

**ALBERTA UTILITIES COMMISSION**  
**Proceeding ID 2581**  
**Review and Variance Applications of Decision 2012-104 Complaint by**  
**Milner Power Inc. Dated August 17, 2005 Regarding Transmission Loss**  
**Factor Rule and Loss Factor Methodology**  
**Related Applications No. 1609554, 1609555, 1609556, 1609557**

**EVIDENCE OF**  
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**ON BEHALF OF**  
**MILNER POWER INC.**

**July 19, 2013**

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# 1 Introduction and Summary

2 This evidence was produced cooperatively by Professor Ross Baldick Ph.D. P.E. and Dr. Steven Stoft  
3 and is intended to be filed with the Alberta Utilities Commission (“Commission”) in Proceeding  
4 2581, on behalf of Milner Power Inc. (“Milner”).

5 Among other things, this evidence addresses the written evidence of the Alberta Electric System  
6 Operator (“AESO”) and the supplemental evidence of the Generator Group (comprised of Capital  
7 Power Corporation, TransAlta Corporation and TransCanada Energy Ltd.), all dated May 27, 2013,  
8 including Appendix 1 to the supplemental evidence of the Generator Group prepared by Dr.  
9 Mobinul Huq.

## 10 1.1 Addressing the Review Panel’s list of applicant objections

11 The essential question for consideration in Proceeding 2581 is whether the hearing panel’s  
12 rejection of MLF/2 was justified. The review panel has helpfully summarized the main objections of  
13 the four review applicants to decision 2012-104.<sup>1</sup> We analyze all four of these objections and find  
14 that:

- 15 • The hearing panel’s analogy not only made sense but was just a simplified view of the ideas it  
16 presented a few pages later with graphs and formulas.

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<sup>1</sup> The review panel stated in Decision 2013-159 at paragraph 30:

30. The review applicants, individually and collectively, assert various grounds in fact and law for the review and variance of the hearing panel’s finding that the 2005 Line Loss Rule does not comply with the 2004 Transmission Regulation. The AESO, for example, claims at paragraphs 13-15 of its review and variance application that the hearing panel committed an error of fact in reaching its determination by virtue of having misunderstood the concept of transmission line losses and the 2005 Line Loss Rule itself. TransAlta Corporation, meanwhile, submits that the hearing panel erred in law by “concluding that economic efficiency is ‘the guiding value’ for market participants” (see TransAlta Corporation’s review and variance application at paragraphs 13-17). The other three review applicants made essentially the same claim. That is, it is alleged that the hearing panel erred in law by placing undue emphasis on economic efficiency relative to other equally important, and statutorily mandated, criteria in interpreting the validity of the 2005 Line Loss Rule. (See, in particular, paragraphs 4-11 of the AESO’s review and variance application, paragraphs 12-16 of TransCanada Energy Ltd.’s review and variance application, and paragraphs 10-12 of Capital Power Corporation’s review and variance application). According to the AESO, the hearing panel also erred in law by confusing the concept of “impact on average system losses” (as prescribed in Section 19 of the 2004 Transmission Regulation) with “average impact on system losses.” (See paragraphs 16-21 of the AESO’s review and variance application. A similar argument is made by TransCanada Energy Ltd. at paragraph 18 of its review and variance application). Capital Power Corporation claims at paragraphs 13-18 of its review and variance application that the hearing panel further erred in law by applying the incorrect legal test in Section 19 of the 2004 Transmission Regulation. In particular, the hearing panel is alleged to have erred in law by adopting a “reasonable man” test instead of the concept of “reasonably recover[ing] the cost of transmission losses” as expressly required by the regulation.

- 1 • The hearing panel did not over-emphasize efficiency, but rather used it appropriately as a  
2 guide to the very principles that the applicants say they favor. These principles are designed to  
3 produce a market that avoids wasting customers' money on inefficient production. The  
4 purported conflict between efficiency and the principles, for example, of cost-causation, non-  
5 discrimination and good market design, is illusory.
- 6 • The one and only time the hearing panel used "average impact" it used it appropriately and  
7 without confusion, which is most likely why the AESO and TransCanada have dropped this  
8 objection from their evidence. A detailed discussion of this point can be found in Appendix A.
- 9 • Capital Power Corporation's attempt to portray Dr. Stoft as supporting MLF/2 is a  
10 mischaracterization.

11 In addition to discussing each of the above points, we also provide a separate analysis showing how  
12 the hearing panel *correctly concluded* that the AESO's MLF/2 approach does not satisfy the  
13 Transmission Regulation's requirement: (a) to base loss factors on each generating unit's  
14 contribution to losses; or, (b) to reasonably recover the cost of transmission line losses.

15 The present evidence should be read in conjunction with Dr. Stoft's earlier evidence in Proceeding  
16 790.

## 17 **1.2 Addressing additional AESO arguments**

18 **Shift Factors.** MLF/2 is simply MLF shifted by a variable amount. So shifting itself is not difficult. But  
19 generators want to know the shift factor in advance, and that requires the use of a true-up  
20 mechanism.

21 **Definition of "Location."** Section 19(1)(a) requires that loss factors be based on each generating  
22 unit's contribution to transmission losses. MLF/2 does not satisfy this, but ILF does. However, if  
23 "location" is defined to be the generator's bus, then our illustrative ILF cannot satisfy Section  
24 19(2)(e), although other variations of ILF can.

25 **Vintaging.** The AESO implies once again that ILF requires vintaging. It does not, and we do not  
26 believe any party in the proceeding has advocated vintaging. Overlapping lock-ins of loss factors  
27 can, however, give rise to a similar, although temporary, effect.

28 **Dispatch Signals and ILF.** Dr. Huq's model is actually a dispatch model, but he uses it to discuss  
29 investment. This is because the same loss factors are optimal for both. It is a standard result that  
30 competitive prices send the right short run and long-run signals. Otherwise competitive markets  
31 would not be efficient. ILF provides the right incentives for both, but MLF/2 provides them for  
32 neither.

33 **Two-Bus Examples.** Although two-bus examples can give misleading results, so can multi-bus  
34 examples. After having problems with its own two-bus examples, the AESO hired Teshmont, which  
35 misinterpreted its own examples. The AESO now asks us to trust it with unspecified complex  
36 models that it interprets for us.

1     **1.3 The Evidence of Dr. Huq**

2           Dr. Huq has taken the proper high-level approach to the analysis of line loss rules, and market  
3           designs in general. He has specified example markets and tested his rule on them to see if it is  
4           efficient. In both of his markets, Case 1 and Case 2, he finds MLF/2 to be efficient. However, Case 1  
5           is so special that it “rarely, if ever” occurs in Alberta according to the evidence in Proceeding 790  
6           and the hearing panel. Moreover, in this case, MLF/2 is mathematically identical to ILF, but only in  
7           this case. In Case 2, Dr. Huq initially got the right answer, which is that MLF/2 is not efficient, but  
8           then assumed the generators would collude perfectly.

9           To build on Dr. Huq’s useful foundation we adopt his model and his method before he veered off  
10          into perfect collusion. We analyze MLF/2, MLF and ILF in his two cases and two, more general,  
11          cases. The result is that ILF is efficient in all four cases and MLF/2 is efficient only in Dr. Huq’s  
12          extremely special Case 1. Interestingly both MLF and MLF/2 are only right when they are  
13          mathematically equivalent to ILF.

## 2 Addressing the Review Panel’s List of Applicant Objections

We will now address each of the main objections of the four review applicants (as listed at paragraph 30 of Decision 2013-159). We will then turn to the essential question of the basis for the hearing panel’s rejection of MLF/2 and whether or not that decision was justified.

### 2.1 Did the hearing panel misunderstand the concept of transmission losses?

Engineers often analogize electrical energy to (litres of) water, and power (the rate of flow of energy) to the rate of flow of water (litres per second). So it is natural for the AESO to think that the litres of water mentioned by the hearing panel represent energy (MWh) and not power or power losses, which are measured in MW. However the analogy actually uses water to represent the available power to customers.

A second confusion apparently stems from the fact that the hearing panel’s litres of water are not losses, but are instead loss reductions. As the panel explains, “When Milner’s last unit of generation **causes a small increase in line losses**, this is analogous to the individual when he **took out the last litre** of water” (emphasis added). But the AESO reads this backwards and says “the example is about how individuals put water (or cause losses) into the reservoir or **take water out of the reservoir (reduce losses)**” (emphasis added).<sup>2</sup> Putting water in is analogous to increasing available power (this should not be so surprising), and increasing available power means reducing and not causing losses (as the AESO knows well). Table 2-1 summarizes:

**Table 2-1.** Water analogy and how power relates to losses

Water in:	More available power:	Reduced losses
Water out:	Less available power:	Increased losses

Moreover, there is a third likely confusion. The lake does not represent only losses, but instead it represents all the power (not energy) available to customers. So the full analogy is simply this:

- The lake = power (in MW) available to customers
- Litres of water = power loss reductions (in MW)

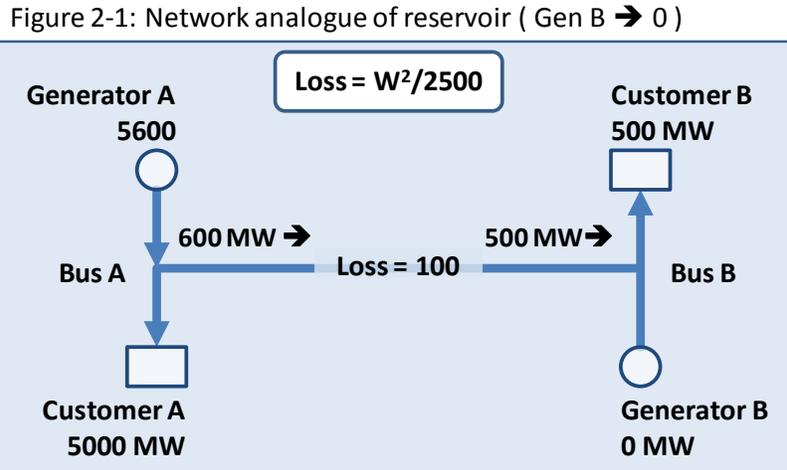
Naturally, adding a litre to the lake increases the lake, just as a “power loss reduction” increases the “power available to customers.”

We will show that this analogy works well to convey some crucial insights, and, indeed, as the hearing panel was careful to say, that was all their analogy was intended to do. Specifically, it shows how a generator that reduces average system losses can be charged by the AESO’s Line Loss Rule for increasing losses. This is the point that the panel referred to in the opening sentence of its decision; this is “The essence of the complaint by Milner Power Inc.” This is also the aspect of the Line Loss Rule that the AESO most wants to hide.

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<sup>2</sup> AESO application for review (1608555) paragraph 14.

1 The hearing panel’s water analogy corresponds closely to a network that is almost the same as they  
 2 show in Figures 1, 2 and 3 of Decision 2012-104. However, in the reservoir analogy, Customer B is  
 3 500 MW instead of 100 MW as in those figures. And Generator B can produce 550 MW instead of  
 4 150 MW.



5 In the water analogy an individual (a generator) “comes along and empties one hundred litres of  
 6 water into the reservoir and then chooses to take out one litre.” As noted above, the one hundred  
 7 litres represents 100 MW of additional power that can be used to serve load. Note that available  
 8 power (water) equals generation minus losses, so the amount of water in the reservoir can be  
 9 affected by changing either generation or losses.

10 At the beginning of the story, Generator B is producing no power. Since there is 500 MW of load at  
 11 the remote bus, there is 500 MW of power flow on the line, which causes the line to heat and use  
 12 up power, which, as the hearing panel explained is the cause of 100 MW of lost power. The formula  
 13 for loss on this particular line is  $W^2/2500$ , and  $500^2/2500 = 100$  MW of loss, and  $W$  = the power  
 14 delivered to load. This is shown in Figure 2-1 above and Table 2-2 below.

