Report-BCTC-R009E

Expected Energy Not Served (EENS) Study for Vancouver Island Transmission Reinforcement Project

(Part V: Monthly Reliability Profile of VITR)

January 24, 2006

Prepared by

Wenyuan Li
System Planning and Performance Assessment
British Columbia Transmission Corporation

DISCLAIMER

This report was prepared by BCTC solely for the purposes described in this report, and is based on information available to BCTC as of the date of this report. Accordingly, this report is suitable only for such purposes, and is subject to any changes arising after the date of this report. Unless otherwise expressly agreed by BCTC, BCTC does not represent or warrant the accuracy, completeness or usefulness of this report, or any information contained in this report, for use or consideration by any third party, nor does BCTC accept any liability out of reliance by a third party on this report, or any information contained in this report, or for any errors or omissions in this report. Any use or reliance by third parties is at their own risk.

COPYRIGHT NOTICE

January 24, 2006

Expected Energy Not Served (EENS) Study for Vancouver Island Transmission Reinforcement Project
(Part V: Monthly Reliability Profile of VITR)
(Executive Summary)

by Wenyuan Li
System Planning and Performance Assessment
British Columbia Transmission Corporation

A report titled "Reliability Evaluation of Three Scenarios for Vancouver Island Power Supply – An Expected Energy Not Served (EENS) Study" was released for the VIGP project in June 11, 2003 [1]. In that report, three scenarios of VIGP (Portfolio 2), 230 kV line and HVDC life extension were evaluated and compared. Based on various technical studies and the VIGP hearing, it was decided to go ahead with the 230 kV line project, which is now called Vancouver Island Transmission Reinforcement (VITR).

The annual EENS index of the VITR project for Vancouver Island supply was assessed and compared with that of other scenarios (doing nothing, HVDC light proposed by Sea Breeze and continuous use of the existing HVDC) in Parts I, II, and IV of the report respectively.

This report (Part V) provides monthly EENS profiles of the VITR project for Vancouver Island power supply. It demonstrates how the EENS index changes in different months and how the monthly peak load level and EENS index are correlated.

The findings are summarized in the following tables and figures. The normalized EENS or normalized peak load refers to a monthly value divided by the maximum monthly value.

Table 1 Monthly EENS
(for 2008 load level)

Month	EENS (MWh/month)	% in annual EENS
Jan	520.09	18.12%
Feb	409.08	14.25%
Mar	285.90	9.96%
Apr	162.71	5.67%
May	91.60	3.19%
Jun	65.25	2.27%
Jul	70.39	2.45%
Aug	72.11	2.51%
Sep	118.40	4.13%
Oct	207.48	7.23%
Nov	368.83	12.85%
Dec	498.16	17.36%

