PUB 10.2
Attachment A

A Report on the Power Restoration Difficulties on the Burin Peninsula and the Solutions Proposed to Address Them

Newfoundland Power Inc.

July 2, 2002

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Introduction

On April 19, 2002, Newfoundland Power's customers on the Burin Peninsula south of Marystown experienced an interruption of their electrical service as a result of the failure of a system transformer at the Company's Salt Pond Substation. On May 11, 2002, those same customers experienced a second service interruption as a result of the failure of the portable power transformer installed at the Salt Pond Substation as a temporary replacement for the transformer that had failed on April 19th. On May 13th, a second portable transformer was installed. The second portable remained in service until the original transformer was repaired and returned to service on May 22nd.

Because of the configuration of the Burin Peninsula system, a system transformer failure at Salt Pond Substation results in a loss of supply to all customers south of the substation. Until the transformer is returned to service, those customers must be supplied from local generation. The local generation in the area is primarily comprised of two gas turbine generators – one at Greenhill, near Grand Bank, and the other at Salt Pond, near Marystown. In the normal course, the events of April 19th and May 11th would merely have resulted in short outages while local generation was brought on line. In both instances, however, difficulties with the Greenhill unit delayed restoration of service.

As a result of the difficulties experienced in restoring power to our Burin Peninsula customers during these incidents, the Company conducted an engineering review of the Burin Peninsula electrical system. This is a report of the results of the review.

The Burin Peninsula Electrical System

The Burin System

Figure 1 is a diagram of the Burin Peninsula transmission system. Energy is supplied to the system via Newfoundland and Labrador Hydro's ("Hydro") Sunnyside Substation (SUN). The system is supplied by two voltage networks – one at 138 kilovolts (kV) and one at 66 kV.

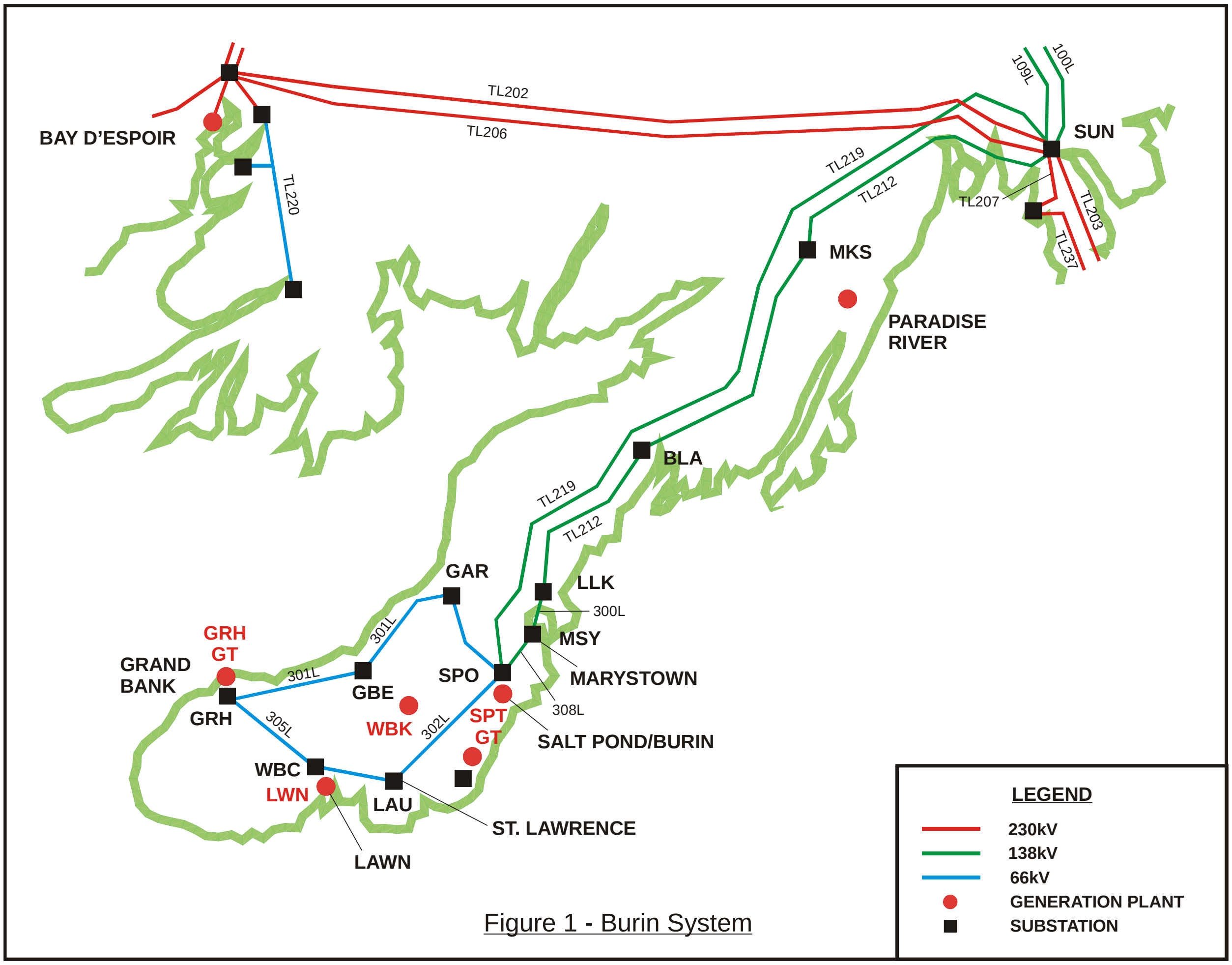

Figure 1 – Burin System

Hydro's 138 kV network is a loop system, consisting of transmission lines between Sunnyside and Salt Pond (SPT) that supplies power at 138 kV to the Monkstown (MKS), Bay L'Argent (BLA), Linton Lake (LLK), Marystown (MSY) and Salt Pond Substations. The original supply consisted of a single transmission line (TL212), which was built in 1966. Until 1990, this line was the sole supply to the Monkstown, Bay L'Argent and Linton Lake Substations. Marystown was supplied via transmission line 300L, which also supplied Salt Pond via transmission line 308L. These two Newfoundland Power transmission lines were rebuilt in 1982.

The 66 kV transmission network provides power to 6 substations, the locations of which are shown in Figure 1. The table below shows the number of customers and the 2001 peak load at each of these substations.