**Table 2-2:** Stage 1 of the Reservoir Analogy

Total generation:	5600 MW	(Gen A → 5600, Gen B → 0)
Total losses:	– 100 MW	
Available power:	5500 MW	← How much water is in the reservoir

15 The analogy considers an individual that “comes along and empties one hundred litres of water into  
 16 the reservoir.” This is analogous to Generator B starting up and producing 500 MW of power which  
 17 exactly serves the local load and stops the flow of power over the line from Bus A. Without any  
 18 power flow, the line loss is zero. So the remote generator (besides its contribution of generated  
 19 power) has contributed 100 MW by reducing losses. This is shown in Table 2-3. The situation on the  
 20 network is shown in Figure 2-2.

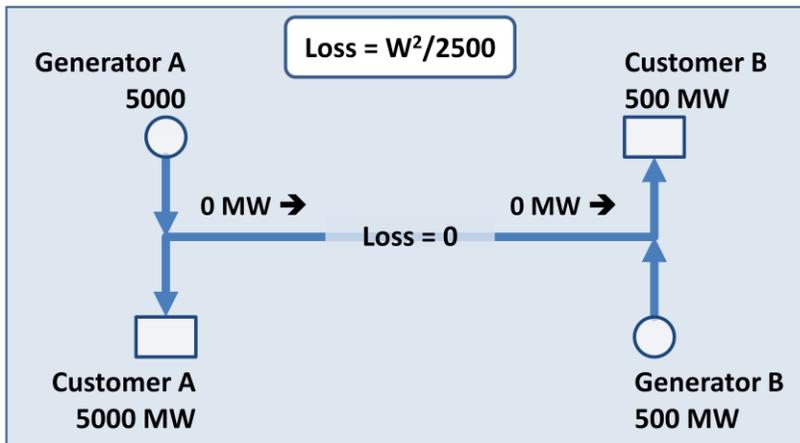
**Table 2-3: Stage 2 of the Reservoir Analogy**

Total generation:	5500 MW	(Gen A → 5000, Gen B → 500)
Total losses:	0 MW	
Available power:	5500 MW	← How much water is in the reservoir

Note that there is no additional water in the reservoir because load is the same and needs no more. So when losses are reduced, generation is reduced and this saves money, which is why it should be rewarded.

- 1 Note that Generator B has contributed to the reservoir (power pool) in two ways. First, Generator B
- 2 has injected 500 MW of new power, and second it has reduced losses by 100 MW. This has allowed
- 3 Generator A to be backed down by 600 MW. The fact that 500 MW of generation from B has
- 4 substituted for 500 MW of generation from A, is not directly relevant to this case. But the fact that
- 5 that substitution reduced losses by 100 MW is relevant, and that is what the reservoir analogy
- 6 describes as putting “one hundred litres of water into the reservoir.” Had Generator B not reduced
- 7 losses by 100 MW (100 litres), there would have been only 5400 MW of power available for
- 8 delivery to customers, given the new generation level, and lights would have gone out.

Figure 2-2: Network analogue of reservoir ( Gen B → 500 )



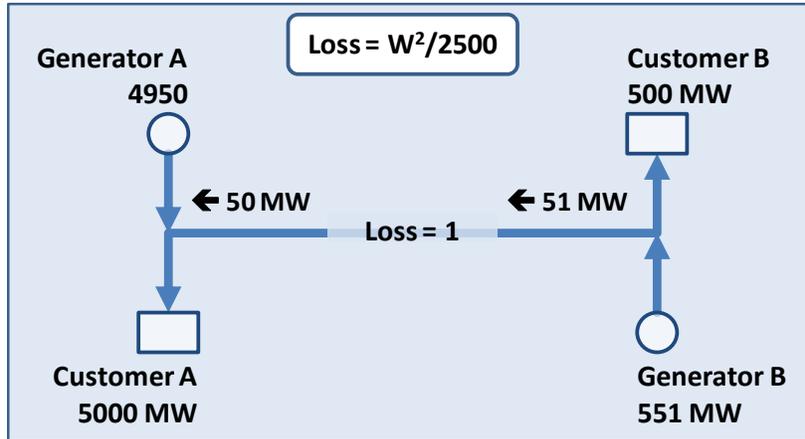
- 9 Then the analogy continues as the same individual “then chooses to take out one litre.” This is
- 10 analogous to Generator B increasing its output from 500 MW to 551 MW. That causes an excess of
- 11 power at Bus B and a flow back toward Bus A, with 50 MW reaching Bus A. The loss from this flow is
- 12  $50^2/2500 = 1$  MW. This situation is described by Table 2-4, and Figure 2-3.

**Table 2-4. Stage 3 of the Reservoir Analogy**

Total generation:	5501 MW	(Gen A → 4950, Gen B → 551)
Total losses:	– 1 MW	
Available power:	5500 MW	← How much water is in the reservoir

1 Note that Generator B has now, in effect taken 1 MW out of the reservoir by creating 1 MW of line  
 2 losses. Of course it has added 50 MW of generation, but how to pay for generation was not the concern  
 3 of the hearing panel, so, for simplicity, the hearing panel only noted the withdrawal from the pool due  
 4 to losses.

Figure 2-3: Network analogue of reservoir ( Gen B → 551 )



5  
 6  
 7 Finally, “Instead of receiving ninety-nine dollars for what he thought was a net addition of ninety-  
 8 nine litres of water, he receives a bill for one hundred and one dollars.” Is this realistic under the  
 9 AESO’s MLF/2 loss-charging scheme? Given the formula for losses ( $W^2/2500$ ), the formula for MLF  
 10 is  $2W/2500$ . So the loss factor is  $100/2500$  or 0.04. This loss factor is applied to the entire output of  
 11 Generator B, which is 551 MW, even though the first 500 MW of generation actually reduced losses  
 12 on the system. The result is that Generator B is charged for  $0.04 \times 551 \text{ MW} = 22 \text{ MW}$  of losses.<sup>3</sup>

13 This differs from the numerical conclusion of the hearing panel, which said that Generator B will be  
 14 charged for 101 MW of losses. So there is a quantitative discrepancy in the example because it  
 15 assumes (for simplicity) a linear loss formula,<sup>4</sup> not a quadratic loss formula, as the panel correctly  
 16 uses in subsequent examples. But this does not change the qualitative conclusions or the basic logic  
 17 behind them.

18 Table 2-5 below, summarizes the reduction of system losses (both total and average) and the  
 19 resulting losses charge placed on Generator B. The point of the analogy, put most simply, is that the  
 20 AESO’s Line Loss Rule will in many cases charge a generator for losses even though that generator  
 21 reduces average system losses dramatically and unmistakably.

<sup>3</sup> Technically, this example uses Bus A as the swing bus for calculating MLF. Since most of the load is there, the qualitative conclusions would be unchanged, if the present example used a more-complex, load-weighted swing bus, as the AESO does.

<sup>4</sup> If the formula were instead,  $\text{Loss} = W/5$ , then Figures 2-1 and 2-2 would be the same, but Figure 2-3 would differ in that Generator B would produce 506 MW. In this case MLF would be 0.2 and  $\text{MLF} \times 506 \text{ MW}$  would be 101MW. So a simple, linear loss formula would make this network match the water analogy perfectly.

**Table 2-5. Charging a generator for reducing losses**

Change in Generator B's output	Reduction in Total System Losses	Reduction in Average System Losses	Losses charge or credit to Generator B
From 0 MW to 551 MW	99 MW	$99/5500 = 1.80\%$ (From 1.82% to 0.02%)	22 MW charge

The analogy considers an MLF rule, but the AESO's MLF/2 Rule would simply charge Generator B half as much.

1

2 The reason for this discriminatory result under MLF (and MLF/2) is that the AESO's Line Loss Rule is  
3 based on marginal losses which can be positive even when the generator's *total contribution* to  
4 losses is a reduction. This is explained in the analogy as follows: "the [loss] charge or credit will be  
5 based on the last action [marginal loss] of the individual [generator], rather than on the net amount  
6 [total contribution] of water [losses] added or removed."

7 In summary, the water analogy is just a simplified and graphic version of the more technical  
8 examples that follow in the hearing panel's decision document. (This is demonstrated by the  
9 similarity between the above three figures and the figures for the panel's first example.) And the  
10 point made is essentially identical. To the extent that the effect of a generator is large compared to  
11 local power flows, as in this example and in Alberta, MLF and MLF/2 do not correctly characterize  
12 the total contribution to losses.

13 The opening sentence of Decision 2012-104 states "The essence of the complaint by Milner Power  
14 Inc. (Milner) in this proceeding can be illustrated by the following example [the water analogy]."  
15 This is followed in Section 2 by five figures and numerous equations that explain the analogy with  
16 mathematics and graphs. Yet in spite of all this, the AESO's only response is to misinterpret the  
17 analogy and ignore the more rigorous examples. It would appear that the AESO has once again  
18 chosen to deliberately avoid the essence of Milner's complaint just as it has been doing for so many  
19 years. Given that its Line Loss Rule has charged Milner for reducing system losses, both total and  
20 average, perhaps this is unsurprising.

## 21 **2.2 Did the hearing panel place too much weight on efficiency?**

22 According to the review panel, the most consistent complaint against the hearing panel was that it  
23 "erred in law by placing undue emphasis on economic efficiency."<sup>5</sup> This is based largely on the  
24 hearing panel's statement that the AESO and AUC "must conduct themselves with economic  
25 efficiency as their guiding value, especially when it comes to the generation market." The review

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<sup>5</sup> TransAlta Corporation, meanwhile, submits that the hearing panel erred in law by "concluding that economic efficiency is 'the guiding value' for market participants" (see TransAlta Corporation's review and variance application at paragraphs 13-17). The other three review applicants made essentially the same claim. That is, it is alleged that the hearing panel erred in law by placing undue emphasis on economic efficiency relative to other equally important, and statutorily mandated, criteria in interpreting the validity of the 2005 Line Loss Rule. (See, in particular, paragraphs 4-11 of the AESO's review and variance application, paragraphs 12-16 of TransCanada Energy Ltd.'s review and variance application, and paragraphs 10-12 of Capital Power Corporation's review and variance application).

1 applicants' criticism of the hearing panel makes little sense, because the review applicants have  
2 thoroughly misunderstood both the term "efficiency" and its role as a "guiding value".

### 3 **2.2.1 What does "Efficiency" mean?**

4 It is helpful first of all to consider what efficiency means. Often called "economic efficiency" it is a  
5 technical term in economics, but it dresses up a rather commonplace notion. It means *not wasting*  
6 *money*. In this case it means not wasting ratepayer money; no more and no less. If the Line Loss  
7 Rule wastes ratepayer money it is not efficient, and if it does not, it is efficient. So, in truth, the  
8 complaint of the review applicants amounts to a complaint that the hearing panel put far too much  
9 emphasis on not wasting ratepayer money. But of course, the review applicants would not want to  
10 phrase their objection so plainly.

### 11 **2.2.2 How was "Efficiency" used?**

12 Given the meaning of efficiency, the importance given to efficiency is understandable. However, it  
13 is clear that the hearing panel's concern with ensuring ratepayer money is not wasted, did not  
14 cause the panel to downplay other principles. In fact, there is no conflict between giving weight to  
15 these other principles and the guiding value of efficiency, because the principles themselves do not  
16 conflict with the guiding value. Most of the design principles that the review applicants feel deserve  
17 more weight are, in fact, largely derived from the use of efficiency as a guiding value, and hence  
18 they support efficiency, and the value of efficiency supports their use.

19 It would have been possible for the hearing panel to use the principle of efficiency directly, as  
20 economists often do, but it avoided direct use almost entirely. Instead it used efficiency as a guide  
21 to many other principles or simply accepted other principles that are consistent with efficiency and  
22 applied these principles directly. To our knowledge it did not rule out any design principles because  
23 they conflicted with efficiency.