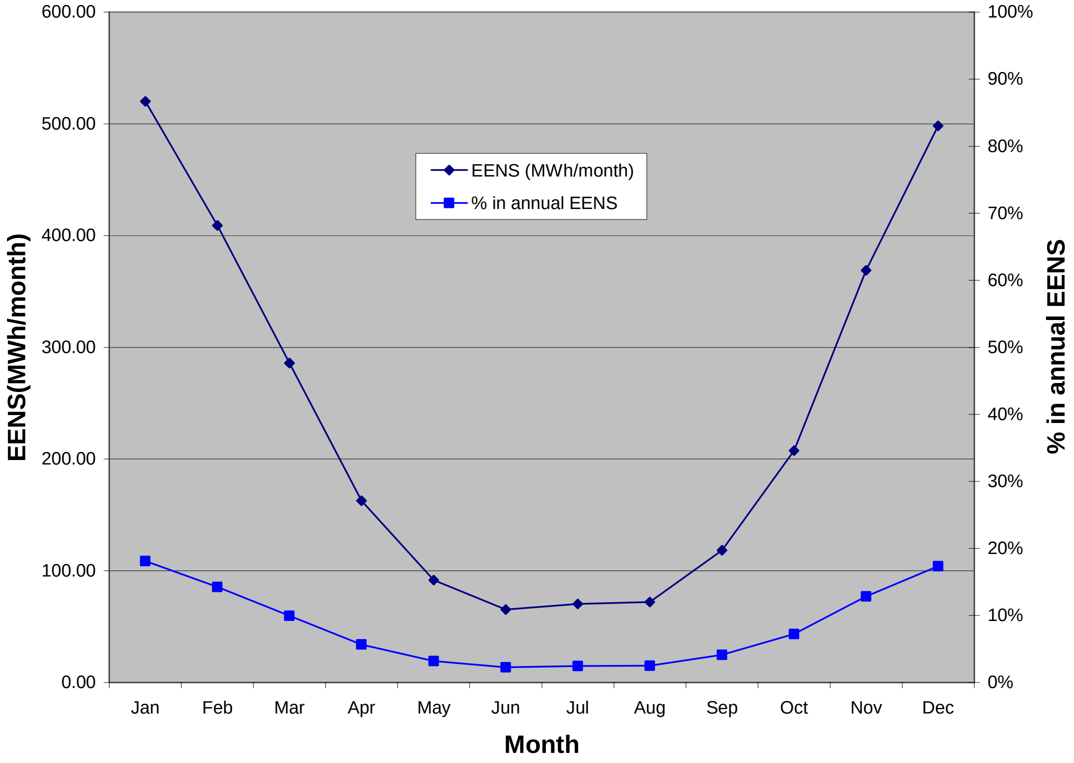

Figure 2 Monthly EENS profile

Table 2 Normalized EENS (%) versus normalized peak load (%)

Month	Normalized EENS (%)	Normalized peak Load (%)
Jan	100.00%	100.00%
Feb	78.66%	88.00%
Mar	54.97%	79.80%
Apr	31.29%	75.80%
May	17.61%	64.50%
Jun	12.55%	76.50%
Jul	13.53%	59.50%
Aug	13.86%	60.20%
Sep	22.77%	84.90%
Oct	39.89%	78.90%
Nov	70.92%	88.00%
Dec	95.78%	90.00%