Substation	Number of Customers	2001 Peak Load (MVA)
Garnish (GAR)	436	2.0
Grand Beach (GBE)	101	0.1
Salt Pond (SPO)	1744	13.4
Greenhill (GRH)	2281	11.8
Webber's Cove (WBC)	808	2.9
Laurentian (LAU)	710	3.8
TOTAL (66 kV)	**6080**	**34.0**

In late 1990, Hydro completed construction of TL219 between Sunnyside and Salt Pond. This second line provided redundancy of supply to the Salt Pond 66 kV transmission system and provided redundancy within the 138 kV loop to Linton Lake and Marystown.

The 66 kV network consists of three Newfoundland Power transmission lines: 301L, originally built in 1966, but currently being rebuilt; 305L, originally built in 1975 and partially rebuilt in 1996 and 1998 due to storm damage; and 302L, originally built in 1958 but partially rebuilt in 1969. A failure on any one of these lines will not affect the ability of the other transmission lines to supply load within the 66 kV system.

Newfoundland Power owns and operates a total of five generating stations on the Burin Peninsula which are capable of providing backup generation to the 66 kV network. The location of each of these stations is shown in Figure 1. The Greenhill Gas Turbine (GRH GT) is a 25 MW generator that was installed near Grand Bank in 1977. The Salt Pond Gas Turbine (SPT GT) is a 14.7 MW generator that was installed at Salt Pond, Burin in 1967. In addition to these two gas turbines, Newfoundland Power operates the Lawn (LWN), West Brook (WBK) and Fall Pond (FPD) hydroelectric stations, which have a combined capacity of 1.8 MW.

Prior to the addition of the second 138 kV line in 1990, the gas turbines at Salt Pond and Greenhill were utilized to provide redundancy of supply to the 66 kV network in the event of loss of supply from the 138 kV network. However, between 1991 and 2000, these gas turbines were operated together on only 6 occasions to provide emergency generation for the area. Of these 6 starts, 3 have been in response to scheduled outages.

The various sources of energy supply available to the Burin Peninsula 66 kV system, and its looped configuration, provides considerable flexibility during power restoration efforts. However, this flexibility is limited by a significant non-redundant component.

The interconnection point between the 138 kV and the 66 kV networks at Salt Pond Substation consists solely of a 1971-vintage system transformer with a total capacity of 41.6 MVA. This is the unit that failed on April 19th. In effect, this transformer comprises a bottleneck in an otherwise redundant system.

The system transformer at Salt Pond serves two functions. Its primary function is to transform voltage from 138 kV to 66 kV to supply the 66 kV network. Secondarily, it provides voltage control to the 66 kV network via its built in on-load tap changer (OLTC). Basically, the OLTC acts as a voltage regulation device so that voltage variations on the 138 kV network are not translated to the 66 kV network.

The Power Interruptions of April and May 2002

At 7:19 pm on April 19, 2002, the system transformer at Newfoundland Power's Salt Pond Substation failed. As a result, Newfoundland Power's 6,080 customers on the Burin Peninsula south of Marystown experienced an interruption of their electrical service.

The Company's immediate response was to attempt to supply the customers using the gas turbine generators at Salt Pond and Greenhill. Due to a number of individual problems with the gas turbines, particularly the Greenhill unit, power restoration to all affected customers was not accomplished until 11:56 pm.

By 7:00 pm on the following day, the Company had completed installation of its largest capacity (50 MVA) portable transformer. Interruptions in service were limited to short outages experienced as the load was transferred from the gas turbines to the portable transformer.

At 8:58 am on May 11, 2002, the portable transformer faulted. As a result, the 6,080 Burin Peninsula customers served by the 66 kV transmission system again experienced a power interruption. Once again, it was necessary to provide service using the gas turbines at Greenhill and Salt Pond. However, problems were again experienced in keeping the Greenhill unit in service, which resulted in delays in permanently restoring power to all customers. Full restoration of power was not achieved until 1:06 pm.

A detailed chronology of both events is attached to this report as Appendix 1.

System Transformers

General

A transformer is an electrical device that is used to transform voltage from one level to another. The power transformer that failed at the Salt Pond Substation steps down the 138 kV supply voltage on Hydro's transmission system serving the Burin Peninsula to the 66 kV voltage of Newfoundland Power's transmission system south of Marystown. The transformer in question is known as a "system transformer", meaning it serves to transform voltage between transmission systems. A photograph of the Salt Pond system transformer is attached to this report as Appendix 2.

There are two primary considerations at play in the management of these assets. First, large power transformers are expensive items. In order to minimize the cost of transformation to ratepayers, existing transformers are maintained in service for as long as possible. Second, the replacement of a large power transformer requires a long lead-time between order and delivery, ranging anywhere from six to eighteen months. Since system transformers typically serve large numbers of customers, and are essential to the supply of electricity, a utility must balance the need to keep costs as low as possible with the need to ensure that it always has the capability to replace any lost transformer capacity.

Response to Transformer Failure

The typical response to the loss of a system transformer is to install a portable transformer to temporarily serve the load. The installation of the portable transformer can be completed within 24 to 48 hours. In the meantime, customers will be without power, unless the utility can supply them from emergency or backup generation.

Depending on the nature of the failure, the time to repair a large power transformer can be significant. For example, a transformer that failed at Grand Bay Substation in December 2001 took 6 months to repair. By the time repairs have been completed on the portable transformer that failed at Salt Pond on May 11th, it is anticipated that it will have been out of service for approximately 7 months. If a significant repair time is anticipated, the portable will be replaced by a spare standard, or permanent, transformer, if one is available. Preparing a standard transformer for transportation, transporting it and installing it in the new location, generally requires from 10 to 14 days.

It is not desirable to use a portable transformer as a replacement transformer for extended periods of time. This is because portable transformers are more expensive than standard transformers, and they are in demand to enable the utility to conduct maintenance and capital work programs without scheduled outages. They must also be available to provide immediate power restoration in the event of the failure of another large transformer. Further, given the greater complexity of portable transformers, and the fact that they are subject to significant stresses as a result of being transported for construction and maintenance work, these transformers are considered to be less reliable than standard transformers. A photograph of the portable transformer that failed in service on May 11th, 2002 is attached to this report as Appendix 3.

Practically, this means that a utility should have spare standard transformers available. Failure to maintain sufficient spare transformation capacity could result in the utility being unable to serve customers for an extended period. This is not acceptable.

Spare Transformer Capacity
At present, Newfoundland Power does not have a spare standard system transformer that is dedicated to that purpose. It does have one large system transformer that could be removed from service and relocated. This is in the Avalon area, where a number of system transformers are used to supply the same 66 kV system. However, removing that transformer would expose the Avalon system to a greater risk of outages.

