CANA HIGH VOLTAGE

AESO Engineering Studies

S4 Report:

Optimized Conductor Vs 100°C Criterion

Final

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1 Background

The Alberta Electric System Operator (AESO) requested CANA High Voltage Ltd. (CHV) to review current ISO Rules Section 502.2 Bulk Transmission Line Technical Requirements (the 502.2 Requirements) as they relate to optimized conductor selection.

1.1 Provisions of the 502.2 Requirements

Clause 17(2)(b) of the 502.2 Requirements document specifies that, for any transmission line below 500kV, the maximum sag conditions for ground clearance will consider unloaded sag at 100^{o}C. The maximum thermal sag condition cannot be capped at the temperature derived from the maximum load transfer rating of the facility specified by the AESO in their Functional Specification for the project.

In contrast, the requirements for line optimization specified in clauses 12(1)(c) and (d) include 240kV and below. They require conductor selection based upon the optimization of capital costs along with the present value of future operating losses.

A suggestion has been presented to the Transmission Rules Working Group (the Working Group) that these clauses work counter to each other; efforts to optimize the conductor are circumvented when the minimum requirement of 100^{o}C is then applied to design clearances during design phases of the transmission line.

1.2 Historical Basis for the 100^{o}C Sag Criterion

In general, the aluminum alloys used in transmission line conductors are able to maintain their properties under long term thermal loadings up to 100^{o}C. At temperatures slightly above this point the alloy will begin to anneal, losing strength, over a period of exposure. Accordingly, most utilities choose this as a maximum operating limit for their lower voltage transmission lines.

With development of the 500kV line facilities, the economics of transmission line optimization became evident. Rather than designing all 500kV lines for 100^{o}C operating temperatures, conductors were optimized to balance the cost of future losses against the capital cost of facility construction. Maximum sag for ground clearances was then found based upon the computed operating temperature at the maximum load transfer rating of the line. This has been a fairly standard approach for North American utilities. While the benefits of such a process were evident at 500kV, and not generally considered for 138/144kV, the impact on Alberta’s 240/260kV systems has been unclear.

2 Investigation of Conductor Optimization

A review of proposed projects within Alberta was conducted to determine if there were 240kV projects planned with the length and other properties which had potential to justify the development of a new tower or tower family. This is the subject of another report[1]; however, early findings of this study were used to evaluate the impact of the 100°C criterion on a real-life project.

2.1 Selection of Proposed Transmission Line for Study

AESO's Regional Plans issued in 2014 were screened for possible projects requiring 240kV transmission line construction. Projects which were identified in the "most likely" scenarios of the regional plans (as they stood in April, 2014) were collected and summarized in one consolidated list. This has been included in Appendix A for reference.

The Hansman Lake to Edgerton line was selected for purposes of an optimization study to determine the need for new tower development. That study is reported separately. However, this report observes the impact of placing a 100°C thermal limit on selected parts of the optimization conducted for that report.

The length of the proposed Hansman Lake to Edgerton transmission line was estimated to be 60km. It was specified as double circuit, one side strung initially, with the second circuit to be added within 5 to 10 years. Its construction was to be through territory largely devoted to agricultural use, likely requiring free standing structures to facilitate permitting.

2.2 Line Optimization for 100°C

Methodology for line optimization is described in more detail in the previously noted report. It does compare present value costs taking into account future energy losses. It also considers total line optimization, not just conductor.

Effectively, the optimization conducted previously was re-run with the condition that, regardless of the conductor chosen, a minimum design temperature of 100°C must be used for line design. The impact of this on line cost was examined.

Only single conductor options were examined; bundled configurations were not pursued. This is because it became obvious that conclusions could be drawn even from this limited analysis. Further analysis of bundled configurations would not alter the primary conclusion.

[1] "S3: 240kV Conductor Sizing for Upcoming Projects in Alberta", Report to AESO Transmission Working Group, May, 2015

3 Findings

Several scenarios were examined to determine the effect of placing a minimum conductor design temperature of 100^{o}C on all conductors, regardless of actual line loads. In each case, the actual AESO-supplied average loads were used to compute losses.

3.1 Light Loading, Low Energy Cost

A scenario was examined where the cost of energy remains fairly low (fixed at $50/MWhr) over the lifetime of the line and the specified rating is at its lowest likely bound. In this case, the impact of future losses is reduced due to the lower projected energy costs. The effect is illustrated in figure 1. The present value shown in the chart only considers partial costs, and these should not be confused with the total line cost for such a facility.