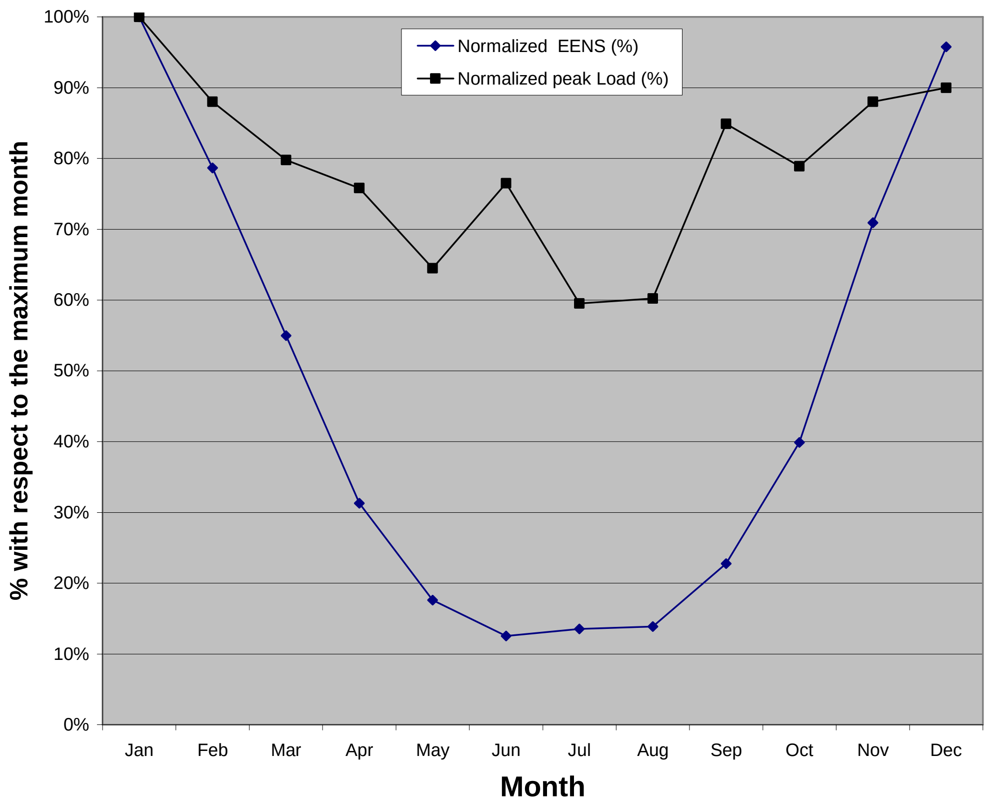

Figure 3 Normalized EENS (%) versus normalized peak load (%)

The following observations can be made:

- The profile of the EENS is quite much varied from January to December. The largest EENS value occurs in January and the smallest EENS value in June. The difference between the two is 8 times.
- There is a tight correlation between the monthly peak load and EENS index. However, it is a non-linear relationship. The EENS drops much more as the monthly peak load drops in terms of a percentage except for December. The exception is because of a more flat load curve shape in December.
- The lowest monthly peak load (in July) and the smallest monthly EENS index (in June) do not occurs in the same month but have one month shift. This is due to the fact that the EENS is impacted not only by the monthly peak load but also by the monthly load curve shape. It is because of the same reason that the EENS indices are different in February and November although the monthly peak load is the same in the two months.

January 24, 2006

Expected Energy Not Served (EENS) Study for Vancouver Island Reinforcement Project
(Part V: Monthly Reliability Profile of VITR)

by Wenyuan Li
System Planning and Performance Assessment
British Columbia Transmission Corporation

1. Introduction

A report titled “Reliability Evaluation of Three Scenarios for Vancouver Island Power Supply – An Expected Energy Not Served (EENS) Study” was released for the VIGP project in June 11, 2003 [1]. In that report, three scenarios of VIGP (Portfolio 2), 230 kV line and HVDC life extension were evaluated and compared. Based on various technical studies and the VIGP hearing, it was decided to go ahead with the 230 kV line option, which is now called Vancouver Island Transmission Reinforcement (VITR).

The annual EENS index of the VITR project for Vancouver Island supply was assessed and compared with that of other scenarios (doing nothing, HVDC light proposed by Sea Breeze and continuous use of the existing HVDC) in Parts I, II, and IV of the report respectively. This part of the report provides monthly EENS profiles of the VITR project for Vancouver Island power supply. The purpose is to demonstrate how the EENS index changes in different months and how the monthly peak load level and EENS index are correlated.

The load level of Vancouver Island in 2008 is used in the study. The 8760 hourly load records in 2004 are used to model shapes of monthly load curves.

2. Method, Computing Tool and Model

The method used to conduct monthly EENS studies is the same as that in Part I of the report [2]. The computing tool used in the study is still the MCGSR program. The EENS evaluation model for Vancouver Island power supply is shown in Figure 1.

12 monthly load curves are first created using the annual peak load of Vancouver Island in 2008 and an annual load curve shape that is based on 8760 hourly load records in 2004. Then the monthly EENS indices are evaluated using individual monthly load curves. Each monthly load curve is modeled using 15-step load levels. The number of samples used in the study was 100,000 for each load level in the 15-step model.

