



REPORT

Cherrywood Circuit Breaker Incident - December 12, 2005

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Table of Changes

Reference (Section and Paragraph)	Description of Change

1. Background

The Cherrywood Transformer Station, operated by Hydro One, is a key station on the east side of the Greater Toronto Area (GTA). The station is connected to the 230kV transmission circuits emanating from the Pickering Nuclear Station and the 500kV circuits emanating from the Darlington Nuclear Station. Four autotransformers connect the 500kV and 230kV stations providing a supply to the GTA load. All of the 500kV breakers and many of the 230kV breakers are air blast breakers connected to three air systems.

The performance of the Cherrywood breakers and air system has been the subject of 15 investigations/incidents dating back to last winter.

During past incidents, breakers on the 500kV system became inoperable during cold weather and the IESO took similar control actions to those outlined in this report.

On December 12, 2005 a circuit breaker air fill valve that failed resulted in a stuck breaker and precipitated the incident described by this report. The incident occurred during temperatures that dropped to -11°C. Investigation by Hydro One has revealed that although the cold temperatures were a factor, this incident is not directly attributed to cold weather.

In recent years, there have been 500kV breaker incidents at Cherrywood TS during cold weather. To help address these incidents, Hydro One has taken a number of remedial actions including the installation of additional mechanism box heaters, replacing a number of air system valves and staffing the station during cold weather periods. On June 1, 2005, the IESO implemented an “Extreme Cold Weather” operating Policy as part of its IESO Grid Operating Policies. This Policy can be viewed in Market Manual 7 part 7.4 entitled “IESO-Grid Operating Policies”:
http://www.ieso.ca/imoweb/pubs/systemOps/so_GridOpPolicies.pdf

- End of Section -

2. Event Description

On December 12, 2005, the incident began with a trip circuit fail alarm followed shortly by a low air pressure alarm on the JL541 500kV breaker. Compressed air problems associated with the 500kV air system at Cherrywood Transformer Station contributed to a System Operating Limit violation. These air problems and resulting breaker operating limitations also forced the IESO to expose the system to additional risk through operation to Emergency Transfer Limits for the Cherrywood area in order to continue supplying GTA load while respecting safe posture limits.

The Cherrywood 500kV yard is comprised of six circuits, twelve air blast breakers and four 750 MVA autotransformers. The AC station service is supplied from two transformers connected to the tertiary windings on T14 and T16. The T14 supplies station service for air pressure to a portion of the 500kV yard and T16 supplies the other portion.

The temperature at the time of the event was -11°C with a 20 km/hr wind. The primary demand was 16,200MW and all operating security limits and operating reserve requirements were being respected. The Transfer East from Cherrywood (TEC) was at 1700MW. The system topology in the area was as follows:

- All Cherrywood TS 500kV breakers were in service.
- All 4 Darlington units in service with a plant output of 3500MW
- The Transfer East from Cherrywood (TEC) flow was at 1700MW.
- No Lennox units were in service.

At 02:56, it was reported to the IESO that the Cherrywood JL541 500kV air blast breaker had a sustained breaker low air pressure and breaker trip circuit fail alarm. Field staffs were subsequently dispatched to the Cherrywood yard and the first was on site in one hour and six minutes.

Following two unsuccessful attempts to remotely open the JL541 breaker, the IESO directed the isolation of the inoperable breaker from the system. In order to isolate the defective breaker, Cherrywood T14, J bus, and circuit B541C (500kV circuit Bowmanville - Cherrywood) were removed from service. The Cherrywood JL541 breaker was isolated from the system by 03:10; 14 minutes after the breaker became inoperable.

To compound the problem, it was then reported that Cherrywood T15 had a sustained cooling failure alarm. This was caused by the interruption of the AC station service supply which is normally supplied from T14. In addition to supplying cooling to the transformer, this station service also supplies some of the air compressors. As a result of the interruption of the service, about 80% of the air pressure system to the 500kV breakers was not operating at full capacity.

With the resulting configuration that existed at Cherrywood, a recognized breaker fail operation of the L540A breaker would remove the connection between Cherrywood TS and Bowmanville TS. At this point, the IESO implemented safe posture limits. This meant that given the prevailing Transfer East of Cherrywood (TEC) flow of approximately 1700MW, the combined output of the Darlington and

Lennox 500kV generation must be less than 2700MW in order to remain stable following the L540A breaker fail contingency. With the Darlington generation at approximately 3500MW, the IESO directed a reduction at the plant of 850MW in order to comply with the safe posture stability limits. Darlington G2 was reduced using condenser steam discharge valves and remained connected to the system.