24 To use efficiency directly, it is necessary to model the market under various possible rules and  
25 calculate how much of the ratepayers money will be wasted. The rule that wastes the least money  
26 is the most efficient and is judged to be preferred for its efficiency. This is the approach pursued by  
27 Dr. Huq and it is an approach that we use. But nowhere in Decision 2012-104 does the Commission  
28 make an efficiency calculation, and only once does the Commission refer to an efficiency  
29 calculation. That is at paragraph 113 of the Decision, where the hearing panel says that "the ILF  
30 method is clearly efficient," and they base this statement on footnote 48 which refers to Dr. Stoff's  
31 analysis.

32 Instead, the panel used efficiency as a guiding value to justify the use of many other design  
33 principles. In this way, these other principles were praised and fully respected. The review  
34 applicants are like someone complaining that you have given too little weight to eating fruits and  
35 vegetables, because you have said that keeping healthy is the guiding principle that leads you to a  
36 diet of fruits and vegetables. Having health as a guiding principle does not indicate a lack of  
37 emphasis on fruits and vegetables.

38 That the review panel did not ignore other principles in favor of efficiency seems obvious even to  
39 non-lawyers when it writes in paragraph 39,

1 The test, therefore, for what ISO rules survive scrutiny and, in effect, the standard of review  
2 by which the Commission must evaluate the Line Loss Rule that Milner complains about is  
3 whether the Line Loss Rule is “unjust, unreasonable, unduly preferential, arbitrarily or  
4 unjustly discriminatory or inconsistent with or in contravention of this Act or the  
5 regulations.”

6 The panel demonstrated in paragraph 67 how the guiding value of efficiency leads to specific design  
7 principles, in this case, “the cost causation principle”:

8 This conclusion was supported by the Board’s observation that “[i]f the cost causation  
9 principle is satisfied by a rate design, then proper price signals will be sent to customers,  
10 and these price signals will act as an incentive for customers to use the system efficiently.”  
11 In fact, the Board observed that it need not “explicitly recognize efficiency” for “efficient  
12 system use is a by-product of a rate design based on a proper cost allocation.”

13 This paragraph also makes our point that the guiding value of efficiency is in no conflict with, and is  
14 in fact almost identical to, the set of design principles that the review applicants believe were  
15 under-emphasized. Here is a list of a few of design principles to which efficiency is a guide.

- 16 • By eliminating “cross-subsidies” more efficiency (less waste of customers’ money) is achieved.
- 17 • By giving no “undue preference” and “unjust discrimination” weight, more efficiency is  
18 achieved.
- 19 • By emphasizing “fair competition,” consumers will be charged less.
- 20 • By emphasizing “open competition” less customer money will be wasted.
- 21 • By making “loss factors representative of the impact on average system losses,” generation  
22 costs will be held down.
- 23 • The “reasonable recovery of transmission line losses” will increase the efficiency of investment  
24 and dispatch.

25 This is not to say that efficiency is the only guiding value. But neither the review applicants nor the  
26 hearing panel claimed that it was all encompassing. The point is that emphasis on that value does  
27 not detract from an emphasis on the other design principles, but instead enhances their legitimacy.  
28 In fact the hearing panel points out (above) “that it need not ‘explicitly recognize efficiency’ for  
29 ‘efficient system use is a by-product of a rate design based on a proper cost allocation.’ “

30 **2.3 Did the hearing panel misunderstand “impact on average system**  
31 **losses”?**

32 The hearing panel used the term “average impact” only once, and in that case it used it correctly in  
33 the water analogy to mean an average taken over a generator’s output from the first MW to the  
34 last. Since this impact can change dramatically over this range, it is the average impact of a  
35 generator’s MWs and not the maximal impact of the last MW which best reflects the generator as a  
36 whole.

37 The question then arises as to what is the impact of the generator (as measured by its average  
38 impact) on the system. Now, in this one instance, the hearing panel did not specify “average system  
39 losses” or “total system losses,” but most likely it meant “average system losses” since this is the  
40 term it later defined and frequently used. So the panel was commenting on:

1 The average impact of a generator’s MWs on average system losses.

2 In other words, both concepts were used together in a completely appropriate way. A more  
3 detailed discussion can be found in Appendix A, but this is likely superfluous, since the AESO and  
4 TransCanada have both dropped this objection from their evidence.

## 5 **2.4 The use of the “reasonable man” test**

6 As part of its argument that the hearing panel erred in law by applying a “reasonable man” test  
7 instead of the concept of “reasonably recover[ing] the cost of transmission losses,” Capital Power  
8 Corporation cites Dr. Stoft. Apparently, they are suggesting that Dr. Stoft approved of MLF/2, which  
9 proves that it does pass the test for at least one man that the hearing panel (the majority)  
10 considered reasonable.

11 Let us review CPC’s contentions. First “Dr. Steven Stoft - whom the hearing panel cited with  
12 approval - described loss factors calculated through a marginal approach as being “nearly ideal” in  
13 many circumstances.”

14 This is true, but the “marginal approach” Dr. Stoft was referring to was definitely not MLF/2, for  
15 which Dr. Stoft had then and has now, no kind words. Moreover, “in many circumstances” does not  
16 qualify a line loss rule as reasonable, especially when it performs egregiously in many other  
17 circumstances that are most relevant to the case at hand. In fact Dr. Stoft’s view has always been  
18 that MLF/2 gives a good signal only in the highly unusual case in which it coincides with ILF. Given  
19 this, selecting MLF/2 instead of ILF does not seem to be a reasonable method of recovering losses.

20 Next, CPC notes that Dr. Stoft “characterized marginal loss factors as both the ‘standard approach’  
21 and the ‘generally accepted standard.’”

22 Again, this refers to “marginal loss factors,” MLF, and not to marginal loss factors chopped in half—  
23 in other words, not to MLF/2. And, as Dr. Stoft explained, MLF is standard in the U.S. because the  
24 U.S. systems generally have a much smaller proportion of remote generation that has large impacts  
25 on local loss factors. But again, it is MLF and not MLF/2 that is well behaved for a fair selection of  
26 generators.

27 Finally, CPC notes, that “Dr. Stoft, although supporting an ILF approach, nevertheless acknowledged  
28 that “MLF/2” has been adopted elsewhere.” On the other hand, ILF has not.

29 What CPC fails to point out is that where MLF/2 was adopted (e.g. in PJM), it was later rejected as  
30 being incorrect.

31 In short, if Dr. Stoft is a reasonable person, then MLF/2 fails the reasonable person test in at least  
32 one instance and MLF/2 is not a way of reasonably recovering the cost of transmission losses.

## 33 **2.5 Why the hearing panel rejected MLF/2**

34 The hearing panel rejected MLF/2 for three sets of reasons listed in three consecutive headings:

35 5.2 MLF/2 does not comply with Section 19 of Transmission Regulation 2004.

1 5.3 The AESO's line loss rule is "unjust, unreasonable, unduly preferential, arbitrarily or unjustly  
2 discriminatory or inconsistent with or in contravention of this Act or the regulations."

3 5.4 The AESO's line loss rule is not in the public interest and does not support a fair, efficient and  
4 openly competitive market.

5 The review panel has stated (at 27) that "The central issue in Proceeding ID No. 790 was whether  
6 the 2005 Line Loss Rule complied with Section 19 of the 2004 Transmission Regulation," and (at 28)  
7 that "The hearing panel's analysis and reasoning in arriving at this determination is found in large  
8 part in Section 5.2 of the decision." For this reason we will focus on the argument presented in  
9 Section 5.2 of the Decision.

10 The argument in Section 5.2 is basically a more rigorous treatment of the argument presented in  
11 the reservoir analogy, which the hearing panel says (at 1) is "The essence of the complaint by  
12 Milner Power Inc." It describes this essential point (at 3) as follows: "In accordance with this rule  
13 [MLF/2], generators are charged one half of the associated line loss of the last unit of power  
14 produced as the price for all units generated, regardless of the losses or reductions in losses caused  
15 by these units of power."

### 16 **2.5.1 Is there simple framework for understanding MLF/2?**

17 Only two key numbers are needed to understand how a generator will be treated by MLF/2 and  
18 what impact it has on system losses. These numbers are the increase (or decrease) in system losses  
19 if the generator produces only 1 MW instead of nothing, and the decrease in system losses if it  
20 were to produce 1 MW less than it is producing. In other words, the loss from the "first MW" and  
21 the loss for the "last MW" tell us all we need to know to make a robust comparison of the various  
22 possible line-loss rules. This is simpler than tracing power flows in transmission networks. This  
23 simple framework will allow us to put much of the hearing panel's analysis in perspective.

24 Since the loss caused by "the last unit of power" is always greater than that caused by any other  
25 unit, the AESO's Line Loss Rule (MLF/2) does not reflect that actual contribution of generating units  
26 with any accuracy. Before delving into Section 5.2, it will be useful to give an overview of the  
27 marginal (last) megawatt problem with regard to loss charging.

28 If any generator produces 1 MW, that will cause some loss, call that L1. If it increases output to  
29 produce 2 MW, the total system loss will increase by some amount L2, so that L1 + L2 is the total  
30 loss from the 2 MW of power injection. Now because losses are "quadratic" in power flow, L2 > L1,  
31 for every generator. And continuing this analysis for successive 1 MW increments we would find L4  
32 > L3 > L2 > L1. Each additional MW of output increases losses by more than the previous MW.  
33 Moreover the increase occurs at a very nearly constant rate, so that if L2 = L1 + d, then L3 = L2 + d  
34 and so on.

35 The total impact of "generator, G, producing 100 MW" on system losses is L1 + L2 + ... + L100. This  
36 is exactly the "incremental loss" caused by the whole power output of the generator. In other  
37 words,

$$38 \quad L1 + L2 + \dots + L100 = (\text{System loss with G at 100 MW}) - (\text{System loss with G at 0 MW}) \quad (2-1)$$

1 The marginal loss factor for this generator is based on the loss caused by its marginal MW and is  
 2 L100, which is the greater than all the other MW losses, L1 ... L99. Under an MLF rule, the generator  
 3 would be charged for  $100 \times L100$ , and under MLF/2 it is charged half of that. So how does that  
 4 compare to the actual loss caused by the generator producing 100 MW? That depends on how  
 5 different L100 is from L1. Table 2-6, show some of the possibilities.

**Table 2-6.** MLF/2 compared to the generators actual impact on system losses

	First MW Loss	Last MW Loss	System loss impact from producing 100 MW *	Loss charged for by MLF/2 **	Upward bias of MLF/2
	L1	L100	$L1+\dots+L100 = ILF$	$100 \times L100$	$MLF/2 - ILF$
1	0.09	0.10	9.5	5	- 4.5
2	0.05	0.10	7.5	5	- 2.5
3	0.00	0.10	5.0	5	0.0
4	- 0.10	0.10	0.0	5	5.0
5	- 0.10	0.04	- 3.0	2	5.0
6	- 0.10	0.00	- 5.0	0	5.0
7	- 0.10	- 0.04	- 7.0	- 2	5.0

\* The sum =  $100 \times (L1 + L100) / 2$ .    \*\*  $MLF/2 = 100 \times L100 / 2$ .  
 The last four cases all have a bias of +5, because L1 is - 0.10 for all of them. Bias =  $-100 \times L1/2$ .

6 Notice that in case 1, MLF (twice MLF/2) is 10, which is very close to the true impact of the  
 7 generator's 100 MW output on system losses. This is the case where generators are nearly price  
 8 takers, because they have very little impact on marginal losses, which only change from 0.09 to  
 9 0.10 MW in this case. In this case MLF has very little bias and that is the point of an MLF design.  
 10 This is more often the case in the deep system, where a generator's output tends to be small  
 11 compared with the total flow on the lines it is using.