Meanwhile, Hydro does have a spare unit that is capable of serving 50% of the Salt Pond system transformer peak load. This unit is available to Newfoundland Power though our Equipment Sharing Agreement with Hydro. Following the recent experience on the Burin Peninsula, the Company reviewed its spare transformer capacity and its plans for responding to transformer failures. A report on this issue is attached as Appendix 4 to this report.

Transformer Age and Failures
The April 19th incident involved the failure of the Salt Pond transformer's on-load tap changer. The transformer itself was not damaged in the incident. However, in conducting its review of the incident, the Company encountered a recently published industry report (the "Hartford Report") that identifies a correlation between the age of transformers and their rates of failure in service.[1] The Hartford Report, which was authored by the principal electrical engineer for a major American utility equipment insurer, states that, under ideal conditions, a transformer can be expected to last between 30 and 40 years. However, the report also notes that many do not last as long as that.

The Hartford Report observes that the massive industrial growth experienced in the United States following the Second World War led to a corresponding growth in the electric utility industry. The peak period for installation of utility transformers, according to the report, occurred during the 1970s. Combined with the deferment of capital expenditures and steady growth in power consumption during the last twenty years, the result is an aging fleet of utility transformers that is required to carry ever-increasing loads. As can be seen on page 3 of Appendix 4, Newfoundland Power's experience is similar. The Hartford Report's author concludes that a rise in end of life failures of transformers is inevitable as the population of transformers ages. Given the age of many of the power transformers in Newfoundland Power's electrical system, this inevitability must be considered in our contingency planning.

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[1] William H. Bartley, P.E., *Failure History of Transformers – Theoretical Projections for Random Failures*, (2001) Hartford Steam Boiler Inspection and Insurance Co.

As indicated in Appendix 4, Newfoundland Power has experienced an annual average of 1.4 failures of large power transformers during the last 7 years. Given the potential for significant outages associated with the failure of system transformers, and the limited spare transformer capacity available, it is prudent to consider adding transformer capacity.

The Salt Pond System Transformer

The system transformer at Salt Pond was installed in 1971. At over 30 years in service, the transformer is approaching the end of its expected life. In light of the conclusions of the Hartford Report, the probability that the transformer will fail in service is high. While it is not economic to retire such a major piece of utility equipment on the basis of age alone, prudence dictates that the Company be prepared for the contingency of failure.

The Company has invested over $6 million in improvements to the Burin Peninsula electrical system since 2000. The rebuilding or substantial upgrading of distribution feeders on the peninsula has resulted in improvements in service reliability. The redundancy of supply provided by Hydro's construction of the second 138 kV transmission line adds another measure of security. However, the reliability of this substantially strengthened system remains dependent on the non-redundant connection between the 138 kV transmission system and the 66 kV distribution system at Salt Pond Substation.

Alternative Solutions

One possible solution is the purchase of an additional portable transformer that could be placed in service at Salt Pond in the event of failure of the existing system transformer. However, a portable transformer is not considered to be a suitable long-term replacement for a standard transformer. As noted above, they are more costly to purchase than standard transformers. In order to provide maximum operational flexibility, portable transformers are designed as self-contained substations. The additional components add significantly to the cost. The estimated cost of a new portable transformer is approximately $2.5 million, compared to an estimated $2.0 million for the purchase and installation of a second standard system transformer for Salt Pond.

In addition to the extra cost, portable transformers are less reliable than permanent transformers. To minimize the time required to put them in service, they are designed so that they can be shipped with oil in their tanks and transformer bushings installed, and with lower overall mass. The lower mass adds complexity in terms of cooling requirements. Newfoundland Power's use of portable transformers for emergency, construction and maintenance purposes means that they are shipped frequently and are subject to the vibration that accompanies transportation. Because of their frequent installation and removal they are subject to greater switching transients. Due to their greater complexity and to the harsher service conditions they are subjected to, portable transformers are not considered as reliable as permanent transformers.

A second alternative to purchasing another standard transformer for the Salt Pond Substation is the conversion of the entire Burin Peninsula electrical transmission system to 138 kV, thereby entirely eliminating the need for the system transformer. This alternative would free up the Salt Pond system transformer for use in another location. However, the cost of the conversion would be higher, by multiples, than the cost of adding a second system transformer. Conversion to 138 kV would necessitate the substantial rebuilding of several substations and the changing out of a number of larger transformers. It would also require that the insulators on the Company's 66 kV transmission lines be replaced.

Converting the entire 66 kV system to 138 kV would be justified only if it were necessary to meet load growth. Appendix 5 is a table showing growth in customers, energy and demand on the Burin Peninsula between 1990 and 2001. As the table shows, despite some growth in the number of customers on the peninsula during the past decade, demand and energy requirements have actually declined. In the absence of a substantial change in growth expectations on the Burin Peninsula, the conversion of the 66 kV system to 138 kV is not justified.

The placement of a second 138 kV – 66 kV system transformer at Salt Pond would provide the additional security required to ensure a failure of the existing system transformer does not result in extended outages to customers. An onsite replacement transformer would reduce dependence on backup generation, and would substantially reduce the likelihood of an extended interruption in service. It would also eliminate the possibility that one of the Company's portable transformers would be required to be placed in service for an extended period.

Given that the other alternatives identified to improve the security of supply for customers served by the 66 kV transmission system on the Burin Peninsula are either impractical or uneconomic, it is recommended that the Company purchase a new 138 kV – 66 kV system transformer to be located at the Salt Pond Substation.

Appendix 6 contains single line diagrams showing the existing and proposed configuration of the Salt Pond system.

The Greenhill Gas Turbine

General

The Greenhill Gas Turbine is a 25 MW generator that was installed near Grand Bank in 1977. At the time, there was only one 138 kV transmission line supplying the Burin Peninsula. The Greenhill unit was used to provide emergency backup power in the event of the loss of either the single 138 kV transmission line or the 138 – 66 kV system transformer at Salt Pond Substation. In addition, the unit would provide voltage support in the event of the loss of either of the 66 kV lines running between Salt Pond Substation and Greenhill Substation. It was also available to provide additional overall system capacity when required.

In 1990, a second 138 kV transmission line was built from Sunnyside Substation to Salt Pond Substation. The building of the second line reduced dependency on the Greenhill unit for emergency power in the event of loss of a 138 kV line from Sunnyside. However, the unit is still available in the event of the loss of the 66 kV transmission system, or the failure of the system transformer at Salt Pond. Its role in providing overall system capacity remains unchanged.

A photograph of the Greenhill Gas Turbine is attached to this report as Appendix 7.