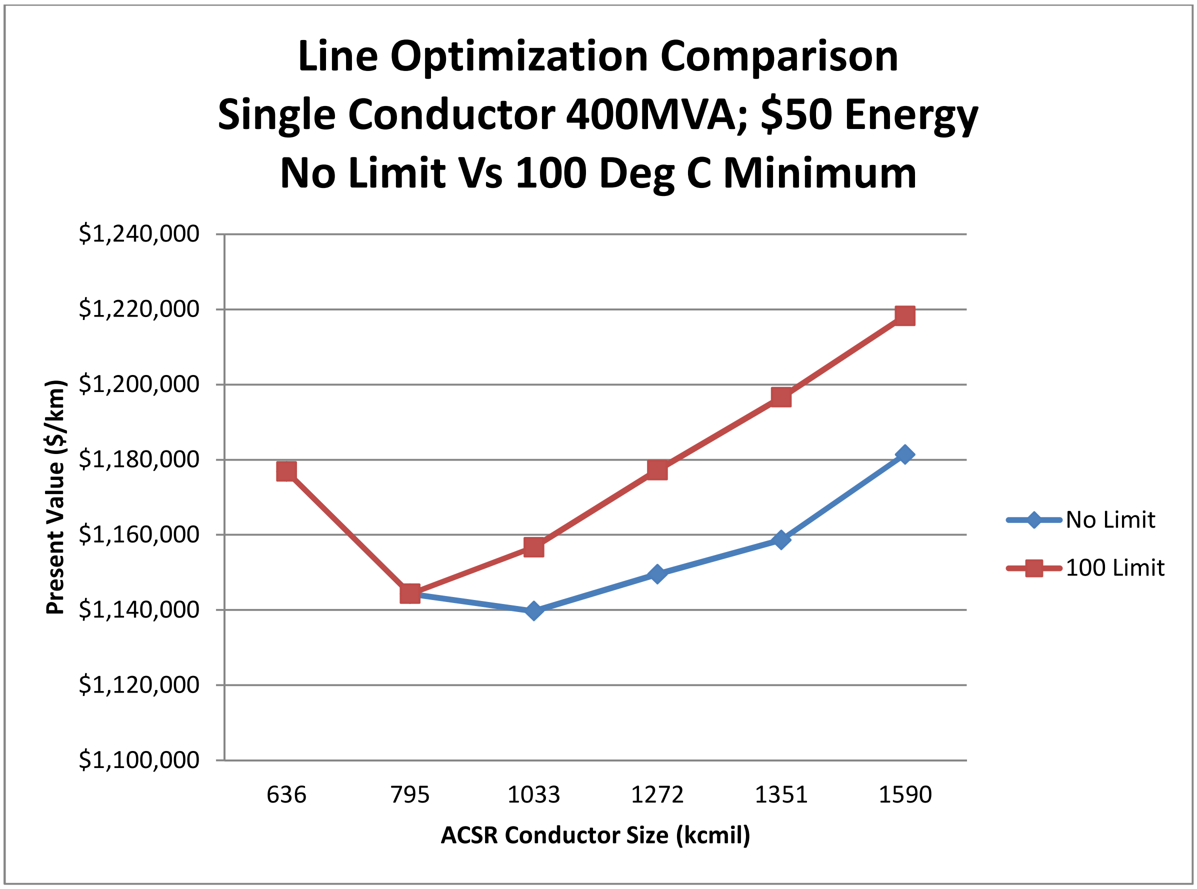

Figure 1: Hansman Lk to Edgerton; low energy cost, lower contingency load

This “bookend” scenario highlights the effect of the 100 degree minimum design condition because it penalizes the larger conductors by eliminating any capital benefit otherwise gained from their selection – support structures would still be required to provide ground clearance for 100^o sag regardless of the actual line rating. In this case, a smaller optimum conductor would be selected rather than that which would otherwise be chosen due to the 100^{o}C minimum design parameter.

In this particular case an optimum conductor of 795kcmil 'Drake' would be suggested if the 100^{o}C limit is imposed and an unexpected premium in future losses would be paid for application of the 100^{o}C minimum design parameter. Without this limit, the larger 1033kcmil 'Curlew' would be chosen and much of the cost in future losses could be avoided.