12 However, precisely because MLF tends to be unbiased in the deep system, MLF/2 tends to be  
 13 biased downward. This is a benefit to generators in the deep system. In case 2, the generator has a  
 14 relatively larger impact on the MLF, doubling it from 0.05 to 0.10 when it runs. In the case MLF/2 is  
 15 less biased in its underestimate of the generator's total impact on system losses.

16 Case 3 is the special case, studied by Dr. Huq (his Case 1), in which  $MLF/2 = ILF$ . In other words  
 17 MLF/2 exactly reflects the impact of the generator's 100 MW on system losses. This case is special  
 18 because there is no flow on the line when the generator is off. This means there is no load nearby  
 19 and no generation nearby or upstream. This is not a typical case and, consequently, conclusions  
 20 based on it will not be typical for the Alberta system.

21 Cases 4 through 7 are all cases in which the generator starts out by actually reducing losses. In Case  
 22 4, it first reduces and then raises losses by same amount for zero effect. In the next two cases it  
 23 reduces losses but is charged by MLF/2 for an increase in losses. In case 7, MLF/2 gives it credit, but  
 24 much less than is deserved.

1 If all generators received the same bias from MLF/2, MLF/2 would still be only half as strong as it  
2 should be, so both investment and dispatch would receive half the loss signal they need to make  
3 generators minimize cost. This would mean wasted money for both dispatch and investment, and  
4 more cost for ratepayers. This is a large part of the efficiency argument against MLF/2. It is  
5 interesting to note that although chastised for placing too much weight on efficiency, this efficiency  
6 argument was for the most part passed over by the hearing panel. Instead the hearing panel  
7 focused on the discriminatory and preferential aspect of the bias.

8 Discrimination plays out in various ways in the hearing panel's examples, but the most systematic  
9 discrimination is between those in the deep system, represented by case 1 above, and those in the  
10 periphery, represented by the other cases and especially cases 4 through 7. This is expressed by the  
11 hearing panel in paragraph 94 as follows.

12 As such it is unduly preferential, because it prefers those generators in the deep system  
13 over those in the remote areas of the province, even though those in the remote areas are  
14 the ones saving the system losses at the periphery.

## 15 2.5.2 Is Table 2-6 a reliable guide to MLF/2?

16 Certainly, the analysis presented in Table 2-6 is simpler than analyzing seven different networks,  
17 but how reliable can it be without talking about buses and power flows? Fortunately, it cuts  
18 through the supposed problem with simple examples. No matter how complex the network, there  
19 will still be well defined values for L1 and L100. And no matter how complex the network, L1, L2, L3,  
20 etc. will still increase (and never decrease) in equal steps because that is the nature of quadratic  
21 losses.

22 These are the foundations of the simple calculations used to construct Table 2-6, so they will hold  
23 in any network. The result is that the above framework can be trusted more than the simple  
24 network examples that are typically used. Fortunately, there is no discrepancy between those  
25 simple examples and the more robust framework used to construct Table 2-6.

## 26 2.5.3 MLF/2 and the Transmission Regulation

27 The hearing panel's case that MLF/2 violates the Transmission regulation rests on the two most  
28 fundamental requirements of that regulation. In paragraphs 44 and 47 we have:

- 29 • Section 19(1)(a) requires the AESO to make rules that, among other things: **reasonably**  
30 **recover the cost of transmission line losses** on the interconnected electric system by  
31 establishing and maintaining **loss factors for each generating unit based on** their location  
32 and **their contribution**, if at all, to transmission line losses....
- 33 • They [the AESO] must also ensure that "the loss factor in each location must be  
34 **representative of the impact on average system losses** by each respective generating unit  
35 or group of generating units relative to load." (Section 19(2)(d)). [Emphasis added.]

36 In paragraph 45, the hearing panel also note that 19(1)(d) reinforces the requirement to  
37 "reasonably recover," by stating that the charges and credits should be anticipated to result in the  
38 "reasonable recovery of transmission line losses."

1 Their technical argument is essentially based on the example illustrated in their Figure 3. This  
2 example is quite similar to case 5 in the Table 2-6 above. The first 100 MW of generation reduces  
3 losses by L (as shown in Figure 3) and then next 50 MW increases them by L/4. The net result is  
4 decrease of 3/4 of L. But in spite of reducing losses, the generator is penalized for creating them by  
5 the AESO's Line Loss Rule. Here is there summary of this result in paragraph 82:

6 Generator B would be lowering line losses to the system by 10,000a [L]. That is the  
7 contribution to the average system losses. It takes into account location, because it  
8 rewards the generator that located close to load. Now if Generator B generates an extra 50  
9 MW to send back to Customer A, Generator B will have lowered losses by 10,000a [L] but  
10 added 2,500a [L/4]. This means that its contribution to the average system losses is a net  
11 reduction of 7,500a [3/4 L]. Under an incremental approach, Generator B would receive a  
12 credit of 7,500a [3/4 L]. Under a MLF approach or MLF/2 approach, Generator B will be  
13 charged for all the loss increasing units generated at a rate proportional to 2,500a.

14 The conclusion which follows immediately in paragraph 83, is that "This rule not only fails to  
15 measure the contribution of Generator B to the line losses, it ...." In other words, this example  
16 shows that the AESO's Line Loss Rule fails to satisfy 19(1)(a) because it does not establish and  
17 maintain "loss factors for each generating unit based on their location and their contribution." In  
18 particular, a loss factor that penalizes a generator for reducing losses cannot actually be based on  
19 the generator's contribution to losses. And in fact it is not. It is based on the impact of an  
20 infinitesimal (to be precise), unrepresentative sliver of the generator's output and not on the  
21 "generating unit's" contribution.

22 In the same vein, in paragraph 86, the panel concludes that "Additionally, Section 19(2)(d) which  
23 states that loss factors must be representative of the impact on average system losses is not  
24 satisfied."

25 The hearing panel also concludes (in paragraph 80), this time using the water analogy, which  
26 corresponds to the example just discussed, that "If the inhabitants wished to reasonably recover  
27 the cost of the water, it would make sense that the net total addition or subtraction from the  
28 reservoir be the basis upon which the charges or credits be assessed, or an incremental approach."  
29 Clearly, the MLF/2 charges and credits are not based on the total addition or subtraction from  
30 available system power because an addition (in the form of reduced losses) is penalized with a  
31 charge.

32 None of these arguments are subtle because the behavior of MLF/2 is not out of line with the  
33 Transmission Regulation in a subtle way. In the Alberta market, MLF/2 goes so far astray that it can  
34 and does penalize generators for reducing losses. This is not representative of the generating unit's  
35 contribution. It is not even related to it. It is, quite simply, nonsense. And, implementing nonsense  
36 when it is such a straightforward matter to simply charge generators for their actual contribution to  
37 losses is unreasonable.

### 3 Additional AESO Arguments

#### 3.1 Does shifting of loss factors constitute a problem?

Does shifting of loss factors create a problem? No, it does not, as Dr. Stoft discussed in Appendix 7 of his written evidence of April 14, 2011.

The AESO has long claimed that shift factors are a problem but has never given an example to show what the problem is. Any past problems were likely due to their inappropriate implementation, since there is no logical reason they need to cause trouble.

The best way to show that they don't need to cause trouble is to show how they actually work by using a simple model, and the simplest is to compare MLF/2 with MLF shifted. So let us suppose that half the generators by output would get an MLF of 2% and half an MLF of 6%. This would mean that half would get an MLF/2 of 1% and half an MLF/2 of 3%. And at first, let us assume that these values are all perfectly accurate.

A perfectly reasonable view of this example is that MLF/2 is really just a non-uniform shift factor applied to MLF. Those with MLF = 2% got a shift factor of minus 1% and the others got a shift factor of minus 3%.

To have the same cost reduction, MLF will need a uniform shift factor of minus 2% (the average of 1% and 3%). That would hardly seem to cause any more trouble than MLF with a non-uniform shift leading to MLF/2.

But the story is that we don't know the 2% value and we do know how to divide by two right from the start. But in fact, by the end of the year, we will know the over-collection and can easily figure out the shift factor.

But perhaps the problem is that generators need to know it in advance, so that they can bid according to their true loss costs which derive from MLF minus the shift. They know their MLF, but they will not know the shift exactly until the end of the year.

This problem could be solved by estimating the shift factor, which is just expected average losses, and locking that in for the year in question. At the end of the year, there will be a small discrepancy. Call that  $d\%$  under-collection. The next year the locked-in shift factor would be the estimated average losses +  $d\%$ . This is a standard true-up mechanism, and it would give generators complete certainty about their current loss charges at all times.

So in fact, the recommended uniform shift is no more difficult or problematic than the non-uniform shift of MLF that we call MLF/2.

#### 3.2 Why ILF does not violate "one loss factor at each location"

The AESO and the GG both claim that when the Transmission Regulation says "location," it means a "power busbar" (bus), and that one bus must have only one loss factor, LF, and that all generators attached to that bus must be charged  $LF \times E \times PP$  on an hourly basis, where **E is the energy injection of the generator** and PP is the pool price. Yet the Transmission Regulation reads as follows:

1 19(1) The ISO must make rules to

- 2 (a) reasonably recover the cost of transmission line losses on the  
3 interconnected electric system by establishing and maintaining loss  
4 factors **for each generating unit** based on their location **and their**  
5 **contribution, if at all, to transmission line losses;**

6 Two things should be noted about paragraph 19(1)(a).

- 7 1. It is loss factors, and not loss charges, that must be based on location and contribution.  
8 2. Location and contribution to losses both refer to “each generating unit.”

9 The first point, is obviously true, and the second point seems to be the clear meaning of the English  
10 and is confirmed by the hearing panel at paragraph 77 of Decision 2012-104, “Finally, a loss factor  
11 must be related to the generator’s contribution to the average losses in the system[.]”

12 This means that loss factors are required to be based on (1) the location of the generating unit, and  
13 (2) the contribution of the generating unit. Again, this seems to be the clear meaning of the  
14 English. We now turn to its implications for the design of loss factors.

15 MLF (and therefore MLF/2) are based only on the bus, which the AESO says is the same as location,  
16 and on the total power flows on the line that the bus is attached to, and, in fact, on all the lines in  
17 the system. But the most relevant power flows may still come mainly from other generators at the  
18 same bus or from many other generators that are very remote from the bus. So it makes no  
19 sense to contend that basing the load factor on these power flows is equivalent to basing them on  
20 the contribution of any particular generating unit at the bus in question. And since, under the  
21 AESO’s interpretation there is only one loss factor at a bus, it would be necessary to contend that  
22 these power flows represented the contribution of each different generator at the bus  
23 simultaneously.

24 If we accept that the system’s power flows cannot be a measure of the contribution to average  
25 system losses by each generator at the bus, then MLF does not meet the second requirement,  
26 19(1)(a), that the loss factors be based on the contribution of each generating unit. Hence MLF  
27 does not satisfy the Transmission Regulation in this respect.

28 Now, consider ILF. There are many ways to design an ILF, but the one we have used as an  
29 illustration computes loss factors that are criticized by the AESO and the Generator Group for not  
30 being determined strictly by location and for being different for different generators at the same  
31 location. Given their definition of location they are correct that the ILF does vary in this way.  
32 However, that variation is because ILF does establish and maintain loss factors for *each* generating  
33 unit based on their location *and* on their contribution, if at all, to transmission line losses.

34 So it is our view that ILF but not MLF satisfies 19(1)(a) of the Transmission Regulation. However this  
35 leaves us with a puzzle concerning 19(2)(e) which requires that “the loss factor must be one  
36 number at each location.” This would seem to contradict having loss factors that are based on the  
37 contribution to system losses of each generator, *if* location means bus. However this seeming  
38 contradiction would be resolved if location were interpreted to mean the generator’s meter.