Turbine Performance

In the ten year period following the installation of the second 138 kV transmission line, the Greenhill Gas Turbine was used to provide emergency generation to the Burin Peninsula only six times. Of these six starts, three involved scheduled outages.

The Greenhill Gas Turbine is tested on a regular basis. Every month, the unit is operated for approximately ¾ of an hour. The unit is placed on line and loaded to approximately 40% of its full load. Such tests are performed under normal system conditions. However, the unit has rarely operated under full load, and rarely for an extended period.

The Company plans to relocate the Salt Pond Gas Turbine to the Wesleyville area in the near future. Following the relocation of the Salt Pond unit, the Greenhill Gas Turbine will be the primary source of backup power on the Burin Peninsula. It is therefore important that the unit be reliable.

Identified Deficiencies

The Greenhill Gas Turbine was called upon to provide emergency generation for the Burin Peninsula during both of the recent outages resulting from the failure of the system transformers. On April 19, 2002, the unit operated for a period of approximately 28 hours. This was the first time since 1997 that the unit had been used for an extended period. During the second outage, on May 11, 2002, the unit operated for approximately 48 hours.

During both of these events, the unit tripped several times due to problems with the temperature and vibration monitoring of the gas turbine components. In order to keep the unit operational, the load had to be limited to a maximum of approximately 14 MW. This reduced the ability to provide emergency service to customers on the 66 kV system, and subjected customers to rotating outages at times when the Salt Pond Gas Turbine was unavailable. The Company's review has identified a number of factors that contributed to the problems experienced with the unit's operation. These are: (1) the "black start" capability of the unit; (2) the amount of vibration present in the unit when it is running under full load; and (3) deficiencies in the unit's temperature monitoring and cooling systems. Each of these items is discussed below.

Black Start Capability

Black start capability is the ability of a generator to start using direct current (DC) battery power when alternating current (AC) power is not available. The Greenhill Gas Turbine's black start capability has been unreliable ever since it was installed in 1977. Addressing the issue was not a priority, however, because the Salt Pond Gas Turbine was available to supply AC power if the Greenhill unit failed to start under outage conditions. When it was decided to relocate the Salt Pond Gas Turbine, the installation of an Auxiliary Power Unit (APU) at Greenhill to provide AC power to enable black start was included in the Company's 2002 capital budget as part of the Salt Pond Gas Turbine relocation project. The APU is scheduled for installation in 2002.

Vibration

A gas turbine is designed to withstand a certain level of vibration. When vibration exceeds this level, the gas turbine could be seriously damaged. Vibration is generally the result of such factors as a misaligned component, an improper component clearance or an imbalance in a rotating component. When the Greenhill Gas Turbine was operated during the recent outages, excessive vibration developed in the unit. On both occasions, the unit's vibration sensors tripped it off line when the load approached 14MW. As a result, the Salt Pond Gas Turbine was also required to carry a significant portion of the load.

As part of the Company's review of the Burin electrical system, a vibration analysis expert from Rolls Royce, the manufacturer of the gas engine, was engaged to perform a vibration analysis of the Greenhill unit. The expert analyzed the unit's vibration signatures at different loads and operating conditions. The overall vibration levels on the gas engine were found to be high and fluctuating at full load, with even higher levels reached during loading. Vibration signatures were also taken on the power turbine, the clutch box, and the exciter bearing. The generator supports were checked and showed significant vibration. The generator exciter bearing is also operating outside recommended levels. The manufacturer's expert has recommended that the power turbine be reinstalled, and the alignment verified to be in accordance with proper installation and tolerances, with particular emphasis on the clutch boxes, engine nose alignment and bearing supports.

The Greenhill unit's vibration monitoring system is an obsolete five-channel system that is no longer supported by the manufacturer. The manufacturer's expert noted that the vibration sensors on the generator alternator and exciter bearings should be relocated to provide more accurate and meaningful vibration measurements. In order to ensure adequate vibration protection and to assist with vibration diagnostics, the Company proposes to incorporate a new 12-channel vibration monitoring system, complete with relocated vibration probes, into the unit's protection and control scheme.

Temperature

A critical component of the Greenhill Gas Turbine is the lubricating oil cooling system. Lubricating oil is used to lubricate the various bearings on the gas turbine. When the lube oil temperature is outside its safe operating range it breaks down and loses its lubricating properties. If this were to occur, there would be major damage to the bearings, resulting in costly and time-consuming repairs.

The Greenhill Gas Turbine's lube oil cooling system is housed in the lube oil room. During the recent operation of the unit, the temperature in the room rose to very high levels. There is a small exhaust fan in place; but it is not adequate to cool the room. The installation of a new cooling ventilation system would lower the room temperature, and improve the effectiveness of the lube oil cooling system.

The Greenhill unit's glycol cooler, which is the unit's primary heat dissipation mechanism, is deteriorated. During operation of the unit in May, the glycol cooler failed to keep the temperature of the lube oil within safe operating limits. With an outdoor ambient temperature of approximately 8 degrees Celsius and a load of approximately 13 MW on the unit, the unit tripped off as a result of excessive lube oil temperature. To reduce the lube oil temperature to acceptable levels, the auxiliary town water supply system had to be used to supplement the cooling system. To correct this problem, it is recommended that the glycol system be refurbished and upgraded.

During its most recent operation, the Greenhill unit also tripped off on several occasions due to high exhaust gas temperatures. Exhaust gas temperature monitoring provides an indication of the internal operating temperature of the gas engine. If the operating temperature exceeds recommended limits for an extended period, the engine could be seriously damaged. The Greenhill unit's exhaust gas temperature is monitored by eight dual element thermocouples. These thermocouples, which are original equipment and are 25 years old, were tested during the Company's review of the unit. One quarter of the sensors proved to be defective. The defective sensors appear to have been responsible for the false high temperature readings that caused the unit to trip off. To correct this problem and avoid a recurrence, it is recommended that the thermocouples be replaced.

The recommended refurbishment of the Greenhill Gas Turbine also provides an opportunity to replace other defective components in a cost-effective manner. For example, original equipment thermocouples are used to monitor all lube oil and bearing temperatures on the unit. Twenty percent of these sensors have been by-passed due to failure in service. It is recommended that all of the original thermocouples be replaced during refurbishment of the unit.

Summary of Recommendations

The System Transformer

It is recommended that the Company purchase a new 138 kV – 66 kV system transformer to be located at the Salt Pond Substation.

