Q. Provide copies of all opinions, reviews, reports, studies and assessments commissioned or obtained by Hydro internally, or commissioned or obtained by Hydro from external sources, which address or discuss, in any respect, Hydro's capabilities for black starting the Holyrood generating units.

A. There are no formal studies discussing Hydro's capabilities for blackstarting the Holyrood generating units.

Prior to the AMEC Assessment Report (issued in December 2011 and attached to Hydro's response to NP-NLH-022 as Attachment 1) blackstart functionality at the Holyrood Thermal Generating Station (HTGS) was provided using the Holyrood Gas Turbine (HRDGT). Procedures were in place to guide operating personnel in the blackstart of the facility and are attached as IC-NLH-010 Attachment 1 and IC-NLH-010 Attachment 2. As indicated in Hydro's response to CA-NLH-004, the requirement for blackstart of the HTGS has been infrequent (with two instances since 1991). In 1994, the HRDGT was called upon to blackstart the HTGS. However, due to issues experienced in starting the gas turbine, these efforts were unsuccessful. At that time, the Holyrood units could not be restarted until station service power was restored from the system. The overall investigation into these events (with report attached as IC-NLH-010 Attachment 3) identified a number of remedial actions, some of which targeted the blackstart ability of Holyrood. An update of these actions was communicated to the Board in January 1996 and is included as IC-NLH-010 Attachment 4.

In January 2012, based on the AMEC assessment report, Hydro determined that the HRDGT could no longer be available for use, for emergency station service, blackstart capability, or otherwise. At this time, Hydro was planning for an addition of a combustion turbine as part of its generation planning for 2015. In January 2012, it was determined that this new unit would be located at Holyrood and configured to provide the required blackstart. In the meantime, Hydro developed a contingency plan to use the Hardwoods gas turbine (HWDGT) to provide blackstart power for the HTGS. Hydro developed procedures to guide operating personnel in the blackstart of the facility in this manner (see CA-NLH-019 Attachment 10). However, it was shown that during the events experienced on January 11, 2013, the HWDGT blackstart contingency plan was inadequate and the duration of the outage was prolonged, due to the planned reliance on the Avalon transmission system. In order to utilize the HWDGT for the blackstart of the HTGS, a transmission path is required from the Hardwoods Terminal Station to the Holyrood Terminal Station (HRDTS). On this day, electrical faults had caused trips and lockouts of the HRDTS so no transmission path was available. There were considerable delays in getting the HRDTS restored due to the blizzard conditions that prevented station maintenance crews from arriving at the station.

In light of the knowledge gained about the prolonged outage resulting from reliance on a Hardwoods based blackstart solution, Hydro took steps towards an alternate HTGS blackstart contingency plan by requesting that Newfoundland Power relocate its mobile generation to Holyrood. An agreement was reached between Hydro and Newfoundland Power to relocate Newfoundland Power’s 6.5 MW Mobile Gas Turbine (NP-MGT) and 2.5 MW Portable Diesel (NP-MD3) to Holyrood and connect them to the HTGS to allow for faster restoration of station service and to provide for plant blackstart capability. These mobile units were also configured to provide power to the interconnected power system via the HRDTS.

Engineering design and construction of a grounding system, overhead lines, and a transformer bay were required for the electrical connection to the HTGS. The engineering and construction work were completed, the units were commissioned and on April 24, 2013, a test to provide station service power into the HTGS was successfully completed. It was proven that the generation could provide for essential services critical to life safety and system operations as it allows for the operation of fans to evacuate smoke, the restart of air compressors, operation of cooling water pumps to maintain equipment temperatures, and operation of extraction pumps to manage water chemistry and exhaust hood temperature.

In order to facilitate a blackstart test of the HTGS, a coordinated effort between Hydro and Newfoundland Power was required along with a window of opportunity when no Holyrood units were required for system support. This window presented itself on May 10, 2013. Blackstart tests were performed; however, the tests showed that the mobile units were inadequate in providing full blackstart capability due to the inability to start up a Holyrood unit boiler feed water pump motor. As a result, Hydro continued to rely on its interim blackstart solution using HWDGT, while the Holyrood combustion turbine application was being advanced.

Following the test, the mobile units were disconnected and returned to Newfoundland Power in late May, 2013 for Newfoundland Power's annual capital and maintenance program.

Although full blackstart capability was not possible from Newfoundland Power’s mobiles, Hydro recognized that one of these units could help to secure the supply to essential services at the Holyrood generating station for the winter seasons. It would also provide the significant benefit of keeping much of plant auxiliary equipment operating in a warm state, thereby reducing the start-up time once the transmission supply is restored. Only one of the mobiles was required for this function. Hydro therefore determined that it would request NP-MGT be returned to Holyrood for each winter season until a new blackstart option was in place.

In October 2013, a letter was received from the Board requesting Hydro to take immediate action to ensure all possible options have been considered to provide reliable Holyrood blackstart capability. In November 2013, a report with the options was completed (attached as IC-NLH-010 Attachment 5). Subsequently, a supplemental capital application was filed with the Board with the preferred option to have a nominal 16 MW diesel plant, on-site, as a blackstart generating solution to be installed and commissioned by February 28, 2014. Please refer to Hydro's response to CA-NLH-006 for the current schedule.

In November 2013, Hydro made the request to Newfoundland Power to have NP-MGT re-connected at Holyrood. This unit was subsequently returned to the HTGS location and reconnected on December 30, 2013.

HTGS Procedures

ISO 14001
QMI-SAI Global

Procedure No: 0864	Entered By: Mary Slaney Date: July 7th, 2003 11:49 AM

Title	POP-133 Partial Stage 1 Black Start Test Procedure

Archive Information

Issue Date:	07/07/2003 July 7th, 2003
Distribution:	Labour Manager Operations - Thermal, Lead Thermal Plant Operator, Shift Supervisor, Thermal Plant Operator, Training Co-ordinator - Operations
Manual/Group:	Plant Operating Procedures
Revision No:	3
Revision Date:	06/09/2008 June 9th, 2008
Prepared By:	Bob Woodman
Controller:	Gerard Cochrane
Reviewers:	Ron Tobin, Gerard Cochrane
Approved By:	Terry LeDrew/HO/NLHydro

Procedure Scope

To return the Plant to Service from a Stage 1 Power Outage by use of a 'Black Start Procedure', for testing purposes.

Reference Information

POP-074

Procedure Details

NOTE: Confirm Status of the following Equipment prior to commencement of Black Start Testing. (1) Air Compressors and (2) Sample Cooling Pumps.

PLANT EMERGENCY DIESEL GENERATOR

Place DBT on manual so that it will not try to close automatically. Request ECC to open B7L2. Breaker C-16 will open to allow the essential services board to be powered by the respective diesel generator.

Stage I Diesel Generator #1 should start automatically and when rated voltage is achieved, breaker C-19 will close automatically, allowing the diesel to re-power the essential service board. Select Stage 1 diesel via the position of the changeover switch located in the Gas Turbine MCC Room.

PROCEDURE

It should also be noted that the Diesel Fire Pump will start and continue to run on loss of AC Power. This should be left in service until AC power becomes available for the electric fire pump.

GAS TURBINE

Before starting the Gas Turbine Operations should: Ensure that Breakers SSB1 and ST 34 are open prior to starting the Gas Turbine to prevent possible overloading if the Gas Turbine Breaker SSB2 is closed on a Dead Bus.

1. Select Manual Sync mode for the Gas Turbine on the Foxboro DCS system in the Plant Control Room. The Synchronizer should also be turned "OFF" in the Gas Turbine Control Room.

2. Ensure that the following 4160V breakers are open (as shown on the Foxboro DCS screen) SSB-1, SSB-2, SSB-3, SSB-4, TB-12, UB2-1, UB1-2, UB2-2, UB1-3.

3. Ensure that the following 600 volt breakers are open (as shown on the FoxboroDCS screen) A-1, A9, B1, B2, C1, C-15, & C-16.

The Gas Turbine can now be started. If the start is successful, the generator will accelerate to and hold at a speed of 4600 RPM. The Operator will then have to raise the speed to 4800 RPM by use of the Raise/Lower control switch. At a speed of 4800 RPM and 60 cycle frequency the Operator can request breaker SSB-2 to close manually.

The Manual Sync Switch must be held selected as breaker SSB-2 is requested to close. Approximately five (5) seconds after breaker SSB-2 closes, the Gas Turbine will switch from Station Service power to its own Unit Service. The Station Board for Unit #1 is now Re-Powered.

Please ensure that whenever the Gas Turbine is Operated, that the Time (Start / Synchronized / Shutdown), Load, and other Pertinent Items Normally checked are entered in the Gas Turbine Log Book.

GAS TURBINE EXHAUST CONE TEMPERATURES 'ECT'

Please be advised that whenever the Gas Turbine is in operation, Channels 17 & 18, on the Temperature Monitor located in the Gas Turbine Control Room, are monitored closely to ensure that the temperatures do not decrease to 565°C. These temperatures are to be recorded, in the Gas Turbine Log Book, each time that the Unit is operated. In the event that the temperatures fall below 600°C, it is essential that a Work Request be submitted to have the thermocouples checked.

Rolls-Royce has suggested that the above measures be taken as a means of detecting and monitoring combustion flame tube, discharge nozzle or burner distress to allow corrective action to be taken.

<u>POWER RESTORATION</u>

If Unit #3 is operating in Generation mode, shutdown the Gas Turbine, open Breaker SSB-2, and close Breaker SSB-1 before restoring power. If Unit #3 is operating in Synchronous Condenser mode, ensure all auxiliaries are powered from Unit Service .

With the Station Board for Unit #1 powered from the Gas Turbine, the following sequence should allow for a rapid, orderly restoration of power .

1. Select screen - Bus UB-2 Control, close breaker UB2-12 if required. (This breaker should be closed already)

2. Selected screen - Bus UB-1 Control, close breaker UB1-1 if required. (This breaker should be closed already)

3. Select screen - Bus SB-12 Control, close and breaker SSB-3 and C-1 should close.

4. Select screen - Bus UB-1 Control, close breaker UB1-3 and A-1 should close.

5. Select screen - Bus UB-2 Control, close breaker UB2-2 and B-1 should close.

NOTE:

After this switching is complete an Operator has to go to Power Centres A, B, and C and manually reclose all feeder breakers with the exception of the Electric Fire Pump breaker. This feeder can be reclosed electrically from the Plant Control Room .

The Operator should reset all undervoltage (type 27) relays as well.

NOTE:

This sequence of events allows for an orderlly restoration of 4160/600v power for Stage 1 units providing all equipment operates normally.

There are povisions for alternate power transfers in case of Breaker or Transformer failure. These should be covered off separately. Emergency Diesel shutdown and Diesel Fire Pump shutdown should also be covered off separately.

> Speed in implementing this sequence is essential but not critical. Top priority must be to get the Gas Turbine running using whatever diesel is available. The UPS Battery Banks must be prevented from running down.
>
> When a unit is available to be placed on-line serious consideration should be given to keeping Station Service supplied from the Gas Turbine until good system stability is achieved. The definition of system stability is a decision which the Plant would have to make in consultation with ECC.

When Testing is complete: return to normal Station Service.

1. Verify SSB-1 open;
2. Request ECC to close B7L2;
3. Select screen SB-1/2 Control.
4. Enable abnormal operation.
5. Close. Breaker SSB-4.
6. Select screen SB-34 Control.
7. Enable normal operation.
8. Select (TB-12) and enable scopes.
9. Check for synchronism and push close. TB-12 should close and ST-34 should open.
10. Select screen SB-12 Contol.
11. Confirm abnormal operation is enabled.
12. Select (SSB-1) and enable scopes.
13. Check for synchronism and push close. SSB-1 should close and all other breakers should stay in the same state.
14. Select screen SB-34 Control.
15. Confirm normal operation is enabled.

16 Select (ST-34) and enable scope.

17. Push close, ST-34 should close and TB-12 should open.
18. Selct screen SB-12 Control.
19. Select (SSB-4).
20. Push open. SSB-4 should open and all other breakers should stay in the same state.
21. Enable normal operation.
22. Shut-off the Gas Turbine, Diesel Generator, and Diesel Fire Pumps. Ensure Diesel

Generators and Fire Pump are placed in Auto.

Note: Breaker SSB-1 will not close if SSB-2 & ST-34 are closed.

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HTGS Procedures

ISO 14001 QMI-SAI Global

Procedure No: 0646	**Entered By:** Cheryl Oliver **Date:** Nov 27th, 2000 10:51 AM

Title	**POP-074 Black Start Procedure**

Archive Information

Issue Date:	**08/15/95 Aug 15th, 1995**
Distribution:	**Labour Manager Operations - Thermal, Lead Thermal Plant Operator, Shift Supervisor, Thermal Plant Operator, Training Co-ordinator - Operations**
Manual/Group:	**Plant Operating Procedures**
Revision No:	**17**
Revision Date:	**04/23/2009 Apr 23rd, 2009**
Prepared By:	**Jerry Goulding**
Controller:	**Gerard Cochrane**
Reviewers:	**Gerard Cochrane, Ron Tobin**
Approved By:	**Terry LeDrew/HO/NLHydro**

Procedure Scope

To return the Plant to Service from a Total Power Outage.

Reference Information

Procedure Details

NOTE: Confirm Status of the following Equipment prior to commencement of Black Start Testing. (1) Air Compressors and (2) Sample Cooling Pumps.

PLANT EMERGENCY DIESEL GENERATORS

On loss of Plant Service, Breaker DBT will try to close to transfer Station Service. If this transfer is unsuccessful, Breaker DBT will Open. Breakers C-16 and DB34 will also Open to allow 600V Essential Services Boards to be

Powered by way of their respective Emergency Diesel Generators.

Stage I & II Emergency Diesel Generators should start automatically and when rated voltage is achieved, the associated Breakers C-19 and D2 should close automatically, allowing the Diesels to Re-Power their respective 600V Essential Service Boards. Two sources of start-up power are now available for the Gas Turbine. Either Diesel can be selected by the position of the Change-Over Switch located in the Gas Turbine MCC Room.

Note: Extra information on Emergency Diesel Generators is located further on in the Procedure

PROCEDURE

It should also be noted that the Diesel Fire Pump will start and continue to run on loss of AC Power. This should be left in service until AC power becomes available for the Electric Fire Pump.

GAS TURBINE (*Impt. SSB1 & ST34*)

Before starting the Gas Turbine, Operations should: Ensure that Breakers SSB1 and ST34 are open prior to starting the Gas Turbine to prevent possible overloading if the Gas Turbine Breaker SSB2 is closed onto a Dead Bus.

1. Select 'Manual' Sync mode for the Gas Turbine on the Foxboro DCS system in the Plant Control Room. The synchronizer should also be turned 'OFF' in the Gas Turbine Control Room.

2. Ensure that the following 4160 V Breakers are Open (as shown on the Foxboro DCS screen) SSB-1, SSB-2, SSB-3, SSB-4, ST3/4, TB12, UT3, (See Note: #3 on the last page of the Procedure), UB2-1, UB1-2, UB2-2, UB1-3, TB-3.

3. Ensure that the following 600 volt Breakers are Open (as shown on the Foxboro DCS screen) A-9, C-15, C-16, B-2, ATB-3, ATB-12, DB-3/4.

The Gas Turbine can now be started. If the start is successful, the Generator will accelerate to and hold at a speed of 4600 R.P.M. The Operator will then have to raise the speed to 4800 R.P.M. by use of the Raise/Lower control switch. At a speed of 4800 R.P.M. and 60 Cycle Frequency the Operator can request Breaker SSB-2 to close 'Manually'.

The 'Manual' Sync Switch must be held selected as Breaker SSB-2 is requested to CLOSE. Approximately five (5) seconds after Breaker SSB-2 CLOSES, the Gas Turbine will switch from Station Service Power to its own Unit Service

Power. The 4160V Station Board for Unit # 1 and 2 (Stage I) is now Re-Powered.

Please ensure that whenever the Gas Turbine is Operated, that the Time (Start / Synchronized / Shutdown), Load, and other Pertinent Items Normally checked are entered in the Gas Turbine Log Book.

GAS TURBINE EXHAUST CONE TEMPERATURES 'ECT'

Please be advised that whenever the Gas Turbine is in operation, Channels 17 & 18, on the Temperature Monitor located in the Gas Turbine Control Room, are monitored closely to ensure that the temperatures do not decrease to 565℃. These temperatures are to be recorded, in the Gas Turbine Log Book, each time that the Unit is operated. In the event that the temperatures fall below 600℃, it is essential that a Work Request be submitted to have the thermocouples checked.

Rolls-Royce has suggested that the above measures be taken as a means of detecting and monitoring combustion flame tube, discharge nozzle or burner distress to allow corrective action to be taken.

POWER RESTORATION

With the 4160V Station Board for Unit #1 and 2 (Stage I) Re-Powered from the Gas Turbine, the following sequence should allow for a rapid, orderly Restoration of Power:

1. Select screen SB-1/2 Control.

2. Select Normal/Abnormal Operation Control.

3. Select Abnormal - Two (2) Breaker Operation (two breaker operation is enabled).

4. Select screen SB-1/2 Control.

5. Select Breaker SSB-4. (See Note: #3 on the last page of the Procedure)

6. Push CLOSE. Breaker SSB-4 should CLOSE and all other breakers should stay in the same position.

7. Select screen SB-3/4 Control.

8. Select Normal/Abnormal Operation Control.

9. Select Abnormal - One (1) Breaker Operation (one breaker operation is enabled).

10. Select Breaker TB12.

11. Push Sync scope on.

12. Push CLOSE TB 12.

13. Select screen UB-3 Control.

14. Select Breaker TB-3.

15. Push CLOSE. TB-3 should CLOSE.

<u>NOTE:</u>

At this point both the 4160 V and 600 V Boards on Unit #3 will be Re-Powered. Unit #3 lighting MCC's and Air Compressors are now available.

16. Select screen - SB-12 Control.

17. Select Breaker SSB-3.

18. Push CLOSE. Breakers SSB-3 and C-1 should CLOSE.

19. Select screen - UB-2 Control.

20. Select Breaker UB2-12.

21. Push close if required. (This breaker should be closed already).

22. Select screen - UB-1 Control.

23. Select Breaker UB1-1.

24. Push CLOSE if required. (This Breaker should be closed already).

25. Select screen - UB-1 Control.

26. Select Breaker UB1-3.

27. Push CLOSE. Breakers UB1-3 and A-1 should CLOSE.

28. Select screen - UB-2 Control.

29. Select UB2-2.

30. Push CLOSE. Breakers UB2-2 and B-1 should CLOSE.

Notes:

After this switching is complete, an Operator has to go to Power Centres A, B, and C and 'manually' Re-Close all Feeder Breakers with the exception of the Electric Fire Pump Breaker. This Feeder Breaker can be Re-Closed Electrically from the Control Room.

The Operator should Reset all Undervoltage (type 27) Relays as well.

Provided all equipment operates normally, this sequence of events allows for an Orderly Restoration of 4160/600V Power for All Three Units.

There are provisions for alternate power transfers in case of Breaker or Transformer failure. These should be covered off separately.
Emergency Diesel Shutdown and Diesel Fire Pump shutdown should also be covered off separately.

Speed in implementing this sequence is essential but not critical. Top priority must be to get the Gas Turbine running using whatever Emergency Diesel Generator is available being aware of where the Gas Turbine Start-Up Supply is being fed from either Stage I or II. The UPS Battery Banks must be prevented from running down.

When a Unit is available to be placed on line, serious consideration should be given to keeping Station Service supplied from the Gas Turbine until Good System Stability is achieved. The definition of Good System Stability is a decision which the Plant would have to make in consultation with ECC.

Emergency Diesel Generators -Extra information relative to POP # 074:

The Black Start Exercise has revealed that in the event of an extreme emergency one Emergency Diesel Generator can be used to Power Both Diesel Busses. This emergency would be defined as only one (1) Diesel Generator running and the GasTurbine beng unavailable for an extended period.

Also be aware that there are Local Control Push Buttons, with respective Operational Instructions, on each Diesel which will allow for the 'Manual'

CLOSING of their respective Breakers.

In this situation, Battery Banks would be rapidly discharged and vital plant equipment such as Air Heater Drives, Turbine Lube Oil Pumps and Turning Gear Motors would be unavailable. To prevent this from happening the following Procedure Scenarios (A & B) could be used:

Scenario (A)

Stage I Emergency Diesel Generator has started automatically on Power Failure after an unsuccessful transfer on Breaker DBT, and has CLOSED-IN Breaker C-19 Re-Powering Stage I Diesel Bus. The Gas Turbine is not available. Stage II Diesel didn't start.

1. Stage II Diesel Generator D2 should be in manual, if not, manual should be selected.

2. Breaker DBT should be Open and in 'Manual'.

3. Breaker DB-34 and D2 should be OPEN, if not OPEN DB-34.and D2.

4. Close Breaker DBT from the Foxboro Station Service Console to Re-Power Stage II Diesel Bus.

5. Critical loads on Stage II Diesel Bus can now be re-started. Monitor kilowatt load on Stage I Diesel as this is being done. Keep kilowatt loading, to within Stage I Diesel Generator Capability, only start Loads that are Critical. Note: Diesel Generator Power Output not sufficient to start the Air Compressors.

Scenario (B)

Stage II Emergency Diesel Generator has started automatically on Power Failure after an unsuccessful transfer on Breaker DBT, and has CLOSED-IN Breaker D-2 Re-Powering Stage II Diesel Bus. The Gas Turbine is unavailable and Stage I Diesel Generator did not start.

1. Stage I Diesel Generator D-1 should be in 'Manual' . If not, select 'Manual'.

2. Breaker DBT should be open and in 'Manual'. If not, OPEN DBT and put it in 'Manual'.

3. Breakers C-16 and C-19 should be OPEN. If not, OPEN C-16 and C-19.

4. Close Breaker DBT from the Foxboro Station Service Console to Re-Power Stage 1 Diesel Bus.

5. Critical loads on Stage I Diesel Bus can now be re-started. Monitor kilowatt load on the Stage II Diesel as this is being done. Keep kilowatt loading to within Stage II Diesel Capability and only start Loads that are Critical. Note: Diesel Generator Power Output not sufficient to start the Air Compressors.

After the Gas Turbine has been started and is on line supplying Station Service Power, Restore Stage I & II Diesel Busses to their normal operating condition i.e. being supplied by way of Breakers C-16 and DB-34, respectively.

RESTORING STAGE I & II 4160V STATION SERVICE FROM THE SWITCHYARD

After the Plant and ECC has decided that System Stability is acceptable, Restore Station Service from the Switchyard:

1. Confirm B6L3 & B7L2 are CLOSED.
2. Select screen SB-1/2 Control.
3. Select Normal/Abnormal Operation Control.
4. Select Abnormal-Two (2) Breaker Operation (two breaker operation is enabled).
5. Select Breaker SSB-1 and select sync scope on.
6. Check for synchronism, push CLOSE. SSB-1 should CLOSE and all other Breakers should stay in the same position.

The Gas Turbine must now be shutdown as ST -34 cannot be closed if SSB -1 and SSB-2 are closed.

7. Select screen SB-3/4 Control.
8. Select Normal/Abnormal Operation Control.
9. Select Normal-One Breaker Operation (one breaker operation is enabled).
10. Select Breaker ST-34 and select Sync scope on.
11. Check for Synchronism, push CLOSE. ST34 should CLOSE and TB12 should OPEN.
12. Select screen SB-1/2 Control.
13. Select Breaker SSB-4.
14. Push OPEN.
15. Select Normal/Abnormal Operation Control.
16. Select Normal-One Breaker Operation. (one breaker operation is enabled).
17. When the Shift Supervisor and ECC determine the system is stable:

a. Shut down the diesels,
b. Re-energize BOTH Diesel Boards, and ensure that Both Diesels are returned to Auto Mode.
c. Shut down the Gas Turbine.

