Q. Please state whether Newfoundland and Labrador Hydro has established, mathematically, that a standard of 2.8 hours of unserved load, per year, yields the same generation capacity planning as a "one event in five years" reliability criterion.

A. Hydro established, through a calibration process, that a standard of 2.8 hours of unserved load per year yields the same generation capacity planning as a "one event in five years" reliability criterion.

The basis of the current "one event in five years" reliability criterion is a report, *Recommended Loss of Load Probability (LOLP) Index for Establishing Generation Reserve Additions – System Planning Department – Newfoundland and Labrador Hydro – May 16, 1977* (see PUB-NLH-118 - Attachment 1). In that report, an LOLP of 0.2 days per year, or one day in five years was recommended. An LOLE (Loss of Load Expectation) of 0.2 days per year was subsequently adopted as the reliability criterion in the SYPCO generation planning software that Hydro used, at the time. (SYPCO used LOLE as its reliability criterion). In 1997, when Hydro replaced the SYPCO generation planning software with ProScreen II (now renamed Strategist) generation planning software, it was necessary to switch to a LOLH (Loss of Load Hours) criterion.

A study was carried out (see PUB-NLH-122 Attachment 1) and it was established that using a reliability criterion of an LOLH of 2.8 hours per year in ProScreen II was equivalent to using a reliability criterion of an LOLE of 0.2 days per year in SYPCO, given Hydro's system and how it was modelled in ProScreen II.

The study demonstrated that with Hydro's existing system, at that time, an LOLE of 0.2 days per year was reached at a peak load of 1,546 MW. A number of cases with different modelling choices within ProScreen II were considered and the LOLH for each of them calculated at a peak load of 1,546 MW (see LOLH versus Peak graph in Attachment 1). An evaluation of the expansion plans for each case, for two alternative forecast scenarios was also considered, and found to be similar.
In the end, the study recommended that:

> [T]he modelling of the System reflect the changes involving (i) hydroelectric unit deration, (ii) the use of emergency energy and (iii) run-of-the-river plants be accepted since they represent the actual mode of operation of the System. It becomes an arbitrary choice as to which probability method to approximate the equivalent load duration curve should be used. Therefore, our evaluation considered the cumulative effect of these three changes with either probability method. Thus, when the default cumulants method is used, the reliability criteria is expressed as 2.07 hours/year.

Using the mixture of normals method, the study indicated that the reliability criteria would be expressed as 2.81 hours/year.

The cumulants method used less computing time, while the mixture of normals method was more accurate (See Attachment). In Hydro's case, the additional computing time to use the mixture of normals method was negligible. Therefore, while it was not indicated in the study, the 2.81 LOLH (now expressed as 2.8) criterion was chosen, using the mixture of normals method, and both the mixture of normals method and the 2.8 LOLH are currently used in Strategist.

HYDRO

INTEROFFICE MEMORANDUM

DATE: February 2, 1998

MEMO TO: Keith Boone

FROM: Ken Hayward

SUBJECT: LOLH Criteria Evaluation

This memo briefly explains the process used in evaluating the ways of expressing our new LOLH criteria (hours/year) in PROSCREEN II that is equivalent to the LOLE of 0.2 days/year which was used in SYPCO.

In early 1997, during the benchmarking process, SYPCO showed that the existing System established a peak of 1,546.05 MW that exactly matches Hydro's reliability criteria of 0.2 days/year. For this peak, the equivalent reliability criteria in PROSCREEN II was 98.08 hours/year. Since then, we have become more familiar with the PROSCREEN II model and have incorporated a number a changes that reflect more accurately the way Hydro operates its system. This evaluation considered the additive effect of these changes on system modelling.

The first change was to accomodate the Forced Outage Rates for hydroelectric units. To do this, hydroelectric units had to be derated by their Forced Outage Rates. This caused a slight change in the equivalent reliability criteria to 98.06 hours/year.

In the system modelling process, PROSCREEN II provides the user with various options that impact reliability criteria. Our analysis evaluated three options which are (a) emergency use of hydro, (b) probability method to approximate the equivalent load duration curve, and (c) dispatch of hydro units.

PROSCREEN II allows for choice in whether or not unutilized hydroelectric capacity is used to offset emergency energy requirements. If the change was made to allow unutilized hydro capacity to offset emergency energy, our reliability criteria is expressed as 0.58 hours/year.

There are two probability methods to approximate the equivalent load duration curve in PROSCREEN II; the *cumulants method* or the *mixture of normals method*. The cumulants method is a very fast and reliable method of approximating the effects of random outages for medium- or larger-sized utilities. The mixture of normals method is a more accurate way but the approximation requires more computing time. For our system, the difference in time requirements between the two methods is unnoticeable! The default method was the cumulants method. Thus, when a change was made to use the mixture of normals method, along with the other changes discussed above, the reliability criteria is expressed as 1.01 hours/year.