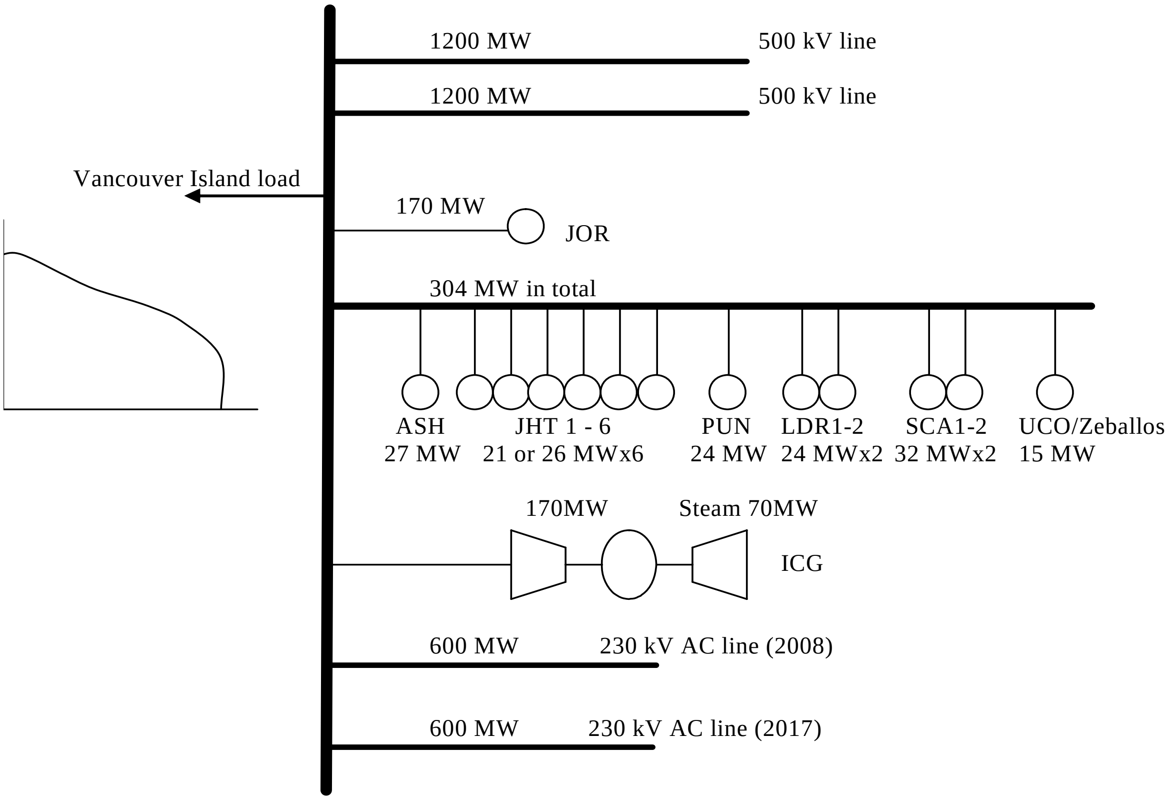

Figure 1 EENS Evaluation Model for Vancouver Island supply

3. Data

3.1 Failure data

The failure data for the 500 kV lines and on-Island generating units were based on historical failure records. The failure data for a new 230 kV AC line includes two portions for overhead line and submarine cable. The failure data for the overhead portion were based on the average of existing 230 kV lines in the BC Hydro system, which were obtained from BCTC's CROW (Control Room Operations Window) system. The failure data for the submarine cable were based on an engineering estimate. This is a relatively pessimistic estimate since the repair time is assumed to be 3 months (2190 hours) considering that repair activities under water will be extremely difficult. The failure data of the phase shift transformer (PST) that is in series with the 230 kV line is based on historical failure records of the PST on 2L112 in the HC Hydro system. These data are the same as those used in Part I of the report [2] and are given in Appendix A and B.

3.2 Load data

The peak load used in the study was based on the most recent Vancouver Island peak load forecast for 2008/09. The 8760 hourly load records in 2004 were used to model the 12 monthly load curve shapes. The peak load forecast and the total VI generation MW are given in Appendix C.

4. Study Conditions

The study conditions are the same as those in Part I of the report. The following are four major assumptions.

- Only the 2008/09 load level is considered.

- HVDC was not included in the model since HVDC is considered to be zero capacity from 2007 (retired) from a planning viewpoint.