18. The Operator should Reset all Undervoltage (type 27) Relays as well.

<u>Notes:</u>

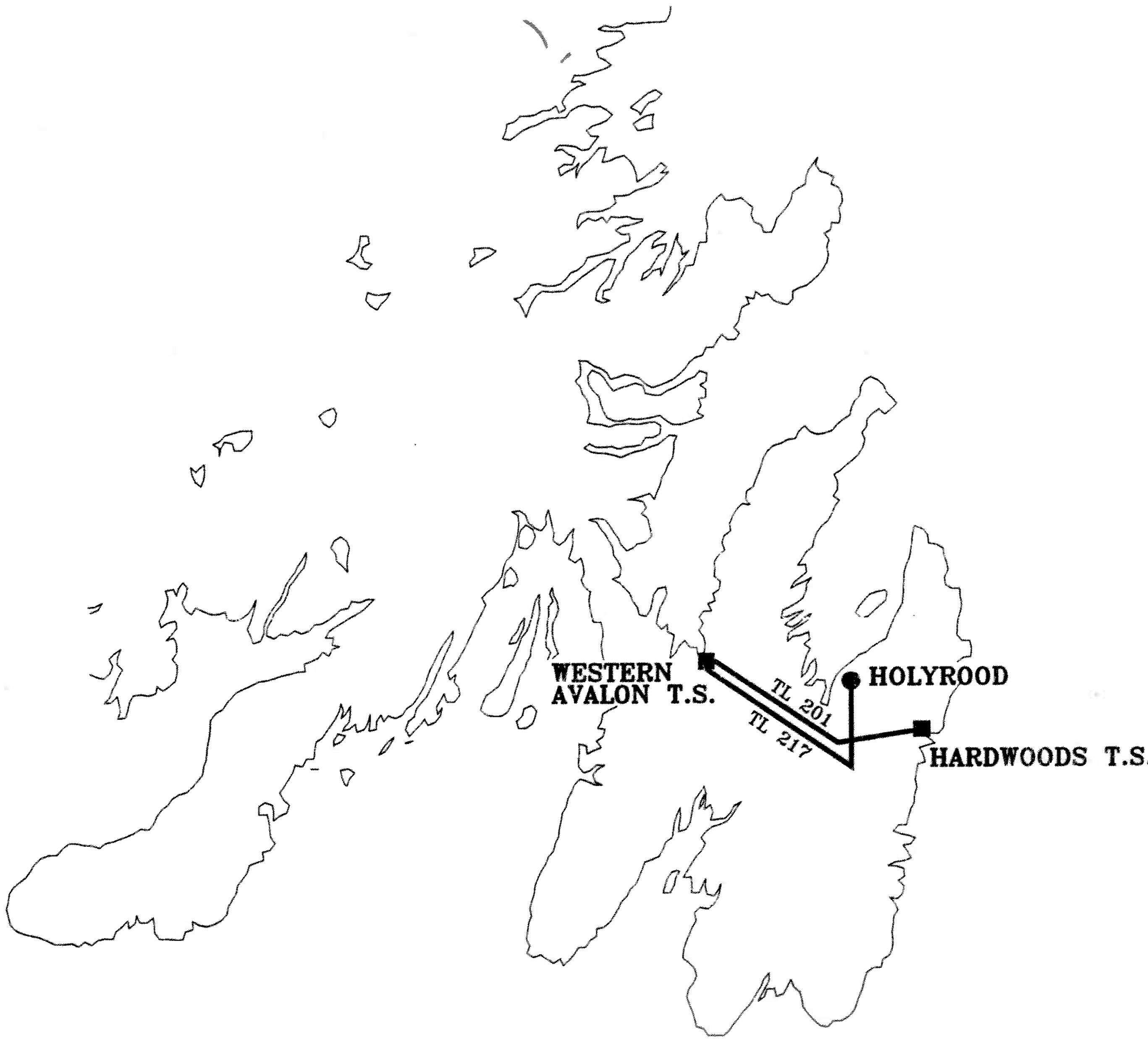
1. Breaker SSB-1 will not close if breakers SSB-2 and ST34 are closed.

2. SSB-3 (Stage I) does not open on undervoltage. The same applies for Stage 2 Aux Transformer Breakers (SAT- 34 and UAT-34).

3. If performing this test with Unit 3 synchronized, do not open UT-3 in Step 2 of the Gas Turbine section and skip Step 5 in the Power Restoration section. Ensure all auxiliaries are on Unit Service.

HYDRO

POWER SYSTEM OUTAGE REPORT



DEC. 8 TO DEC. 11 1994

NEWFOUNDLAND AND LABRADOR HYDRO

DECEMBER 8 - 11, 1994

POWER SYSTEM OUTAGE REPORT

Newfoundland and Labrador Hydro

TABLE OF CONTENTS

1.0 SUMMARY:

During the evening of Thursday, December 8, 1994 and early morning of Friday, December 9, 1994, the Avalon Peninsula experienced a severe wind and snow storm. The storm was characterized by high winds, blowing snow and freezing rain causing ice build-up on transmission and terminal structures. Winds gusting up to 126 km/hr, combined with build-up of wet snow of up to four (4) inches in diameter on Hydro's transmission line conductors in some locations was observed. The heavy icing on transmission lines, conductors and towers combined with high winds caused damage to Transmission Line 201 (TL 201) and Transmission Line 217 (TL 217). These are the only two 230 kV transmission lines which connect the Holyrood Generating Station and Avalon electrical grid to all of Hydro's other generating stations on the Island of Newfoundland. The high winds also caused heavy salt contamination in terminal station equipment at Hardwoods (HWD), Western Avalon (WAV) and Holyrood (HRD), causing electrical flashovers and equipment failure.

This report summarizes the sequence of events that took place on Hydro's power system, outlines the problems experienced and damage incurred, and identifies remedial action being taken as a result of follow-up investigations.

2.0 SEQUENCE OF EVENTS:

The following is the chronological description of the events during this storm. (For equipment location see Figure 1 and system Single Line Diagram, Appendix A).

December 8, 1994

At 23:04 hrs, TL 201 (230 kV line from Western Avalon to Hardwoods Terminal Station) tripped. There was no power interruption to the customers due to this trip of TL 201. An attempt to re-energize this line was unsuccessful. Subsequent line patrols identified significant damage to a number of spans on this line adjacent to the Western Avalon Terminal Station, which would require several days to repair.

December 9, 1994

At 01:33 hrs, TL 217 (230 kV line from Western Avalon to Holyrood Terminal Station) tripped, resulting in the Avalon Peninsula's electrical load and the Holyrood Generating Station being isolated from other generating stations on the Island grid, resulting in two separate electrical systems.

At 01:39 hrs, Holyrood unit # 1 tripped due to severe frequency swings on the system, resulting in some load shedding on the Avalon Peninsula.

At 01:43 hrs, TL 217 was restored to service. At this point ample generation was available to meet the load demand on the Avalon Peninsula.

At 08:53 hrs, TL 217 tripped. An attempt to re-energize the line was unsuccessful, indicating a permanent fault on the line. However, two generating units (No. 2 and No. 3) at Holyrood were operating and supplying the Avalon Peninsula load.

At 14:48 hrs, Holyrood unit # 1 was synchronized to the system serving only the Avalon Peninsula load. The reason for the longer restoration period was the loss of station service at Holyrood due to other system problems caused by the storm at the Holyrood Terminal Station. At this point Hydro had enough generation available from the Holyrood Generating Station to meet the Avalon Peninsula load.

At 23:12 hrs, to increase the system security, Hardwoods gas turbine was synchronized to the system.

December 10, 1994

At 12:44 hrs, TL 217 was successfully energized from the Western Avalon end. At this point the other end of this line at Holyrood Terminal Station was not closed. This step was taken as a precaution to ensure that TL 217 was in good condition and available for service.

At 13:25 hrs, after successfully ensuring that TL 217 was suitable for service, an attempt was made to synchronize this line at the Holyrood Terminal Station and thus to synchronize the Holyrood Generating Station with the remainder of the Island grid. However, a 230 kV line circuit breaker at the Holyrood Terminal Station faulted and tripped TL 217, all three generating units at the Holyrood Generating Station and the Hardwoods Gas Turbine, resulting in a complete blackout on the Avalon Peninsula.

At 14:29 hrs, TL 217 was restored to service successfully.

At 14:51 hrs, Hardwoods gas turbine was synchronized to the system. At this point some load (approximately 150MW) was picked up on the Avalon Peninsula from Bay D'Espoir. Holyrood generating units were not available and restarting of the units was slow due to the loss of station service.

At 18:09 hrs, TL 217 faulted and tripped. As a result Hardwoods gas turbine also tripped. Loss of TL 217 caused the second blackout of the day on the Avalon Peninsula. Subsequent line patrol revealed that the line conductor had broken at a span near the Western Avalon Terminal Station.

At 21:28 hrs, Hardwoods gas turbine was synchronized to Newfoundland Power's hydro generation source and power to some parts of the Avalon Peninsula was restored by Newfoundland Power.

December 11, 1994

At 09:19 hrs, TL 217 was successfully restored to service following repairs to the line near Western Avalon. As a result, power was restored to some parts of the Avalon Peninsula.

At 12:46 hrs, Holyrood unit # 2 was synchronized to the system.

At 13:35 hrs, Holyrood unit # 3 was synchronized to the system.

At this time Hydro's available supply exceeded the demand on the Avalon Peninsula. Following this, the remainder of the power system was restored to the normal mode of operation.

3.0 EQUIPMENT TROUBLE & DAMAGE:

The following is a summary of the damage caused by the storm. In some cases, where applicable, details of repairs carried out by Hydro's maintenance staff are also included.

3.1 Transmission Lines

An area near Western Avalon, where both TL 217 and TL 201 parallel each other, experienced a high incidence of freezing precipitation, causing an excessive accumulation of ice (wet snow) on the transmission line conductors. This heavy ice accumulation, combined with high winds caused damage to both these transmission lines.

TL 201

Near Western Avalon Terminal Station, seven (7) wooden structures (structures # 2 to # 9) failed (see photographs #5 to #9, Appendix A). In addition, at structure # 134, near Brigus Junction, an eyebolt supporting the line conductor failed.

Repairs to structure # 2 to # 9 commenced immediately and were completed in fourteen (14) days. The damaged eyebolt at structure # 134 was also replaced.

TL 217

This line also experienced heavy icing on the conductors, combined with high winds and suffered damage at two locations. Between structure # 76 and # 77 the conductor sagged to near ground level and at structure # 5 and # 6 the conductor broke and fell to the ground. Temporary repairs were carried out immediately by i) removing the ice at structure # 76 and # 77 and, ii) by repairing and restringing the conductor at structure # 5 and # 6. Permanent repairs were completed following the completion of repairs of TL 201.

Cause of Failures

It is concluded that the excessive ice accumulation, in excess of design, (2 inch radial) on transmission line conductors combined with high winds (126km/hr or higher) was the major cause of structure and hardware failure during the storm. These lines were originally designed for a load of one (1) inch radial ice on the conductor and a wind speed of 176 km/hr.

Repairs and Upgrade

During the repairs to the damaged sections, the design of these sections of line was upgraded to withstand the climatic loading conditions which were actually experienced.

3.2 230 kV Circuit Breakers

A 230 kV line circuit breaker for TL 217 at Holyrood faulted at 13:25 hrs on Dec. 10th. It was in an open position but energized on both sides by the two unsynchronized systems (from Bay D'Espoir by line TL 217 and by the Holyrood Generating Station). The breaker flashed over and a grading capacitor on the circuit breaker exploded causing damage to the other components. The explosion resulted in a "double phase to ground fault". High salt contamination on the breaker was the major contributing factor to the failure of this breaker. The breaker was repaired, tested successfully, and restored to service.

Heavy salt contamination on other 230 kV circuit breakers at Western Avalon and Hardwoods Terminal Stations caused limited damage to breaker components.

3.3 Holyrood Generating Plant

Throughout the storm the Holyrood generating units were experiencing severe frequency problems due to system load swings and faults on the transmission and distribution lines. The following is a summary of the sequence of events related to the Holyrood Generating Plant.

Dec. 9, 1994

At 01:39 hrs Unit No. 1 tripped due to severe frequency swings on the system. Due to other system problems, the station service supply was also lost shortly after. To restore the station service and to allow the start up of unit No. 1, the gas turbine at Holyrood was started. The gas turbine started properly, but difficulties were experienced with loading the unit. It took until 8:30 hrs to overcome these difficulties. It operated for six hours without further problem. At 14:48 hrs unit No. 1 was synchronized to the system and the gas turbine was shut down. The problems experienced with the station service and the gas turbine were the major reasons for the longer restoration period for this unit.

Dec. 10, 1994

The major system event affecting Holyrood occurred at 13:25 hrs on Dec. 10th, 1994, when the Energy Control Center was preparing to synchronize the Holyrood units to the main grid using a 230 kV circuit breaker at the Holyrood Terminal Station. This breaker flashed over causing part of the breaker to explode and damage other components of the breaker. The protection system operated correctly and cleared the fault. The fault on the breaker was a "double phase to ground fault" which resulted in all three units at Holyrood tripped off the system causing a complete blackout on the Avalon Peninsula. Further investigations were carried out to determine the cause for the tripping of the Holyrood units under simulated system conditions. It was concluded that a "double line to ground fault" at the Holyrood 230 kV bus would cause prolonged under voltage conditions at Holyrood 230 kV bus and hence on the station service bus. These low voltage conditions affected generating unit auxiliaries, i.e. fuel pumps, which could not supply the fuel to the boilers and hence tripped the units.

With the loss of all three generating units, there was again a complete loss of station service at the Holyrood Generating Station. The immediate priority of plant staff was to facilitate the orderly shutdown of the generating units and to initiate the black start sequence. Both emergency diesels were started and ran properly, but electrical distribution equipment problems within the plant prevented the Essential Services Busses from being energized and consequently the start up of the Holyrood gas turbine.

At 14:29 hrs, station service power was restored to Holyrood from the system when TL 217 was returned to service. Immediately following this, steps to start unit No. 2 were initiated. Also, at 15:42 hrs, the Holyrood gas turbine was synchronized to the system for voltage support. By 18:09 hrs unit No. 2 was at its final stage of starting sequence when transmission line TL 217 faulted again, tripping the Holyrood gas turbine and resulting in complete loss of station service.

This event at 18:09 hrs on Dec. 10th was a significant obstacle to the imminent return to service of either generating unit at Holyrood. Plant personnel were once again faced with having to complete an orderly shutdown of the turbine generating unit (unit 2) in the absence of normal supply of station service power, and avoid causing major damage to rotating equipment, e.g. turbine shaft, etc. Further problems with critical systems within the plant frustrated operating personnel in starting up the emergency power sources.

During this period, problems were experienced with the station battery banks (i.e. low supply) due to extended loss of normal station service. Intermittent unavailability of the emergency diesels compounded the Plant's difficulties in restarting the gas turbine. By 23:30 hrs the gas turbine was finally started and operating properly. During this time the compressed air system had also lost air pressure and was not capable of operating essential auxilliaries until recharging could take place. Following the successful loading of the gas turbine, the station service system was restored to its normal mode of operation and two air compressors were started.

Dec. 11, 1994

Based on the plant conditions at Holyrood and the duration of downtime of the generating units, it was decided to initiate start on unit No. 3 first. At 01:30 hrs igniters were established on this unit to pre-warm the boiler. Preparation for unit No. 2 start up was initiated at 02:30 hrs on Dec. 11th. Due to the lengthy period of time that power was unavailable to the plant, several hours were now required to build up boiler pressures and temperatures.

At 07:30 hrs while unit No. 3 was being brought up to speed, vibration levels on the turbine-generator became too high, requiring a hold on that unit until the vibrations dropped to an acceptable level. This type of problem, which is not unusual in bringing large steam turbine units into service, frustrated even further the restoration of the generating station to full service. Unit No. 2 and unit No. 3 were synchronized to the system at 12:44 and 13:35 hrs respectively.

As it can be seen from the above, following the trips at 13:25 hrs on Dec. 10th, it took Holyrood personnel approximately 23 hrs before units were reconnected to the system. Loss of station service (the second time) at 18:09 hrs practically wiped out the progress made to start a unit up to that point. Approximately six additional hours were lost in the restoration of the station service, which further delayed the restoration of the generating units. It must be highlighted that the total starting time required for a thermal unit is directly proportional to the unit down time, prior to the start up. Hence, the longer station service power outage prolonged the units downtime and the total time required for startup.

Generally speaking, the generating units at Holyrood performed better than would have been expected for similar base load thermal units operating under such adverse conditions when isolated from the main power system.

3.4 Hardwoods Gas Turbine

From December 6th to December 9th, exciter testing was being carried out on the Hardwoods gas turbine, and the unit was not available for service. On the morning of December 9th it was decided to cancel further testing and prepare to put the unit back in service. (Testing was approximately 80% complete at this time). The gas turbine was synchronized at 23:12 hrs on December 9th.

Following the Hardwoods gas turbine trip at 18:09 hrs on December 10th, there was a complete loss of station service and hence the gas turbine had to go through the black start procedure. In addition, there were numerous alarms after the trip and the station operator worked to clear these alarms so that the unit could be restarted. During this troubleshooting period the dc loads exhausted the batteries to a point where the gas turbine could not be started. At this stage the diesel was started to re-charge the batteries, which further delayed the starting of the gas turbine. At 20:43 hrs the gas turbine was started successfully but tripped on overload and finally at 21:28 hrs the Hardwoods gas turbine was synchronized with the Newfoundland Power (NP) system.

4.0 PROTECTION SYSTEM PERFORMANCE:

Overall the protection system performed as designed and required. In all cases for transmission line faults, the line protection operated correctly and isolated the faults. In some cases, breaker fail protection operated due to the nature and the location of the fault or due to the fact that some breakers had faulted and loss of operating air prevented the operation of these breakers on protection trip command, hence initiating the breaker fail protection operation.

5.0 PERSONNEL RESPONSE & POWER RESTORATION:

Immediately following the initial system trouble (TL 201 and TL 217 trips) Hydro maintenance personnel responded to trouble shoot and to restore the power system. Transmission line maintenance crews from Whitbourne patrolled the lines at night under intense storm conditions. After the initial assessment of the damage to the transmission line structures (TL 201), line crews from Bishops Falls were also mobilized. Simultaneously, support staff groups were organized to facilitate the restoration of the power system. These groups included, warehousing, transportation, engineering and operating personnel. For switching and isolation of the damaged equipment, maintenance staff was dispatched to various Terminal Stations. Terminals maintenance crews performed various operating and maintenance functions under severe weather conditions. Throughout the duration of the storm maintenance crews were stationed at Western Avalon, Hardwoods and Holyrood terminal stations.

Material procurement from Central stores (Bishops Falls) and transportation to the repair site near Western Avalon was organized and executed in a highly professional and efficient manner. For the transportation of heavy materials, Hydro's own fleet and some private trucking firms were utilized. Materials were delivered to the repair site on the night of December 9th and throughout the day of December 10th. Bishops Falls and Whitbourne crews worked simultaneously to repair the lines at different locations. Engineering design review and modifications were also completed simultaneously and were incorporated into the repair work.

Throughout the transmission line repairs Hydro was self sufficient in terms of repair crews, construction tools and equipment and mobile equipment. The only exceptions were a large boom truck and an excavator which were rented. Also a contractor blasting crew was hired for the excavation of pole holes.

To complete the temporary repairs to TL 217, the Whitbourne crew worked throughout the night under intense weather conditions. By the time these repairs were completed, this crew had been working continuously for twenty-seven (27) hours. Throughout the repairs of TL 201, a workforce of forty (40) personnel worked fifteen (15) hours per day.

Maintenance and operating personnel at the Holyrood Generating Station worked continuously throughout the storm duration under difficult conditions where there was no station service power available.

The first total loss of power to the Avalon Peninsula occurred at 13:25 hrs on December 10th. At 14:29 hrs on December 10th, TL 217 was restored to service and hence power was restored to some parts of the Avalon Peninsula. Hardwoods and Holyrood gas turbines were synchronized to the system at 14:51 and 15:42 hrs respectively.

At 18:09 hrs on December 10th, TL 217 faulted again and tripped along with Hardwoods and Holyrood gas turbines. This was the second complete blackout of the day. From this point onward Hydro's staff concentrated on two simultaneous remedial actions namely i) reactivation of Holyrood Plant, and ii) investigation and repairs of TL 217.

At 21:28 hrs on December 10th Hardwoods gas turbine was synchronized to the Newfoundland Power system, thus restoring power to some parts of the Avalon Peninsula. At 09:19 hrs on December 11th TL 217 was restored to service and at 12:46 hrs Holyrood unit 2 and at 13:35 hrs Holyrood unit 3 were synchronized to the system. At this point Hydro's available supply exceeded the load demand on the Avalon Peninsula.

6.0 REPAIR COSTS:

Final costs of the repairs necessitated by the storm damage are being accumulated. It is estimated that the total cost of repairs to the transmission lines and terminal equipment will be approximately $750,000.

7.0 POWER OUTAGE ANALYSIS:

Transmission Lines

Based on the field observations (see Table 4.1, Appendix A), it is concluded that the excessive ice accumulation, in excess of design, on the transmission line conductors combined with high winds was the major cause of structures and hardware failure during the storm. In the case of TL 201, the failure at both locations was initiated by the heavy icing of the conductors and the failure of a welded eyebolt used in the guying at certain types of structures.

Similarly, heavy icing of the conductors initiated the failure of a clamp holding the conductor on TL 217. The investigation showed that perhaps this clamp was also weakened by the aeolian vibrations (conductor galloping caused by certain wind conditions) experienced on this transmission line.

In reviewing the mode of failure of the transmission line TL 201, it is concluded that the use of certain hardware, i.e. welded eyebolts and guying design using a single eyebolt, holding the conductor in the strain position, is inadequate to meet the conditions actually experienced during this storm. Remedial action is recommended to replace this type of welded eyebolt design.

Holyrood Generating Station

The major factor in the long restoration time for the Holyrood generating units was the frequent loss of station service power supply from the system. This necessitated the initiation of the black start procedure at Holyrood.

The emergency diesel generators, the Holyrood gas turbine and associated distribution switchgear experienced a number of difficulties. These standby systems are tested on a weekly basis, however, due to system design, these routine testings were not able to simulate the real loss of station service conditions.

8.0 REMEDIAL ACTION:

As a result of the investigation carried out by Hydro personnel following the December 8 - 11th outage, a number of remedial actions have been identified. A summary of the more significant actions is provided.

8.1 Transmission Lines

1) It is concluded that heavy icing of the conductors, in excess of design, initiated the failure of a welded eyebolt at both locations on TL 201. It has been decided to review the use of the "welded eyebolts design" of transmission line hardware on all transmission lines and determine the need for replacement.

2) It is probable that aeolian vibration was a factor in the failure of the conductor clamp on TL 217. Presently, Hydro is studying the problem of aeolian vibration on transmission lines on the Avalon Peninsula. This work will be continued so as to cover all the transmission lines exposed to aeolian vibration, particularly on the Avalon Peninsula.

3) A contributing factor to the failure of TL 201 (Str.#2 - #9) is the existence of long spans in the range of 1500 ft to 2000 ft. Although constructed to meet the design criteria, with the type of icing and winds experienced on the Avalon Peninsula, these spans can leave the line severely exposed. A review of the lines will be undertaken to identify the areas with these long spans.

8.2 230 kV Breakers

Most of the 230 kV circuit breakers on the system are now more than twenty-five (25) years old. Though these breakers are well maintained and some overhaul work has been carried out on major parts of selected breakers, it is planned that the performance and maintenance history of all these breakers will be reviewed individually and manufacturer's recommendations for major overhaul or upgrade, etc., will be implemented.

8.3 Holyrood Generating Plant

1) A detailed review of the existing black start facilities at Holyrood will be carried out. This review will include the design modifications necessary to allow for the realistic routine testing of the black start equipment. This study will also address if a second black start generating unit is required at Holyrood.

2) A study of the complete station service breaker control, bus transfer system, and associated circuit breakers will be completed. Based on past experience, modifications may be required for additional bus transfer flexibilities during emergency conditions.

3) In view of the difficulties experienced with the loading of this gas turbine, a procedure/guidelines for the loading of the gas turbine will be developed.

4) Holyrood operating staff will develop a reasonable unit start up time estimate guide under various contingency conditions for communication to Energy Control Centre (ECC) and to our customers.

8.4 <u>System Performance & ECC</u>

1) Based on the difficulties experienced in picking up even small blocks of load by Holyrood generating units and by Hardwoods gas turbine, the need for a detailed study of the governor settings for these units will be assessed.

2) With only one 230 kV transmission line (e.g. TL 217) in service and the Holyrood units unavailable, load transfer capability (to the Avalon Peninsula) is limited to approximately 150MW due to limited voltage support. A complete review of existing load transfer capabilities under various emergency operating conditions will be carried out. In addition, this review will explore the possibility of additional voltage support at this end of the system.

3) During the storm there were severe salt contamination conditions in the Terminal Stations. It is concluded that several breakers and buses faulted due to this contamination, particularly during switching operations. Further investigations will be carried out to determine the best course of action under similar conditions, e.g. delay switching, possible cleaning of the salt contamination, etc.

4) Based on the concerns expressed by Newfoundland Power, present switching request procedure for Newfoundland Power will be reviewed and reconfirmed. All switching requests must come through the Energy Control Center, and Newfoundland Power must be asked to specify the time of switching required at the time of request. Overall, the communications procedure with Newfoundland Power will be reviewed for possible improvements to deal with similar conditions in future.