Up to this point, our modelling had assumed that all hydro plants were dispatchable. To more accurately model the System, small hydro units, (ie., Paradise River, Snook's Arm and Venam's Bight and customer's hydro units) should be modelled as run-of-the-river units. With the additive effect of this change, the reliability criteria is expressed as 2.81 hours/year.

We reccommend that the modelling of the System reflect the changes involving (i) hydroelectric unit deration, (ii) the use of emergency energy and (iii) run-of-the-river plants be accepted since they represent the actual mode of operation of the System. It becomes an arbitrary choice as to which probability method to approximate the equivalent load duration curve should be used. Therefore, our evaluation considered the cumulative effect of these three changes with either probability method. Thus, when the default cumulants method is used, the reliability criteria is expressed as 2.07 hours/year.

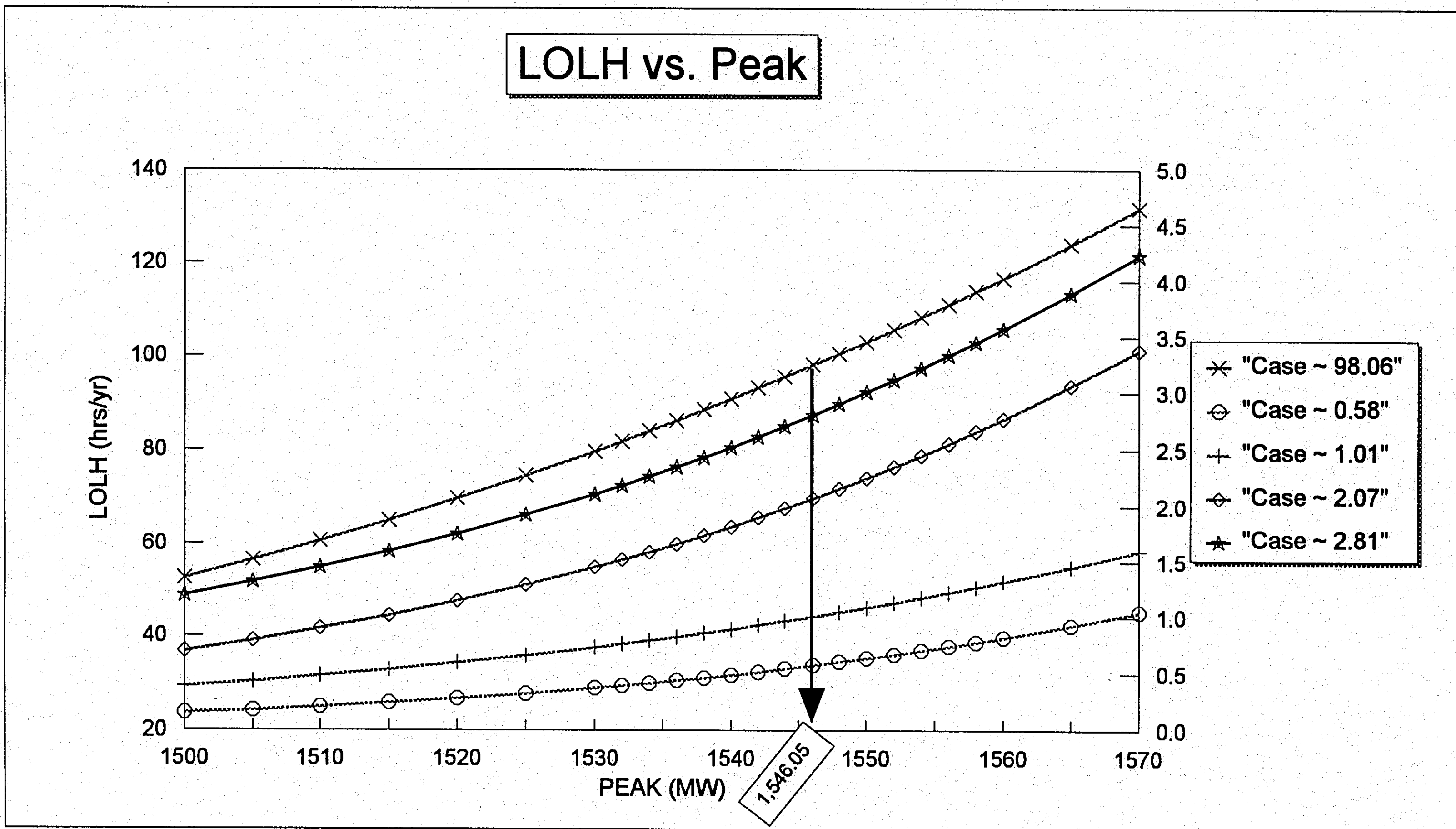
Attached is a graph plotting LOLH (hours/year) versus System Peak (MW) for the cases evaluated.