At 04:59, the disconnect switches on the bus side of the defective JL541 were opened. This enabled the IESO to restore the J bus, T14 and associated station service. With the equipment restored, the contingency that would have resulted in the separation of Cherrywood and Bowmanville no longer existed and the output restrictions at Darlington were no longer required. Darlington was permitted to load to its pre-incident loading at 05:00. It is worth noting that even though the AC station service supply was restored, additional time was required to restore the air system to normal by manually performing low voltage switching and compressor restarts. Once the air compressors were restarted, the restoration to normal operating pressure is dependent on how low the pressure had become.

At 05:12, with the air system still operating at degraded capacity, the manual process to restart the compressors had just begun when low air pressure alarms were received on the W3L540, JL550 and JL543 breakers. These breakers and associated disconnects were isolated at 05:14.

At this point, the Cherrywood configuration was such that the IESO was unable to respect the post-contingency thermal 15 minute Limited Time Rating on T14 for both NPCC recognized single and double element contingencies. In addition, the IESO was unable to respect the safe posture stability limit for the separation of Cherrywood TS from Bowmanville TS following a Cherrywood AL542 breaker fail operation. It was decided to operate to Emergency Transfer Limits at 05:16 and the Interconnections were subsequently notified via the NERC Reliability Coordinator Information System (RCIS).

At 05:27, while attempting to return circuit B541C to service, it was automatically removed from service from HIROP (high resistance open phase) protection. It was later reported that the circuit was correctly removed from service by the HIROP protection as a result of only one phase of the motor operated line disconnect at Cherrywood being closed.

At 05:35, recognizing that the T14 post-contingency thermal rating and the stability limit for the Cherrywood to Bowmanville separation were continuing to be exceeded for all single element contingencies, the IESO directed Darlington to reduce its plant output by 450MW. At this point, the plant had not returned to its pre-contingency loading. The reduction was completed by 5:38 and as a result emergency transfer limits were now being respected. The stability limit and the post-contingency thermal limit for recognized single contingencies were violated for 24 minutes.

During the next several hours, in addition to the Darlington generation reductions, the IESO took the following control actions to continue respecting the Emergency Transfer Limit on T14:

- Constraining eight Saunders units to TranEnergie
- Constraining generation down, east of Cherrywood
- Curtailing import transactions, east of Cherrywood
- Constraining off export transactions
- Constraining on import transactions west of Cherrywood

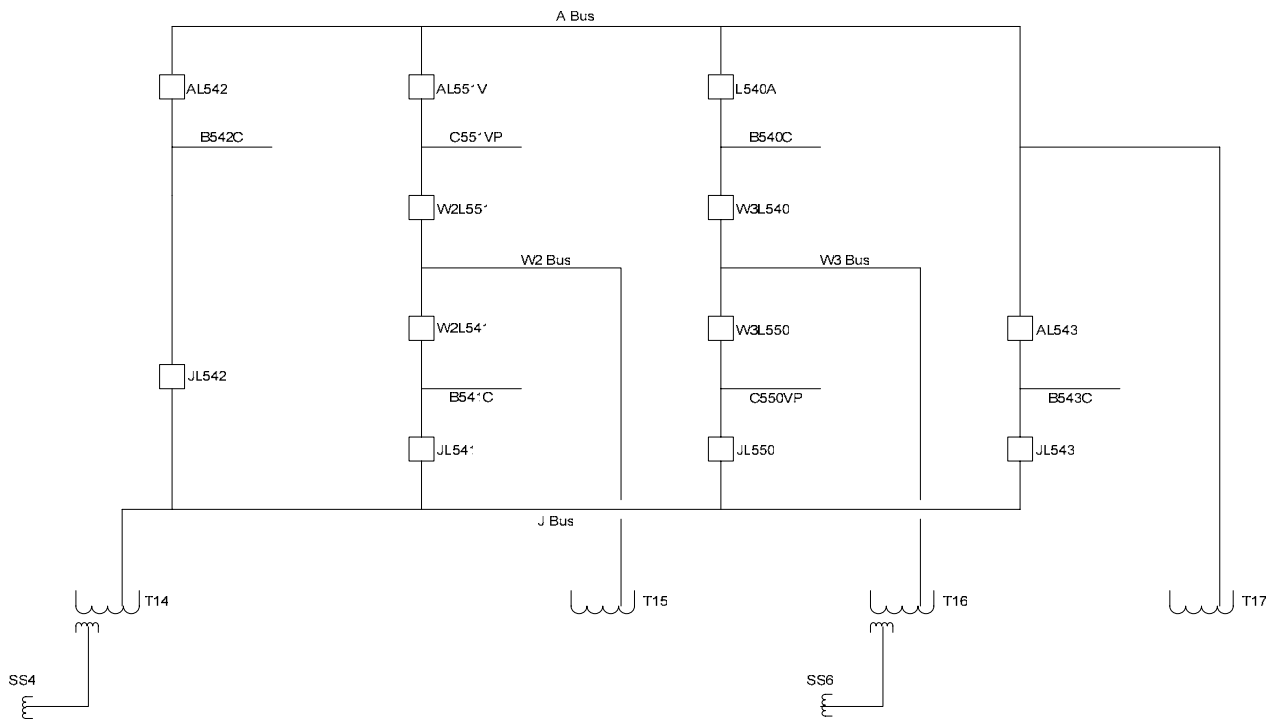
- Purchasing emergency energy from the NYISO
- Constraining generation on for late day adequacy