- The phase shifting transformer (PST) was modeled by assuming that it is in series with the 230 kV line and no bypass operation for the PST. This is a pessimistic assumption because in real life, when the PST fails, it can be bypassed and the 230 kV line will continue to supply in most cases according to the design.

- The capacity of two 500 kV lines is assumed to be the continuing rating (1200 MW). A short time (2 hours) overloading capacity (1300 MW) is not considered since the repair time used in the simulation (138 hours) is much longer than 2 hours. In other words, considering a 100 MW higher capacity for only 2 hours will not have effective impacts on the results for one year's simulation.

5. Monthly profiles of EENS

The monthly EENS indices of the VITR project for Vancouver Island power supply in the 2008/09 load level are summarized in Table 1 and depicted in Figure 2. The percentages of EENS indices normalized by its maximum monthly value versus the percentages of peak loads normalized by the annual peak load are given in Table 2 and shown in Figure 3.

The following observations can be made:

- The profile of the EENS is quite much varied from January to December. The largest EENS value occurs in January and the smallest EENS value in June. The difference between the two is 8 times.
- There is a tight correlation between the monthly peak load and EENS index. However, it is a non-linear relationship. The EENS drops much more as the monthly peak load drops in terms of a percentage except for December. The exception is because of a more flat load curve shape in December.
- The lowest monthly peak load (in July) and the smallest monthly EENS index (in June) do not occurs in the same month but have one month shift. This is due to the fact that the EENS is impacted not only by the monthly peak load but also by the monthly load curve shape. It is because of the same reason that the EENS indices are different in February and November although the monthly peak load is the same in the two months.

Table 1 Monthly EENS
(for 2008 load level)

Month	EENS (MWh/month)	% in annual EENS
Jan	520.09	18.12%
Feb	409.08	14.25%
Mar	285.90	9.96%
Apr	162.71	5.67%
May	91.60	3.19%
Jun	65.25	2.27%
Jul	70.39	2.45%
Aug	72.11	2.51%
Sep	118.40	4.13%
Oct	207.48	7.23%
Nov	368.83	12.85%
Dec	498.16	17.36%