The Greenhill Gas Turbine

It is recommended that the following upgrades and improvements to the Greenhill Gas Turbine be carried out immediately:

(a) reinstallation and realignment of the power turbine to reduce overall vibration levels;
(b) installation of a new vibration monitoring system into the unit's protection and control scheme;
(c) installation of a new cooling ventilation system to lower the lube oil room temperature;
(d) refurbishment and upgrading of the glycol cooler;
(e) replacement of all exhaust gas temperature monitoring thermocouples; and
(f) replacement of all lube oil and bearing temperature monitoring thermocouples.

Appendix 1

Chronology of Events
Surrounding the Recent Burin Transformer Failures

Chronology of Events Surrounding Recent Burin Transformer Failures

Newfoundland Power Inc.

June 28, 2002

Substation: SPO **Equipment: SPO-T4** **Date: 2002/04/19**

General Description:

At 7:19pm on April 19, 2002, the Westinghouse T4 transformer at NP's Salt Pond substation faulted leaving 6,080 customers on the 66kV loop without power. These customers are served by feeders from the Salt Pond (SPO), Laurentian (LAU), Webber's Cove (WBC), Greenhill (GRH), Grand Beach (GBE) and Garnish (GAR) substations.

Immediate Response:

The Salt Pond and Greenhill gas turbines were started and at 7:46pm the Salt Pond unit's breaker was closed successfully. At 8:48pm the Greenhill gas turbine's breaker was closed and an attempt to pick-up the load of the GRH-03 feeder was made. However, this feeder subsequently tripped out due to under frequency. A second attempt to parallel the two gas turbines was made by bringing the Greenhill unit online again at 9:07pm and energizing the entire 66kV system. This time attempting to pick up load on GRH-01 caused the Salt Pond unit to trip off. At 9:18pm an emergency stop was required on the Greenhill unit because of high voltages on the 12.5kV bus at GRH.

The 66kV buses at Salt Pond and Greenhill were isolated at 9:20pm by opening the transmission breakers at SPO and GRH. At 9:35pm the Greenhill unit was again brought online and shortly afterwards the GRH feeders were energized.

At 10:15pm the 305L breaker was closed, allowing the Greenhill turbine to energize Webbers Cove and Laurentian substations. The WBC and LAU feeders were closed in shortly afterwards. At 11:06pm the 301L breaker was closed which supplied the substations at Grand Beach and Garnish from the Greenhill turbine.

At 11:28pm the Salt Pond unit's breaker was again closed allowing this unit to supply the SPO feeders in isolation from the Greenhill unit. By 11:56pm, all of the SPO feeders were energized. Power was restored to all customers at this point.

In addition to the problems encountered in paralleling the Salt Pond and Greenhill gas turbines, there were a number of other problems with these units that restricted the load these units could carry. These problems included: a pressure switch on the Salt Pond turbine, problems with the Greenhill turbine breaker, and concerns over vibration at the Greenhill gas turbine.

Intermediate-Term Response:

In response to this event, NP's largest capacity portable transformer (P-435) was mobilized to Salt Pond substation and arrived on-site at about 10:00am on Saturday, April 20, 2002. The set-up and energizing of this unit required until about 7:00pm at which time the transfer of load from the gas turbines to the portable commenced. Customers on the SPO feeders (1742 in total) experienced an outage from 6:53pm to 8:00pm (1 hour and 7 minutes in total) while transferring load from the Salt Pond gas turbine. Customers served by feeders from the GAR, GBE, GRH, LAU and WBC substations (4329 in total) experienced an outage from 8:05pm to 8:15pm (10 minutes in total) while transferring load from the Greenhill gas turbine.

On Thursday, April 25, 2002 a representative of Siemens-Westinghouse from Hamilton, Ontario arrived on-site and commenced testing of the damaged SPO-T4 transformer. This testing required approximately 1.5 days and concluded that the transformer could be repaired on site. Siemens-Westinghouse committed to sourcing the required replacement parts and providing a complete cost estimate for the necessary repair as soon as possible.

Repair of SPO-T4 transformer commenced on May 17th and the unit was returned to service on May 22nd.

Substation: SPO **Equipment: P-435** **Date: 2002/04/19**

General Description:

At 8:58am on May 11, 2002, NP's 50MVA portable transformer P-435 (in service at the time at Salt Pond substation) faulted leaving 6,080 customers on the 66kV loop without power. This portable was replacing the permanent 138/66kV SPO-T4 which faulted on April 19th and was in the process of being repaired. The customers affected were served by feeders from the Salt Pond (SPO), Laurentian (LAU), Webber's Cove (WBC), Greenhill (GRH), Grand Beach (GBE) and Garnish (GAR) substations (i.e. the same customers affected by the April 19th outages).

Immediate Response:

The Salt Pond gas turbine was started at 9:30am and again at 9:35am but tripped both times when the breaker was closed. At 10:50am, the Salt Pond gas turbine was again started and was successful in picking up load until 12:05pm when the unit tripped when paralleled with the Greenhill unit. The unit was restarted at 12:15pm and served the SPO load until 5:30pm when a solenoid failed in the unit's governor system. After repair of this component, the unit was restarted at 11:00pm. [Note that the Salt Pond unit's governor and control system is being replaced in conjunction with the GT relocation project]

A start on the Greenhill gas turbine was tried at 10:21am. After 6 unsuccessful attempts at starting, the unit was started with AC power supplied from Salt Pond at 11:20am. The unit tripped twice between 12:08pm and 1:06pm due to a faulty thermocouple in the thrust bearing and was restarted. From 1:06pm, the Greenhill unit carried load successfully until 6:13pm when the unit tripped due to vibration at a load of 14.9MW. The unit was restarted at 6:33pm and was run throughout the night of May 11th at a load of approximately 10MW.

Power was restored to some customers as early as 10:53am. However, as a result of the gas turbine troubles noted above, most customers experienced intermittent outages throughout the restoration effort. All customers had power restored from the initial outage by 1:06pm. Customers served by SPO feeders (1742 in total) experienced a further outage of 115-144 minutes as a result of the mechanical problems with the Salt Pond unit. Due to load restrictions on the Greenhill unit (resulting from the vibration problems), power was rationed to all customers on the 66 kV loop while the Salt Pond unit's governor solenoid was repaired.

Intermediate-Term Response:

In response to this event, NP's second largest capacity portable transformer (P-335) was relocated to Salt Pond substation from Grand Bay substation where it had been in service.

This unit arrived on-site on Monday, May 13, 2002. The set-up and energizing of this unit required an outage of approximately one hour to customers served by the GAR, GBE and SPO substations (2281 in total).