At 08:27, with the air system operating to normal capacity as a result of manual switching, the W3L540 and JL550 breakers were returned to service.

At 08:30, The IESO was in position to respect all normal transfer limits.

During this event, operating security limits constrained generation at Darlington for a total of 5 hours and 26 minutes.

Cherrywood 500kV Yard



- End of Section -

3. Sequence of Events

Time	Summary
02:56	Cherrywood JL541 500kV breaker low air pressure and breaker trip circuit fail alarms were received. Following two unsuccessful attempts to open JL541, IESO directed the isolation of the inoperable breaker from the system.
03:10	Cherrywood JL541 breaker isolated through the removal of Cherrywood T14, J bus and B541C (500kV circuit Bowmanville – Cherrywood) from service. Cherrywood T15 subsequently suffered a cooling failure due to the interruption of SS4 normally supplied from T14.
03:22	IESO requested the output of Darlington down 850MW due to a security limit violation to respect a Cherrywood L540A breaker fail which would disconnect Cherrywood TS from Bowmanville TS.
03:33	Darlington G2 reduced by 890MW and TEC flashover limits/safe posture now being respected. Recovery time from violation was 23 minutes. Unit remained connected to the ICG on Condenser Steam Discharge Valve.
03:35	IESO requested a 14:00 start for Lennox G1 (230kV) in service for adequacy concerns over evening peak due to uncertainty regarding the Darlington G2's ability to reload.
04:12	Closed the air pressure valve where the air leak was present on the Cherrywood JL541 breaker. IESO stated that opening the breaker disconnects of JL541 is first priority in order to put the Cherrywood J bus back in service.
04:59	J bus disconnect of JL541 opened and Cherrywood J bus in service. This allowed the IESO to restore the J bus, T14 and SS4 to service.
05:00	IESO informed Darlington that the restriction on generation can be lifted as there were no longer concerns with separating Cherrywood TS and Bowmanville TS following a respected double element contingency.
05:09	Reported low air pressure alarms on the Cherrywood W3L540, JL550 and JL543 breakers.
05:12	IESO directed the start of the two remaining available Lennox units as soon as possible for reliability concerns.
05:14	Cherrywood W3L540, JL550 and JL543 breakers and associated disconnects opened. Cherrywood T14 post contingency thermal rating as well as stability limits for the separation of Cherrywood TS from Bowmanville TS following a respected breaker fail of Cherrywood AL542 were now being violated. IESO declared Emergency Condition Limits/Emergency Transfer Limits for Cherrywood contingencies.
05:27	Line side disconnects of JL541 opened.
05:33	Circuit B41C returned to service only to be automatically removed from service on HIROP (high impedance open phase) protection at 05:34.

