the unit’s third pump, the DC pump.
- The root cause analysis is still ongoing to address these and other findings.
Comparison of Units One and Two

- Unit Two is an identical unit with three separate lubricating pumps (two AC & one DC).
- The loss of pressure needed to deliver sufficient lubricating oil to the unit was ultimately a result of the failure of the DC pump system.
- The DC pump on Unit Two did not experience the same problem as Unit One.
Investigation and Analysis of Work

• Parallel approach for investigation and analysis:
  1. Comprehensive system analysis
     • three-phased approach to assess damage, determine repair and develop restoration plan
  2. Complete root cause investigation using TapRooT methodology
1. Comprehensive System Analysis

- Phase 1 – Preliminary Assessment
  - undertaken immediately following Jan. 11\textsuperscript{th} incident
  - detailed visual inspection of unit
  - developed plan for full assessment
  - work completed by Hydro, Alstom and AMEC
Phase 1 – Preliminary Assessment

- Hydro completed preparatory work
- Alstom engaged as main contractor
- Oversight provided by:
  - Hydro's internal experienced project execution and engineering team
  - AMEC turbine-generator specialist
Phase 1 Preliminary Assessment

• Results:
  – Damage to a number of components of the unit
  – Extensive babbitt damage (bearings) resulting from loss of lubrication during failure event
  – Contact established between stationary and rotating assemblies requiring a complete unit disassembly.
  – Mechanical vibration
Turbine/generator set view from generator end
Bearing babbit damage

Heat stress marks on rotor bearing journal

Generator bearing bottom half - undamaged
Phase 2 – Full Assessment

• Completed an assessment of the damage to Unit One
• Disassembled, inspected and comprehensive testing of all equipment
• Turbine & generator lubrication system inspected
• Developed a plan for repair
• Work determined detailed scope of work and estimate for Phase 3 (restoration)
Steam Turbine HP Bottom Casing with Rotor Removed
Damage on Rotor Due To Contact with Diaphragm Spill Strips
Phase 3 – Repair & Return to Service

- Phase 3 includes the repair and reassembly based on Phase 2 findings
- Work outlined in Board submission
- Total cost of all three phases is estimated at $13.2M
TapRooT Analysis

• TapRooT System looks at the failure and finds causal factors which are safeguards that could, would, or should have significantly lowered the risk of the failure.

• The team found four risk causal factors

• Root cause analysis undertaken

• Information on three causal factors still in the process of being collected
## Project Schedule

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Next Steps

• Root cause analysis on other factors is ongoing and, depending on the outcome of the analyses, further corrective actions may be taken by Hydro to manage the risk of future failures.
Next Steps

• Repair of Unit One is necessary for Hydro to perform necessary maintenance work and capital upgrades.

• The Holyrood plant must be ready for service prior to the 2014 peak winter demand period.

• Completion of the TapRooT analysis and filing the results with the Board.