1 If however, the Commission agrees with the AESO’s interpretation, this does not rule out the use of  
2 some type of ILF, because ILF can be designed in many ways, just like the AESO’s MLF/2 could have  
3 been designed differently. Several ILF designs would comply with 19(2)(e) under the AESO’s  
4 interpretation of “location.” The most obvious of these uses a reference generator, of say 100 MW  
5 to compute the ILF at every bus, regardless of the size of generators connected to the bus.  
6 Currently MLF is, in effect, computed by using a reference generator with a capacity of one Watt.  
7 So this simplified ILF would be a step in the right direction. However, this design, like MLF and  
8 MLF/2, would not seem to satisfy 19(1)(a), the very first loss-charging requirement of the  
9 Transmission Regulation.

### 10 **3.3 Why vintaging is not a problem for ILF**

11 In paragraphs 18 and 47–50 (written evidence) the AESO criticizes ILF on the basis that it would  
12 discriminate by “vintage.” In paragraph 47 it states that “At paragraph 92 of the Decision 2012 the  
13 Majority acknowledged and effectively condoned that an ILF approach resulted in vintaging by  
14 creating *different loss factors* for generation *at the same location*” (emphasis added).

15 Unintentional although it may be, this is a fabrication. Paragraph 92 states. “While this incremental  
16 approach advantages older plants at the expense of newer ones, creating a vintaging issue, the  
17 Commission does not see this as an issue for an ILF approach. ...” Nowhere does the Decision  
18 discuss generators under ILF being “at the same location,” an impression the AESO would seem to  
19 like to create. Nowhere does the Majority discuss “different loss factors” under ILF. Moreover, the  
20 AESO’s statement makes it seem that an ILF approach actually does result in vintaging.

21 During these proceedings it has been implied many times, as the AESO again implies in paragraph  
22 47, that the ILF leads inevitably to vintaging and that Milner favors vintaging and that this is a  
23 motivating factor for suggesting the ILF design. In fact Milner has not advocated vintaging and it is  
24 not naturally a part of ILF. A definition of vintaging may be helpful.

#### 25 **3.3.1 True vintaging defined**

26 **Vintaging:** If, in a given calculation of loss factors, the construction order of generators plays a role,  
27 then there is vintaging.

28 A useful test for vintaging is this. If generators that are identical except for age can be given  
29 different loss factors during the same loss-factor calculation, then there is vintaging. An example  
30 would be two 100 MW generators at a bus with the older one assigned an incremental loss based  
31 on a power-flow change from zero to 100 MW and the other assigned an incremental loss based on  
32 a change from 100 to 200 MW.

33 In contrast, the ILF design proposed by Milner and ATCO would base the ILF of both generators on a  
34 change from 100 to 200 MW if they were both running, regardless of their ages. Since none of the  
35 possible ILFs put forward include vintaging, it is unreasonable for the AESO to criticize the ILF  
36 approach for resulting in vintaging. It does not.

37 Another concept is sometimes referred to as vintaging, but it has nothing to do with ILF, and is just  
38 as likely to occur under any line loss rule. This concept might be called ‘overlapping lock-in of load

1 factors'. It is the requirement that loss factors be established and stable over extended periods that  
2 implies that loss factors could be different at any given time for identical generators at a given bus.  
3 The particular loss mechanism is irrelevant to this requirement.

4 For example, suppose that a generator connects to a bus in January of one year and AESO  
5 calculates a loss factor for that generator that is held fixed for a year. If a second generator  
6 connects to the same bus in July, its very connection would change the conditions assumed by  
7 AESO in its loss calculations, so the loss factor calculated for the second generator would be  
8 different to the first. This issue arises because of the requirement to maintain loss factors stable  
9 for an extended period, and because of a desire to keep the factors as up-to-date as possible.

10 This means that different generators will be exposed to loss factors locked in on various start dates  
11 meaning that they were calculated at different times. The commitment to a loss factor by AESO for  
12 each generator is akin to a "forward contract." As with forward contracts, the terms of such  
13 contracts vary as information changes. This is not a defect of the forward contract, but simply  
14 reflects the updating of information.

### 15 **3.3.2 Locking-in permanent loss-factor differences is not recommended**

16 As mentioned in the previous section, the requirement to establish loss factors for extended  
17 periods necessarily implies that loss factors in place for two generators at a given bus could be  
18 different if these factors were established at different times. However, since loss factors are  
19 periodically re-evaluated, no permanent discrepancy would be in place for loss factors of two  
20 generators located at a particular bus. That is, there is no justification for locking-in a *permanent*  
21 difference in loss factors based on different start dates, and Milner has not and does not advocate  
22 this.

## 23 **3.4 Why ILF handles both Dispatch and Location signals**

24 Much of the discussion of the AESO implies a distinction between signals for dispatch and signals  
25 for location of new generation. However, this distinction is unnecessary under ILF. ILF aligns  
26 generator decisions with economic dispatch and therefore provides incentives for dispatch  
27 efficiency. The discussion in Appendices B and C is primarily focused on operational decisions and  
28 shows that ILF provides revenue to a generator that is reflective of the difference in dispatch costs  
29 with and without that generator. That is, the revenue reflects the reduction in dispatch costs for  
30 the rest of the system due the presence of the generator.

31 Turning to a private investment perspective, investment takes place if the revenue from the energy  
32 market is anticipated to exceed the capital and operating costs of the generator. Given that the  
33 revenue from the energy market reflects the reduction in dispatch costs for the rest of the system,  
34 we have the result that new investment will take place if the anticipated capital and operating costs  
35 are less than the improvement in dispatch costs of the rest of the system made possible by the new  
36 investment. This is precisely the condition for correct generation investment. Since this signal is, in  
37 principle, available for each possible location for investment, the ILF provides both signals for  
38 optimal dispatch and also for efficient location of new generation. There is no tension or  
39 contradiction between dispatch and location signals under ILF.

1 Perhaps the easiest way to understand the similarity between investment and dispatch signals is to  
2 note the Dr. Huq’s example contains nothing in it that differs from a model of dispatch efficiency,  
3 yet his point is that he is considering investment efficiency.

#### 4 **3.4.1 Dispatch efficiency is inconsistent with MLF/2**

5 In paragraph 22, AESO emphasizes dispatch efficiency as a goal of Alberta legislation. As discussed  
6 in Appendix C, the gold standard for dispatch efficiency in the presence of losses is based on an  
7 optimal economic dispatch formulation that is well known in the power systems literature. It  
8 involves finding the dispatch of the generators that meets the demand plus the losses at least cost.  
9 Any loss charging and pool pricing mechanism that purports to be efficient should be judged by  
10 how closely it brings the actual dispatch to the optimal dispatch.

11 Since the AESO has emphasized dispatch efficiency, it will be useful to introduce the standard  
12 formulation of optimal economic dispatch with losses. Dr. Huq, citing Dr. Stoft, has stated the  
13 condition for dispatch efficiency, and it is derived in Appendix C. The condition is that for each  
14 generator k, it should generate at a level  $W^*_k$  that satisfies:

$$15 \quad P^* - MC(W^*_k) = P^* \times MLF_k \quad [Eq. 3-1]$$

16 where  $P^*$  is the pool price,  $MC_k(W_k)$  is the marginal cost of generator k, and  $MLF_k$  is the marginal  
17 loss factor for generator k, evaluated at the operating condition corresponding to optimal dispatch.

18 The question arises as to how to induce generators to behave consistently with [Eq. 3-1]. In the  
19 next paragraphs, the question will be answered for competitive conditions. The case of non-  
20 competitive conditions will be analyzed in Appendix C. In neither case does the AESO’s approach of  
21 MLF/2 lead to optimal economic dispatch. Dispatch efficiency is inconsistent with using MLF/2 as a  
22 loss factor.

23 Under competitive conditions, where generator k is too small to affect the marginal losses, AESO  
24 could simply evaluate the marginal loss factor at a convenient operating condition and publish  $MLF_k$   
25 for each generator k. From the generator’s perspective, its revenue is  $P^* \times W^*_k$ , whereas its charge  
26 for losses is  $P^* \times W^*_k \times MLF_k$ . Maximizing profit for generator k involves maximizing its revenue  
27 minus its costs minus its loss charge. The necessary condition for profit maximization is [Eq. 3-1].  
28 To summarize, with each generator acting in its own self-interest to maximize profit, and again  
29 assuming that offers into the Alberta market were competitive, each generator k would find that it  
30 maximized its profit by arranging that it generated at a level  $W^*_k$  that satisfied [Eq. 3-1]. That is,  
31 dispatch efficiency would be ensured. This result is general in that it does not rely on any  
32 assumption about the location of load of the configuration of the transmission system.

33 It is important to notice that there is no division by two of the marginal loss factor in [Eq. 3-1]. In  
34 contrast, AESO has chosen to expose generators to a charge for losses that is given by  $P^* \times MLF_k/2$ .  
35 This means that when competitive generators seek to maximize their profits, they will not satisfy  
36 [Eq. 3-1], but rather they will seek to satisfy the analogous condition with the modified losses.  
37 Dispatch efficiency will not be achieved in the case of MLF/2, violating AESO’s express desire in  
38 paragraph 22.

### 1 3.4.2 AESO loss factors are themselves not representative of actual dispatch 2 conditions

3 In paragraph 30 of its Written Evidence, AESO claims that the methodology to estimate losses must  
4 model typical conditions. However, as mentioned in paragraph 25 of its Written Evidence, the use  
5 of a single, averaged loss factor means that the resulting loss estimate is not actually representative  
6 of any actual dispatch conditions. In particular, as paragraph 59 states, loss factors change by a  
7 factor of 10 or more under different conditions. Averaging loss factors that vary in such a huge  
8 range will result in factors that likely bear no resemblance to *any* actual dispatch condition. AESO  
9 criticizes ILF on the basis that it requires evaluation of dispatch that might not be realistic. AESO's  
10 criticism of ILF would, however, rule out the averaging that it performs for *any* loss approach.

### 11 3.5 Why the AESO's complaint about two-bus examples should be ignored

12 Appendix C derives the standard conditions for optimal dispatch in the presence of losses. The  
13 derivation is not restricted to two bus examples, but is general, and the general conditions match  
14 the conditions that have been stated in several contexts in the proceeding. While many of the  
15 examples in this proceeding have been of two-bus systems, this choice is for explanatory purposes  
16 only and does not *necessarily* limit the applicability of the conclusions.

17 Ironically, a use of a two-bus example that was *not* correctly illustrative of a general principle was  
18 by the Generator Group's expert Dr. Huq who used the specific case of a two-bus example having  
19 an even more specific assumption of a generator and no load at one of the buses. As discussed in  
20 section 2.5.1 and in section 4 below, this very particular assumption led to the apparently positive  
21 result for MLF/2 that is presented by Dr. Huq. When a more representative example is used, even a  
22 more representative two-bus example, section 4 shows that MLF/2 does not provide the correct  
23 incentives for efficiency.

24 It should also be noted that, after analyzing some two bus examples of its own, the AESO hired  
25 Teshmont to produce its "Two-Bus Test System Report on Loss Factor Methodology," dated March  
26 8, 2011. The Teshmont report proved to be a largely economic exercise that was conducted virtually  
27 without any knowledge of economic theory, as was documented in detail by Dr. Stoft in his  
28 Evidence of April 14, 2011 (Appendix 3). Here he demonstrated that because Teshmont did not  
29 understand that locational incentives depended on the difference between loss factors in different  
30 locations and that investors would take into account that by investing they would change the loss  
31 factor at the point of investment, every conclusion regarding locational incentive was incorrect.

32 It seems odd to suggest that what is needed is more complex models when the AESO has been  
33 unable to correctly analyze two bus models. In fact, what is needed is not more complexity but a  
34 keener understanding of economic principles, for the point of these models is to reveal how  
35 investors will behave, in the short run, and the long run, when faced with loss charges derived from  
36 the various line loss rules.