A generation expansion was also carried out using each of the above LOLH criteria for two forecast scenarios; impacts of Voisey's Bay smelter included and not included. The attached tables show the results from both SYPCO and PROSCREEN II. Please recall that unlike SYPCO, PROSCREEN II provides the optimized placement of new generation plant. From the tables, it can be seen that the generation plans for either expression of LOLH criteria are similar.

At your convenience, let's get together to discuss this analysis in more detail and come to an agreement as to which LOLH criteria should be adopted for generation planning purposes.

Ken Hayward, Planning Engineer
Generation and Rural

kh
cc H. Budgell


LOLH vs. Peak
140
120
100
80
60
40
20
LOLH (hrs/yr)
1500
1510
1520
1530
1540
1550
1560
1570
PEAK (MW)
1,546.05
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
"Case ~ 98.06"
"Case ~ 0.58"
"Case ~ 1.01"
"Case ~ 2.07"
"Case ~ 2.81"

Evaluation of LOLH Equivalency

Forecast without Voisey's Bay

Year	SYPCO Expansion Plan	SYPCO Percent Reserve	MAX. LOLH = 98.06 hr/yr Expansion Plan	MAX. LOLH = 98.06 hr/yr Percent Reserve	MAX. LOLH = 0.58 hr/yr Expansion Plan	MAX. LOLH = 0.58 hr/yr Percent Reserve	MAX. LOLH = 1.01 hr/yr Expansion Plan	MAX. LOLH = 1.01 hr/yr Percent Reserve	MAX. LOLH = 2.81 hr/yr Expansion Plan	MAX. LOLH = 2.81 hr/yr Percent Reserve	MAX. LOLH = 2.07 hr/yr Expansion Plan	MAX. LOLH = 2.07 hr/yr Percent Reserve
			# *Same as Base Case*		# *Emergency energy offset by unutilized capacity.*		# *Emergency energy offset by unutilized capacity.* # *Probability method to approximate ELDC changed to mixture of normals method*		# *Emergency energy offset by unutilized capacity.* # *Probability method to approximate ELDC changed to mixture of normals method* # *Run - of - the - River' plants*		# *Emergency energy offset by unutilized capacity.* # *Run - of - the - River' plants*	
2000		23.0		21.8		21.8		21.8		21.8		21.8
2001		21.5	GC	23.0	GC	23.0	GC	23.0	GC	23.0	GC	23.0
2002		19.8		21.2		21.2		21.2		21.2		21.2
2003	GC	20.5		19.3		19.3		19.3		19.3		19.3
2004		19.0	IP	19.9		17.8	IP	19.9	IP	19.9	IP	19.9
2005	IP+55HW	22.8		18.3	IP+55HW	21.6		18.3		18.3		18.3
2006		20.8	CC00	28.2		19.6	CC00	26.4	CC00	26.4	CC00	26.4
2007	CC00	28.4		24.0	CC00	27.2		24.0		24.0		24.0
2008		26.1		21.8		24.9		21.8		21.8		21.8
2009		24.0		19.8		22.9		19.8		19.8		19.8
2010		22.3		18.1		21.2		18.1		18.1		18.1
2011		20.4		16.3		19.3		16.3		16.3		16.3
2012		18.6		14.5		17.5		14.5		14.5		14.5
2013	55ST	19.3		12.5		15.4	55HW	15.4	55HW	15.4	55HW	15.4
2014	55NW	20.8	55HW	14.0	55ST	16.8	55ST	16.8	55ST	16.8	55ST	16.8
2015		18.8		12.2	55NW	17.8		15.0		15.0		15.0
2016	55NW	20.3		10.8		16.4	CCG1	22.3	CCG1	22.3	CCG1	22.3
2017	CCG1	27.3	CCG1	18.0	CCG1	23.6		20.8		20.8		20.8
2018		25.8		16.6		22.1		19.4		19.4		19.4
2019		24.3		15.3		20.7		18.0		18.0		18.0
2020		22.9		13.9		19.3		16.6		16.6		16.6
2021		21.4		12.6		17.8		15.2		15.2		15.2
2022		20.0		11.2		16.4		13.8		13.8		13.8
2023		18.5		9.9		15.0	55NW	15.0		12.5	55NW	15.0
2024	55NW	19.7	55ST	11.2	CCG2	21.5	CCG2	21.5	55NW	13.7	CCG2	21.5
2025		18.3	HLRD	16.3		20.1		20.1	CCG2	20.1		20.1
2026	55NW	19.3		14.9		18.6		18.6		18.6		18.6
2027		17.9		13.6		17.3		17.3		17.3		17.3
2028	HLRD+55NW	25.2		12.2		15.9		15.9		15.9		15.9
2029		23.8		10.9		14.5		14.5		14.5		14.5
2030		22.3		9.6	55NW	15.5		13.1		13.1		13.1
PW	N/A		1,875.1		1,903.9		1,902.3		1,899.0		1,896.5	

Note: Peaking plant assumed in-service on January 1; Energy plant assumed in-service on November 1.