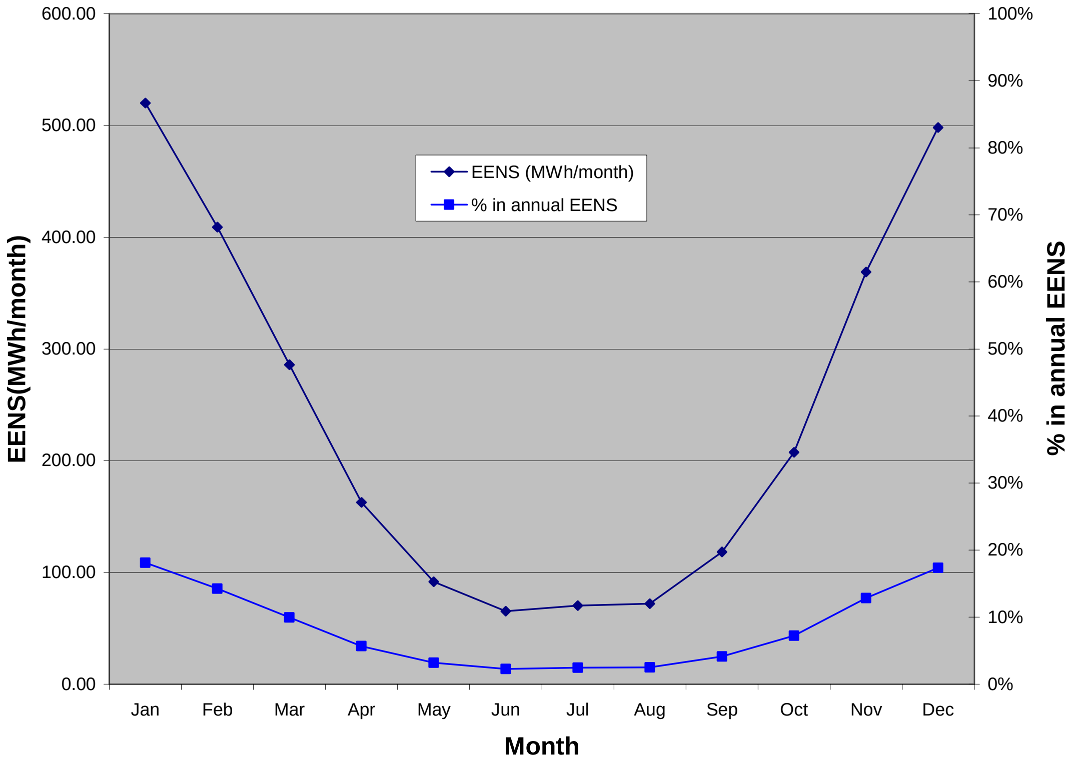

Figure 2 Monthly EENS profile

Table 2 Normalized EENS (%) versus normalized peak load (%)

Month	Normalized EENS (%)	Normalized peak Load (%)
Jan	100.00%	100.00%
Feb	78.66%	88.00%
Mar	54.97%	79.80%
Apr	31.29%	75.80%
May	17.61%	64.50%
Jun	12.55%	76.50%
Jul	13.53%	59.50%
Aug	13.86%	60.20%
Sep	22.77%	84.90%
Oct	39.89%	78.90%
Nov	70.92%	88.00%
Dec	95.78%	90.00%

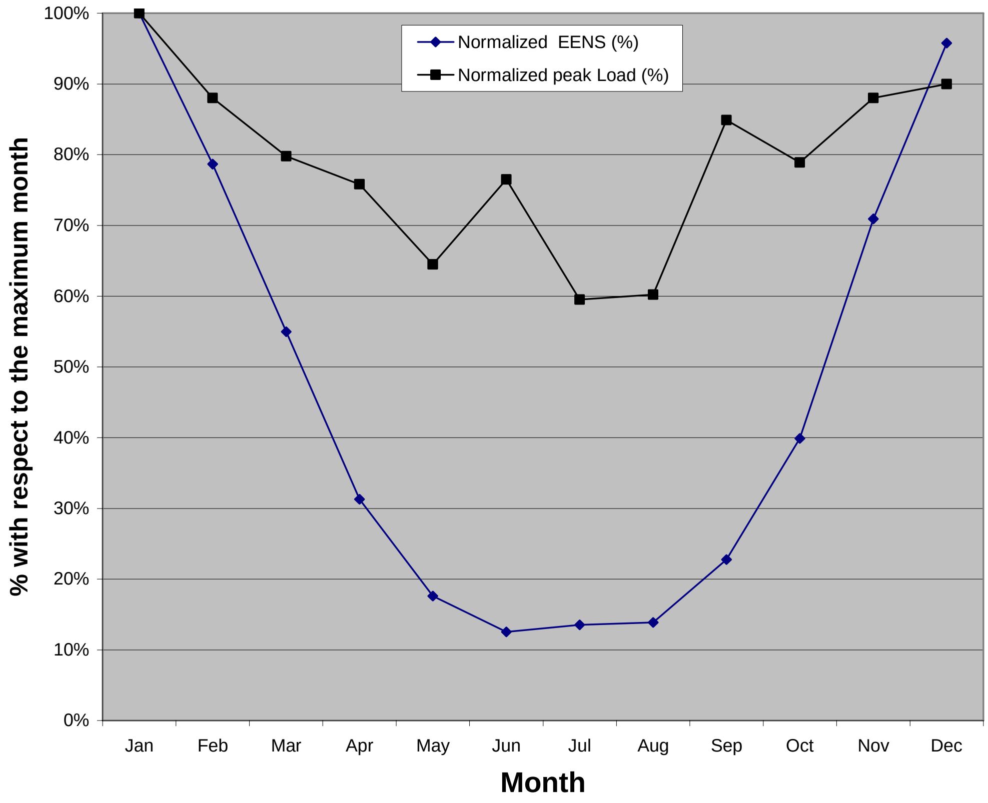

Figure 3 Normalized EENS (%) versus normalized peak load (%)

6. Conclusions

This report provides monthly EENS profiles of the VITR project for Vancouver Island power supply. It demonstrates how the EENS index changes in different months and how the monthly peak load level and EENS index are correlated.