APPENDIX A

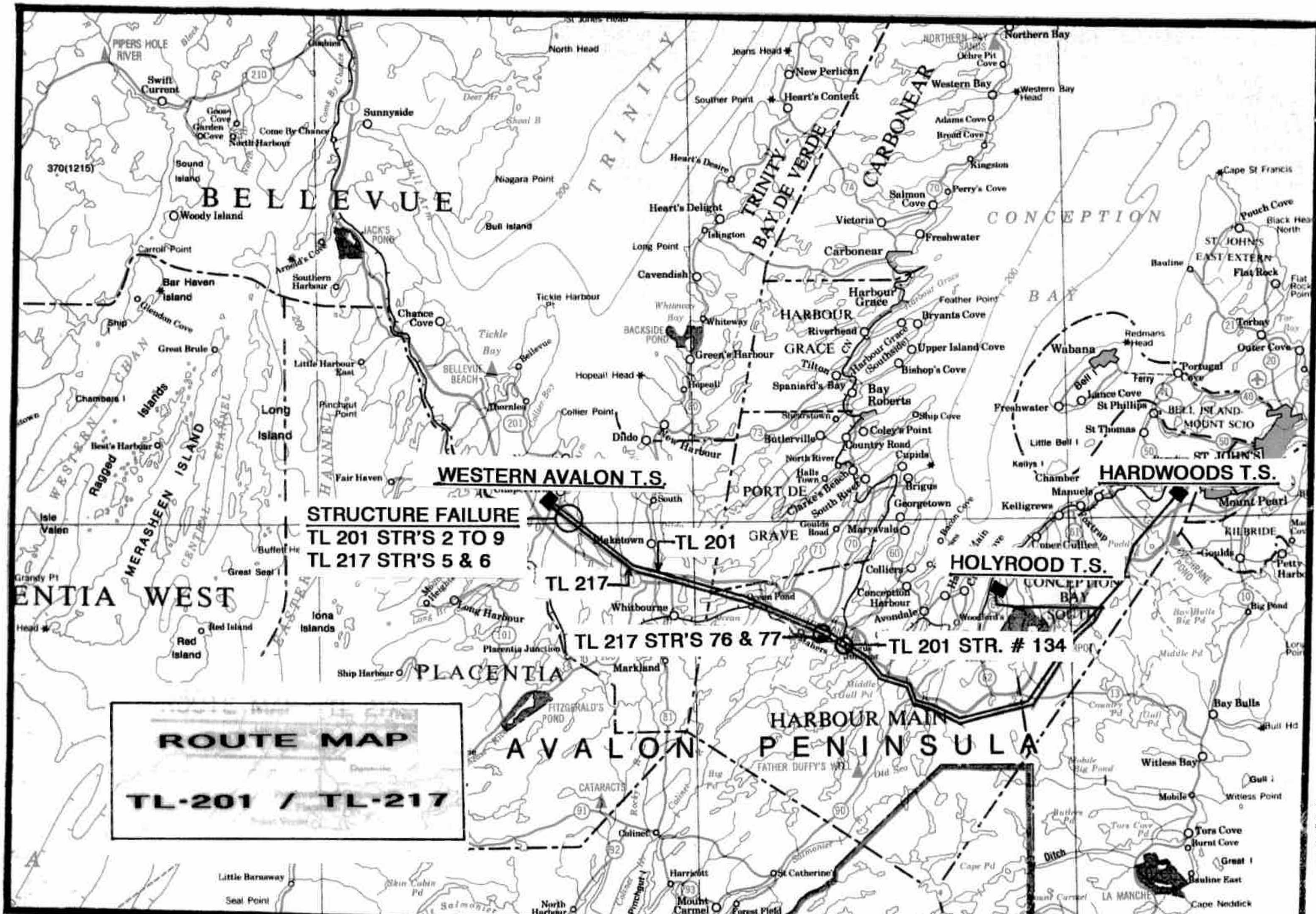
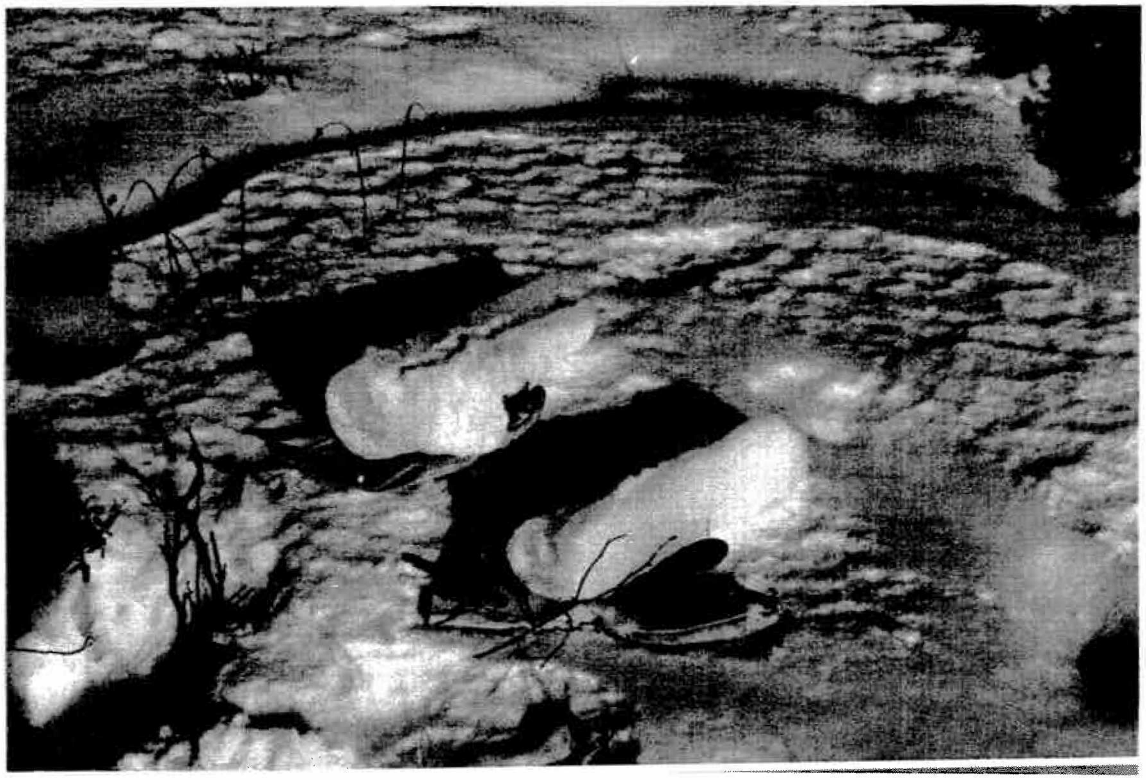

ROUTE MAP
TL-201 / TL-217
WESTERN AVALON T.S.
STRUCTURE FAILURE
TL 201 STR'S 2 TO 9
TL 217 STR'S 5 & 6
TL 201
TL 217
HOLYROOD T.S.
HARDWOODS T.S.
TL 217 STR'S 76 & 77
TL 201 STR. # 134
BELLEVUE
CONCEPTION BAY
TRINITY BAY DE VERDE
CARBONEAR
HARBOUR GRACE
PORT DE GRAVE
CONCEPTION BAY SOUTH
HARBOUR MAIN
AVALON PENINSULA
PLACENTIA
PLACENTIA WEST
ST. JOHN'S
BELL ISLAND MOUNT SCIO
ST. JOHN'S EAST EXTERN

FIGURE 1



Ice observed between Str.#5 and #6 on TL 201

Field Observations

Location	Conductor Diameter (Inches)	Diameter Ice - Radial (Inches)
TL 201 Str.#3 - #4	1.0	1.5
TL 201 Str.#5 - #6	1.0	1.5 - 2.0

TABLE 4.1

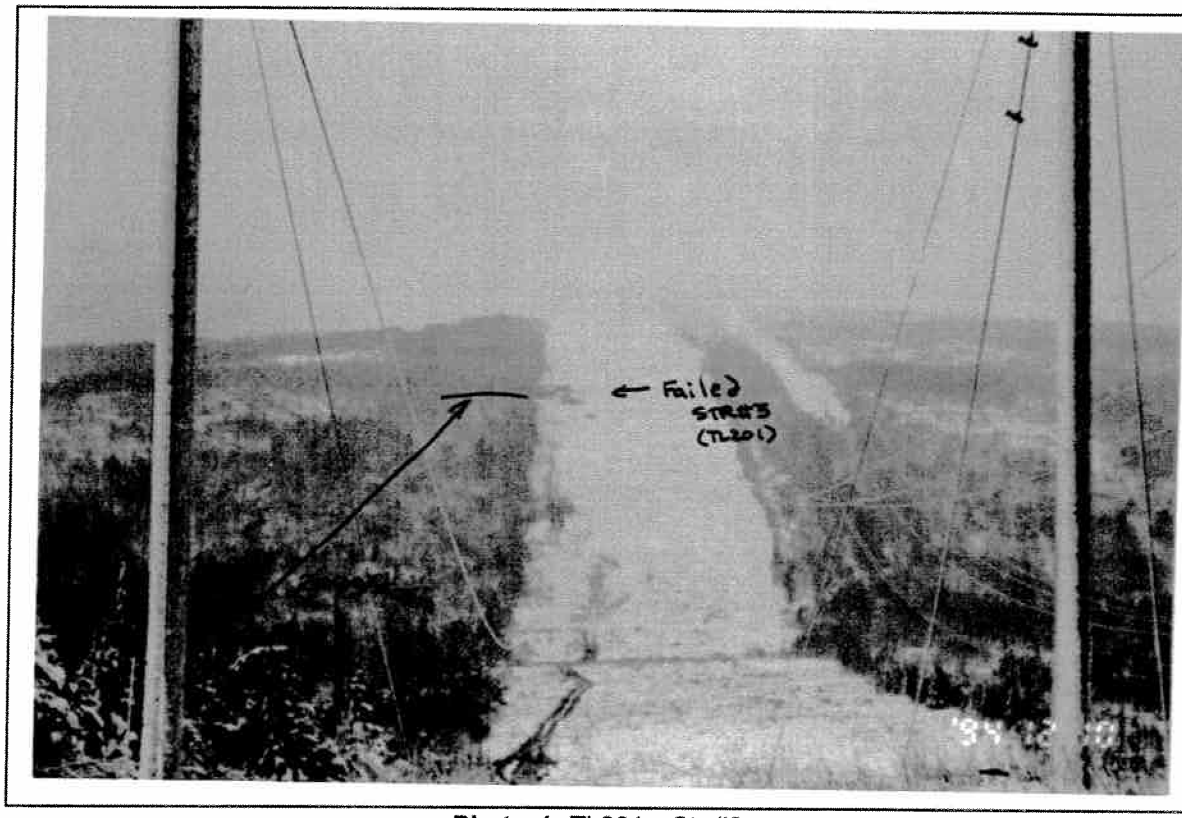


Photo 1: TL201 - Str.#2
Looking towards Whitbourne

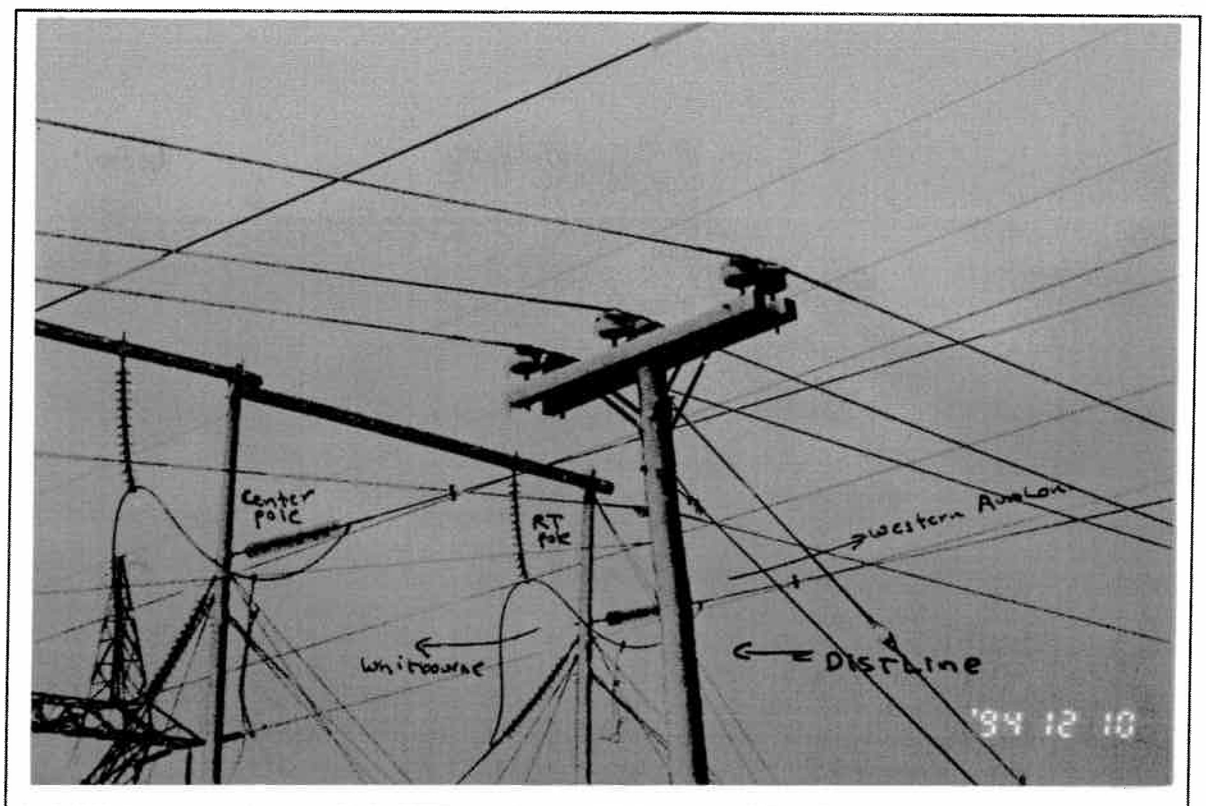


Photo 2: TL201 - Str.#2 - Type D
Near Chapel Arm Road: Structure shaken but intact.

Photo 3: TL201 - Str.#3 - Type D. Failed Welded Eyebolt.
Right pole broken at guy attachment.

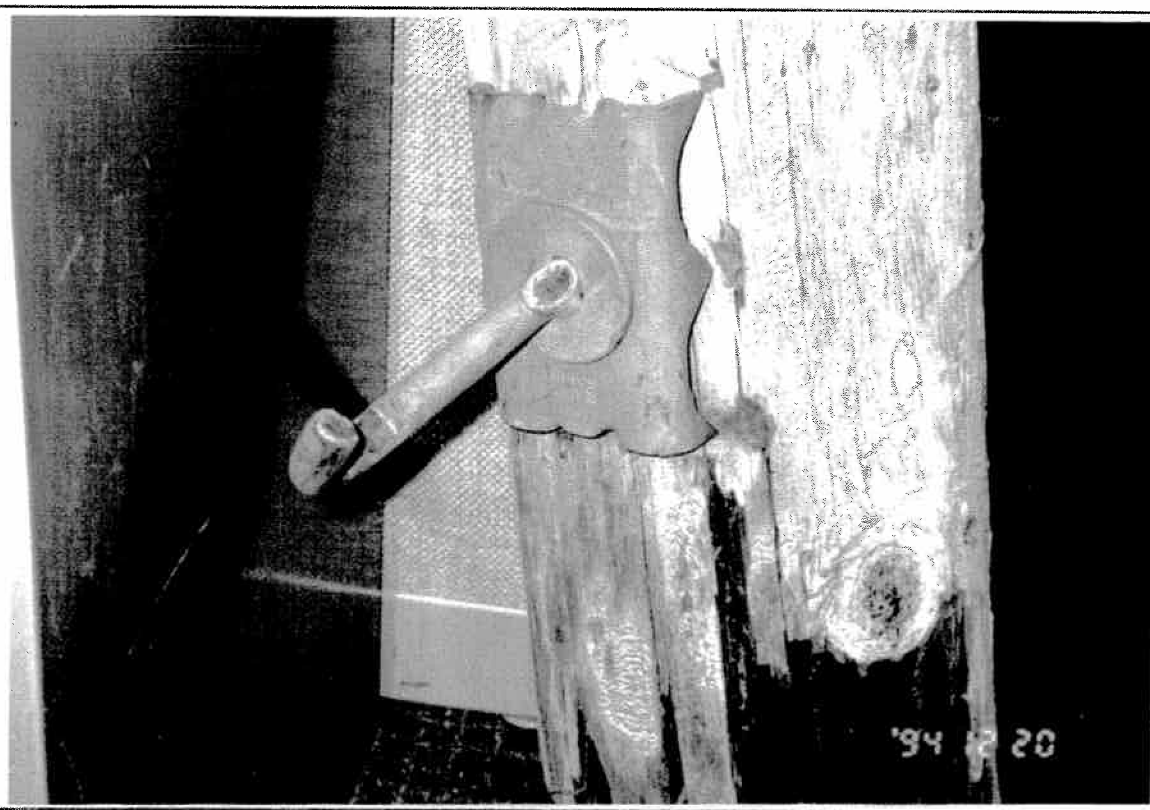


Photo 4: TL201 - Str.#3 - Type D.
Failed 7/8" Welded Eyebolt.

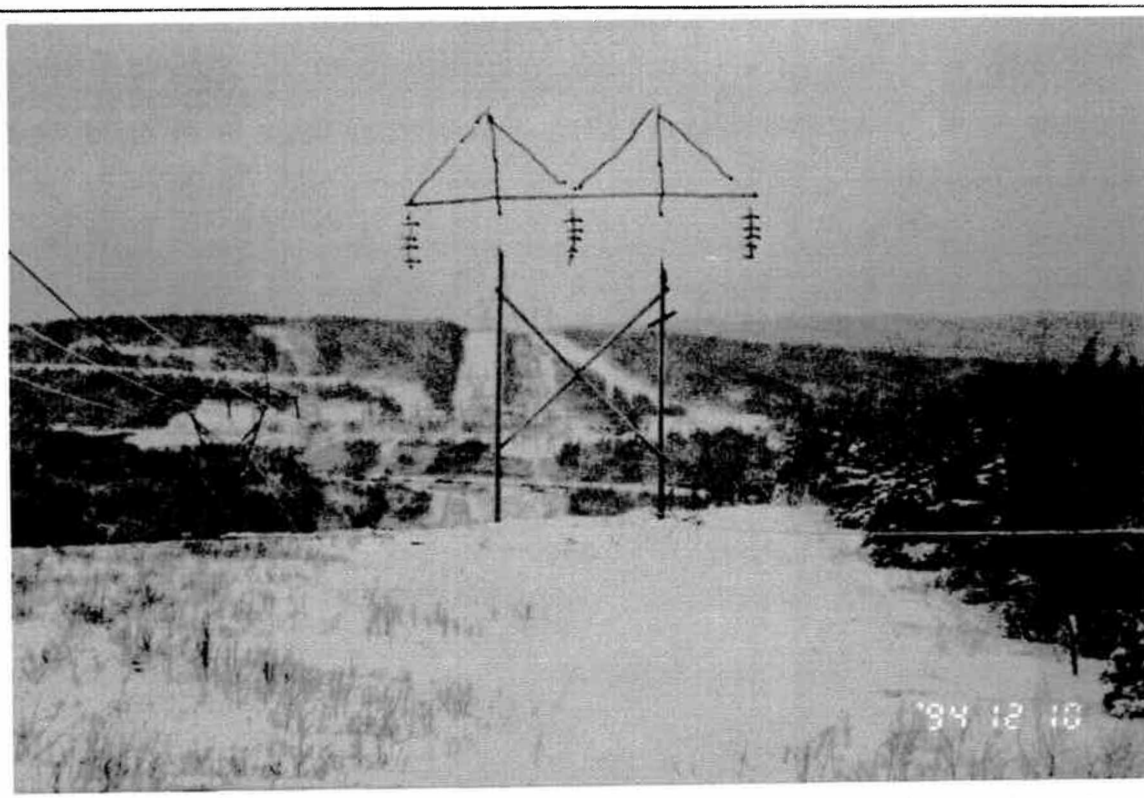


Photo 5: TL201 - Str.#4 - Type A
Pole tops and crossarm on ground.

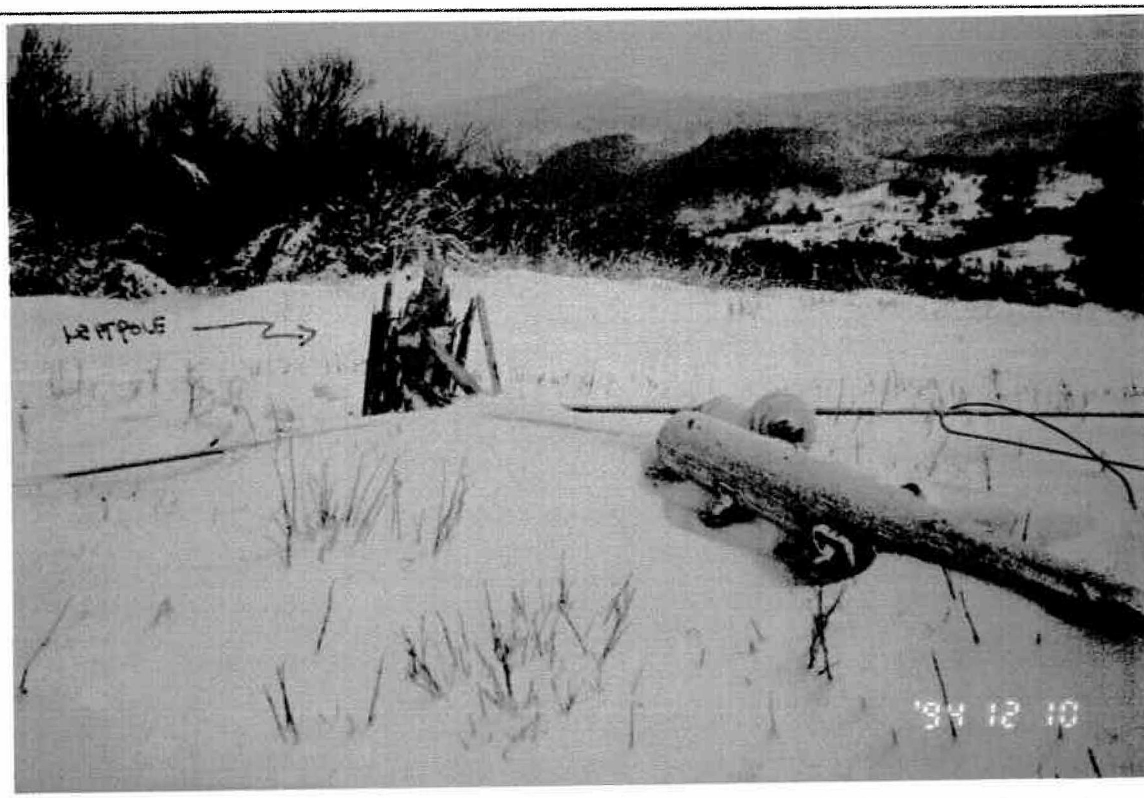


Photo 6: TL201 - Str.#5 - Type B
Left pole cracked at ground-line.

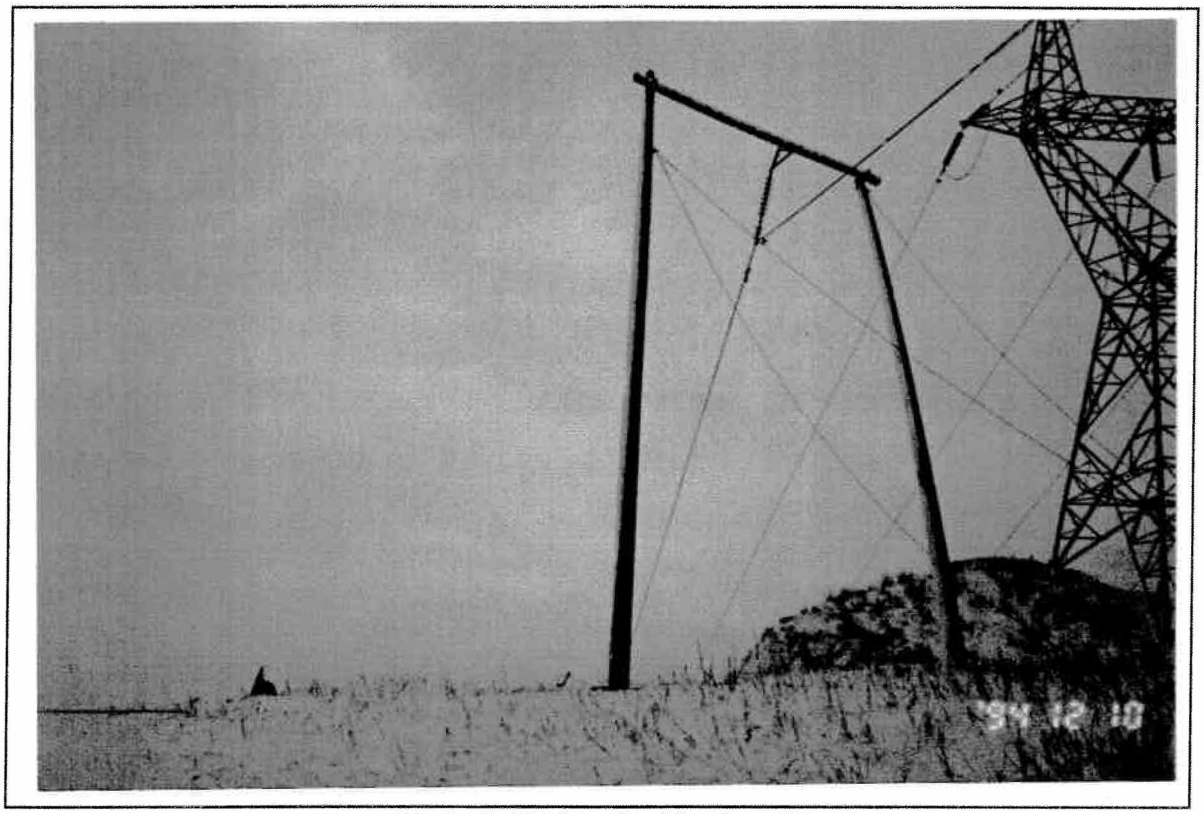


Photo 7: TL201 - Str.#5 - Type B
Center and right pole leaning heavily towards Whitbourne.