1 **4 The Evidence of Dr. Huq**

2 Dr. Huq has provided an example and two basic cases. In both cases he finds MLF/2 to be efficient.  
3 That is, he finds that the AESO’s MLF/2 rule would cause generators to produce exactly the amount  
4 of power that minimizes the total cost of producing power. This is production efficiency. If the  
5 market is competitive so there are no excess profits, electricity consumers will waste no money.  
6 This is the meaning of an efficient market.

7 So Dr. Huq’s argument on behalf the Generator Group, is that MLF/2 will do all that can be done by  
8 a Line Loss Rule to make the market efficient and to prevent consumers from being forced to waste  
9 their money on inefficient power production. This in turn would indicate that the various  
10 injunctions and regulations that have been written into the Electric Utilities Act and the  
11 Transmission Regulation to guide the design towards efficiency were likely wise and were likely well  
12 followed by the AESO. In other words, this efficiency check would indicate that the entire  
13 procedure from law to regulation to implementation had worked as intended.

14 There are two problems with this conclusion. First, Dr. Huq’s Case 1 is so specialized that the  
15 hearing panel concluded that it would probably never occur in Alberta. Second, Dr. Huq’s Case 2  
16 was analyzed incorrectly by Dr. Huq, and in this case, MLF/2 would not be efficient.

17 Still, Huq’s example is quite valuable because it shows how to proceed with checking a Line-Loss  
18 Rule. And so we take his procedure and apply it to ILF and MLF as well as MLF/2. And to gain a  
19 more accurate picture we will include two more cases. Case 1nz,<sup>6</sup> is like Dr. Huq’s case one, except  
20 it does not make the unrealistic assumption of no flow on the line in the absence of the generator  
21 at the remote bus. (When the flow is not zero, there could be a load or generator at the remote  
22 bus, or even at a distance on the same line.) Case 3 is the case in which generators are too small to  
23 affect their loss factor (their per-MW impact on losses) when they start up or shut down. This is  
24 never perfectly true, but it is a good approximation for a significant number of generators in the  
25 deep system. Note that in this case, MLF/2 is quite wrong. Table 4-1 describes these four cases, and  
26 Table 4-2 shows our findings.

**Table 4-1.** Four cases using Dr. Huq’s example

	Number of Generators	Line flow when one generator is off
Case 1 (Huq)	1	Zero
Case 1nz	1	Non-Zero
Case 2 (Huq)	2	Non-Zero
Case 3	many	Large relative to any one generator

<sup>6</sup> Case 1nz means Case 1 Non-Zero.

**Table 4-2.** In which cases are the different line-loss rules are efficient?

Efficient?	MLF/2	MLF	ILF
Case 1 (Huq)	Yes	No	Yes
Case 1nz	No	No	Yes
Case 2 (Huq)	No	No	Yes
Case 3	No	Yes	Yes

1 As Table 4-2 indicates, MLF and MLF/2 both fail in three out of four cases, while ILF is efficient in all  
 2 four cases. To demonstrate these results we will use Dr. Huq’s equations for profits and electrical  
 3 losses, but we will not solve them. Instead, since the idea is to find what generators would do by  
 4 way of maximizing profits, we will guide the reader in the use of a simple spreadsheet that makes it  
 5 possible to quickly discover what the generators would do.

6 But first, we need to determine what we hope they will do, and we hope they will be efficient and  
 7 not waste money. Begin by reviewing Dr. Huq’s example (except for the specification of the  
 8 generation set at the remote bus), depicted in Figure 4-1.

Figure 4-1. Dr. Huq’s Example



9 Not wasting money means maximizing the cost savings from using cheap, \$46/MWh power instead  
 10 of the \$50/MWh power available in the deep system. But if too much cheap power, W, is used, so  
 11 much power will be lost in transmission that there will be no savings. If W is produced at the  
 12 remote bus, only W – L will be delivered at the system bus. So,

$$13 \quad \text{Net savings from } W = \$50 \times (W - L) - \$46 \times W \quad (4-1)$$

14 But, since loss, L, equals  $0.004 W^2$ , this is the same as:

$$15 \quad \text{Net savings from } W = \$50 \times (W - 0.004 W^2) - \$46 \times W \quad (4-2)$$

16 To find the optimal dispatch, we can just try different W’s in the formula so see which one gives the  
 17 greatest savings. The accompanying spreadsheet (Appendix D) makes that easy and the table below  
 18 shows three different test values of W. From these it is clear that W = 10 MW maximizes savings  
 19 and this is exactly what Dr. Huq reports as “the social optimum level of output, W\* = 10” on page 3,  
 20 line 11 of his evidence.

**Table 4-3.** Finding the cost-minimizing power flow

W	Net Savings from W	
5 MW	\$15/hour	
10 MW	\$20/hour	← Max Savings
15 MW	\$15/hour	

1 This answer is correct no matter how many generators are located at the remote bus, as long as  
 2 they all have a cost of \$46/MWh. This is because W is simply the total input at the remote bus and  
 3 not just the input from a specific generator.

#### 4 **4.1 Case 1: One investor**

5 Case 1, specifies there is only one investor at the remote bus in Figure 4-1. This makes Case 1 very  
 6 special, but not because there is only one investor at the bus in question. Rather it is special  
 7 because the line ends there and there is no load there. This peculiar combination means that when  
 8 the generator’s injection W goes to zero, the power flow on the line goes to zero and the losses and  
 9 marginal losses, MLF(W=0), also go to zero. As the hearing panel noted (at paragraph 111):

10 The evidence during the hearing was that the only time that MLF/2 would be the same as  
 11 ILF was when the MLF of the first contribution from the generator was zero and this rarely  
 12 occurs.

13 So, not only does Case 1 “rarely occur,” it is the only case when MLF/2 = ILF. This identity holds  
 14 because ILF is the average of MLF with the generator’s injection equal to zero and with the  
 15 generator’s injection at the level W. So

$$16 \quad \text{ILF} = [\text{MLF}(0) + \text{MLF}(W)]/2 = [0 + \text{MLF}(W)] / 2 = \text{MLF}(W) / 2 = \text{MLF}/2 \quad (4-3)$$

17 This coincidence will simplify our analysis because the analysis will be the same for ILF as for MLF/2.  
 18 To perform this analysis we need the profit function for a generator exposed to MLF/2 and also the  
 19 profit function under MLF. This gives us the two necessary profit formulas:

$$20 \quad \text{ILF and MLF/2: Profit} = \text{Revenue} - \text{Generation cost} - \text{Losses charges} \quad (4-4)$$

$$21 \quad \text{Profit} = (\$50 \times W) - (\$46 \times W) - \$50 \times (\text{MLF}/2) \times W \quad (4-5)$$

22 Similarly

$$23 \quad \text{MLF: Profit} = (\$50 \times W) - (\$46 \times W) - \$50 \times (\text{MLF}) \times W \quad (4-6)$$

24 Since losses =  $0.004 \times W^2$ , differentiation tells us that  $\text{MLF} = 0.008 \times W$ , and we use this formula in  
 25 the spreadsheet to help calculate the profit levels from W.

26 The question, once again, is what will a profit maximizing generator do? And this is most easily  
 27 understood by trying out different power levels in the accompanying spreadsheet (Appendix D).  
 28 The relevant results are shown below.

**Table 4-4** Three values of W and the resulting profits under MLF/2 and ILF

MLF/2 or ILF	MLF/2 or ILF	MLF/2 or ILF
Cost Minimizing W	Higher W	Lower W
W = 10 MW	W = 11 MW	W = 9 MW
Maximum Profit	Profit	Profit
\$20.00/hour	\$19.80/hour	\$19.80/hour

1

**Table 4-5** Two values of W and profits under MLF

MLF	MLF
Profit Maximizing W	Cost Minimizing W
5 MW	10 MW
Maximum Profit	Profit
\$0.00/hour	\$10.00/hour

2

3 We can see from Table 4-4 (and it is easy to test this more thoroughly in the spreadsheet) that  
 4 under both MLF/2 and ILF the cost minimizing (efficient) power injection, W = 10 MW, is the same  
 5 as the power injection that maximizes profits. Hence, an investor will voluntarily choose to produce  
 6 the amount of power that minimizes total system generation costs, and that is what we mean by  
 7 the efficient outcome. So, in this one unique example MLF/2 and ILF are both efficient.

8 In contrast, under MLF, the profit maximizing output is 4.6 MW, only half the cost-minimizing,  
 9 socially optimal value of 10 MW. Hence MLF will not induce generators to act efficiently, and  
 10 consumers will suffer higher electricity prices. This finishes the analysis of Dr. Huq’s Case 1. It is an  
 11 extremely special case, and one that may never occur on the AIES, but we have verified his  
 12 conclusion.

13 **4.2 Case 2: Two Investors**

14 This case has two generators, but otherwise it is the same as Case 1. As noted, the optimal total  
 15 production is the same, 10 MW, and since the two generators are identical, that would mean 5 MW  
 16 from each of them. The profit of generator i (for i = 1 or 2) for each loss rule is simply:

17 MLF/2: Profit(i) = (\$50 – \$46) × Wi – \$50 × Wi × MLF/2 (4-7)

18 MLF: Profit(i) = (\$50 – \$46) × Wi – \$50 × Wi × MLF (4-8)

19 ILF: Profit(i) = (\$50 – \$46) × Wi – \$50 × Wi × (MLF<sub>MIN</sub> + MLF<sub>MAX</sub>)/2 (4-9)

20 The fact that there are two generators enters into the computation of MLF, which is based on  
 21 W1+W2. Also MLF<sub>MIN</sub> is based on only the output of the “other” generator, while MLF<sub>MAX</sub> = MLF,  
 22 because it includes both outputs.

1 These profit formulas are programmed into the spreadsheet where it is possible to try different  
 2 values for  $W_1$  and  $W_2$ .

Table 4-6. A wasteful outcome with MLF/2

More profitable Behaviour		Efficient Behaviour	
W1	W2	Efficient W1	Efficient W2
6.67 MW	5 MW	5 MW	5 MW
Profit 1	Profit 2	Profit 1	Profit 2
\$11.11/hour	\$8.33/hour	\$10/hour	\$10/hour

3 Table 4-6 shows that for Generator 1, it is more profitable to increase its output from the socially  
 4 optimal value of 5 MW to 6.67 MW. And, in fact, the spreadsheet shows that if they both do this,  
 5 then neither one can do any better without colluding with the other. This is exactly what Dr. Huq  
 6 reports on page 6, line 5: “In the identical investor case  $w_i = w_j$  gives the solution  $w_i = w_j = 6.67$ .”

7 Hence, our conclusion must be that barring perfect collusion (an assumption made by Dr. Huq that  
 8 we will discuss shortly), *MLF/2* will lead to *over-production* and higher than necessary generation  
 9 costs. Table 4-7, below, shows that this is not the case for ILF and reveals that the profit maximizing  
 10 outcome is also the efficient, cost-minimizing outcome.

Table 4-7. ILF is efficient in Case 2

ILF		ILF		ILF	
W1	W2	W1	W2	W1	W2
5 MW	5 MW	6 MW	5 MW	4 MW	5 MW
Profit 1	Profit 2	Profit 1	Profit 2	Profit 1	Profit 2
\$5.00 /h	\$5.00 /h	\$4.80 /h	\$3.00 /h	\$4.80 /h	\$7.00 /h

11 Table 4-7 first shows the profit maximizing solution under ILF (on the left). In this case both  
 12 generators together produce 10 MW, which is the cost minimizing, socially optimal, efficient  
 13 outcome, as shown in Table 4-3. In the centre, we see that if Generator 1 increases its output to 6  
 14 MW, its profit will decline, and on the right we see that a reduction in output would reduce profit  
 15 the same amount. Hence 5 MW each is both profit maximizing and socially optimal. ILF has aligned  
 16 private interests with the public good, which is the point of markets and good market design.