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Evaluation of LOLH Equivalency
Forecast with Voisey's Bay

	SYPCO		MAX. LOLH = 98.06 hr/yr		MAX. LOLH = 0.58 hr/yr		MAX. LOLH = 1.01 hr/yr		MAX. LOLH = 2.81 hr/yr		MAX. LOLH = 2.07 hr/yr	
Year	Expansion Plan	Percent Reserve	Expansion Plan	Percent Reserve	Expansion Plan	Percent Reserve	Expansion Plan	Percent Reserve	Expansion Plan	Percent Reserve	Expansion Plan	Percent Reserve
			# *Same as Base Case*		# *Emergency energy offset by unutilized capacity.*		# *Emergency energy offset by unutilized capacity.* # *Probability method to approximate ELDC changed to mixture of normals method*		# *Emergency energy offset by unutilized capacity.* # *Probability method to approximate ELDC changed to mixture of normals method* # *Run - of - the - River' plants*		# *Emergency energy offset by unutilized capacity.* # *Run - of - the - River' plants*	
2000	CC00	19.9	GC+CC00	21.2	GC+CC00	21.2	GC+CC00	21.2	GC+CC00	21.2	GC+CC00	21.2
2001	55HW	21.8		19.9		19.9		19.9		19.9		19.9
2002	GC	22.6		18.4	IP	20.3		18.4		18.4		18.4
2003		20.8	IP	18.6		18.6	IP	18.6	IP	18.6	IP	18.6
2004	IP	21.5		17.4		17.4		17.4		17.4		17.4
2005		19.9	55HW	18.8	55HW	18.8	55HW	18.8	55HW	18.8	55HW	18.8
2006	HLRD	25.8	HLRD	24.7	HLRD	24.7	HLRD	24.7	HLRD	24.7	HLRD	24.7
2007		23.6		22.6		22.6		22.6		22.6		22.6
2008		21.6		20.5		20.5		20.5		20.5		20.5
2009		19.8		18.8		18.8		18.8		18.8		18.8
2010	55ST	21.0		17.3	55ST	20.0		17.3		17.3		17.3
2011		19.3		15.6		18.3	55ST	18.3	CCG1	24.0	55ST	18.3
2012	55NW	20.4	CCG1	22.3		16.7	CCG1	25.1		22.4	CCG1	25.1
2013	CCG1	26.6		20.3	CCG1+55NW	25.6		23.0		20.3		23.0
2014		25.2		19.0		24.2		21.6		19.0		21.6
2015		23.4		17.3		22.5		19.9		17.3		19.9
2016		21.9		15.8		20.9		18.4		15.8		18.4
2017		20.4		14.4		19.5		16.9		14.4		16.9
2018		18.9		13.0		18.0		15.5	55ST	15.5		15.5
2019	55NW	19.9		11.6		16.6	CCG2	21.7		14.1	55NW	16.6
2020	55NW	20.9		10.3		15.2		20.3	55NW	15.2		15.2
2021		19.5	55ST	11.4	55NW	16.2		18.8		13.8	55NW	16.2
2022	55NW	20.5		10.1	55NW	17.2		17.5	55NW	14.9	CCG2	22.2
2023		19.1	55NW	11.2		15.9		16.1		13.5		20.8
2024	CCG2+55NW	27.2	CCG2	17.1	CCG2	21.7		14.8	CCG2	19.4		19.4
2025		25.8		15.8		20.4		13.5		18.1		18.1
2026		24.4		14.5		19.0	55NW	14.5		16.8		16.8
2027		23.0		13.2		17.7		13.2		15.5		15.5
2028		21.7		12.0		16.4	55NW	14.2		14.2		14.2
2029		20.6		11.0		15.4		13.2		13.2		13.2
2030	55NW	21.6		9.9		14.3	55NW	14.3		12.1	55NW	14.3
PW	N/A		2,776.8		2,810.1		2,807.2		2,802.0		2,806.0	

Note: Peaking plant assumed in-service on January 1; Energy plant assumed in-service on November 1.

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