Time	Summary
05:35	IESO directed Darlington to reduce plant output by 450MW.
05:38	Darlington G2 reduced to 0MW alleviating violations on the Cherrywood T14 post-contingency thermal limit for single elements and stability limit for the Cherrywood to Bowmanville separation. Recovery time was 24 minutes. Violation remained for T14 thermal limits based on double element contingencies.
05:39	Activated 500MW of Operating Reserve.
05:55	Deactivated 300MW of Operating Reserve.
06:04	Deactivated remaining 200MW of Operating Reserve.
06:07	IESO requested the Brighton Beach units in service at 08:00 for IESO adequacy.
06:08	IESO requested the Nanticoke and Lambton units to full load for adequacy concerns. Chenaux GS also requested to reduce output from 116MW to 0MW.
06:09	IESO requested 175MW delivery on P33C be reduced to 0MW due to security concerns.
06:11	IESO directed the exporting of 8 Saunders units to Quebec (TransEnergie).
06:17	IESO requested Chats Falls G4 and G5 to Speed No Load to respect security limits, generation reduction of 70MW.
06:20	IESO curtailed 400MW of exports to NY due to adequacy concerns with the Saunders units being removed from the ICG paired with the restrictions in loading generation east of Darlington.
06:24	IESO curtailed 160MW of Michigan exports for hour ending 8 for adequacy.
06:25	IESO recalled circuit D26A (230 kV Dryden x Mackenzie) due to adequacy concerns.
06:31	Lennox G3, G4 units in service loading to minimum.
07:09	IESO requested down Chenaux from 120MW to 0MW and Stewartville from 50MW to 0MW due to Cherrywood T14 exceeding its thermal limit for the loss of Cherrywood T17.
07:22	IESO requested 300MW of emergency energy purchase from the NYISO to begin at 07:30.
07:40	IESO maximum constrained a number of Eastern generating resources to their present outputs in order to avoid dispatching the units up and to avoid the scheduling of Operating Reserve from the units.
07:45	IESO requested 500MW of emergency energy purchase from the NYISO for hour ending 9.
08:00	Cherrywood W3L540 breaker closed.
08:02	Michigan, New York, Manitoba and Minnesota import transactions maximized and exports cut for hour ending 10 for adequacy concerns.

Time	Summary
08:27	Cherrywood JL550 breaker closed.
08:30	IESO returned to Normal Condition Limits/ Transfer Limits. No longer violating Cherrywood T14 thermal limits based on double element contingencies. Recovery time was 3 hours and 16 minutes.
08:48	IESO contacted Darlington and informed that the units can load to max values. Operator reports that units will be increased by a total of 535MW.
08:56	Cherrywood JL543 returned to service.
09:11	Saunders units back in Ontario with B31L/B5D in 2 terminal mode.
10:46	Circuit B541C returned to service.

- End of Section -

4. NPCC Reportable System Operating Limit Violation

As indicated in section 1, the IESO could not respect the Cherrywood T14 post-contingency thermal limit for NPCC recognized double element contingencies or normal transfers from 05:16 until 08:30. As defined in NPCC Document A-2 “Basic Criteria for Design and Operation of Interconnected Power Systems” section 6.3 “System adjustments shall be completed as quickly as possible, but in all cases within 30 minutes after the occurrence of the contingency.”

All control actions were exhausted in an attempt to respect normal condition limits. When this was not possible without shedding GTA load, the IESO implemented Emergency Transfer Limits.

- End of Section -

5. Market Observations

The objective of this section is to detail the cost as a result of applying operating policy during this incident.

5.1 Market Costs

There is an inherent cost to operating the power system. It can be further described as a cost to operate the system reliably. The following is a breakdown of the associated costs as a result of the incident.

- Congestion Management Settlement Credits (CMSC) for the incident totaled approximately \$1,000,000. These credits are attributed to the resources that were constrained due to transmission constraints during the event. CMSC is designed to ensure that when dispatch instructions differ from the market schedule (due to congestion on the grid) market participants do not lose or profit by being constrained on or off.
- Emergency Energy Purchases totaled \$189,396.00. The basis of this out of market cost is driven by an agreed to formula in the appropriate Interconnection Agreement. This cost is shown as an uplift to the market.
- Total \approx \$ 1,189,396.

5.2 Market Clearing Price Impact

The impact on the market clearing price for the event is in the form of an upward pressure. This was caused by the de-rating of Darlington G2 which effectively lowered the unit's value in the market schedule. With IESO's dispatch scheduling program potentially having to reach deeper into the offer stack for the replacement MWs, an upward pressure on price was observed.

5.3 Market Participant Impact

From the beginning of this event, the IESO dispatched Darlington G2 to alleviate the Operating Security violations. As a result of these maneuvers, the unit was eventually forced to de-rate from its full capability due to physical limitations between the periods of 05:00, December 12th to 01:01, December 14th. During this de-rated period, OPG was ineligible to receive Congestion Management Settlement Credits (CMSC) for the full name-plate rating of the unit.