The results indicate:

- The profile of the EENS is quite much varied from January to December. The largest EENS value occurs in January and the smallest EENS value in June. The difference between the two is 8 times.
- There is a tight correlation between the monthly peak load and EENS index. However, it is a non-linear relationship. The EENS drops much more as the monthly peak load drops in terms of a percentage except for December. The exception is because of a more flat load curve shape in December.
- The lowest monthly peak load (in July) and the lowest EENS index (in June) do not occurs in the same month but have a one month shift. This is due to the fact that the EENS is impacted not only by the monthly peak load but also by the monthly load curve shape. It is due to the same reason that the EENS indices are different in February and November although the monthly peak load is the same in the two months.

References

[1] BCTC Report, *Reliability Evaluation of Three Scenarios for Vancouver Island Power Supply – an Expected Energy Not Served (EENS) Study*, filed to BCUC in June 2003

[2] BCTC Report, *Expected Energy Not Served (EENS) Study for Vancouver Island Transmission Reinforcement Project - (Part I: Reliability Improvements due to VITR),* December 8, 2005

Appendix A: Local Generating Unit Reliability Data

Generating unit	Capacity (MW)	FOR	Repair time (hrs)
ASH	27	0.004	15.35
JHT-1	21 *	0.0795	926.51
JHT-2	21 *	0.0008	2.31
JHT-3	21 *	0.003	36.32
JHT-4	21 *	0.0026	7.84
JHT-5	21 *	0.0096	28.70
JHT-6	21 *	0.0003	3.77
PUN	24	0.0010	13.74
LDR-1	24	0.0063	19.15
LDR-2	24	0.0026	6.60
SCA-1	32	0.0027	5.33
SCA-2	32	0.0218	28.26
UCO/Zeballos	15	0.004	15.35
JOR	170	0.0124	5.99
ICG	240	0.1065 **	50.30 **
Total	714		

Note:

1. The reliability data for the local hydro generating units are based on historical outage records. These data are the same as those used in the following previous reports:

[1] BC Hydro technical report, “Reliability Assessment of Vancouver Island Supply 2000/01”, Section 3 of “Vancouver Island Operation Plan 2000/01” produced by NOS (Network Operation Services), Grid Operation Division, BC Hydro, January 15, 2001
[2] BC Hydro technical, “Reliability Assessment for Vancouver Island Supply Options”, produced by NPP (Network Performance Planning), BC Hydro, December, 2001
[3] BC Hydro technical report, “Probabilistic & Economic Assessment of HVDC Short-term Investment Strategies”, produced by NOS (Network Operation Services), Grid Operation Division, BC Hydro, June 2002

2. * The 6 units at JHT are assumed to increase their capacity by 5 MW each by 2009/2010.
3. ** The failure data for the ICG are based on historical statistics from the NERC database for combined cycle turbine units from 1977 to 2001. The raw data can be found at http://www.nerc.com/~filez/gar.html. The breakdown of forced and planned failure data is as follows:

Unit	Capacity (MW)	Unavailability		Failure Frequency (f/year)		Repair time (hrs)	
		Forced	Planned	Forced	Planned	Forced	Planned
ICG	240	0.03238	0.07407	13.22	5.32	21.46	122.0

Appendix B: 500 kV Line and 230 kV Line Reliability Data

Line	Capacity (MW)	FOR	Repair time (hrs)
500 kV line	1200	0.0293	137.81
500 kV line	1200	0.0293	137.81
230 kV line	600	0.0259	383.74
Second 230 kV line	600	0.0259	383.74
Phase shift transformer	600	0.000116	3.06
Common cause failure of two 500 kV lines		0.0004	2.98