### 17 4.3 Cases 1nz and 3

18 We have now considered the two Cases proposed by Dr. Huq. The, two additional cases that we  
 19 propose, Case 1nz (i.e. non-zero flow) and Case 3, are also analyzed in our spreadsheet and  
 20 summarized in Table 4-2, which we reproduce here for convenience.

**Table 4-2** In which cases are the different line-loss rules are efficient?

Efficient?	MLF/2	MLF	ILF
Case 1 (Huq)	Yes	No	Yes
Case 1nz	No	No	Yes
Case 2 (Huq)	No	No	Yes
Case 3	No	Yes	Yes

1 To verify one of the entries in the table, say Case 3 for MLF, check the corresponding spreadsheet  
2 entry. It shows the profit-maximizing power levels for the 10 competing generators. This is not  
3 perfect competition, but it is getting close to it. To check that these power levels are indeed profit-  
4 maximizing, change the power output of one of the 10 identical generators, Generator 1. You will  
5 notice that this causes that generator to lose profit. Now notice that the combined output of the 10  
6 generators is 9.09MW, which is quite close to the optimal value of 10 MW. If we had assumed 100  
7 generators the total output would have been even closer to 10 MW. So we credit MLF with being  
8 perfectly efficient in Case 3 which is “perfect competition” (and not just competition between 10  
9 generators).

10 The first thing to notice about Table 4-2 above, is that MLF/2 and MLF are each right in only one out  
11 of the four cases, while ILF is efficient every time. It is especially telling that the only case in which  
12 MLF/2 is efficient is the case in which it is mathematically identical to ILF, and the same is true for  
13 MLF.<sup>7</sup> In other words, the other two Line-Loss Rules can only succeed when they perfectly mimic  
14 incremental loss charges. This is because ILF is based on the actual impact of a generating unit on  
15 average system losses. ILF is just “losses with the generating unit” minus “losses without the  
16 generating unit” all divided by the unit’s power output. The loss charge then multiplies ILF by this  
17 power output, and the result is that the unit is charged precisely for its impact on system losses.  
18 MLF and MLF/2 are efficient only when they manage to charge exactly this amount, and on the  
19 Alberta system, that may be never.

20 Case 3 is a somewhat special case, even though it is standard in economics to assume perfect  
21 competition. In fact it is a case that is never quite realized, but there are likely many generators in  
22 Alberta for which it is quite a good approximation. So it is somewhat surprising that Dr. Huq did not  
23 consider the standard economic case, case 3. Had he done so, he would have found, as he almost  
24 admits, that MLF/2 is not efficient.

25 Case 1nz is interesting because it is actually a large set of cases. In almost all cases, a generator will  
26 find itself connected to a line that has some power flow on it, even when it is not producing power.  
27 In this situation, Case 1 is not applicable because it assumes zero power flow when the generator

---

<sup>7</sup> Now here’s why  $MLF = ILF$  when loss factors not affected by a generators output. Suppose there is a power flow of 100 MW on the line and the Generator has a capacity of 1 MW. And suppose losses are given by  $0.001 \times W^2$ , so that the MLF is  $0.002 \times W$ . Then the MLF without the small generator is  $0.2 = 20\%$ , and the MLF with the small generator at full capacity is  $0.202 = 20.2\%$ . The change is so small the generator will ignore its effect on it. It’s MLF will be very near  $20.1\%$  no matter what it does. In this case, the  $ILF = (20\% + 20.2\%)/2 = 20.1\%$ . And so we see that when a generator cannot have an impact on MLF (or ILF), then  $MLF = ILF$ . So in Case 3,  $MLF = ILF$ .

1 shuts down. As we noted, in Case 1, MLF/2 is identically equal to ILF, which is why Dr. Huq finds  
2 that MLF/2 is efficient in this case. But in all the sub-cases of Case 1nz, MLF/2 does not equal ILF, so  
3 of course it is not efficient, since ILF is. The spreadsheet allows the user to enter any value for the  
4 flow on the line and then confirm that under ILF, profit maximization will lead to cost minimization  
5 for ratepayers.

6 As the hearing panel said (at paragraph 109), “Generators rarely, if ever, have zero losses from their  
7 first MW of generation.” This would be Case 1 if it happened, and it is the only case in which MLF/2  
8 passes Dr. Huq’s and our test for efficiency. In the three much more general cases, MLF/2 wastes  
9 ratepayers money.

#### 10 **4.4 Why Dr. Huq gets a different answer**

11 On page 6, Dr. Huq first solves the MLF/2 problem correctly and gets exactly the answer presented  
12 above:

13           5           In the identical investor case  $w_i = w_j$  gives the solution  $w_i = w_j = 6.67$   
14           6           Total  $W = w_i + w_j = 6.67 + 6.67 = 13.33$ .  
15           7           The profit level of each firm will be  
16           8           =  $\$50 (6.67) - \$46 (6.67) - 50 (0.004(6.67 + 6.67) 6.67) = \$8.89$ .

17 But  $W_i = W_j = 6.67$ , as noted above, is not the socially optimal solution, so this is a strike against  
18 MLF/2. So Dr. Huq offers up an interesting new theory of Alberta’s electricity market. In “all cases  
19 where an investor is not a price taker,” the investor will collude perfectly with any other investors  
20 that affect his cost of losses. This would probably include all investors in Alberta’s generation,  
21 although perhaps not in all locations if “price taker” is not too strictly defined.

22 This is the only case we are aware of where an expert on the supplier side has testified that what  
23 the market needs is perfect collusion on the part of his clients to make the market work.  
24 Remarkably, there is a grain of truth to this view. As long as suppliers manage to collude perfectly  
25 to control loss prices, while avoiding any collusion with regard to the pool price, we should be in  
26 good shape. Unfortunately, such perfect collusion is rather difficult to arrange. Try as they might,  
27 OPEC has more often gone at each other’s throats than colluded ‘optimally’. So Alberta would likely  
28 need to facilitate such collusion.

29 Also, it should be noted that Dr. Huq’s example has nothing in particular to do with MLF/2. For  
30 example, if the generators were each charged for half the losses no matter what, Dr. Huq would  
31 have found on page 6, lines 5 – 8, that  $W_i = W_j = 10$  MW. He then would have reasoned that they  
32 could do much better by cutting back to 5 MW each; they would have agreed on this and shaken  
33 hands. This would have maximized their profits and produced the optimal outcome. As long as we  
34 impose the total cost of system losses on all generators as a group, it will be in their collective self  
35 interest to take them into account and act in the public interest. But as he says, this is a “co-  
36 operative solution.” And it will require serious cooperation, for once the agreement is reached, it  
37 will be in each generator’s self-interest to cheat on it, provided the others hold to it.

38 So there are two problems with suggesting the MLF/2 will work optimally because generators will  
39 collude perfectly. First, perfect cooperation is difficult, and second, if it were achieved over loss

1 prices, it seems likely that it would extend to the far-more-lucrative realm of collusion to set the  
2 pool price.

3 Now, lest anyone think that we are naively assuming in our analysis, or that Dr. Huq assumed in his  
4 analysis, that the market was perfectly competitive, we did not. We and Dr. Huq (before he  
5 suggested perfect collusion) assumed that generators would fully exercise their unilateral market  
6 power. To the extent they could, without collusion, manipulate the price of losses they would do so  
7 to their benefit. That is what is allowed in most U.S. markets (but not in electricity markets).

8 So, our suggestion is that the AESO design for a reasonably competitive market, in which  
9 generators that are not price takers do take account of their effect on, at least with regard to  
10 losses. But we suggest that designing for perfect collusion, say by setting loss factors to MLF/2, is  
11 not what the Regulation likely had in mind.

## Appendix A: Average Impact

The AESO and TransCanada have claimed that the hearing panel erred in law by confusing the concept of “impact on average system losses” with “average impact on system losses.” To decide this question, we need to define several concepts.

**Total System Losses:** Total annual injections minus total annual withdrawals.

“Injections” are of course the power contributed by generators, and “withdrawals” are the power taken out and consumed by load.

**Average System Losses:** Total System Losses divided by total annual injections.

This is the definition given by the hearing panel at paragraph 74, and at paragraph 73 they say “The Commission notes that there was little disagreement over the term ‘average system losses’ among the various parties.” Nonetheless it gives numerous citations to back up its definition.

**System Losses:** Could mean either “Total System Losses,” or “Average System Losses,” since an X% impact on one indicates an X% impact on the other.

The first point to understand about this controversy is that “impact on average system losses” and “impact on total system losses” have extremely similar meanings. For example, suppose annual injections were 50 TWh and the withdrawals were 48 TWh, then total system losses would be 2 TWh and average system losses would be  $2/50 = 4\%$ . Now if some (huge) generator reduced losses by 0.5 TWh, then its “impact on total system losses” would be to reduce them from 2 TWh to 1.5 TWh, for a reduction of 25%, and the “impact on average system losses” would be to reduce them from 4% to 3%, for a reduction of 25%. Table A-1 may help highlight this:

Table A-1. Impacts on Total and Average System Losses are proportional

	Losses “Before”	Losses “After”	Absolute Impact	Percentage Impact
Total System Losses	2.0 TWh	1.5 TWh	– 0.5 TWh	– 25%
Average System Losses	4%	3%	– 1%	– 25%

So if a certain loss factor “is representative of the impact” on one measure of losses, it is representative of the impact on the other. The two measures of loss are the same except for a scale factor. So, when the hearing panel used the phrase “impact on system losses,” it might have been short for “impact on total system losses” or for “impact on average system losses.” But it really doesn’t matter.

Now the majority uses the phrase “average impact” only once, and this is how it was used:

The new pricing system, it is explained to him, considers his final action of withdrawing one litre as representative of **his average impact on the system.** (paragraph 2)

The meaning of this is best explained by reference to the following table

Table A-2. “Average impact” is more accurate when discussing “impact on Average System Losses”

Contribution	Impact on losses	Full description of impact
Reality		
1 <sup>st</sup> litre	– 1	First-litre Impact on total system losses
100 <sup>th</sup> litre	– 1	100 <sup>th</sup> -litre Impact on total system losses
Final (101 <sup>st</sup> ) litre	+ 1	101 <sup>st</sup> -litre Impact on total system losses
All litres	– 99	All-litre Impact on total system losses
Average litre	– 0.98 (– 99/101)	Average-litre Impact on total system losses
According to the “new rule” (MLF in the analogy)		
All litres	+ 101	Final litre (MLF) counts for all litres
Average litre	+ 1.00	Fictitious average-litre impact on total system losses as calculated by the new rule (MLF/2)

- 1 The hearing panel’s focus was on the requirements of Transmission Regulation 19(2)(d):
- 2 “the loss factor in each location must be representative of the impact **on** average system
- 3 losses **by** each respective **generating unit.**”
- 4 There are two halves to this requirement, (1) the impact **by** generating unit,” and (2) the impact **on**
- 5 average system losses. Here the panel is concerned, quite rightly, with the first half. Because the
- 6 “new rule” looks only at the last bit of contribution (MLF), it views the entire contribution as if it
- 7 produced losses at the rate of the final contribution. So it finds an average impact **by** the
- 8 “generating unit” to be 1 unit of loss **increase** per unit of generation. When in reality the average
- 9 impact **by** the “generating unit” is 0.98 units of loss **reduction** per unit of generation.
- 10 To hearing panel said “average impact” because it meant “average impact” and not “marginal-MW-
- 11 approximate-impact.” That is not a confusion, but rather an untangling of the marginal-MW
- 12 confusion.