Photo 8: TL201 - Str.#7 - Type A
Left pole moved through ground.

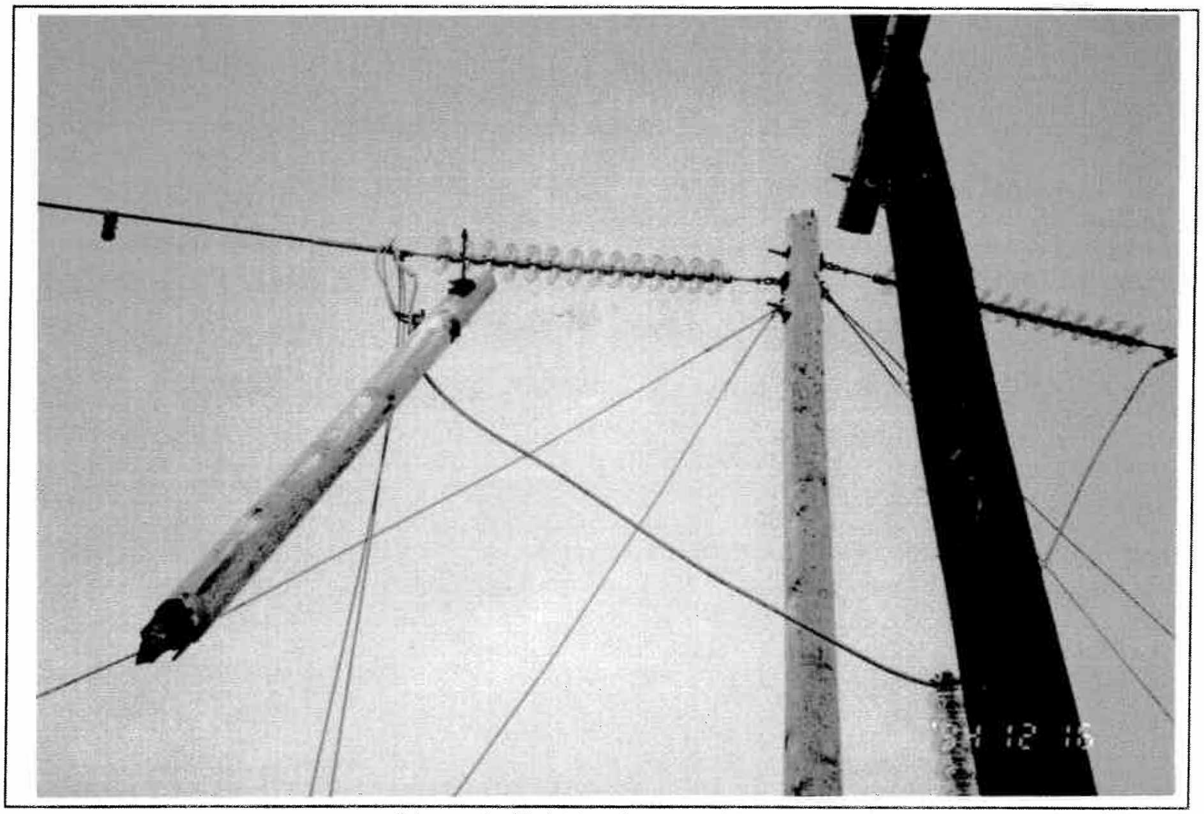


Photo 9: TL201 - Str.#3 - Type D
Crossarm hanging on jumper.

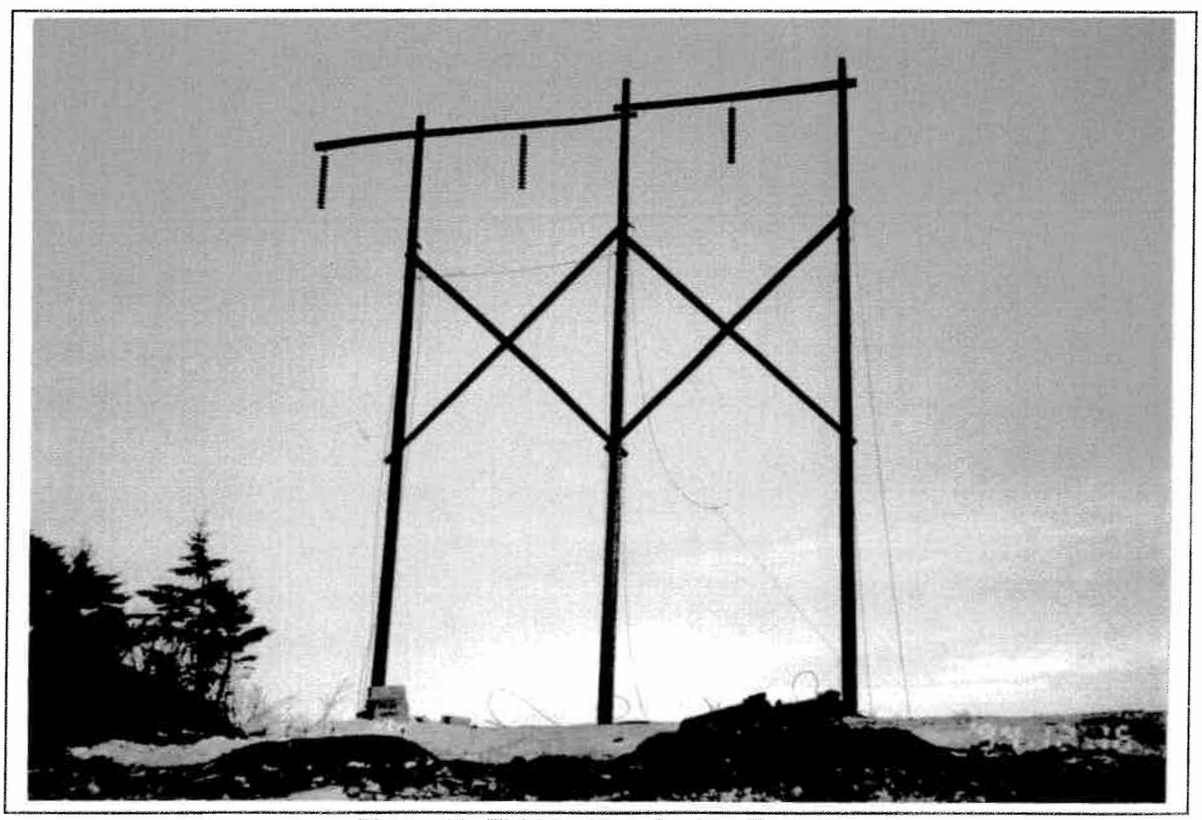


Photo 10: TL201 - New Str.#3 - Type G
3-Pole - 230 kV - In-line Deadend.

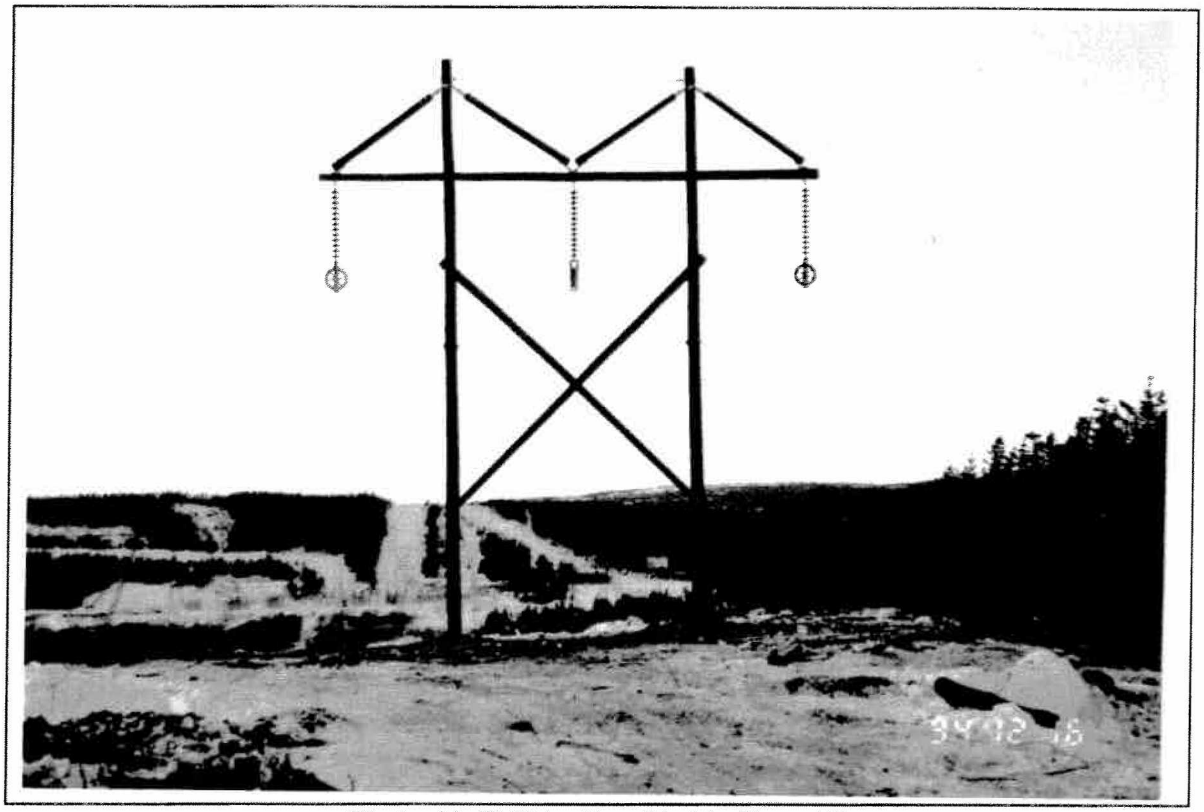


Photo 11: TL201 - New Str.#4 - Type AX
2-Pole Tangent Structure (0 - 3°)

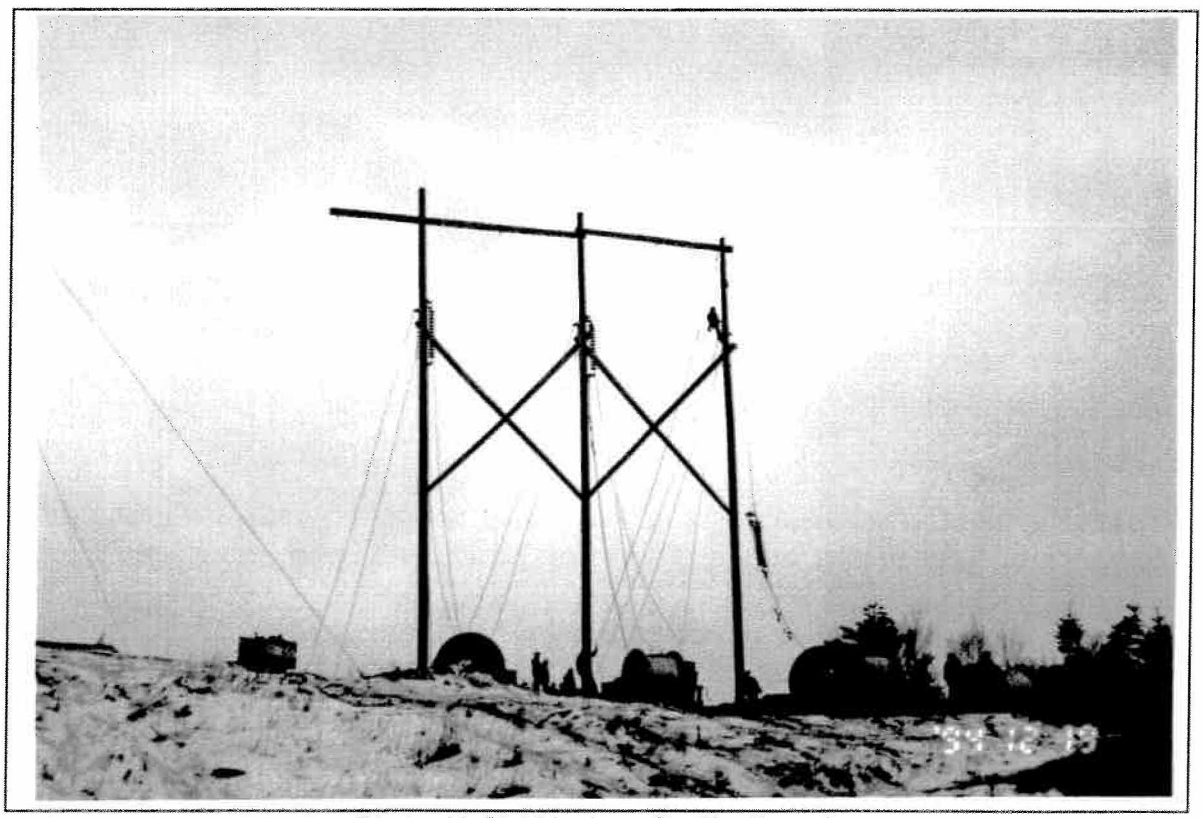
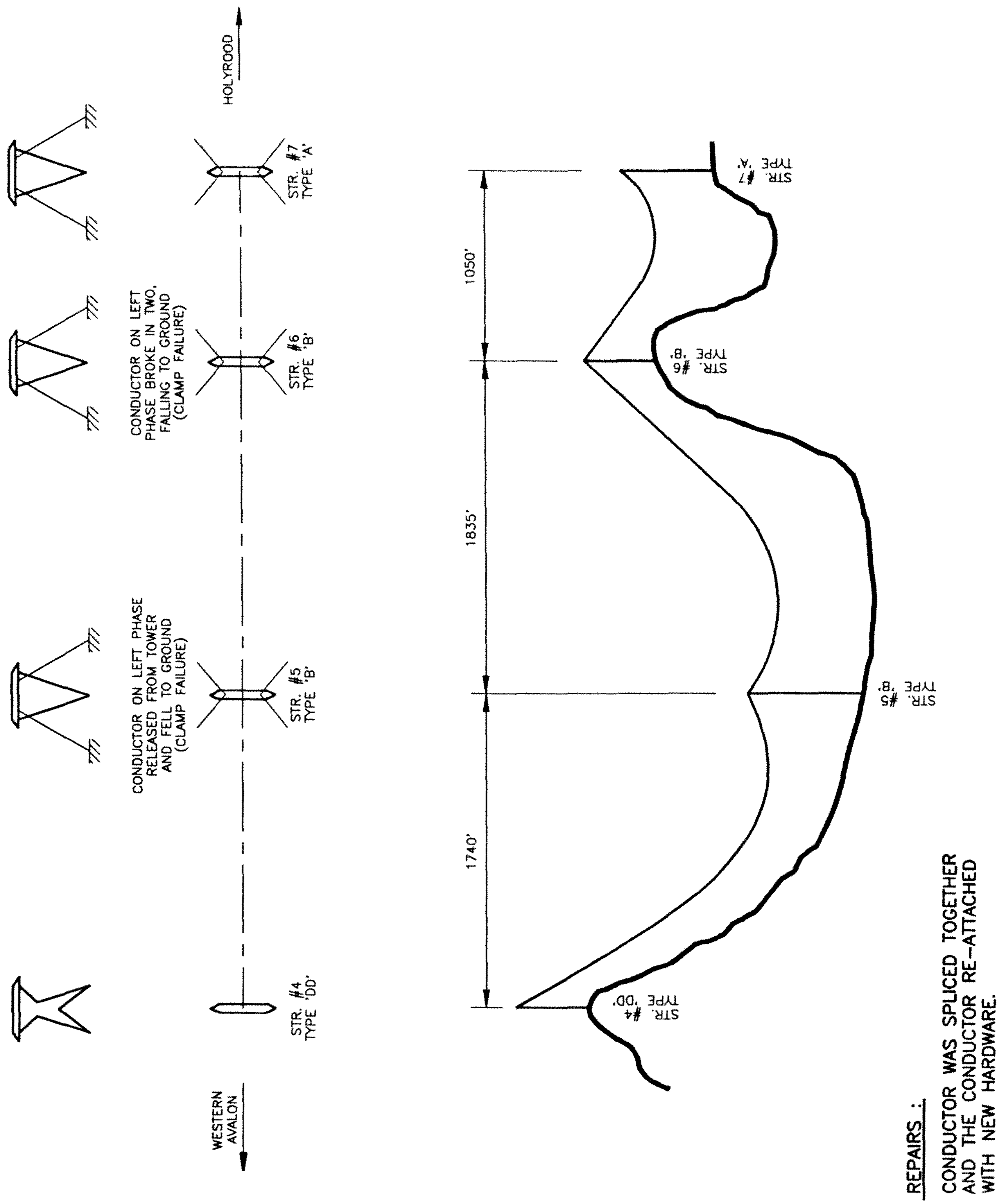


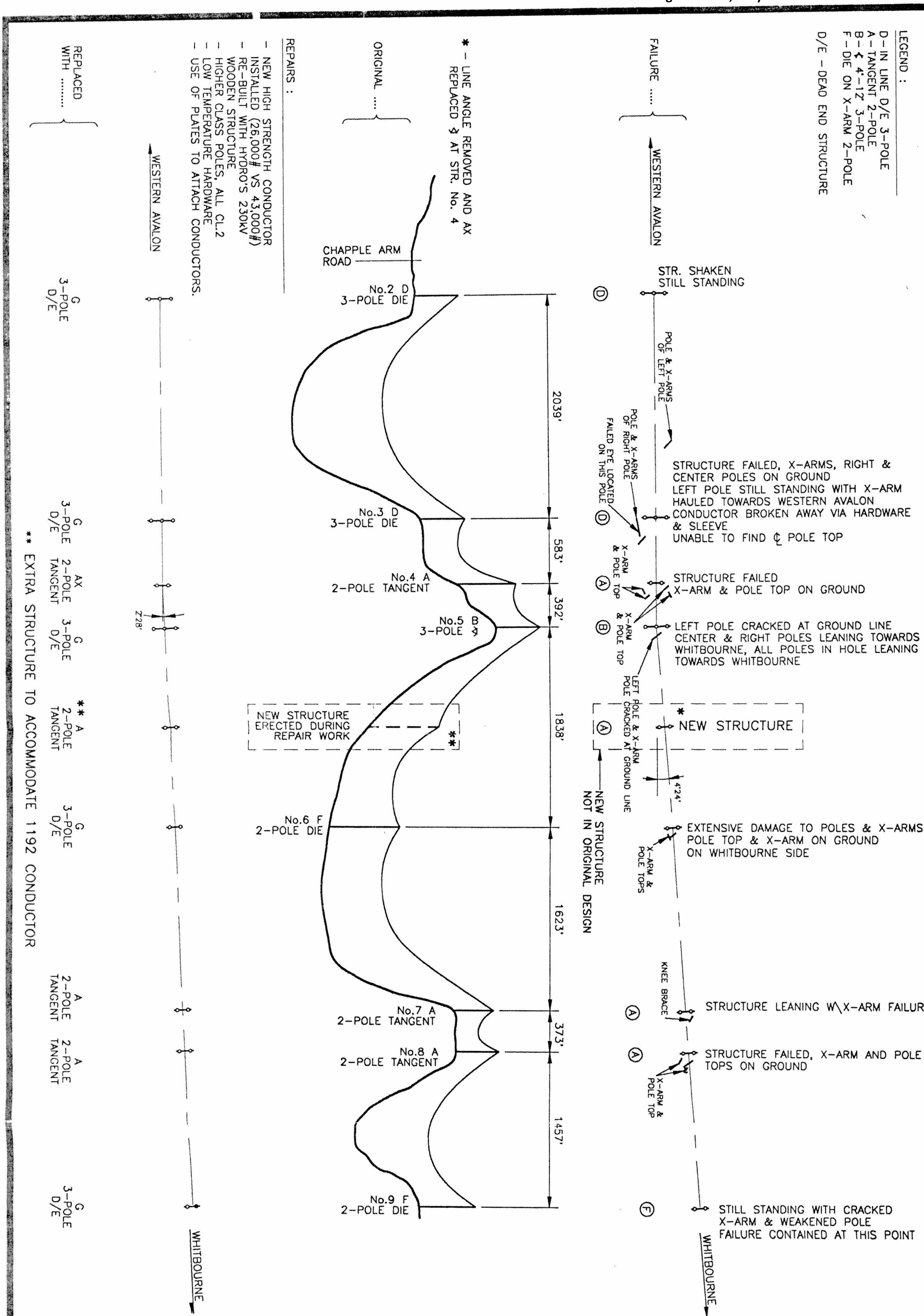
Photo 12: TL201 - New Str.#6 - Type G
3-Pole - 230 kV - Deadend



HYDRO

NEWFOUNDLAND AND LABRADOR HYDRO

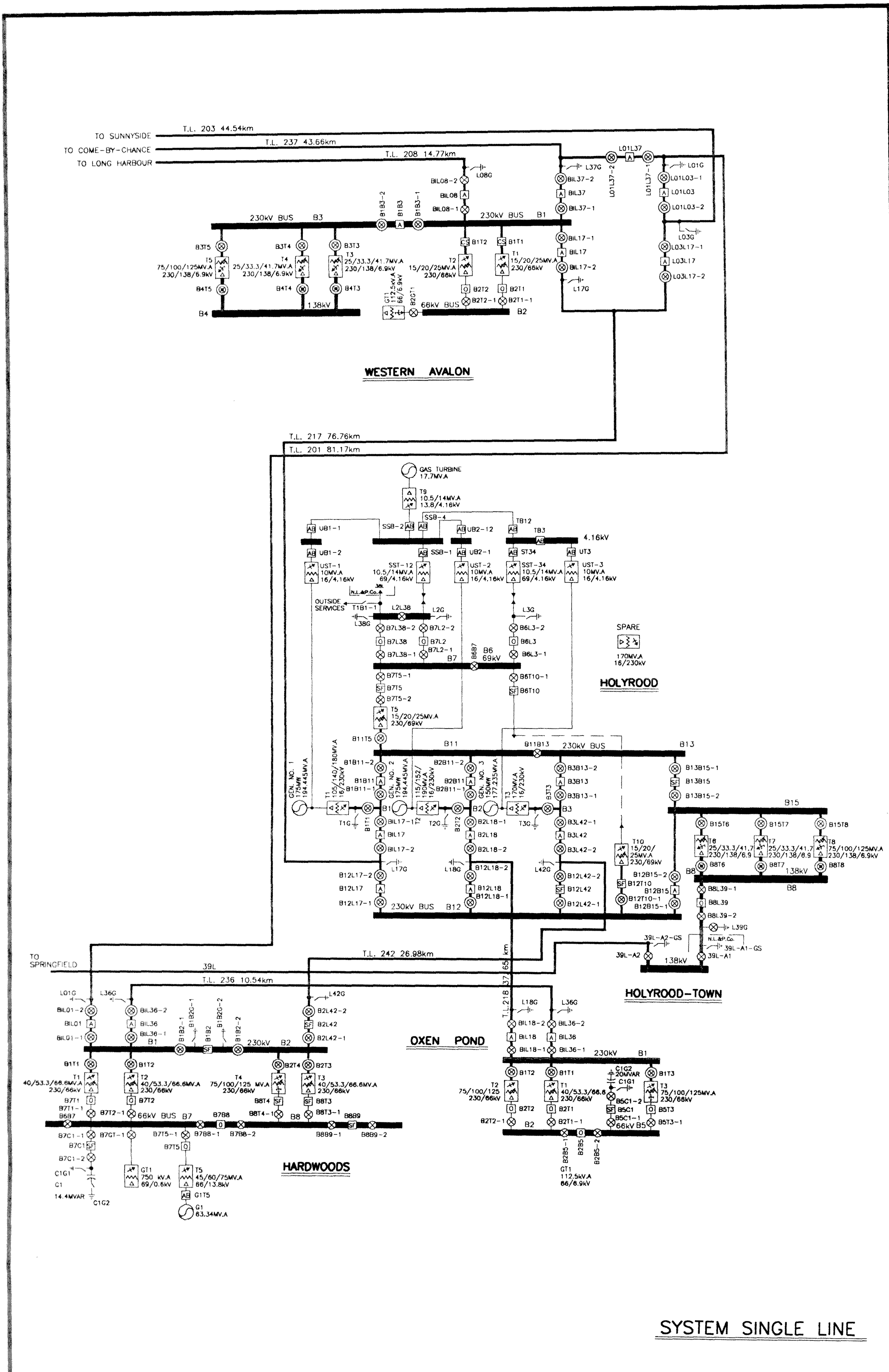
SCALE 1:10,000	TL.217 LINE FAILURE STRUCTURE No.4 TO No.6	DATE: 1995-01-16		
DRAWN D.C.M.		W.O. NO.		
CHECKED		DWG.NO. 217-T-24		REV. 0
APPROVED				



HYDRO

NEWFOUNDLAND AND LABRADOR HYDRO

SCALE 1 : 10 000	TL.201 LINE FAILURE STRUCTURE No.2 TO No.9	DATE: 95-01-16	
DRAWN K.B.R.		W.O. NO.	
CHECKED		DWG.NO. 201-T-108	REV. 0
APPROVED			


TO SUNNYSIDE
T.L. 203 44.54km
TO COME-BY-CHANCE
T.L. 237 43.66km
TO LONG HARBOUR
T.L. 208 14.77km
230kV BUS B3
230kV BUS B1
66kV BUS
B2
B4
138kV
WESTERN AVALON
T.L. 217 76.76km
T.L. 201 81.17km
GAS TURBINE 17.7MV.A
4.16kV
SPARE
170MV.A 16/230kV
HOLYROOD
B6 69kV
B7
B11
230kV BUS
B13
B15
138kV
B8
230kV BUS B12
TO SPRINGFIELD
39L
T.L. 242 26.98km
T.L. 236 10.54km
T.L. 218 37.65 km
138kV
HOLYROOD-TOWN
OXEN POND
230kV B2
230kV B1
66kV BUS B7
B8
HARDWOODS
G1 83.34MV.A
SYSTEM SINGLE LINE

January 18, 1996

Mr. David A. Vardy,
Chair and Chief Executive Officer
Board of Commissioners of Public Utilities
Prince Charles Building
120 Torbay Road
P.O. Box 21040
St. John's, Newfoundland
A1A 5B2

Dear Mr. Vardy:

We are pleased to submit five (5) copies of the attached report "Update to the Report to the Board of Commissioners of Public Utilities on the Status of Remedial Actions Arising out of the December 1994 Outage" which was jointly prepared by both utilities, as per your letter of December 8th, 1995.