- End of Section -

6. Conclusions

1. The precipitating failure was improper operation of the air fill valve in the system supplying air to the JL541 breaker.
2. Investigation by Hydro One has determined that the failure of the JL541 air fill valve is attributed to a combination of excessive grease further compounded by the introduction of aluminum and zinc which may have accelerated the failure of the grease in cold temperatures. On December 21, 2005, analysis of the substance taken from the JL541 was completed. The report indicates the presence of zinc (13ppm) and aluminum (78ppm). The source of the aluminum is suspected to be from the air fill valve housing which were rebuilt by the original equipment manufacture less than 12 months ago. The source of zinc is undetermined at this time. Neither metal was introduced by the high-pressure air system.
3. The failure to check the B541C line disconnect switch closed is a work practice issue for Hydro One that requires further investigation.
4. The physical connections of the transmission and generation in the Cherrywood area magnify the severity of consequences that result following NPCC recognized contingencies. The work that Hydro One has undertaken to address 500kV breaker reliability at Cherrywood is recognized (Appendix B). However, this incident again emphasizes the problems experienced when a 500kV breaker becomes inoperable at this station and cannot be easily isolated from the system due to the station configuration. This risk must be understood and reasonable options developed to address it.

- End of Section -

7. Recommendations

1. Hydro One should review the incident and develop a plan to prevent a recurrence. This should include a review of the feasibility of establishing the auto-transfer scheme for the AC station service. An update is provided by Hydro One in Appendix B. The review and recommendations to be complete before winter 2006.
2. Hydro One is asked to report on the level of risk of a 500kV breaker becoming inoperable at this station including the impact of incorporating the major plans identified in Appendix B. This report is requested by July 1, 2006. The IESO will review the report and should the report identify a level of risk above that experienced at other 500kV stations, or an otherwise unacceptable level of risk, further changes at the station level will need to be considered. The IESO is supportive of Hydro One's efforts to address these problems.
3. Hydro One is requested to identify reasonable mitigating actions which may be taken to minimize system impact while isolating an inoperable breaker at the station.
4. The IESO will continue to implement its "Extreme Cold Weather" policy for this station at a temperature of -10°C until station performance justifies a change back to -20°C.
5. The IESO should review communication protocols with Hydro One including the reporting of alarms that impact equipment restoration.
6. IESO should consider modeling the loss of the station service transformers as it relates to the post contingency thermal rating on the autotransformers.

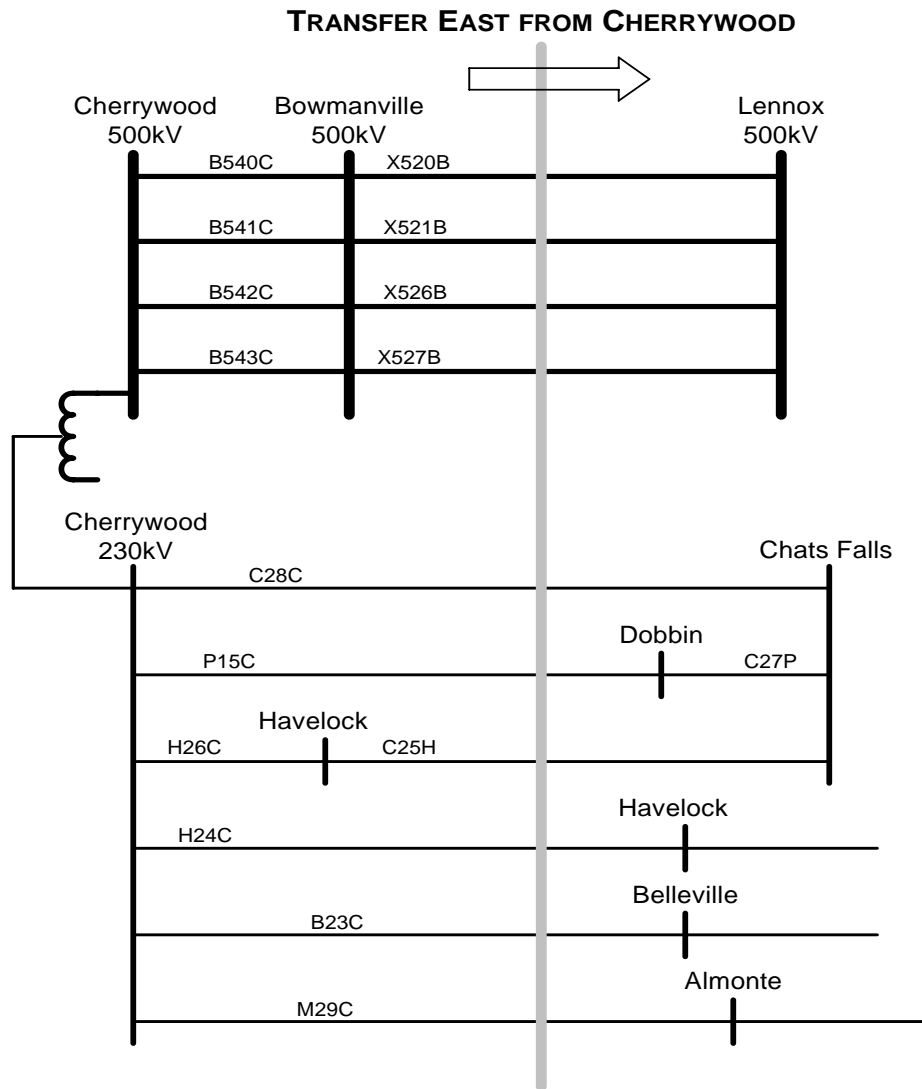
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Appendix A: Definition of Operating Terms