To address the system vulnerability caused by the damage to P-435 and the temporary emergency requirement for P-335, Newfoundland Power requested and received the cooperation of NLH in delaying the planned deployment of their portable transformer P-235 for construction purposes at Cow Head on the Northern Peninsula. NLH representatives at Bishop's Falls agreed to delay this work by 1-2 weeks until such time as NP has SPO-T4 back in service.

Repair of SPO-T4 transformer commenced on May 17th and the unit was returned to service on May 22nd.

The portable transformer P-435 has been transported to the Siemens-Westinghouse facility in Hamilton, Ontario for further assessment and repair. This unit will be out of service until December 2002. Portable transformer P-335 will remain on the Burin Peninsula unless required to address any unplanned substation outage elsewhere on the island.

Appendix 2

Photograph of Existing
Salt Pond System Transformer

Appendix 3

Photograph of Failed Portable Transformer

Appendix 4

Newfoundland Power System Transformers
The Implications of and Response to a Unit Failure

Newfoundland Power System Transformers
The Implications of and Response to a Unit Failure

Newfoundland Power Inc.

June 28, 2002

Geoff Emberley, P. Eng.

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Impetus for review

As a result of the recent power system events that occurred on the Burin Peninsula electrical system, especially the failure of the Salt Pond 138/66 kV system transformer and the subsequent failure of the portable transformer installed as its temporary replacement, the Company has reviewed the degree to which it has depended on portable transformers as backup to system transformers. As well, the Company has reviewed the aging nature of its transformers and the probability of an increasing rate of failure.

Newfoundland Power's past practice with respect to transformer backup has two aspects: quick restoration of service through the temporary installation of a portable transformer; and replacement with a standard transformer if the anticipated repair time is significant or the failed transformer is beyond repair. At present, the Company has three portable transformers. Two of these are configured such that they can be used to quickly replace a failed system transformer. One of these portable transformers has capacity of 25 MVA and the other 50 MVA. The third portable is not large enough to be used to replace the Company's large system transformers. Given that the Company has a number of 42 MVA system transformers in service, the largest portable, the 50 MVA transformer, is critical to the Company's transformer backup strategy.

Transformer reliability: Portable vs. Standard

Compared to a standard transformer, portable transformers are mounted on a trailer with associated switchgear and protection. While they are called portable transformers, they are in effect portable substations. These portable features result in significantly greater cost for a portable transformer compared with a standard transformer. As noted above, portables can be transported and installed quickly. The standard transformer however is much larger physically and heavier. It requires significant time to get ready for transport, shipping usually takes longer, and there is significant installation time. Compared to one or two days for a portable transformer it takes on average 10 to 14 days to get such a standard transformer ready for shipment, transport it, reassemble it and energize it. Based on this, the Company's strategy has been to use portables to quickly restore power. If the transformer can be repaired within a reasonable time, the portable is left in place until the repair is completed. Based on past experience, transformers with significant damage can take between 6 to 18 months to be repaired or replaced with a new unit. If the repair is expected to take a long time, consideration will be given to installing a standard transformer for the longer term or as a permanent replacement. Unfortunately, at this point in time, the Company does not have a spare standard system transformer that could be used for the longer term.

The use of portables for backup has resulted in both reliable service and in a lower cost than having an on site spare for each system transformer. In addition to the use of portables as backup transformers in the case of transformer failure, the Company uses the portable transformers to permit preventative maintenance on transformers and associated bus work in substations. While the increasing use of these portable transformers for ongoing construction and maintenance purposes has been very productive in terms of cost and customer service, it has raised the question of whether these portable transformers should be used to meet longer term system outage circumstances. Using a portable on a long-term temporary basis as a replacement for a failed transformer not only makes it unavailable for other possible system transformer failures, it also makes it unavailable for construction and maintenance purposes.

Given their construction and use, portable transformers do not have the same reliability as a standard system or power transformer. In order for them to be mounted on a trailer ready to be energized they contain less mass than equivalent capacity standard transformers. With this smaller mass, forced cooling with associated pumps and fans are critical components. Generally they are more complex and more prone to failure than standard transformers.

As well, portable transformers are shipped from location to location and installed for short periods of time. This frequent shipping subjects them to greater vibration and associated degradation. They are subject to greater switching demands, with the associated switching transients. This can shorten their service lives and impact their reliability.

Portable transformers are shipped with oil in their tanks, and transformer bushings installed. Standard transformers are typically drained of oil to lower weight and have the bushings disconnected to maintain transportation height limitations.