Note:

1. The reliability data for the 500 kV lines (including the common cause failure data) are the same as those used in the following previous reports:

[1] BC Hydro technical report, “Reliability Assessment of Vancouver Island Supply 2000/01”, Section 3 of “Vancouver Island Operation Plan 2000/01” produced by NOS (Network Operation Services), Grid Operation Division, BC Hydro, January 15, 2001
[2] BC Hydro technical, “Reliability Assessment for Vancouver Island Supply Options”, produced by NPP (Network Performance Planning), BC Hydro, December, 2001
[3] BC Hydro technical report, “Probabilistic & Economic Assessment of HVDC Short-term Investment Strategies”, produced by NOS (Network Operation Services), Grid Operation Division, BC Hydro, June 2002

2. The common cause failure of two 500 kV lines refers to their simultaneous outage due to a common cause (lightning and terminal breaker failures).

3. The failure data of phase shift transformer is based on historical failure records of the PST on 2L112 in the HC Hydro system. There were only 5 forced failures with a total of outage duration of 15.28 hours in the past 15 years since it was in service in 1990. This translates into the unavailability (FOR) of 0.000116, a forced failure frequency of 0.3333 failures /year and the repair time of 3.06 hours/repair.

4. The reliability data for the overhead portion of the new 230 kV line is based on the average of historical records of 230 kV lines in the BC Hydro system. The reliability data for the submarine portion is estimated as failure frequency=1/10 years and average repair time = 3 months. The total equivalent reliability data are calculated as follows (planned outage not considered):

Submarine portion:

f(cable)=1/10 years=0.1 f/year   r(cable)=3 months =2190 hrs
FOR(cable)=f(cable)∗r(cable)/8760 =0.025

Overhead portion- Line-related failure

f1=0.6945 /year/ 100 km*40 km=0.2778/year r1=16.85 hours

Overhead portion- terminal-related failure

f2=0.2136 r2=16.40 hours

Overhead portion – total

f(overhead)=0.2778+0.2136=0.4914
r(overhead) = Σfr/Σf = (0.2778*16.85+0.2136*16.40)/(0.4914)=16.65

FOR(overhead)=f(overhead)*r(overhead)/8760 = 0.00093

The total reliability data for the new 230 kV line is estimated as:

FOR(total) = FOR(cable) +FOR(overhead) – FOR(cable)*FOR(overhead)

= 0.025+0.00093-0.025*0.00093 =0.02591

f(total) = 0.1+0.4914=0.5914

r(total) = FOR(total)*8760/f(total) = 0.02591*8760/0.5914 = 383.74 hours

Appendix C: Load forecast and resources balance for 2005/06 to 2025/26

Vancouver Island Demand and Resource Balance

(Based on the BC Hydro Dec 2005 load forecast)

	VI Demand	VI Dep_Gen*	500 kV	HVDC	1st cct	2nd cct	Balance
	MW	MW	MW	MW	MW	MW	MW
05/06	2318	698	1300	240			-80
06/07	2349	714	1300	240			-95
07/08	2370	714	1300				-355
08/09	2397	714	1300		600		217
09/10	2425	744	1300		600		219
10/11	2454	744	1300		600		190
11/12	2470	744	1300		600		174
12/13	2498	744	1300		600		146
13/14	2531	744	1300		600		113
14/15	2561	744	1300		600		83
15/16	2589	744	1300		600		55
16/17	2628	744	1300		600		16
17/18	2668	744	1300		600	600	576
18/19	2710	744	1300		600	600	534
19/20	2753	744	1300		600	600	491
20/21	2800	744	1300		600	600	444
21/22	2847	744	1300		600	600	397
22/23	2892	744	1300		600	600	352
23/24	2937	744	1300		600	600	307
24/25	2983	744	1300		600	600	260
25/26	3030	744	1300		600	600	214

* The VI dependable generations are assumed to be same as the previous (NITS2004 dependable resource).