Yours truly,

T. David Collett, Executive
Vice-President Production
Newfoundland Hydro

Wallace W. Pinhorn
Vice-President Technical Services
Newfoundland Power

TDC/kdc
Attachments (5)

UPDATE TO THE REPORT TO THE BOARD OF COMMISSIONERS OF PUBLIC UTILITIES ON THE STATUS OF REMEDIAL ACTIONS ARISING OUT OF THE DECEMBER 1994 OUTAGE

JOINTLY PREPARED BY:
NEWFOUNDLAND & LABRADOR HYDRO
AND NEWFOUNDLAND LIGHT & POWER

JANUARY, 1996

At the December 4th, 1995 meeting between the Board of Commissioners of Public Utilities ("Board"), Newfoundland & Labrador Hydro ("Hydro") and Newfoundland Light & Power Limited ("NP"), the Board requested both companies to update their May 20th, 1995 Joint Report relative to the December /94 storm and the initiatives that have been completed and/or are in progress. The following information is provided in response to that request and is presented in the same format as the May 20th, 1995 Joint Report.

1. ***"Any plans for the improvement of communication between both utilities and for a co-ordinated method of communication between the utilities and the public".***

Four (4) separate means of communications are to be operational between the Control Centers of the two utility companies, namely:

(i)	Ring down system (auto dial-direct link)	(in operation)
(ii)	Dial up (normal telephone system)	(in operation)
(iii)	VHF Radio	(in operation)
(iv)	Power Line Carrier phone	(in progress)

The first two systems above use the Newfoundland Telephone Company's system, the last two systems are independent systems owned and operated by Hydro. At present, the equipment required for the carrier phone for the NP Control Center has been received and it will be installed soon.

2. ***"Many problems experienced by both utilities were caused locally by weather conditions occurring in that locality. Do the utilities propose to develop a consolidated map of areas of intense wind and sleet conditions for their future planning? If so, please provide the Board with such a map."***

Following discussion and further clarification at the December 4th meeting with the Board both utilities agreed to collaborate on the preparation of such a map indicating relative severity of those conditions where such are known.

3. ***"Both utilities indicated specific problems. If such problems expanded it could be a major factor in another storm of similar magnitude. These include:***
   (a) The strength of welded eye bolts,
   (b) Conductor galloping,
   (c) Areas of extra long spans, and
   (d) Salt contamination of insulators (would insulator washing create a significant reduction in salt contamination?)"

Hydro (refer to Hydro's previously submitted report "Power System Outage Report" Section 8)

(8.1) <u>Transmission Line</u>

An internal review to fully investigate the transmission line problems experienced in the December 1994 outage is now being completed. The purpose of the review is to assess the reliability of the existing line from Sunnyside to St. John's with respect to checking the welded eye bolt design, reviewing the design criteria for long spans and the impact of aeolian vibration on these transmission lines. In addition return periods of icing storms, conductor ice loading and strength of the existing transmission lines is also being studied.

To date, the review has confirmed the following:

- the transmission lines have performed satisfactorily under conditions equal to those specified in the original design.

- in the area of the failure in December 1994, the actual meterological conditions experienced were one and one-half to two inches of radial ice and a wind speed of 40-60 miles per hour which exceeded the transmission line design criteria of one inch radial ice at 0 miles per hour wind speed.

- tests have been performed on selected hardware from the site of the December 1994 failure. The results confirmed that all hardware tested met the minimum design qualifications.

- there is no need to replace specific components until the study into return periods for severe ice conditions and the subsequent ice loading on transmission lines is finalized.

Following completion of this review, cost effective ways to make improvements to the existing lines will be evaluated for future capital programs. No money has been budgeted for such work in Hydro's 1996 capital program.

(8.2) 230 KV Breakers

Hydro's Terminal Maintenance Committee has completed a review of all 230 KV breaker maintenance and performance history. It is concluded that Hydro's maintenance practices meet or exceed those recommended by the manufacturer. Further, this review concludes that breaker age or maintenance did not contribute to the problem experienced. As a result no further action is planned except to continue with normal maintenance and performance monitoring.

(8.3) Holyrood Generating Plant

As a result of the December 1994 power system outage a review of the Holyrood Station Services and black start facilities was initiated. Simultaneously, a field work program covering a number of items was initiated as follows:

- The control panel replacement program for the station service has been completed. New control panels with CRT displays and WDPF (Westinghouse Distributed Processing Family) is a major improvement in terms of ease of operation and station service controls.

- Black start and station services operating procedures were reviewed and revised to reflect the WDPF changes. A program for starting a Holyrood generating unit under black start conditions has been initiated. This annual program will provide training to the operators under such emergency conditions. During 1995, Unit 3 was successfully started under black start conditions.

- The refurbishing program for 600 V switchgear has been completed.

- The 4.16 KV breaker refurbishing program was initiated in 1995 and refurbishing of critical breakers has been completed. The refurbishing of other breakers will be completed by 1997.

- Synch check relays for the 4.16 KV system were upgraded.

- Synch check relays for Diesel I are on site and will be installed in the near future.

- Loading guidelines for the Holyrood Gas Turbine have been prepared and the associated governor problem has been resolved.

- Generating unit start up times under various contingency conditions have been prepared and provided to the ECC (Energy Control Center).

<u>Station Services Review</u>

This review has now been completed. It has concluded that the existing station service and black start facilities at the Holyrood Generating Station are adequate. Facilities available at Holyrood were compared with similar plants in other utilities. It is further concluded that a second black start generating unit (in addition to the existing gas turbine) is not required.

At present, black start conditions can only be simulated when all three generating units at Holyrood are "off line". This limits the opportunities for black start simulation to practically once a year and for one unit only, which also reduces the opportunities for an operator training program. Based on these limitations, Hydro is evaluating the possiblity of modifying the station service from the Gas Turbine so that Unit 3 may be black started independent of Units 1 and 2 and vice versa.

Overall, it is concluded that the above mentioned new station services controls, implementation of new operating and maintenance procedures, breaker refurbishing and further operator training will reduce and hopefully eliminate the problems experienced at the Holyrood Generating Plant.

(8.4) System Performance & ECC

A review of governor performance and settings for the Hardwoods Gas Turbine and Holyrood Generating Units was initiated and has been completed. Following are the results of this review.

(a) Hardwoods Gas Turbine

The loading rate initially recommended by the manufacturer was once again discussed with the manufacturer and loading problems effecting the System were discussed. As a result, the manufacturer has agreed that the loading rates for both Hardwoods and Stephenville Gas Turbines may be increased to a maximum of 8 MW/min. Based on this, the loading rate for the Hardwoods Gas Turbine has been changed to 8 MW/min (both ends running) and testing and commissioning is in progress.

(b) Holyrood Generating Units

For the review of the governors for Holyrood Units, a computer model based on the field tests carried out by General Electric in 1978-79 was utilized. Performance of the Holyrood units under "Avalon isolated" system conditions was studied.

It is concluded that the existing governor settings for Holyrood units are adequate to operate in an "Avalon isolated" mode and a change in droop settings when operating under isolated conditions would not significantly affect the capability of picking up a greater block of load by the Holyrood units.

It is also hypothesized that the difficulties experienced in picking up a block of load (up to 20 MW) could have been caused by:

(i) unit load limits (which are controlled by operators); and/or

(ii) load blocks being actually larger than 30 MW due to cold load pick up conditions

It is further concluded that when operating the Holyrood units in an isolated mode, all operating units must be loaded equally. With units base loaded at approximately 100 MW, there should not be any difficulty in picking up a load block of up to 25 MW.

In addition it is recognized that after a load block has been picked up, a minimum time of ten (10) minutes is required to permit the recovery of boiler steam capacity before any additional load pick up is attempted. This will require co-ordination between Holyrood, ECC and Newfoundland Power Control Center personnel. It is planned to have meetings with these personnel for their information and future co-ordination.

East Coast Voltage Study

This study was initiated in October 1994. The scope of the study was to review the eastern transmission system load transfer capabilities under various system contingency conditions, i.e. one line out of service or Holyrood units out of service, etc. The study also determined the level of load transfer that is possible under these conditions.

This study has been completed and it is concluded that a load level on the Avalon of 365 MW could be met when all Holyrood units are out of service. To meet this load, additional voltage support in terms of static capacitors (approximately 60 MVARS total) would be required at Oxen Pond and Hardwoods Terminal Stations. In addition, under certain contingency conditions, some transmission line reconductoring may be required. The recommendations of this study are under review and may result in a future capital budget proposal.

Aeolian Vibration

This is a vibration which can occur on transmission lines during light winds (between 2 to 15 miles per hour). These vibrations can cause premature wear in conductors and hardware. Presently all lines on the Avalon are equipped with anti-vibration dampers, however some of these are close to the end of their useful life. It was recognized some years ago that work had to be done on improving the performance of these dampers and to this end Hydro carried out studies to evaluate this vibration on several of its lines. TL217 (Western Avalon to Holyrood) was studied and it was determined that the dampers required replacement. New dampers have been purchased and approximately 50% of these have been installed with the remaining being installed during this upcoming winter.

During the past year TL237 (Come by Chance to Western Avalon) was studied and this information is now being analyzed in preparation of ordering new dampers. This work will be done under the 1996 capital plan.

It is anticipated that over the next 5 to 7 years, all 230 KV transmission lines on the Avalon Peninsula will have been fitted with new dampers.

<u>Insulator Contamination</u>

Hydro has completed its review of possible alternatives for lessening the effects of salt contamination on its terminal station equipment.

The investigation explored three sources of information.

- A market search for new products that may now be available
- Contacts with other utilities who have experienced contamination problems, and
- Hydro's own experience

The review determined that the available options in dealing with contamination on insulators include: silicon greasing; cleaning (routine, continuous or prior to storms); delay or if possible, complete switching operations at another location; and a new compound called RTV silicone coating.

The most promising of these is the RTV silicone coating which is a rubber based compound which hardens into a rubber coating. This material is very resistant to contamination and water build up, has a long life and is able to be cleaned. If recoating is necessary, this can be done without removal of the old coating.

The review determined that there is no singular solution, however it is expected that with a combination of the above items, contamination could be reduced. Suggestions from the investigation are:

1. Complete a yearly washing of breakers which are in areas of known contamination.

2. During storms, if possible, inspect for contamination and if present evaluate the risk of switching. If there is a high risk, then evaluate if the switching can be delayed or done at another location of lesser or no contamination.

3. Conduct a test program on the new coating compound RTV silicone coating. While other utilities have used this compound and have had good success with other contaminants (dust, road salt, etc.), there is still a concern that this compound may not be suitable for our application. Therefore a test will be conducted by installing the coating on one of our breakers at the Holyrood terminal station during the summer of 1996. If the results of this test are positive, then the use of this compound will be expanded in a staged manner to other areas of concern on the Hydro system.

NP (refer to NP report "Blackout '94 Storm Report", Section 16)

(16.1) Cold Load Pick-up

To promote better public awareness of Cold Load Pick-up implications a bill insert was prepared and distributed to all customers in September and December 1995.

(16.2) Tree Trimming

To promote better public awareness of Tree Trimming necessity and requirements, a bill insert was prepared and distributed to all customers in September, 1995.

(16.3) Engineering Changes

(1) Sectionalizing switches were inserted on the long sections of line away from the road on two feeders from Northwest Brook substation and on one from Sunnyside substation. The existing sectionalizing switches were relocated to make them more accessible.

This work was completed in November, 1995.

(2) A section of line (7 poles) in Salvage on the Eastport Peninsula has been rerouted to bring it closer to the road.

(3) The distribution line crossing at South West Arm in Terra Nova National Park was completed in December 1995.

(16.5) Fuel

Ultramar have provided an island wide listing of service stations with backup generation and have given permission to NP to temporarily install portable generators at any of their outlets which do not have generation.

4. ***"Problems experienced with batteries, gas turbines and supplemental diesel systems, as they relate to "black starts" and station service."***

Previously addressed.

5. ***"A study of current breaker performance and maintenance. (Does the age of equipment play a significant role?"***

Previously addressed.

6. ***"In reviewing governor performance it is important to ensure that protective relay settings are well coordinated. How can you ensure that whenever there is a bus fault at Holyrood the whole system will not be placed in jeopardy? The Board is requesting that you pay special attention to the design of the switching station as well a to its maintenance and treatment during severe storm conditions."***

Previously addressed.

7. ***"What criteria are used to determine the amount of back-up capacity required for both system reliability and voltage support? We learned at the meeting that the South Side Plant has effectively been decommissioned. On the basis that this plant is no longer used and useful, what are your plans to replace that capacity, from the standpoint of system reliability and voltage support?"***

Hydro has not changed its position which was outlined to the PUB on May 30, 1995 regarding the necessity to add new capacity, from the standpoint of system reliability and voltage support, due to the mothballing/decommissioning of Newfoundland Power's Southside steam plant.

Based on Hydro's most recent load forecast and assuming that 38 MW will be purchased from NUGs in late 1998, Hydro does not foresee a requirement for new energy or capacity until at least 2003 and 2007 respectively.

New generation additions must be based on least cost planning with consideration given to reliability of the overall system. If at the time the requirement for a new generation source is identified and the preferred alternative is hydro-electric, then it would obviously be located at the site of the resource. If however the preferred alternative is thermal based, such as a combustion turbine, then there may be some flexibility in selecting a location where the supply to a region may be enhanced. This will be a consideration at the time a decision is required to meet the deficits in 2003 and 2007.

8. ***"Any other problems and proposed solutions that may be identified, and for which remedial action could play a significant role in dealing with the results of any future storm."***

Nothing further to report.

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November 18, 2013

Ms. Cheryl Blundon, Director
Corporate Services and Board Secretary
Newfoundland and Labrador
Board of Commissioners of Public Utilities
120 Torbay Road
P. O. Box 12040
St. John's, NL A1A 5B2

Dear Ms. Blundon:

Re: Holyrood Black Start Capability

This is in response to your letter from the Board of October 17, 2013 requesting Hydro address two issues regarding black start at the Holyrood Thermal Generating Station (HTGS).

The first request regarding options to provide full black start capability was as follows:

The Board will therefore require Hydro to take immediate action to ensure all possible options have been considered to provide reliable Holyrood black start capability. The Board notes that Hydro failed to answer the Board's July 23, 2013 request to provide a cost benefit analysis as to alternatives in relation to Holyrood black start, including the procurement of an onsite gas turbine for black start at Holyrood. Hydro should make the necessary inquiries on an urgent basis and report back to the Board immediately as to the available alternatives. To be clear Hydro is required to inquire, investigate, analyze and report within 30 days as to whether an appropriately sized gas turbine is available to be purchased or leased and installed for Holyrood black start. Hydro should also advise as to the timeframes and costs associated with refurbishing the existing Holyrood gas turbine.

The second request was regarding communications with the Board as follows:

The Board requires Hydro to undertake a review to determine what caused the failure in communication and then report to the Board as to the steps that have been taken to ensure better regulatory reporting in the future.

Hydro addresses each of these requests below.

1.0 Black Start Alternatives

In response to this request please see the attached report summarizing the availability and the options for providing on site black start capability at the HTGS.

1.1 Availability of a Gas Turbine Option

The report identifies two feasible gas turbine options. The least cost gas turbine option is a three unit 16.7 MW solution. It is estimated to cost $12.8 Million with a scheduled completion of approximately 12 to 13 weeks upon project approval. The other solution is a single unit 22.5 MW plant at a cost estimate of $22.4 Million with a 17 to 18 week schedule upon project approval.

1.2 Least Cost Near Term Black Start Option

The report identified a nominal 16 MW mobile diesel plant as being the least cost technical solution to provide full black start capability in the near term:

> The 16MW mobile diesel plant would be leased for a period of 18 months to provide black start capability to the Holyrood Thermal Plant for the 2013 – 2015 period. Current estimates suggest that it can be installed within 11 weeks of Board and internal Hydro approval.

This solution has a capital cost of $8.2 M.

Project Cost: *($ x1,000)*	**2014**	**2015**	**Beyond**	**Total**
Material Supply	175.0	0.0	0.0	175.0
Labour	381.0	228.0	0.0	609.0
Consultant	0.0	0.0	0.0	0.0
Contract Work	625.0	0.0	0.0	625.0
Other Direct Costs	3,330.0	1,344.0	0.0	4,674.0
Interest and Escalation	330.1	646.0	0.0	
Contingency	0.0	1,216.6	0.0	1,216.6
TOTAL	**4,841.1**	**3,434.6**	**0.0**	**8,275.7**

Ms. Cheryl Blundon
Director of Corporate Services and Board Secretary
November 18, 2013
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1.3 Timeframe and Cost of Refurbishing the Existing Gas Turbine

The existing Holyrood CT cannot be refurbished prior to the upcoming winter period. However, it can be ready for the 2014/2015 period. It would require a temporary generation option for this upcoming winter period. This increases the cost of this option. The following is the capital cost estimate:

Project Cost: *($ x1,000)*		2014	Beyond	Total
Material Supply	0.0	1,256.0	0.0	1,631.0
Labour	0.0	2,696.0	0.0	3,551.0
Consultant	0.0	156.0	0.0	195.0
Contract Work	0.0	225.0	0.0	225.0
Other Direct Costs	0.0	2,160.0	0.0	2,160.0
Interest and Escalation	0.0	461.7	0.0	669.8
Contingency	0.0	0.0	0.0	1,071.2
TOTAL	**0.0**	**6,954.7**	**0.0**	**9,503.0**

1.4 Use of the Newfoundland Power Mobile Generation

As mentioned in the letter from the Board, during the winter of 2013 following the January 11 disturbance, Hydro made arrangements with Newfoundland Power to move their mobile gas turbine and a mobile diesel unit to Holyrood. Hydro established an electrical infrastructure in the station to connect mobile generation to the plant. It was hoped that the Newfoundland Power mobile generation would provide black start functionality. However, as noted in the attached report, the units were unable to start a boiler feed pump motor. The units did, however, provide the security of alternative generation that can provide significant benefit to the plant in a situation where supply from the grid is unavailable. In particular all station auxiliary loads other than the boiler feed pump motor can be started. This provides the benefit of keeping equipment warm and operating to enable a quicker plant restart once the supply from other remote generation is available. They were also available for grid support in the event of a generation contingency.

The Newfoundland Power mobile units were removed from Holyrood in late May as Newfoundland Power required them to perform their annual maintenance program. Hydro had intended to request Newfoundland Power to relocate this mobile generation to Holyrood for each winter season until the new 60 MW CT is placed in service. This had not been mentioned to Newfoundland Power until a recent meeting between the companies. Newfoundland Power asked for a formal Hydro request and also expressed a concern that the units be able to be quickly disconnected for deployment in an emergency. Hydro has since formally requested Newfoundland Power to relocate the Mobile Gas Turbine (MGT) to Holyrood and committed to work with Newfoundland Power to put procedures in place to allow for quick removal to address sustained localized transmission reliability issues. Hydro requested only the MGT as it is sufficient to meet all required station requirements during a grid supply interruption. Hydro indicated to Newfoundland Power in its request, that it was assessing options for full black start capability and therefore the relocation need be only temporary.

2.0 Communications Failure and Steps for Better Regulatory Reporting

The review and the proposed steps to be taken with respect to the communications breakdown are provided below.

2.1 Regulatory Reporting of the Holyrood Gas Turbine Station

Hydro regularly reports to the Board through a number of mechanisms established by the Board for its oversight of Hydro. All of these mechanisms are reasonably adhered to with respect to content and timing. Most of this reporting is of a routine nature such as quarterly reporting, annual reporting and specific reporting related to applications presented to the Board. Reporting of a non-routine nature is made with respect to incidents related to power system equipment affecting reliability or safety.

The reporting of plant conditions and capability has been generally addressed in the context of capital budget applications to the Board for equipment upgrades, refurbishments or replacements. There has been no mechanism established which clearly identifies the requirements to report to the Board of changes in equipment status or capability. It was in this context that Hydro did not report the change in status of the Holyrood Gas Turbine in January 2012.

2.2 Background of Status of the Holyrood Gas Turbine

The Holyrood Gas Turbine was established in the Holyrood Generating Station to provide emergency standby power to the plant for black starting the plant in the event the grid supply was interrupted. The gas turbine is intended to enable the starting of all systems within the plant to enable a large steam generating unit at the plant to be placed on line to restore service to customers through available transmission lines connecting the plant to load centres. If the transmission lines are unavailable, the gas turbine enables plant systems to be placed in a warm stand-by state which facilitates a faster customer load restoration when the transmission connection is established.

The gas turbine has been very rarely required to perform the black start function. However, it has been maintained and routinely operated to ensure availability. It has also been function tested in simulated black start scenarios when the entire Holyrood plant has been shut down for maintenance.

Due to the age of the gas turbine, Hydro undertook and proposed to the Board as part of the 2011 capital program, a major overhaul work project on the gas turbine to be completed in 2011. Subsequent to proposing this work, an inspection of the unit resulted in a stop work order being placed on the unit by the Department of Government Services, Occupational Health and Safety Inspection Branch (OHS). This resulted in Hydro withdrawing the overhaul proposal and assessing other options. These options included acquiring a replacement facility.

As a result of the withdrawal of the overhaul proposal in the capital program, Hydro informed the Board of this condition and that it was working on solutions. At the time, the Board expressed its concern with the lack of black start capability. In order to expeditiously resolve the situation, Hydro addressed the problem by determining new generation options and also addressing the OHS stop work order concerns. The least cost option was to address the OHS concerns while assessing longer term solutions for the plant. As a result, in February, 2011, the stop work order was removed and the gas turbine was made available with restricted use. The restriction imposed was primarily that it be used only in emergency conditions to black start the plant. This situation was communicated to the Board at that time.

2.3 Actions resulting in unavailability of the Holyrood Gas Turbine

During 2011, Hydro engaged AMEC Consulting to do a condition assessment of the gas turbine plant to assist Hydro in determining the long-term solution for black start of the Holyrood plant. This report was received by Hydro on December 19, 2011; a subsequent meeting with AMEC was held on January 17, 2012, to discuss and better understand the details in the report. This report revealed that there was risk of significant catastrophic failure of the gas turbine if it was operated and AMEC recommended discontinuing for any purpose. As a result, Hydro decided the unit would no longer be available for black start capability. This condition resulted in discussion within Hydro on options to provide the black start capability. Part of this consideration was that Hydro was preparing an estimate for the new gas turbine to be installed in 2015 on the Avalon Peninsula. The site for this had not been determined at this time but one option was the Holyrood site. A decision was made by Hydro in January 2012 that the Hardwoods gas turbine would be used to black start Holyrood under the circumstance that the transmission supply to the Avalon Peninsula was interrupted. This was Hydro's established plan for the unavailability of the gas turbine. This was considered a short term measure until a new black start unit was established. It was also decided that the options for the black start requirement of Holyrood would be assessed in the context of the site location decision for the new 50 MW combustion turbine. The decisions and considerations that occurred in January 2012 were not communicated to the Board as there were no pending applications before the Board.

There was no intention for Hydro not to communicate the decision to discontinue black start operation using the Holyrood gas turbine and the short-term measure of using Hardwoods. It was more related to the fact that normal reporting of these circumstances is communicated in the context of capital project submissions. It was Hydro's intention to report this circumstance as part of an application to the Board for the proposed replacement black start facility.

During 2012, Hydro assessed the option for location of the new 50 MW combustion turbine and concluded that the least cost option was to locate the combustion turbine in Holyrood. This decision involved a number of factors, one of which was the unit would be able to provide black start capability to Holyrood. This decision and recommendation will be included in Hydro's application for the new combustion turbine to be filed later in 2013.