## Appendix B: Dr. Huq's Evidence and efficient dispatch

### 1. Using a loss factor of MLF/2 does not result in efficient dispatch with large generators

The key derivation in Dr. Huq's appendix purports to show that the setting the loss factor to MLF/2 will result in economic efficiency in the case where market participants are large enough to affect loss factors. Dr. Huq's derivation makes a very specific assumption about the losses. In particular, he assumes that they are purely quadratic<sup>8</sup> as a function of generation. In this case, but in no other case, it is true that setting loss factors to MLF/2 would result in economic efficiency. This result is confirmed above in Section 4 with numerical examples, which complements the theoretical derivation in Appendix C. As the Board has recognized, and as detailed in the evidence of Dr. MacCormack, the assumption of purely quadratic losses is unrealistic. That is, the conditions assumed by Dr. Huq are unrealistic. His conclusion is therefore unrealistic.

### 2. Detailed technical critique of Dr. Huq's appendix.

The key derivation on page 5 of Dr. Huq's appendix compares:

the correct efficiency condition from page 3, line 2, equation (2), (and also derived in Appendix C), with

paying a generator the pool price times its production times  $(1 - LF)$ , where LF is the loss factor.

Dr. Huq considers the case where the generator is large enough that its actions can affect the loss factor, and asserts that choosing LF equal to half the marginal loss factor will result in efficient dispatch. However, Dr. Huq's supposed solution provides the correct incentives only in the very particular case where the losses are a *purely quadratic* function of the injection of the relevant generator; that is, they only give the correct conditions in the case that the linear term in the dependence of losses on injection is zero. As discussed in the evidence of Dr. MacCormack this is not generally true.

As in Appendix C, define  $MLF_k = \partial \text{Loss}(W) / \partial W_k$  to be the marginal loss factor for generator k, that is, the partial derivative of losses with respect to its generation level  $W_k$ . Now suppose that:

the efficient pool price is  $P^*$ , and

the marginal costs of generation of generator k are  $MC(W_k)$ .

Then the first order necessary conditions for generation  $W_k$  by a generator k to be efficient are (as derived by Dr. Huq on page 3, line 2, equation (2)):

$$P^* - MC(W_k) = P^* \times MLF_k. \tag{B.1}$$

---

<sup>8</sup> By purely quadratic, we mean that when the generator's power injection goes to zero, the losses on the line go to zero, because there is no other cause of power flow, such as load or other generation, on the line.

1 Dr. Huq suggests charging for losses in the form  $P^* \times (MLF_k / 2) \times W_k$ . However, the first order  
2 conditions for the generator's optimization problem would then be:

$$3 \quad P^* - MC(W_k) = P^* \times (MLF_k/2 + (\partial MLF_k/\partial W_k) \times W_k/2), \quad (B.2)$$

4 where  $\partial MLF_k/\partial W_k$  is the partial derivative of  $MLF_k$  with respect to  $W_k$ , which is the second  
5 derivative of losses with respect to  $W_k$ . Unless the losses are purely quadratic, these conditions  
6 (6.2) will be different to the first order necessary conditions for efficiency (6.1) since, in general,  
7  $MLF_k$  is not equal to  $(MLF_k/2 + (\partial MLF_k/\partial W_k) \times W_k/2)$ . The *only* case where these two terms are  
8 equal is where the losses are purely quadratic, which is precisely the case that Dr. Huq analyzed.

9 As Dr. MacCormack emphasizes, it is not realistic to assume that the losses are purely quadratic. In  
10 the absence of the assumption of purely quadratic losses, using the loss factor equal to half the  
11 marginal loss factor will not result in efficient generation levels.

12 To summarize, Dr. Huq has tried to find the conditions that align generator profit maximization  
13 incentives with optimal dispatch when the generator is large enough to affect the determination of  
14 the loss factors. Dr. Huq's approach only works in a very special and unrealistic case.

15 There are two directions to proceed from this observation. The first is to ask what conditions align  
16 generator profit maximization with optimal dispatch when the generator is *not* large enough to  
17 affect the determination of the loss factors. The second is to ask what conditions correctly align  
18 generator profit maximization when the generator is large enough to affect the loss factors. These  
19 questions of incentives for efficient dispatch will be explored in the next two sections.

### 20 **3. Using MLF would result in efficient dispatch with small generators**

21 The question of what conditions align generator profit maximization with optimal dispatch when  
22 the generator is not large enough to affect the determination of the loss factors is easy to answer.  
23 When the generator is too small to affect the determination of the loss factors and as discussed in  
24 the numerical examples in section 4, the value of  $MLF_k$  is independent of  $W_k$  so  $MLF_k$  can be  
25 evaluated at any convenient operating point. Using this fixed loss factor will make the generator  
26 optimality conditions identical to:

$$27 \quad P^* - MC(W_k) = P^* \times MLF_k.$$

28 As Dr. Stoft has pointed out, this standard prescription from economics is the correct one when  
29 market participants are too small to affect the determination of the marginal loss factor.

### 30 **4. Using ILF would result in efficient dispatch with large generators and** 31 **small generators**

32 We now ask what conditions correctly align generator profit maximization when the generator is  
33 large enough to affect the loss factors. When the generator is large, one solution to aligning  
34 incentives, as proposed by Milner and emphasized by Dr. Stoft, is to set the total loss charge to  
35 generator  $k$  equal to  $P^* \times (\text{Loss}(W) - K)$ , where, in principle,  $K$  is any constant that does not depend

1 on the level of generation by generator k. In this case, the optimality conditions are again identical  
2 to:

3 
$$P^* - MC(W_k) = P^* \times MLF_k.$$

4 Since there is flexibility in choosing K, it can be chosen to satisfy other requirements. For example,  
5 under the condition of not generating,  $W_k = 0$ , from the perspective of fairness, there should not be  
6 a charge or surplus paid to the generator. This then requires that  $K = \text{Loss}(W')$ , where  $W'$  is a vector  
7 with all entries the same as  $W$ , except for the k-th entry, which is zero. That is, the constant term is  
8 given by evaluation of the losses with the generator not producing, as used in the numerical  
9 examples in section 4. As Dr. MacCormack argues, this condition of no generation is presumably  
10 the status quo before the generator came to service. Even if it is atypical of current operation, the  
11 purpose of this condition is simply to establish a baseline for fair charging practice. Moreover, in  
12 the case of a generator that is small enough not to affect the loss factors, charging  $P^* \times (\text{Loss}(W) -$   
13  $\text{Loss}(W'))$  is equivalent to charging  $P^* \times MLF_k \times W_k$ ; that is, for small generators ILF is equivalent to  
14 marginal loss charging and therefore results in efficient dispatch for small generators as well as  
15 large generators.

# Appendix C: Optimal economic dispatch with losses

## 1. Introduction

By definition, optimal economic dispatch means meeting demand at the least cost. With losses, this means that the generation in the system must supply both demand and losses at least total cost. This appendix describes the formulation of this problem and the conditions that characterize its solution. This standard power system economics formulation to describe the most efficient dispatch appears in any typical undergraduate or graduate textbook on power systems. (For example, see Bergen and Vittal, *Power Systems Analysis*, Prentice-Hall, 2000; Glover, Sarma, and Overbye, *Power System Analysis and Design*, Thomson,; Wood and Wollenberg, *Power Generation, Operation, and Control*, Wiley, 1996).

## 2. Slack bus and losses.

Evaluation of losses requires solution of power flow. Since the value of the losses is not known in advance of solving the power flow, a standard numerical approach is to single out a bus or buses and, assume that it matches or balances the power needed, in conjunction with the other generators and demand in the system, so that total generation equals demand plus losses. That is, this bus “takes up the slack.” With this interpretation, we can think of the solution of power flow as a process that takes generation and demand levels everywhere except at the slack bus as input and returns information about the resulting flows, including the losses in the system.

That is, if we define  $W$  to be a vector representing the injections at all generators in the system except at the slack bus, we can think of power flow as evaluating a function  $\text{Loss}(W)$ . In addition, partial derivatives of the loss function can be calculated using power flow software. If  $D$  is the total demand in the system, then the requirement that generation equal demand plus losses can be expressed as:

$$D + \text{Loss}(W) = \sum_k W_k. \tag{C.1}$$

(The case where there is a generator located at the slack bus can also be handled, but we omit this case for notational simplicity.)

## 3. Cost functions

In making offers into the market, generators are specifying the minimum price that they accept at each level of generation. Implicitly, this defines a cost function for each generator. In particular, generator  $k$ , generating  $W_k$ , has cost  $C_k(W_k)$ .

## 4. Formulation

By definition, optimal dispatch is the solution of an optimization problem, which is symbolically expressed as:

$$\min_W \{ \sum_k C_k(W_k) \mid D + \text{Loss}(W) = \sum_k W_k \}. \tag{C.2}$$

1 The meaning of (2) is as follows. The dispatch or levels of generation of the generators are decided  
 2 by the ISO and so are decision variables. They are written as subscripts to the “min” symbol in  
 3 order to denote that we are trying to find the minimum of an “objective function” over choices of  
 4 these variables. The objective function for this problem is the cost of dispatch,  $\sum_k C_k(W_k)$ , while the  
 5 constraints are that generation equals demand plus losses, which can also be expressed as:

$$6 \quad D + \text{Loss}(W) - \sum_k W_k = 0. \quad (\text{C.3})$$

7 We will write  $W^*$  for the particular values of  $W$  that specifies optimal dispatch. There are several  
 8 possible ways to solve this problem and its generalizations that include additional issues. A  
 9 standard approach to solving the problem uses the method of Lagrange (which dates to just after  
 10 the beginning of the nineteenth century) to form the Lagrangian:

$$11 \quad \text{Lagrangian}(W, P) = \sum_k C_k(W_k) + P(D + \text{Loss}(W) - \sum_k W_k). \quad (\text{C.4})$$

12 In addition to the generator dispatch variables,  $W$ , there is another variable,  $P$ , in the Lagrangian,  
 13 which corresponds to the constraint and is referred to as the dual variable. We will write  $P^*$  for the  
 14 value of  $P$  that comes from the solution of the problem. It will turn out that  $P^*$  is the pool price and  
 15 is called the shadow price or Lagrange multiplier. Interestingly, in “Appendix 1 to the  
 16 Supplemental Evidence of the Generator Group dated May 27, 2013 (Revised June 6, 2013)” by Dr.  
 17 Mobinul Huq, there appears to be no reference to this standard approach to evaluate the efficiency  
 18 of dispatch with losses.

19 The solution of the economic dispatch is given by the simultaneous solution of several equations,  
 20 one corresponding to the constraint requiring generation meet demand plus losses and one  
 21 additional constraint corresponding to each generator. Each equation involves taking the partial  
 22 derivative of the Lagrangian with respect to one of its variables and setting the partial derivative  
 23 equal to zero. These conditions are:

$$24 \quad 0 = \partial \text{Lagrangian}(W, P) / \partial P = D + \text{Loss}(W) - \sum_k W_k, \quad (\text{C.5})$$

$$25 \quad \text{For each } k, 0 = \partial \text{Lagrangian}(W, P) / \partial W_k = MC_k(W_k) + P(\partial \text{Loss}(W) / \partial W_k - 1), \quad (\text{C.6})$$

26 where  $MC_k(W_k)$  is the marginal cost of generator  $k$  and the symbol  $\partial$  denotes partial derivative. The  
 27 term  $\partial \text{Loss}(W) / \partial W_k$  is the marginal loss factor. For brevity and consistency with other discussions,  
 28 we will denote it  $MLF_k$ .

29 If  $W^*$  and  $P^*$  solve (C.5) and (C.6) then they specify optimal dispatch. Rearranging (C.6), we obtain:

$$30 \quad P^* - MC(W^*_k) = P^* \times MLF_k. \quad (\text{C.7})$$

31 This is consistent with the condition derived by Dr. Huq in “Appendix 1 to the Supplemental  
 32 Evidence of the Generator Group dated May 27, 2013 (Revised June 6, 2013),” on page 3, line 2,  
 33 equation (2).