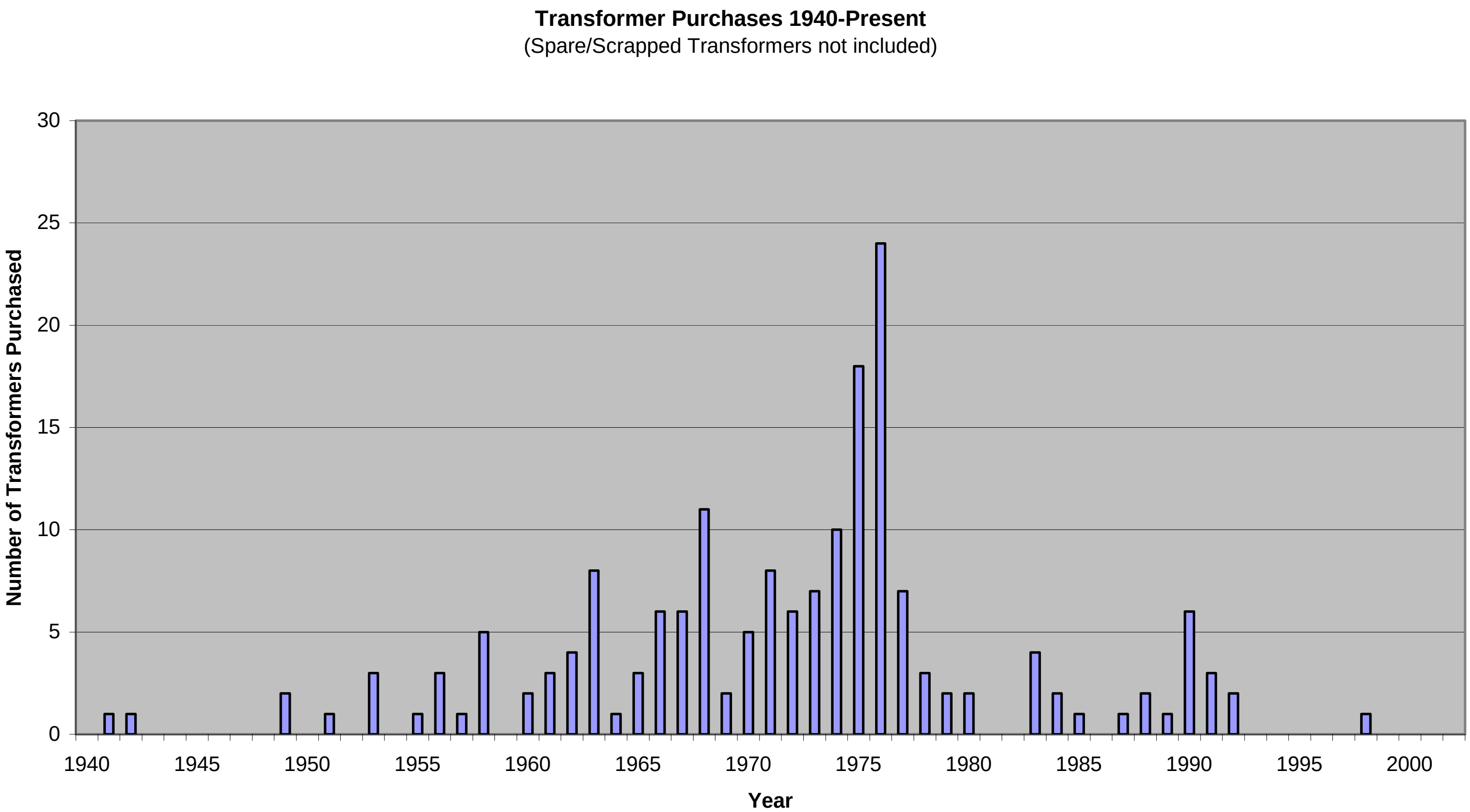
Newfoundland Power Transformers

The recent failure of the Salt Pond system transformer, and the subsequent failure of the company's largest system portable transformer have raised concerns about the ageing nature of the company's transformers and the probability of increased transformer failure rates in the future.

The following is a list of Newfoundland Power's large system transformers, indicating, among other factors, the purchase date of each transformer:

NP System Transformer	Voltage	Size	Age
Blaketown	138/66 kV	**42 MVA**	25
Bay Roberts	138/66 kV	42 MVA	26
Bay Roberts	138/66 kV	42 MVA	18
Catalina	138/66 kV	16.6 MVA	30
Clarenville	138/66 kV	25 MVA	35
Gambo	138/66 kV	42 MVA	26
Cobbs Pond	138/66 kV	42 MVA	23
Gander	138/66 kV	27 MVA	35
Grand Falls	138/66 kV	30 MVA	33
Salt Pond	138/66 kV	42 MVA	31

The following chart indicates the purchase dates of Newfoundland Power system, power and plant transformers.



The average purchase date of Newfoundland Power's system, power and plant transformers is 1971, with 75% of all transformers being purchased between 1960 and 1980. The average purchase date of Newfoundland Power's large system transformers is 1974, with all being purchased between 1967 and 1984.

Industry experience indicates that given the age of our transformer stock, we can expect to see an increasing failure rate of transformers in the coming years. A recent paper, "Failure History of Transformers – Theoretical Projections for Random Failures", by William H. Bartley, P.E., 2001; reviews the U.S. past and probable future experience with transformer life. The author notes that under ideal conditions a transformer can be expected to last between 30 and 40 years. He also indicates that under practical conditions, many do not last that long. For example, in his modeling of data he posits that failure rates of 1972 vintage transformers should over take failure rates of 1964 transformers in 2006, indicating that increasingly there are fewer 1964 vintage transformers in the system due to failure, and that increasing numbers of 1972 transformers are failing. For Newfoundland Power, given the age profile of its transformers, this means that more of these transformers can be expected to fail than we have experienced in the past. It also means that Newfoundland Power must plan to accommodate these increased transformer failure rates if it is to maintain a reasonable quality of service for its customers.

The following table lists Newfoundland Power substation transformers that have failed over the past 7 years. With 10 failures over this period of time, there are an average of 1.4 failures per year.

Transformer	Voltage	Size	Purchase	Incident & Date
Rattling Brook (2)	66/6.9 kV	9 MVA	1958	2001 Test / Retire 2002
Portable P435	138/66 kV	50 MVA	1992	May 2002 Failure/ Repair
Salt Pond T4	138/66 kV	42 MVA	1971	April 2002 Failure/ Repair
Grand Bay Sub	66/12.5 kV	12 MVA	1971	Dec 2001 Failure/ Repair
Bonavista	138/12.5 kV	25 MVA	1990	July 1999 Failure / Repair *
Cape Broyle	66/12.5 kV	8.4 MVA	1954	Spring 1996 Failure / Retire
Lookout Brook	32/ 2.4 kV	7.5 MVA	1954	Mar. 1996 Failure / Retire
Clarenville	138/ 12.5 kV	20 MVA	1968	July 1995 Failure / Retire
Kenmount	66/25 kV	25 MVA	1988	Feb. 1995 Failure / Repair

* Lightning strike

The failures of the Portable P435 and the Salt Pond T4 involved system transformers. These are of special concern as they normally supply large numbers of customers dispersed over a significant geographic area.

Implications of system transformer failure

As noted in the table on page 2 there are 10 locations where system transformers are utilized within the Company. Each location can be analyzed as to the impact of the system transformer failure.

The Avalon area system is supplied through two system transformers at Bay Roberts and one system transformer at Blaketown. The loss of one system transformer will result in the remaining two transformers being close to the limit where significant overload or voltage drop will occur.

There is one system transformer at Salt Pond. The lost of the system transformer at Salt Pond results in the loss of service to a large number of customers until such time as the Greenhill Gas Turbine comes on line or a portable transformer is installed. While the gas turbine can carry the load for most of the year, there are significant periods of time when the gas turbines capacity is exceeded by the load. Further, gas turbines are both expensive to operate and not reliable to operate on the long term basis that would be necessary while awaiting the replacement of a failed transformer.

The Bonavista area system has two system transformers, one at Clarenville and the other at Catalina. With loss of the Catalina transformer, load can be supplied from Clarenville; however, there would be voltage problems on peak. With loss of the Clarenville transformer, only a portion of the load can be carried from the Catalina transformer.

There is one system transformer at the Gambo substation, which serves the Bonavista North area. The loss of the system transformer at Gambo results in the loss of service to a large number of customers until such time as a portable transformer can be installed. When the Salt Pond Gas Turbine is relocated to Wesleyville in 2003, the length of such an outage will be significantly reduced as a result of the Gas Turbine being able to be operated until the portable transformer is installed.