2.4 Future Reporting Recommendation

As a result of the concerns raised by the Board in their letter of October 2013, Hydro proposes that in future, Hydro will report within forty-eight (48) hours, as part of its incident reporting system, any changes to plant generating capacity as a result of condition assessments or equipment failure that will require capital investment or an extended time to correct.

Included in these reports will be the corrective measures being undertaken by Hydro to mitigate the capacity deficiency to minimize the impact on the reliable supply to customers during the period the long-term solution is put in place.

3.0 Summary

In summary, Hydro shares the Board's concern for the safe and reliable supply of electricity to consumers. The contingency plan Hydro implemented using the Hardwoods gas turbine proved to be inadequate in the circumstances experienced on January 11, 2013. In response to that, Hydro took steps to move the Newfoundland Power mobile generation to Holyrood. Hydro established a safe and reliable connection in Holyrood to connect this mobile generation. This solution has proven to be unable to provide full black start as it cannot start the large boiler feed pump motors. However, it does provide some substantial station service benefits that will provide both safety and reliability benefits. The recommended long term black start option is use of the new 60 MW CT at Holyrood. In the interim there are leasing options to establish full black start capability during the upcoming winter with the least cost estimated to cost $8.2 Million.

Hydro recognizes that communications with regard to black start at Holyrood and the loss in capability have not met the Board's expectations. Hydro is committed to improving communications with the Board and has proposed a solution to deal with the specific issue of significant changes in system equipment capability. However, Hydro would also welcome an opportunity to meet with Board staff to discuss other areas of concern to ensure a full understanding of the Board's expectations with regard to communications on Hydro's activities and that these are met.

Sincerely,

R. J. Henderson
Vice-President
Newfoundland and Labrador Hydro

RH:bt

.cc Mr. Geoff Young, Senior Legal Counsel
Ms. Jill Chisamore, Regulatory Coordinator

Analysis of Options to Provide Black Start Capability to Holyrood Thermal Generating Station

Nov 18, 2013

Executive Summary

The Holyrood Thermal Generating Station is required to have black start capability in the event of a loss of grid power. In light of the unavailability of the existing Holyrood Gas Turbine and concerns with the use of the Hardwoods Gas Turbine as a reliable short term alternative, the Public Utilities Board (PUB) has recently asked that Hydro consider options to provide black start capability to the Holyrood plant for the 2013 – 2014 heating season and beyond.

Hydro has performed a technical analysis of the options that could provide black start capability to the Holyrood plant. This analysis modeled several different generator solutions interconnected to the Holyrood plant. By modeling a black start event, Hydro was able to predict the ability of a particular generation solution to start the thermal plant and in particular the large boiler feed pump motors.

Additionally, Hydro has worked with generator suppliers to source units that could be delivered to the Holyrood plant on very short notice, in order to meet the needs of the 2013-2014 heating season. There are several technically viable options, however it is worth noting that recent infrastructure devastation in the Philippines has greatly increased the demand for mobile generation units. This may change the availability of the generators modeled in this study.

This project will require an exemption from the Department of Environmental Affairs so as to meet the project schedule. The current legislation process would effectively cause this solution to miss much, if not all, of the 2013 – 2014 heating season. While approval of an exemption is outside of the control of Hydro, Hydro is cautiously optimistic that such an exemption can be received.

Hydro has identified the least cost option is a 16MW Diesel Plant leased for a period of 18 months to provide black start capability to the Holyrood Thermal Generating Station for 2013 – 2015 heating seasons. Current estimates suggest that it can be installed within 11 weeks of PUB and internal Hydro approval.

Contents

1 Introduction

The Holyrood Thermal Generating Station is required to have black start capability in the event of a loss of grid power. This capability had been provided by a 15MW Combustion Turbine (CT) located at the Holyrood facility. However, because of its age and technical issues with the unit, Hydro undertook a study in 2011 to determine if the existing CT should be refurbished, or replaced with another generation solution. That study recommended that the existing unit be replaced with a new combustion turbine. Hydro has been advancing that option through the preparation of a capital project application to the Public Utilities Board (PUB) for the approval of a 60 MW CT in Holyrood for in-service in late 2015. In the interim due to the condition of the existing Holyrood CT and significant safety risks with its operation, Hydro decided to disable its use and put in place an interim black start plan utilizing the Hardwoods Gas Turbine and the multiple transmission paths between it and Holyrood.

The PUB has recently asked that Hydro reconsider options to provide black start capability to the Holyrood plant due to reliability risks associated with Hydro's interim black start solution using the Hardwoods Gas Turbine. Part of that analysis must include the option of refurbishing the existing Combustion Turbine.

This report will review the results of the 2011 Condition Assessment of the Holyrood Gas Turbine, and carry them forward to 2013. It will also consider several alternatives involving leasing or purchasing generators.

2 Operational Requirements

The operational requirements for the Holyrood black start unit are listed below:

- Hydro is required to maintain an operational ability to restart the Holyrood thermal generating unit in the case of a loss of grid power. This ability must be available throughout the year when Holyrood is operating. This is most significantly in the fall through spring period (the "heating season").
- This ability must be maintained during any refurbishment or replacement of the existing black start system. This particular criterion impacts any refurbishment of the existing Holyrood Gas Turbine, as that project must bear the cost of providing standby generation during the refurbishment period.
- Black start capability must be capable of starting any of the three thermal units located at the plant.
- The black start solution is desired to be located at the Holyrood facility where it is less dependent on transmission infrastructure that could be exposed to severe weather conditions.

3 Basis of Technical Analysis

An analysis of the Holyrood Thermal Generating Station has determined plant specific electrical criteria that the black start system must meet or surpass. These criteria are related to the specific start-up and trip characteristics of motors and other systems found in the plant, as well as previously established system planning criteria for the electrical system.

In general, a black start generator must supply motor starting currents to the largest motor in the system, while maintaining other electrical parameters within normal system specifications. As a result, the most critical aspect of any proposed generator solution is its short circuit current rating, rather than the overall power rating of the unit. Furthermore, the available short circuit current from a generator will be reduced or diminished by any transformers which may be required to change or transform its output voltage to the rated voltage of the motor. As such, Hydro has developed models which consider both the generator and any transformers required for interconnection to the thermal plant.

The station service voltage must be maintained during motor start, as a severe voltage drop may cause other thermal plant equipment to cease operation during a critical motor starting event. The voltage must not drop below 81 percent during a motor start. However, given the fact that there is expected to be some discrepancy between the model predictions and the real world observations, any solution which only marginally meets this requirement must be studied in greater detail before final acceptance of the solution.

The largest motor to be started during black start is a boiler feed pump motor. There are six of these units, any one of which may need to be started during a black start event. Appendix A contains technical details for the largest boiler feed pump motor to be started.

The analysis in this study was completed using the Siemens Power Technologies Int. software package PSS®E version 32.0. It must be noted that there is expected to be some discrepancy between the predicted electrical behaviour and the real world system behaviour.

3.1 Planned Infrastructure for Holyrood Thermal Generating Station

Hydro will be requesting PUB approval for a 60MW Combustion Turbine to be installed in late 2015 at the Holyrood Thermal Generating Station. If approved, that gas turbine could provide black start capability to the station, and replace any temporary black start solution recommended in this analysis.

The timeline of the 60MW Combustion Turbine project suggests that a temporary black start generation solution would be needed until the end of the 2014 – 2015 heating season. However, because of potential risks in the 60MW project schedule, it is prudent to recommend a solution which would be available during the 2015 – 2016 heating season if required. All solutions evaluated in this report can be extended to the 2015 – 2016 heating season.

3.2 Existing Infrastructure at Holyrood Thermal Generating Station

The plant contains existing infrastructure which impacts this project and is detailed below.

3.2.1 Civil Infrastructure

As shown in Figure 1, there is one area which is suitable for a temporary black start generator solution. It consists of flat land across from the thermal plant. This area will be adjacent to the proposed 60MW combustion turbine for Holyrood, hence it is prudent to situate this project so as to allow for the construction of a 60MW plant at that location. In order to maximize the space available, and allow for future projects, this location will require some civil work.

Figure 1. Location of Generator Solution

3.3 Electrical Infrastructure

There is existing electrical infrastructure installed at Holyrood which can be used for this project. Some of the infrastructure is currently connected to the existing combustion turbine, and would ease any connection from a new combustion turbine to the plant. Other infrastructure has recently been installed to connect Newfoundland Power's Mobile Combustion turbine and diesel unit to potentially provide black start. This infrastructure serves as the bulk of the connections required to connect a mobile black start generating plant to Holyrood.

Hydro has estimated the cost and schedule impacts of connecting generation units to this existing infrastructure.

3.4 Mechanical Infrastructure

The Holyrood facility includes fuel tanks and piping currently used to supply the existing gas turbine as well as other generators in the Holyrood facility. This infrastructure could be modified to supply fuel to a proposed gas turbine. Because black start diesel solutions typically include onboard fuel tanks, the existing tank infrastructure would not be needed if a diesel generator is installed at the facility.

The cost of piping has been included in the estimates.

4 Basis of Financial Analysis

Each solution will be evaluated based on the capital cost for equipment or rental cost for the equipment.

5 Constraints

This project assumes that the project can be exempted from the typical environmental approval process required under current legislation for a diesel plant of this size. Under that assumption, it is expected that an exemption could be obtained, and relevant permits received within 60 days. This is an aggressive assumption.

It is assumed that Hydro staff will maintain and operate the generator solution, with technical assistance from the manufacturer as required.

Currently, Hydro has been asked to provide a black start solution for late Dec 2013. A black start solution must remain at Holyrood until the decommissioning of the plant which is scheduled after 2020. As indicated in section 3.1. Hydro will be requesting PUB approval for a 60MW CT to be installed at Holyrood in late 2015 or early 2016. That project would be expected to provide black start capability from 2016 until plant decommissioning.

6 Technical Options considered

Hydro has considered several technical options to provide black start capability to the Holyrood thermal plant. Each is described below:

- Refurbish Existing GT, and rent a generator for black start capability during the refurbishment.
- Lease a diesel generator solutions
  - Nominal 14MW Diesel Plant consisting of seven 1.825MW units at 480V with additional transformers installed.
  - Nominal 16MW Diesel Plant consisting of eight 2MW units operating at 480V with additional transformers installed.
- Lease a Combustion Turbine Solution
  - 15.9MW CT Plant consisting of three 5.3MW units operating at 13.8kV
  - 16.6MW CT Plant consisting of one 5.2MW and two 5.7MW Units operating at 13.8kV
  - Single 25MW CT Plant operating at 13.8kV
- Use the Newfoundland Power Mobile CT and diesel generator.

Another potential option would be to install Variable Frequency Drives (VFD) on the large boiler feed pump motors which could reduce the cost of black start generation. However it will require significantly more engineering to determine its feasibility. For the 2013 / 2014 heating period, Hydro would still be required to install diesel or CT generators to provide black start. During that time, Hydro could study the feasibility of installing VFD's on the large boiler feed pump motors.

If feasible, these units would reduce the cost of renting generators required for future heating seasons. A more detailed technical study of this option would have to be completed in order to estimate cost and schedule implications.

6.1 Analysis of Refurbishment of Existing 15 MW Holyrood CT

The Holyrood Thermal Generating station is required to have black start capability to start the plant in the event of a loss of grid power. This capability has been provided with a 15MW gas turbine (GT) located at the Holyrood facility. However, because of the age and condition of the unit, Hydro undertook a study in 2011 to determine if the existing GT should be refurbished, or replaced with another generation solution. The study recommended that the existing unit be replaced. Currently the existing combustion turbine has been left in a cold standby state with all combustible fluids removed.

Hydro has reviewed the results of the Condition Assessment of the Holyrood Gas Turbine, and carried them forward to 2013.

6.1.1 2013 Analysis of Gas Turbine Condition Assessment

In reconsidering the cost and schedule required to refurbish the existing gas turbine located at Holyrood, Hydro has considered the following sources of information:

- The 2011 “Gas Turbine Condition Assessment and Replacement Options Study”
- Schedule differences between the 2011 analysis and 2013 analysis.
- Updated costs to provide full black start capability to the plant during the refurbishment of the existing Gas Turbine.

6.1.2 Analysis of 2011 Gas Turbine Condition Assessment

This study estimated the cost to refurbish the existing gas turbine so that it could remain in service until 2020. Because a full teardown of the equipment was not authorized prior to estimating the needed repairs, the report invited suppliers to consider both the observed system failures as well as suspected repairs that would typically be required on a unit built in 1966. As a result, in 2011 suppliers estimated an appropriate scope of work which is expected to be valid today despite any further degradation of the unit during the past two years. Nevertheless, should this alternative be selected, Hydro will undertake a 4 month review of the CT to determine if further deterioration of the unit has occurred. Assuming a Jan 1, 2014 start date, the project will be complete March 4, 2015, or 428 days after project start.

6.1.3 Schedule differences between the 2011 analysis and 2013 analysis

In order to reduce cost, the 2011 analysis relied upon a novel method of supplying Black Start capability during the refurbishment of the Gas Turbine. Hydro proposed leasing replacement units for several of the generator subsystems that required lengthy repairs. Other original gas turbine systems could be repaired relatively quickly (4 months) and reassembled with the leased units. The resulting system could then operate and temporarily provide black start capability, at a marginal rental cost of approximately $173,000. Note however that there are significant technical and equipment supply challenges associated with this approach.

While this option would meet the schedule demands for the 2014 – 2015 heating season, it does not meet the schedule demands for the 2013 – 2014 season. As such, Hydro must consider a more expensive option of leasing a complete generation unit that could provide power during the 2013 – 2014 operating season. Providing a generation solution to provide black start capabilities to the plant during the 2013 – 2014 heating season will cost $1.7M.

Hence, as a result of the schedule impact, the capital cost to refurbish the Gas Turbine has increased from approximately $4.8M (2011 dollars) to $8.7M today.

6.1.4 Safety Risk

Because of the age and condition of the generator as outlined in the 2011 study, there is a risk that a significant catastrophic mechanical failure could put personnel in the vicinity of the unit at risk of severe injury. As a result, Hydro decided after receiving the final 2011 study to not operate the unit without refurbishment.

6.1.5 Cost and Schedule Risk

These repairs will be carried out on a machine manufactured in 1966, with the understanding that many replacement parts are obsolete and must be re-engineered or obtained from OEM suppliers. It is therefore prudent to assume that technical issues may require rework or re-engineering during the commissioning process. While the class 5 cost and schedule estimates incorporate appropriate contingencies, it is worthwhile noting that the age and obsolesce of the machine present the very real possibility of fully or over expending those contingencies.

6.1.6 Technical Analysis

Assuming that the equipment can be fully refurbished to a reliable state, it could provide black start capability to the plant.

6.1.7 Cost

As indicated, the expected cost to refurbish the existing Holyrood CT is $9.5M. This solution has considerable technical risk owing to the advanced age and current state of the unit.

Project Cost: *($ x1,000)*		**2014**	**Beyond**	**Total**
Material Supply	0.0	1,256.0	0.0	1,631.0
Labour	0.0	2,696.0	0.0	3,551.0
Consultant	0.0	156.0	0.0	195.0
Contract Work	0.0	225.0	0.0	225.0
Other Direct Costs	0.0	2,160.0	0.0	2,160.0
Interest and Escalation	0.0	461.7	0.0	669.8
Contingency	0.0	0.0	0.0	1,071.2
TOTAL	**0.0**	**6,954.7**	**0.0**	**9,503.0**

6.2 Nominal 14MW Diesel Plant

This project involves the following equipment:

- Installation of seven 1.825MW mobile diesel generators with a 480V operational voltage.
- Installation of transformers to convert the 480V diesel generator output to 4160V.

6.2.1 Technical Analysis

Hydro analyzed the generator solution to determine if it meets the technical requirements as indicated in Section 3. The analysis shown in Figure 2 indicates that the system voltage will fall below the 0.81pu (81% of nominal) voltage threshold requirement. Figure 3 indicates that the generator can supply the motor current, and it does not exceed the motor thermal limit shown in Appendix A.

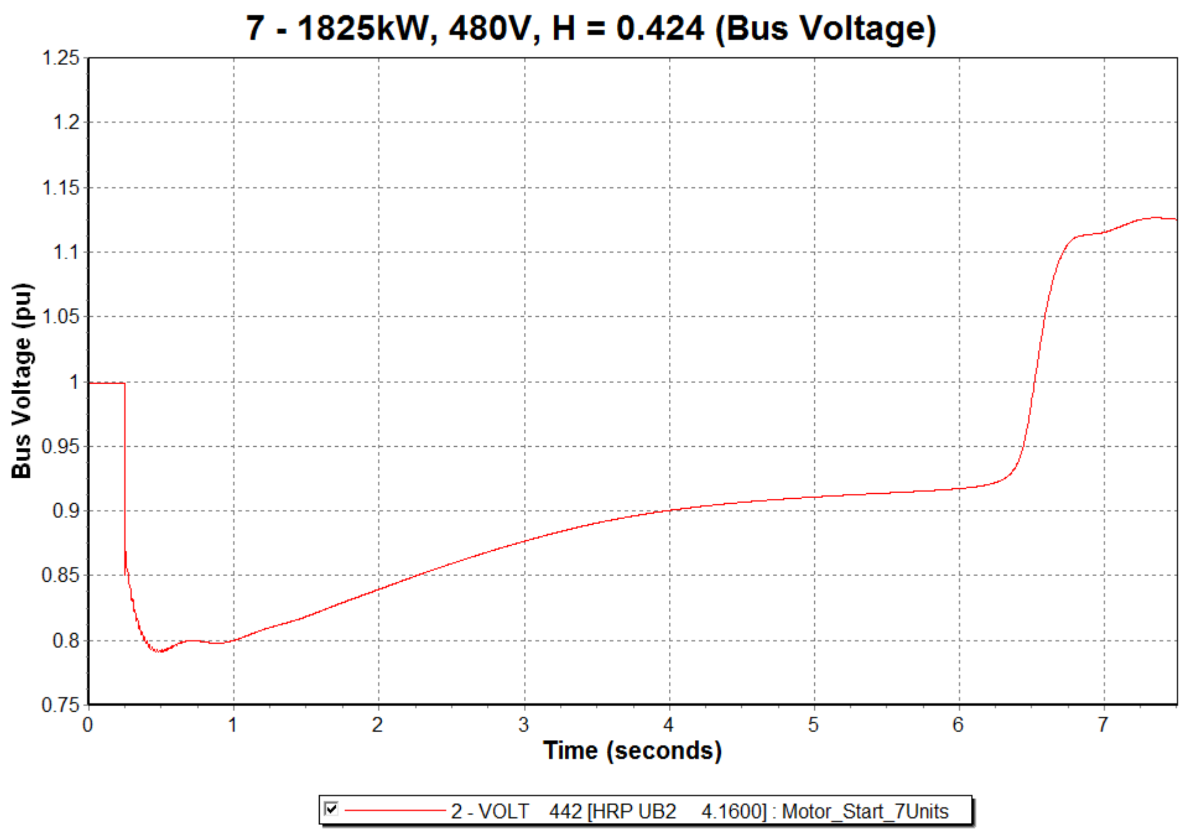

Figure 2. System Voltage Response of 7 - 1825kw Diesel Generators

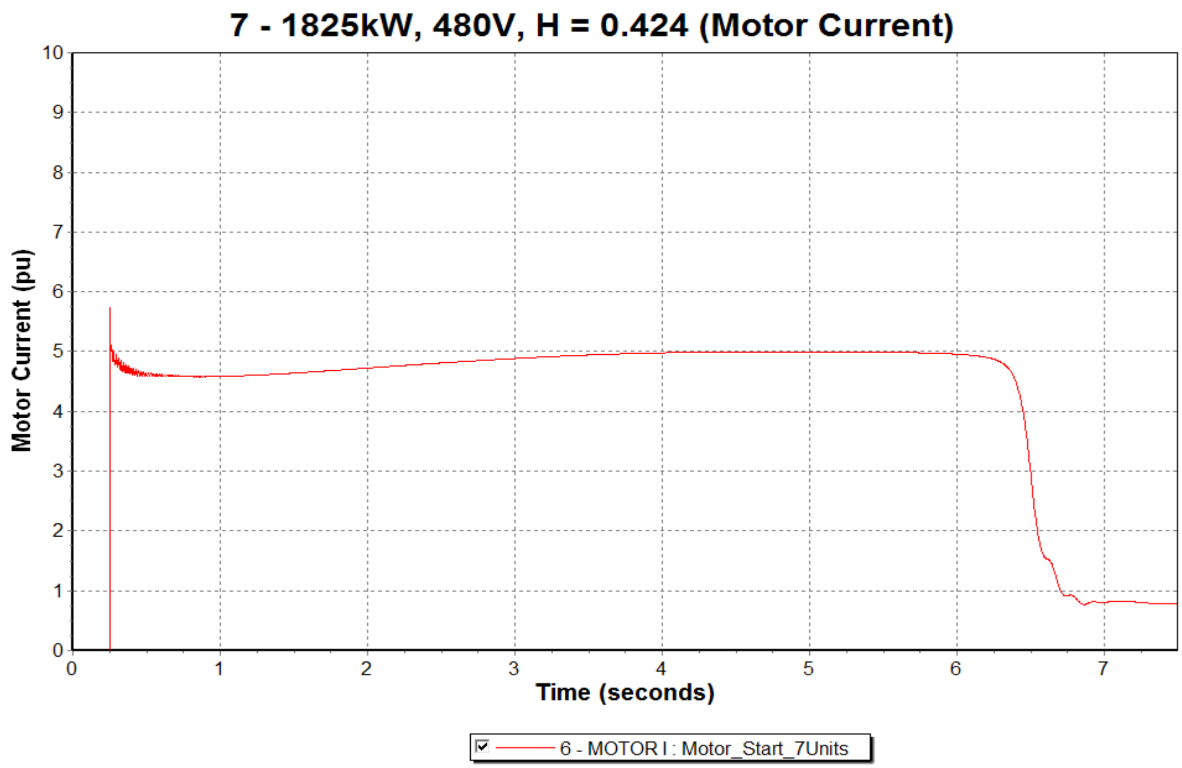

Figure 3. System Current Response on Motor Start

6.2.2 Conclusion

This option does not meet the technical requirements for black start and is rejected on that basis.

6.3 Nominal 16MW Diesel Plant

This project involves the following equipment:

- Installation of eight 1.825MW mobile diesel generators with a 480V operational voltage.
- Installation of transformers to convert the 480V diesel generator output to 4160V.

6.3.1 Technical analysis

Hydro has analyzed the generator solution to determine if it meets the technical requirements as indicated in section 3. The analysis shown in Figure 4 indicates that the system voltage does not fall below the 0.81pu voltage threshold requirement. Figure 5 indicates that the generator can supply the motor current, and it does not exceed the motor thermal limit shown in Appendix A.