A.1 Transfer East from Cherrywood (TEC)

During normal conditions, for up to any one single element out of service, the TEC flow is not limiting. During multiple outages or during operation of Safe Posture limits it may be necessary to limit the Transfer East from Cherrywood.

Limits may be imposed on TEC whenever the loss of the 500 kV Bowmanville to Lennox interface is possible.



A.2 Safe Posture Operating Limits

Safe Posture is defined as an operating strategy which will ensure the secure operation of the IESO Controlled Grid following the occurrence of any recognized Normal Condition contingencies and specific Extreme Contingencies.

During certain outage conditions at Cherrywood that would result in the separation of the Cherrywood interface for a recognized contingency, safe posture limits are imposed. These limits are a function of the TEC flow and the net generation at Darlington and Lennox.

A.3 Emergency Transfers - NPCC Document A-2

When firm load cannot be supplied within normal limits in an Area, or a portion of an Area, transfers may be increased to the point where pre-contingency voltages, line and equipment loadings are within applicable emergency limits. Emergency transfer levels may require generation adjustment before manually reclosing elements.

Stability of the bulk power system shall be maintained during and following the most severe of the following contingencies, and with due regard to reclosing:

- a. A permanent three-phase fault on any generator, transmission circuit, transformer or bus section, with normal fault clearing.
- b. The loss of any element without a fault

Immediately following the most severe of these contingencies, voltages, line and equipment loadings will be within applicable emergency limits.

A.4 Normal/Emergency Transfer and Single and Double Element Contingencies

For the purposes of this report, the terms operating to Normal Transfer limits is the same as respecting NPCC recognized Double element contingencies. The term operating to Emergency Transfer limits is the same as respecting NPCC recognized single element contingencies.

- End of Section -

Appendix B: Hydro One Actions

In recent years there have been a number of 500kV breaker incidents at Cherrywood TS during cold weather. As a result, Hydro One completed a detailed internal audit of Cherrywood TS and subsequently implemented or acted upon all the findings. Subsequent to the December 12, 2005 incident, Hydro One has taken the additional steps outlined below.

1. The air fill valves have been replaced on the following breakers: JL541, AL551, JL550, JL543, AL542, W3L540 and AL543. At this time seven of twelve 500kV breakers air fill valves have been replaced.
2. Additional air valves and rebuild kits are ordered. The prioritized list of replacement is JL542, L540A, W2L551, W3L550 and W2L541.
3. Two emergency spare fill valves will be maintained on site.
4. Installed additional heaters in all mechanism boxes.
5. Staffing Cherrywood when temperature forecasts are to reach or fall below -10°C.
6. Increasing the frequency of visual inspections

Hydro One Major Plans include:

1. Tendering the increase of the air capacity at Cherrywood by installing additional air receivers
2. Taking steps to correct the 600V AC station service automatic transfer scheme.
3. Updating all work standard documentation on maintaining the air system at Cherrywood
4. Initiate a review to ultimately replace the automatic transfer scheme and incorporate a generator
5. Reviewing the replacement of all of the 500kV micro switches associated with the air replenishing system
6. Reviewing and implementing numerous recommendations from a summer 2005 consultants report provided on the Cherrywood air system
7. Evaluating a breaker mid life re-build/replacement strategy.

- End of Document -