The Gander area system has two system transformers, one at Cobb's Pond and the other at Gander substation. With loss of the Gander transformer, the Cobb’s Pond transformer can supply the entire load. However that is not the case with the loss of the Cobb’s Pond transformer. Further, these transformers are connected to different transmission lines that supply the Gander North customers. Loss of one transmission line requires that the load be supplied through the other transmission line, and consequently the other transformer. Loss or removal of one transformer or transmission line means that this redundant supply to Gander North is removed, with a consequent reduction in reliability to this system.

The Grand Falls system has one system transformer at Grand Falls. Loss of this transformer may result in customer outages if other elements of the local system are out of service, especially the Rattling Brook generation and associated transmission lines.

In many of the circumstances noted above, the system can still supply peak load despite the loss of one system transformer. However, with the subsequent loss of another system component, the system may not be capable of supplying all customers. This could occur, for example, with the loss of a transmission line, which is a much more common event than the loss of a transformer.

Increasing reliance on a small number of portable transformers for most transformer contingencies, and for some transmission line contingencies, is creating a situation where multiple contingencies within a period of up to a year could result in long term customer outages as a result of the long time required to replace a system transformer. Multiple contingencies do happen, as was recently experienced at Salt Pond.

Recommendations

In order to address these concerns, it is recommended that the Company purchase a 138 / 66 kV, 42 MVA transformer as a system replacement. The transformer should be installed and energized at a location where, in the event of a system transformer failure at that location, it will prevent a loss of supply. Keeping it energized not only ensures that service can be restored to that location on loss of its system transformer, but also provides ongoing assurance that the transformer is in good working order. On failure of a system transformer at some other location in the Newfoundland Power electrical system, a portable transformer would still be used to restore service quickly. However, if the failed transformer was totally destroyed, or if repairs would take on the order of months, the replacement system transformer would be transported to that location and put in service. The portable could then released for use elsewhere.

Appendix 5

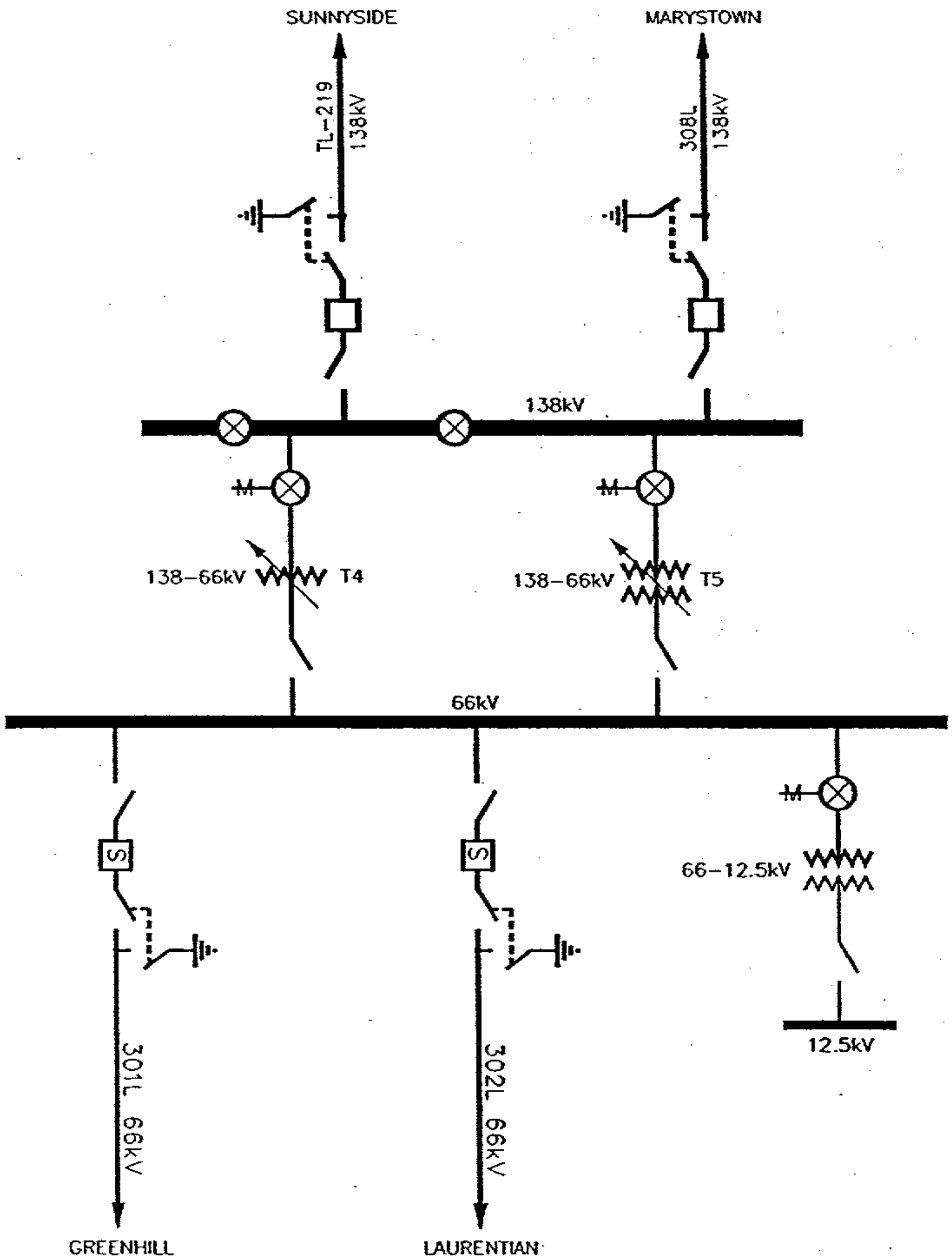
Customer Demand and Energy Growth
Burin Area

Customer Demand and Energy Growth
Burin Area

	1990	1995	2001
Customers	10,519	11,165	11,275
Energy Sales (MWH)	249,237	241,522	239,620
Peak Demand (kVa)	65,720	60,334	59,675

Appendix 6

Existing and Proposed Single Line Diagrams
Salt Pond Substation



SINGLE LINE DIAGRAM

NEWFOUNDLAND POWER
A FORTIS COMPANY

PROVINCE OF NEWFOUNDLAND
PERMIT HOLDER
This Permit Allows
NEWFOUNDLAND POWER INC.
To practice Professional Engineering
in Newfoundland and Labrador.
Permit No. as issued by APEGN P0080
which is valid for the year 2001.

SALT POND (SPT) Proposed

Date:	
App:	SLD No.

Appendix 7

Photograph of Greenhill Gas Turbine


23. 5. 2002