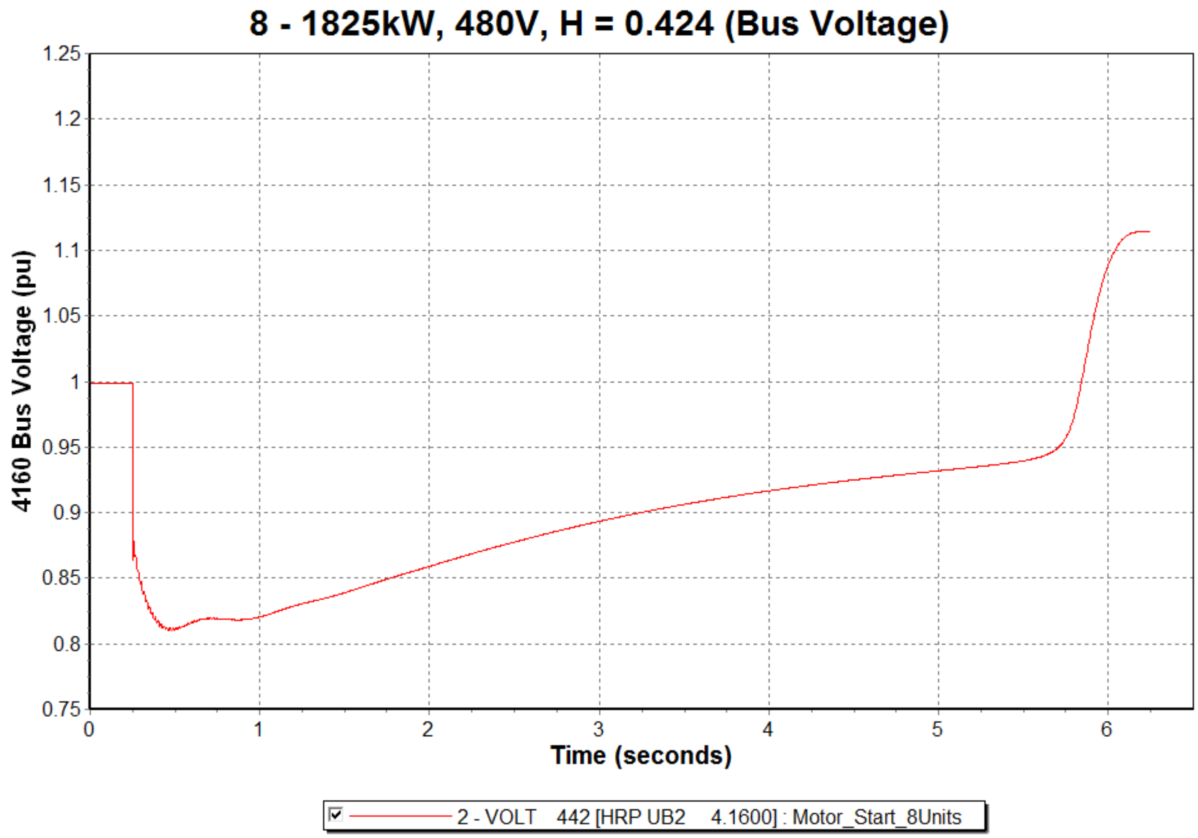

Figure 4. System Voltage Response of 8 - 1825kW Diesel Generators

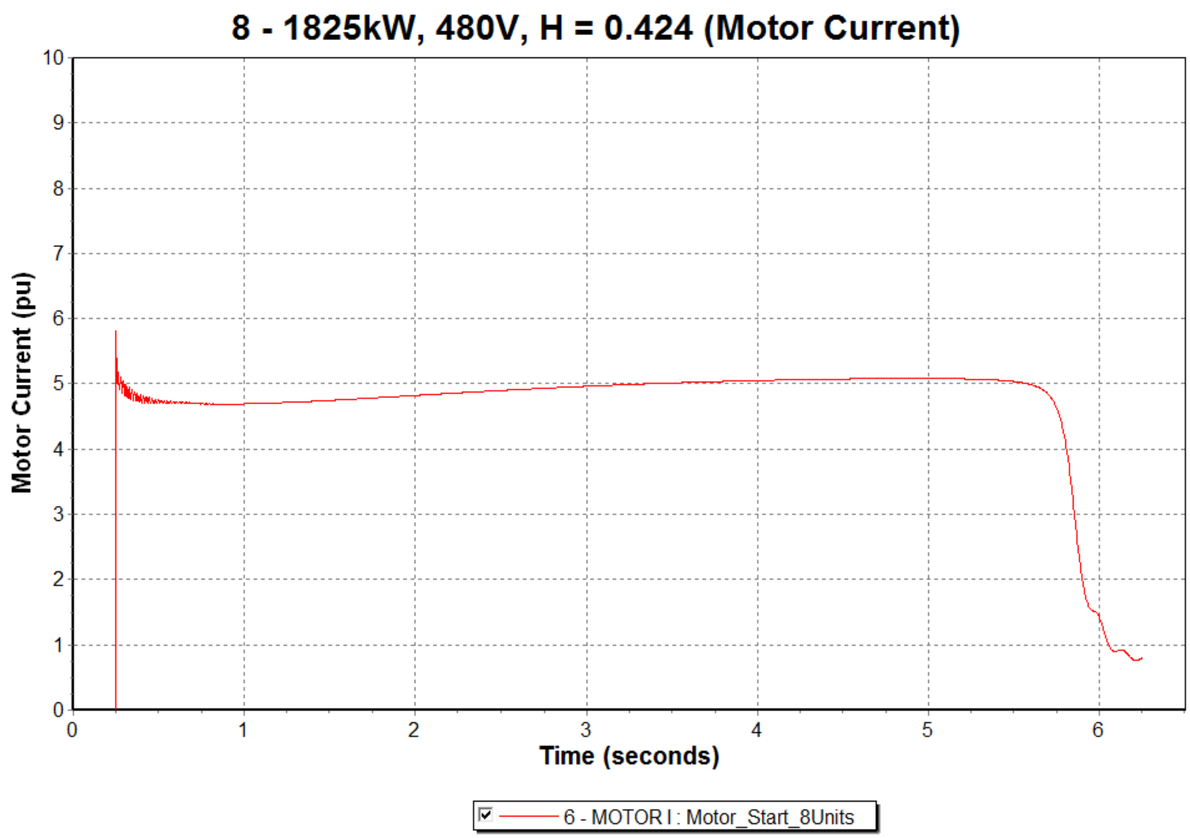

Figure 5. System Current Response on Motor Start

6.3.2 Schedule and Cost

This rental solution has a capital cost of $8.2M.

Project Cost: *($ x1,000)*	**2014**	**2015**	**Beyond**	**Total**
Material Supply	175.0	0.0	0.0	175.0
Labour	381.0	228.0	0.0	609.0
Consultant	0.0	0.0	0.0	0.0
Contract Work	625.0	0.0	0.0	625.0
Other Direct Costs	3,330.0	1,344.0	0.0	4,674.0
Interest and Escalation	330.1	646.0	0.0	
Contingency	0.0	1,216.6	0.0	1,216.6
TOTAL	**4,841.1**	**3,434.6**	**0.0**	**8,275.7**

This solution can be installed within 6 weeks of signing a purchase order with the supplier. Given the delays associated with the Hydro tendering process, the project will take an additional 4 -5 weeks to implement, once PUB approval is received and Hydro agrees to expedite a solution.

Note: Given the recent events in the Philippines, there is a worldwide demand for generation units to be shipped that country. This may affect the availability of this solution, and is outside the control of Hydro.

6.3.3 Conclusion

This option is a technically feasible solution for black start capability, with a favorable schedule.

6.4 15.9MW Combustion Turbine Plant

This project involves the following equipment:

- Installation of three 5.3MW combustion turbine generators with a 13.8kV operating voltage.
- Connection of the combustion turbine output to the existing 13.8kV – 4.160kV transformer (T9) located at the Holyrood facility.

6.4.1 Technical analysis

Hydro has analyzed the generator solution to determine if it meets the technical requirements as indicated in section 3. The analysis shown in Figure 6 indicates that the system voltage does fall below the 0.81pu voltage threshold requirement. Figure 7 indicates that the generator can supply the motor current, and it does not exceed the thermal limit shown in Appendix A.

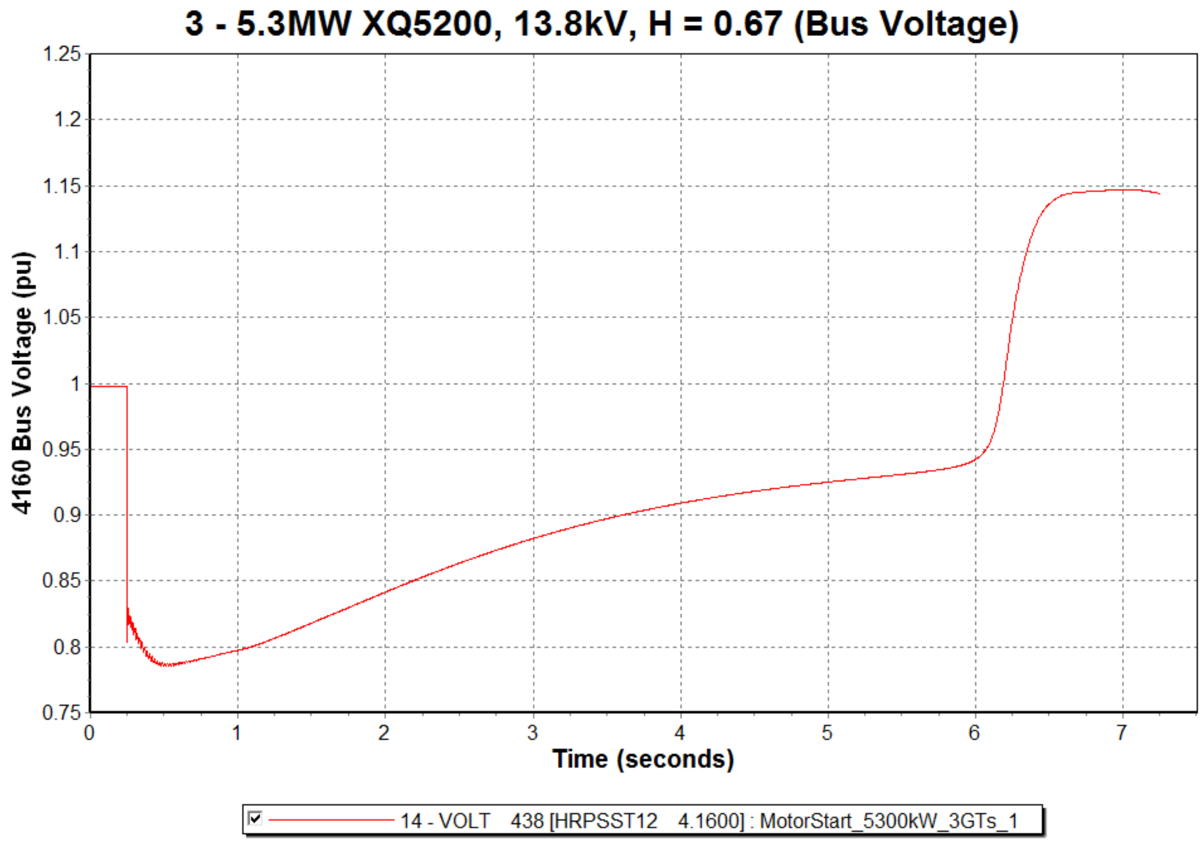

Figure 6. System Voltage Response of 3 - 5.3MW CT's during Blackstart

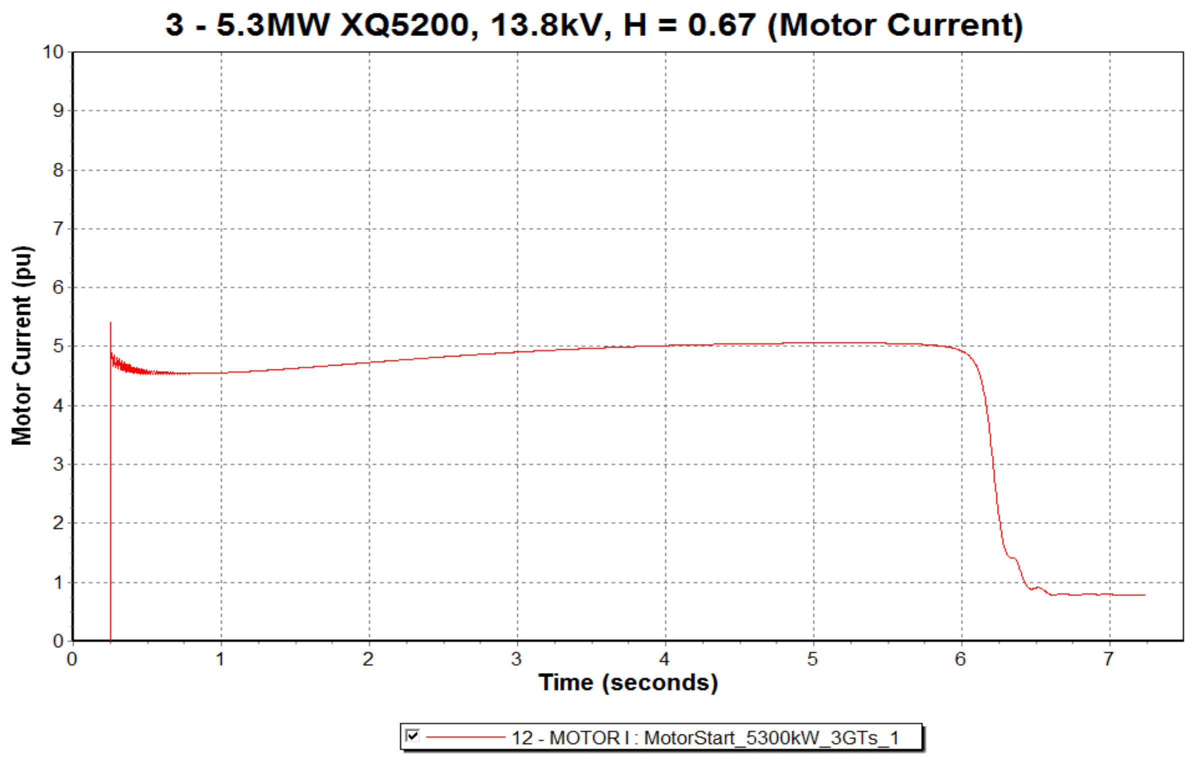

Figure 7. System Current Response during Blackstart

6.4.2 Schedule Availability

Currently these units are unavailable to meet the project schedule.

6.4.3 Conclusion

This option does not meet the system voltage requirements during motor startup. Additionally these units are not available on the market to meet the project schedule. As a result this option is rejected on that basis.

6.5 A 16.7MW Combustion Turbine

This project involves the following equipment:

- Installation of one 5.3MW mobile combustion turbine generator with a 13.8kV operating voltage.
- Installation of two 5.7MW mobile combustion turbine generators with a 13.8kV operating voltage.
- Connection of the combustion turbine output to the existing 13.8kV – 4.160kV transformer (T9) located at the Holyrood facility.

6.5.1 Technical analysis

Hydro has analyzed the generator solution to determine if it meets the technical requirements as indicated in Section 3. The analysis shown in Figure 8 indicates that the system voltage does not fall below the 0.81pu voltage threshold requirement. However, because the system voltage comes quite close to the threshold, verification of the Hydro model would be required from the manufacturer during the tendering process.

Figure 9 indicates that the generator can supply the motor current, and it does not exceed the motor thermal limit shown in Appendix A.

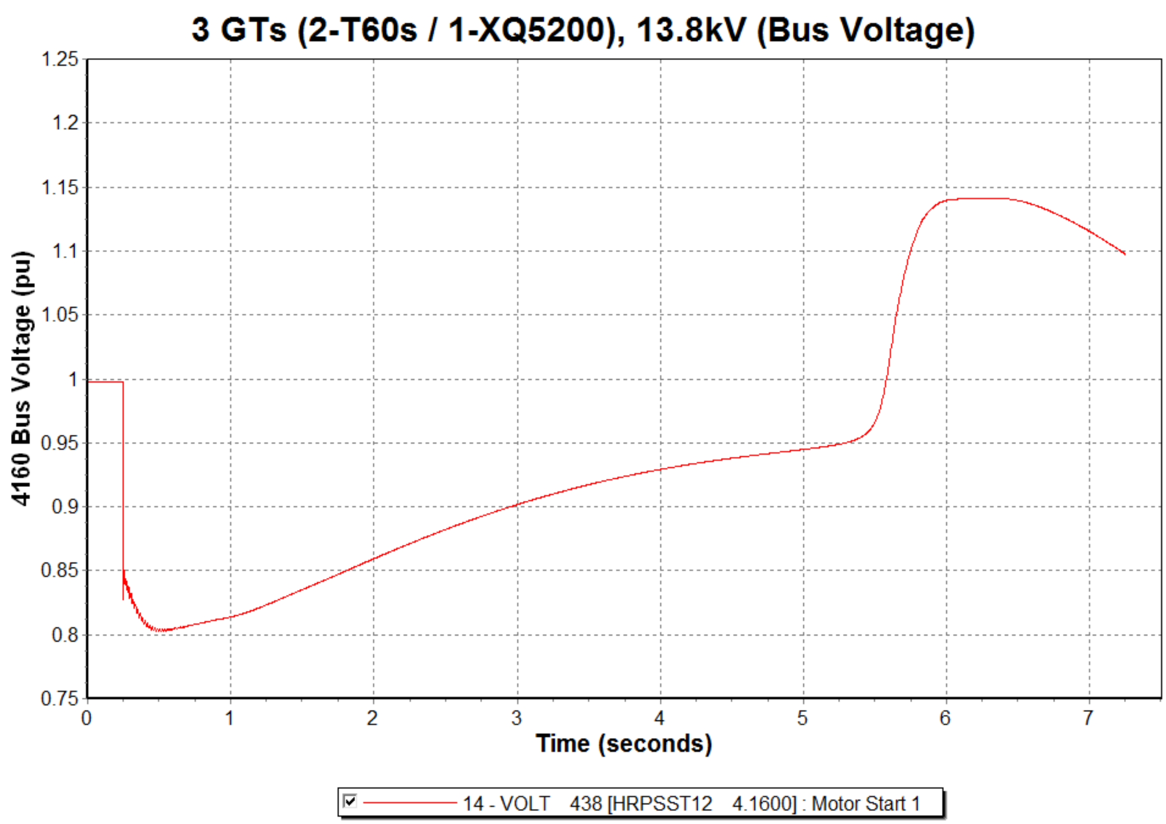

Figure 8. System Voltage Response of a 16.7MW CT plant on Blackstart

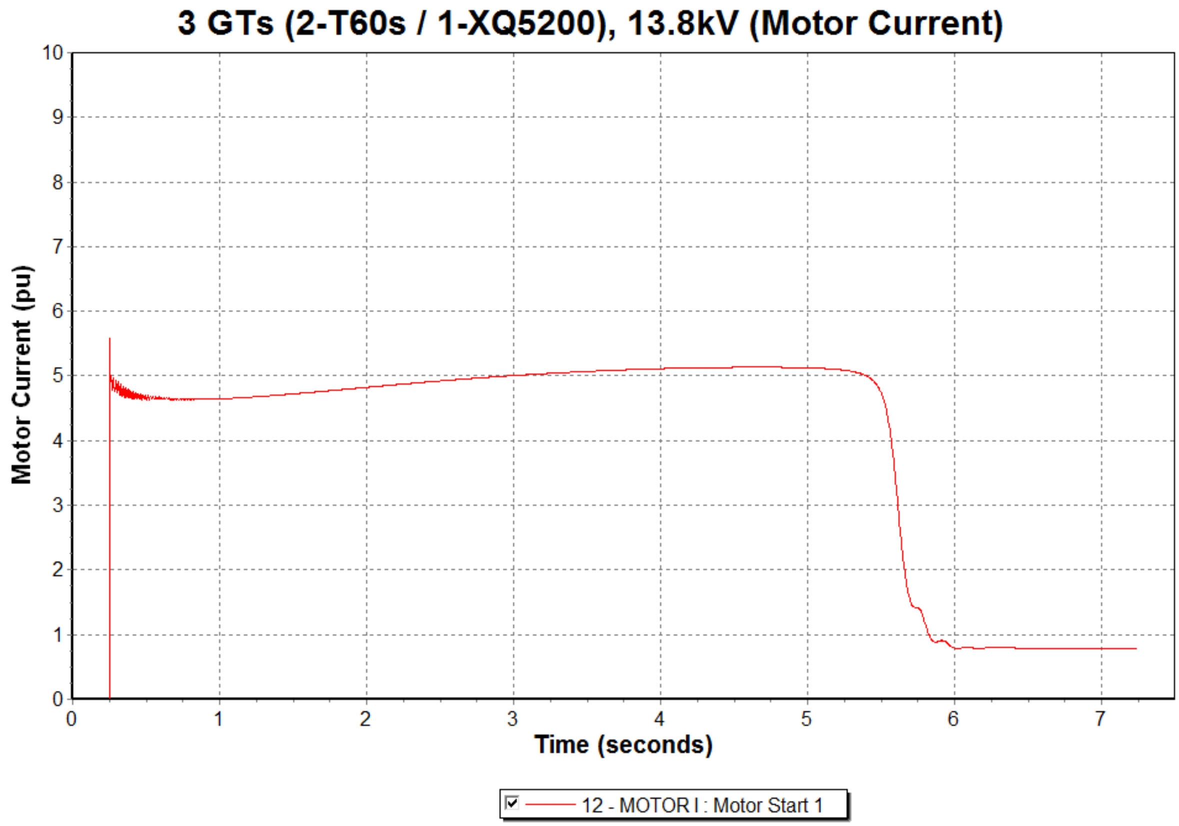

Figure 9. System Current Response of a 16.7MW CT Plant during Blackstart

6.5.2 Schedule and Cost

This solution has a project cost of $12.8M.

Project Cost: *($ x1,000)*	**2014**	**2015**	**Beyond**	**Total**
Material Supply	375.0	0.0	0.0	375.0
Labour	120.0	0.0	0.0	120.0
Consultant	0.0	0.0	0.0	0.0
Contract Work	500.0	0.0	0.0	500.0
Other Direct Costs	5,091.0	3,744.0	0.0	8,835.0
Interest and Escalation	444.4	1,015.4	0.0	1,459.8
Contingency	0.0	1,474.5	0.0	1,474.5
TOTAL	**6,530.4**	**6,233.9**	**0.0**	**12,764.3**

This solution can be installed within 8 weeks of signing a purchase order with the supplier. Given the delays associated with the Hydro tendering process, the project will take an additional 4 -5 weeks to implement.

Note: Given the recent events in the Philippines, there is a worldwide demand for generation units to be shipped that country. This may affect the availability of this solution and is outside the control of Hydro.

6.5.3 Conclusion

This solution can meet the project requirements.

7 Single 22.5MW CT Plant

This project involves the following equipment:

- Installation of one 22.5MW combustion turbine generator with a 13.8kV operational voltage.
- Connection of the combustion turbine output to the existing 13.8kV – 4.160kV transformer (T9) located at the Holyrood facility.

7.1 Technical Analysis

Hydro has analyzed the generator solution to determine if it meets the technical requirements as indicated in section 3. The analysis shown in Figure 10 indicates that the system voltage does not fall below the 0.81pu voltage threshold requirement. Figure 11 indicates that the generator can supply the motor current, and it does not exceed the thermal limit shown in Appendix A.

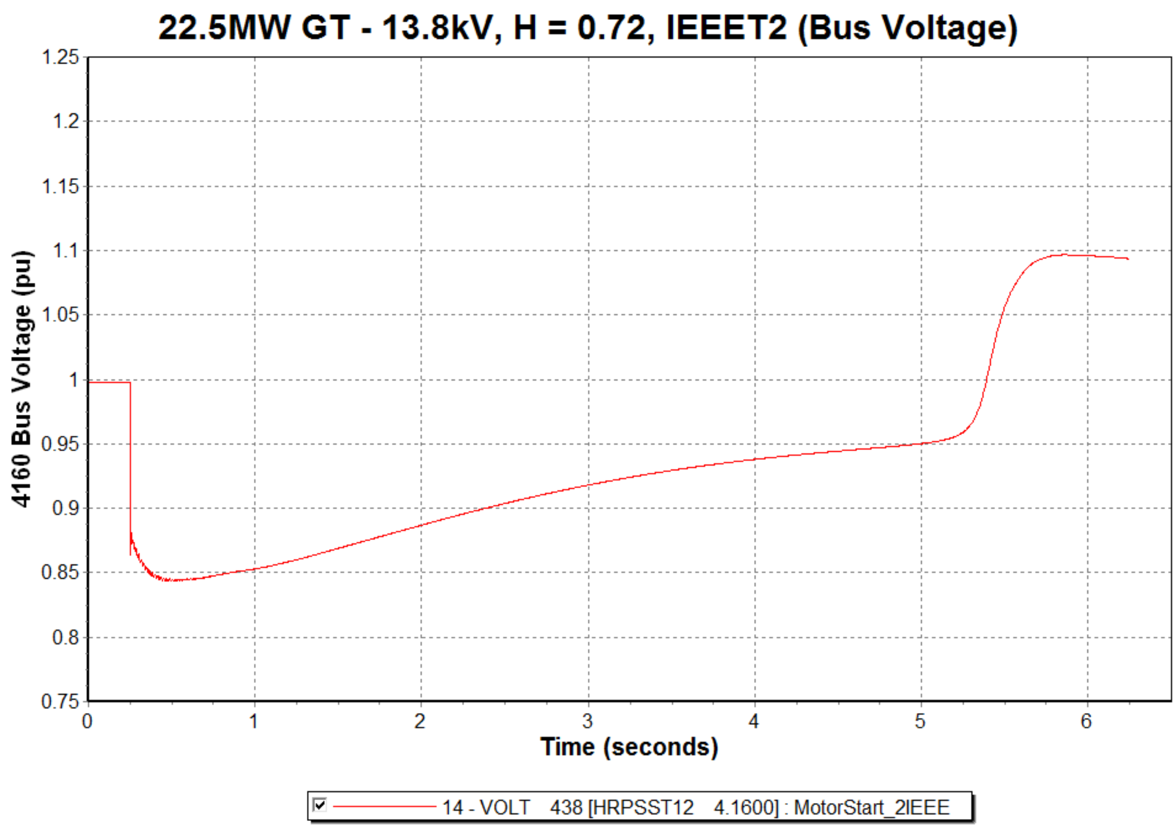

Figure 10. System Voltage Response of a 22.5MW CT during Blackstart

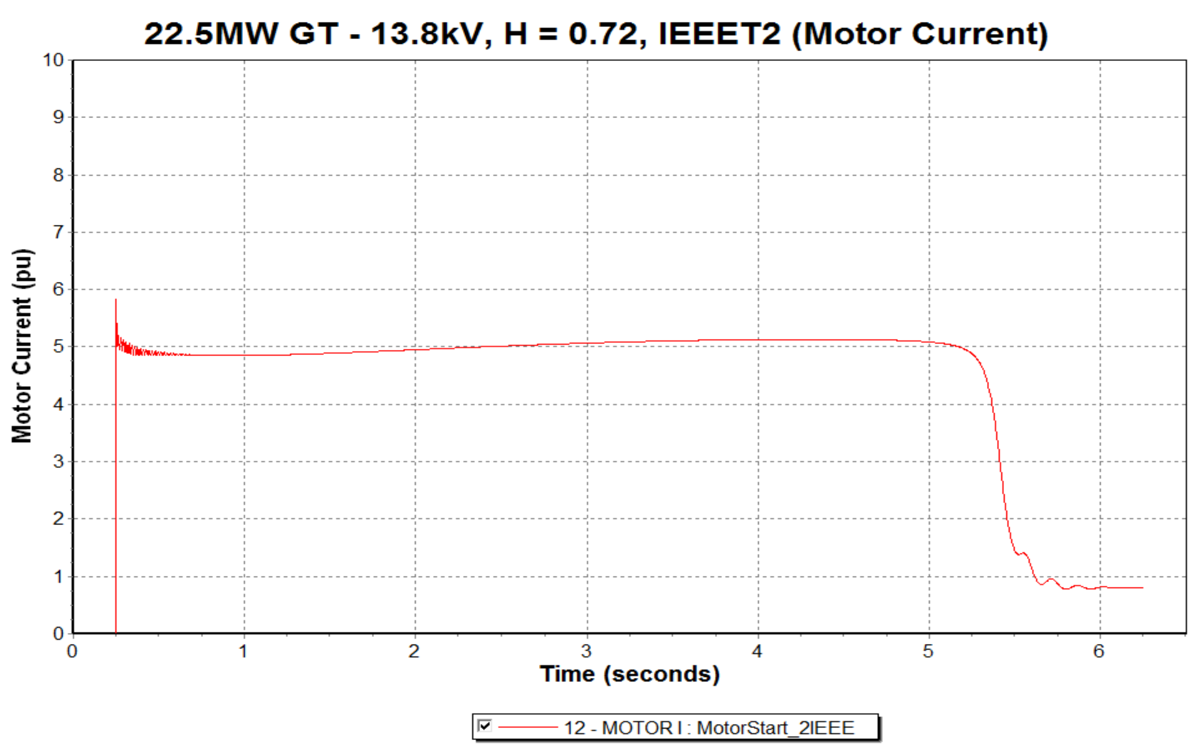

Figure 11. System Current Response of 22.5MW CT during Blackstart

7.2 Schedule and Cost

This generator is available 90 days after signing a contract, assuming imminent contact signing and current equipment availability. Given the delays associated with the Hydro tendering process, the project will take an additional 4 -5 weeks to implement.

Note: Given the recent events in the Philippines, there is a worldwide demand for generation units to be shipped that country. This may affect the availability of this solution and is outside the control of Hydro.

Although this solution could meet part of the 2013 – 2014 heating season, it would not provide black start for the full heating season.

This generator rental will cost $22M for a 16 month term.

Project Cost: *($ x1,000)*	**2014**	**2015**	**Beyond**	**Total**
Material Supply	175.0	0.0	0.0	175.0
Labour	120.0	0.0	0.0	120.0
Consultant	816.0	272.0	0.0	1,088.0
Contract Work	500.0	0.0	0.0	500.0
Other Direct Costs	10,944.0	3,648.0	0.0	14,592.0
Interest and Escalation	862.3	1,753.2	0.0	2,615.5
Contingency	0.0	3,295.0	0.0	3,295.0
TOTAL	**13,417.3**	**8,968.2**	**0.0**	**22,385.5**

7.3 NF Power Mobile CT and Diesel Generator

In March 2013, Hydro prepared a report “Analysis of Holyrood Unit 2 Boiler Feed Pump East Start-up using Newfoundland Power’s Gas Turbine/Mobile Diesel”. This report modeled the ability of the two Newfoundland Power generators to provide black start capability to the Holyrood Thermal Plant. The report concluded that while the units could theoretically start the plant, there was a significant voltage drop on the 4160V bus, as well as increased motor starting time. The areas of concern were:

- Under voltage relay settings on the 4610V or 600V system within the plant that could cause equipment tripping as a result of the depressed voltages during motor starting[1].
- The NP Mobile Gas Turbine / excitation system may not have the capability to supply up to 150% of nameplate rating for several seconds without tripping off-line.

In the spring of 2013, Hydro installed both the NP Mobile Gas Turbine and the NP Mobile Diesel Generator at the Holyrood plant. A black start was attempted several times. During each attempt, the NP Mobile Gas Turbine tripped off-line and could not start the large boiler feed pump motors.

[1] Analysis of Holyrood Unit 2 Boiler Feed Pump

7.3.1 Conclusion

This option does not meet the technical requirements to provide full black start capability to the Holyrood thermal plant.

8 Financial Analysis

The financial analysis of the various options is tabulated below. It clearly indicates that the rental of a 16MW Diesel plant is the least cost solution for Holyrood black start capability.

Description	Cost	Project Availability
Rental of 16MW Diesel Plant	$8,275,000	11 weeks after PUB Approval
Refurbishment of Existing Holyrood CT	$9,503,000	March 4, 2015, with interim diesel rental available 11 weeks after PUB Approval
Rental of 16.7MW CT	$12,495,000	13 weeks after PUB Approval
Rental of 22.5MW CT	$22,385,500	18 weeks after PUB Approval

9 Recommendation

Hydro has identified the least cost option is a 16MW Diesel Plant leased for a period of 18 months to provide black start capability to the Holyrood Thermal Generating Station for 2013 – 2015 heating seasons. Current estimates suggest that it can be installed within 11 weeks of PUB and internal Hydro approval.

10 Appendix A: Motor Data

TECO-WESTINGHOUSE MOTOR COMPANY
ROUND ROCK, TEXAS U.S.A.

CUSTOMER NEWFOUNDLAND & LABRADOR HYDR   DATE - FEB 19, 2013
CUSTOMER ORDER NO. 1022269
APPLICATION ELECTRIC UTILITY PUMP
S.O. 8052AA

DATA FOR WORLD SERIES, HORIZONTAL, BRACKET TYPE INDUCTION MOTOR

1. RATING

HP	3000	HERTZ	60.0	INSUL CLASS	F
RPM FL	3580	SERVICE FACTOR	1.15	KVA CODE	E
VOLTS	4160	RISE C (1.00 SF)	80	DUTY	CONTINUOUS
AMPS FL	350	METHOD	RES	NUMBER OF POLES	2
PHASES	3	AMBIENT C	40		

2. MECHANICAL

FRAME	5011	BRG TYPE	SLEEVE	END PLAY INCH	0.50
ENCL TYPE	WP2	LUBE TYPE	FLOOD	MOTOR WK2	423
		ROTATION(FROM NDE)	CCW	LOAD WK2	70

3. STARTING PERFORMANCE - NOMINAL, VALUES WITH (*) ARE GUARANTEED

	100% VOLTS	90% VOLTS
AMPS (LR)	2032	1789
AMPS (LR) %	581	511
POWER FACTOR %	15.2	14.8
START TORQUE %	78	60
ACCELERATION SEC	2.0	2.9
SAFE LOCK SEC FROM HOT	9.2	11.8
SAFE LOCK SEC FROM COLD	10.7	13.7

PULLOUT TORQUE AT 100% VOLTS = 248 %

4. EFFICIENCY - NOMINAL

LOAD %	115	100	75	50
EFFICIENCY %	96.67	96.86	97.03	96.82

5. POWER FACTOR - NOMINAL

LOAD %	115	100	75	50
POWER FACTOR %	91.2	91.6	91.3	88.6

6. POWER FACTOR CORRECTION

MAX KVAR = 327 MAX FL P.F. = 95.8 %

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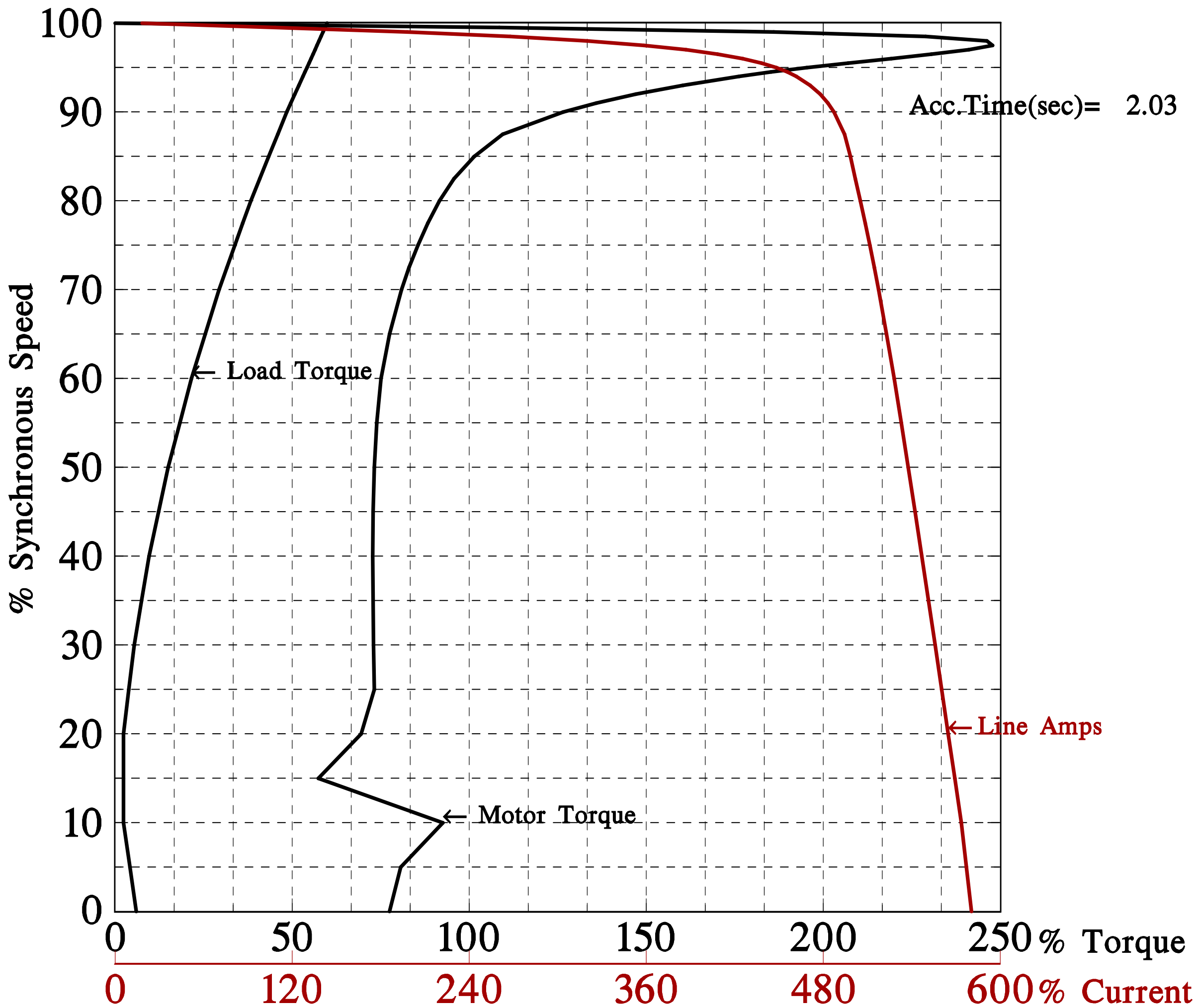
Induction Motor Starting Characteristics

Calculated at 100% Line Voltage

Design.ID	8052AA	Customer	NEW FOUNDLAND & LABRADOR
Engineer	T.NGUYEN	Application	ELECTRIC UTILITY PUMP

Poles	2	Volts	4160	Rpm(fl)	3580	Load Curve	ASSUMED
Hp	3000	Fl Amps	350	Rpm(syn)	3600	Lock Amps(%)	581
Pf	0.92	Frame	5011	Load Wk^2	70	Fl Torque(lb-ft)	4400
Phase	3	Hertz	60.0	Motor Wk^2	423	Lock Torque(%)	78



TECO-Westinghouse Motor Company Round Rock, Texas

Signature ______________________ Curve No.

Curve 1 of 4

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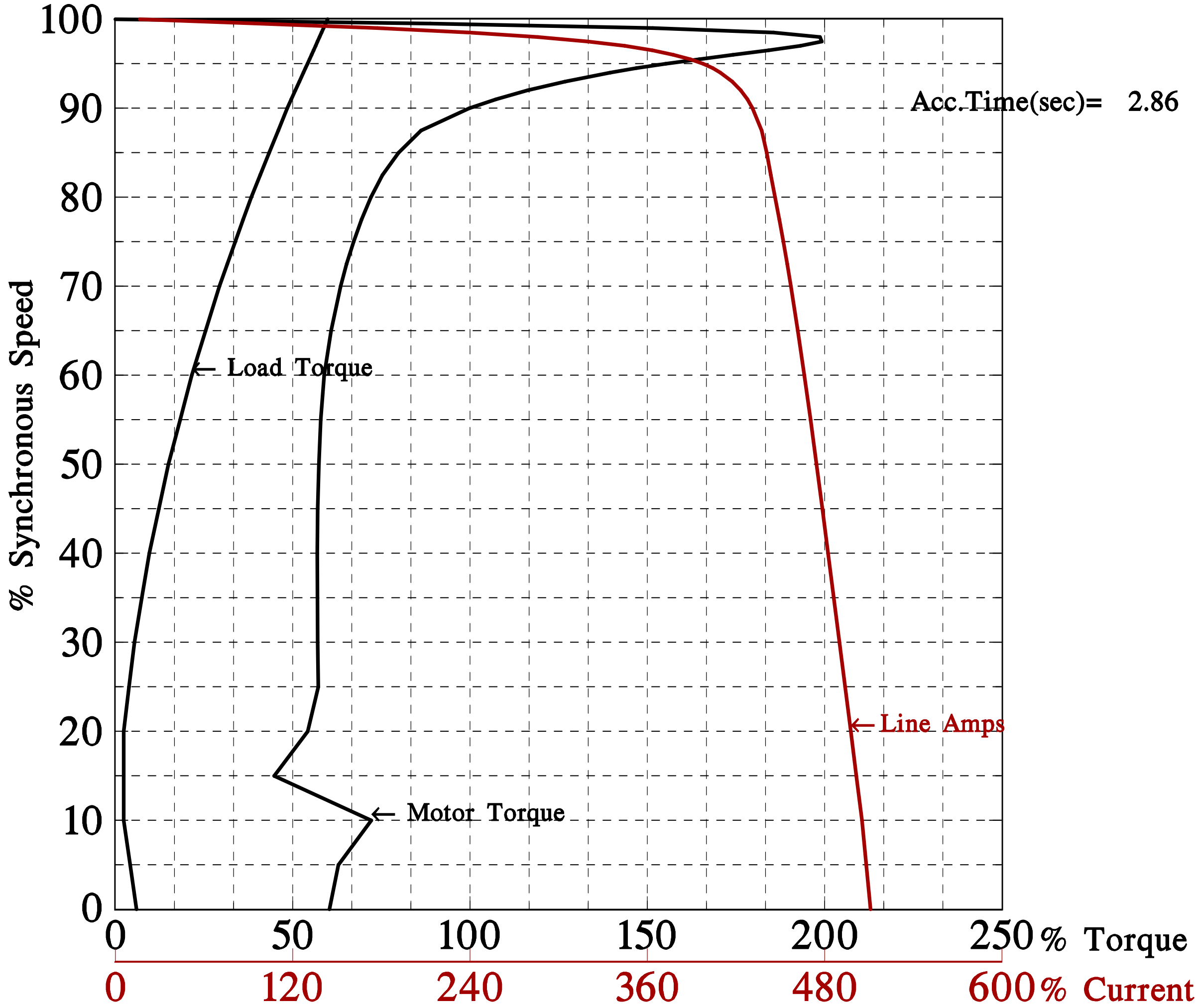
Induction Motor Starting Characteristics
Calculated at 90% Line Voltage

Design.ID	8052AA	Customer	NEW FOUNDLAND & LABRADOR
Engineer	T.NGUYEN	Application	ELECTRIC UTILITY PUMP

Poles	2	Volts	4160	Rpm(fl)	3580	Load Curve	ASSUMED
Hp	3000	Fl Amps	350	Rpm(syn)	3600	Lock Amps(%)	511
Pf	0.92	Frame	5011	Load Wk^2	70	Fl Torque(lb-ft)	4400
Phase	3	Hertz	60.0	Motor Wk^2	423	Lock Torque(%)	60



TECO-Westinghouse Motor Company Round Rock, Texas

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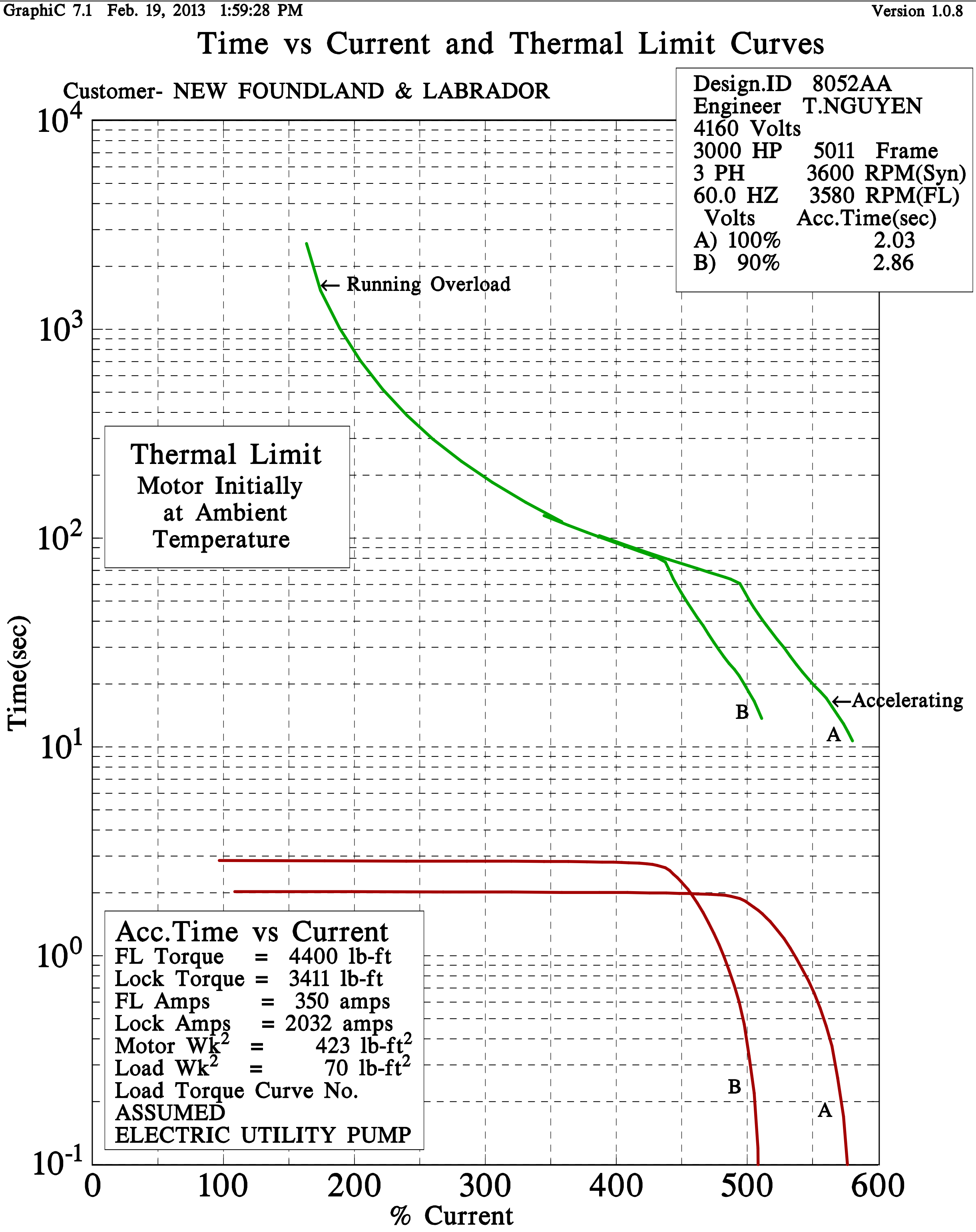
Curve 2 of 4



TECO-Westinghouse Motor Company Round Rock, Texas

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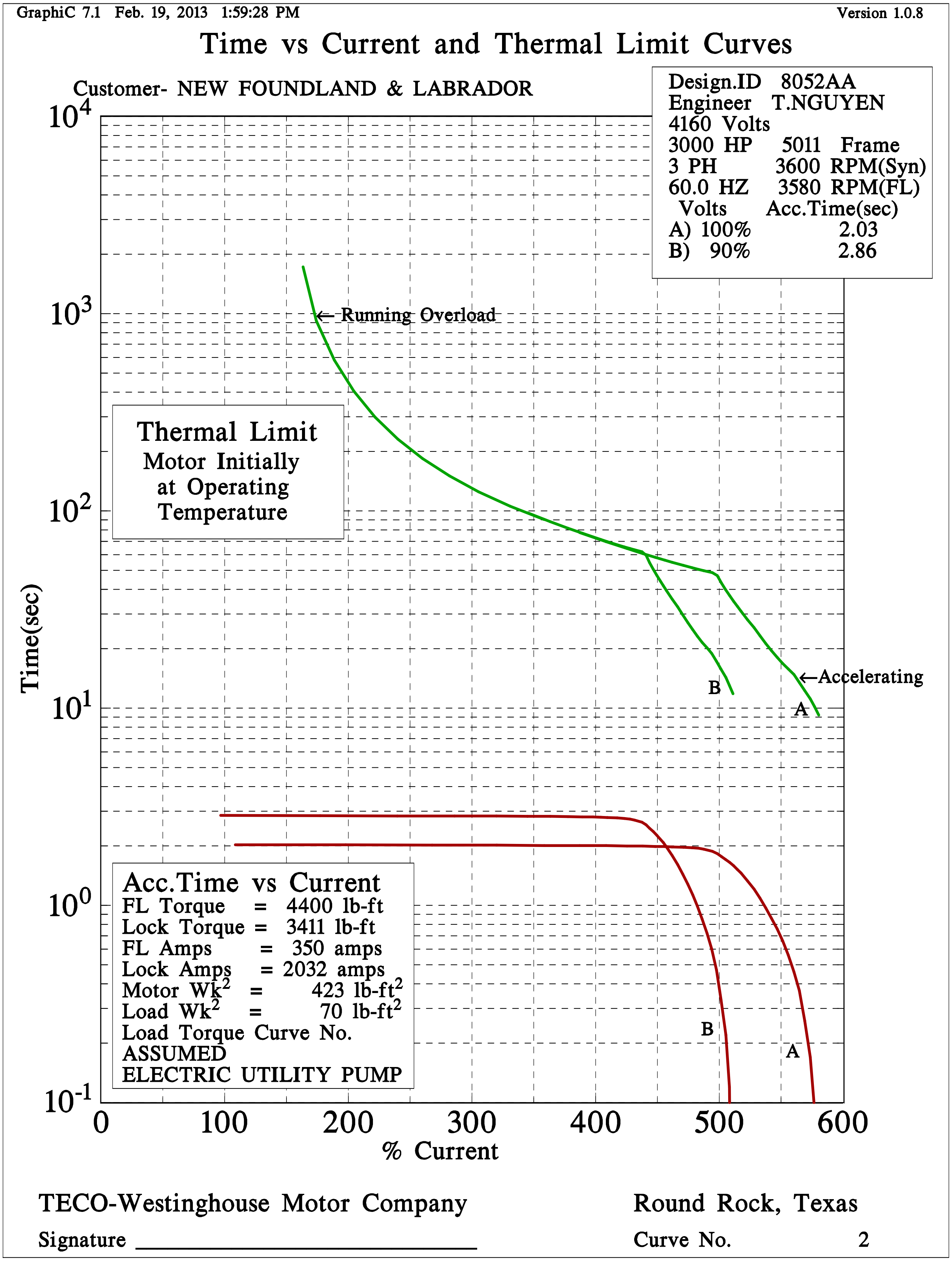
Curve 3 of 4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Version 1.0.8
Time vs Current and Thermal Limit Curves
Customer- NEW FOUNDLAND & LABRADOR
Design.ID 8052AA
Engineer T.NGUYEN
4160 Volts
3000 HP 5011 Frame
3 PH 3600 RPM(Syn)
60.0 HZ 3580 RPM(FL)
Volts Acc.Time(sec)
A) 100% 2.03
B) 90% 2.86
←Running Overload
Thermal Limit
Motor Initially at Operating Temperature
←Accelerating
A
B
Acc.Time vs Current
FL Torque = 4400 lb-ft
Lock Torque = 3411 lb-ft
FL Amps = 350 amps
Lock Amps = 2032 amps
Motor Wk2 = 423 lb-ft2
Load Wk2 = 70 lb-ft2
Load Torque Curve No.
ASSUMED
ELECTRIC UTILITY PUMP
Time(sec)
10^4
10^3
10^2
10^1
10^0
10^-1
0
100
200
300
400
500
600
% Current
TECO-Westinghouse Motor Company
Round Rock, Texas
Signature
Curve No. 2

Curve 4 of 4