Of course, in practical terms, a single 'Drake' conductor may not be acceptable for other reasons. Its diameter would be considered marginal for this voltage and might result in the onset of positive corona. Should this occur, it would produce unacceptable levels of electromagnetic interference.

3.2 500MVA Contingency Load; AESO Forecast Energy Cost

The light load, low energy cost scenario of 3.1 is contrasted with the scenario illustrated in figure 2. In this case, the AESO forecast energy costs are used along with their currently requested line rating for the Hansman Lake to Edgerton line – this was considered the most likely scenario.

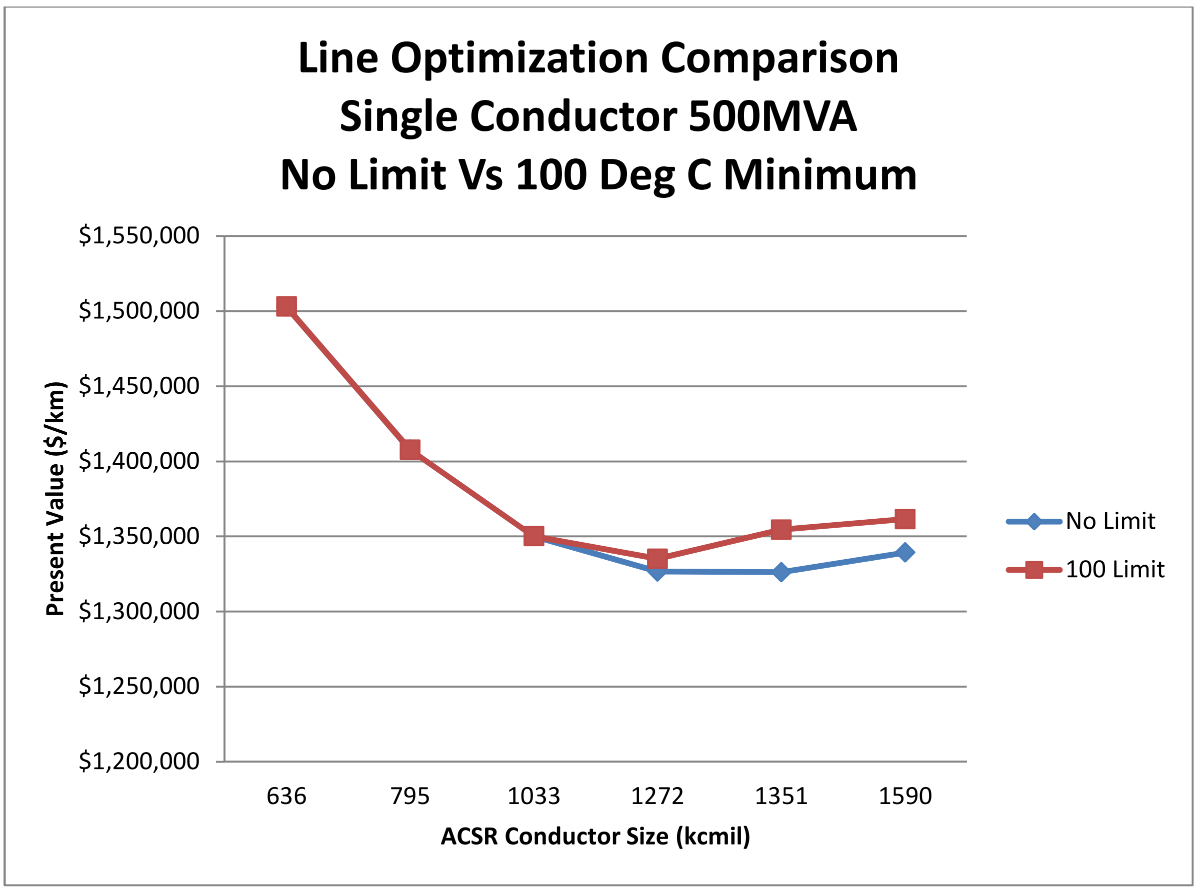

Figure 2: Hansman Lk to Edgerton; AESO Forecast Energy Cost, 500 MVA Rating

Again, the two plots begin to diverge at the conductor size which approaches 100^{o}C at the specified contingency load. In this case the higher future energy costs over-ride the up-front capital costs incurred with the larger conductor even when forced to design for 100°C clearances. Both analyses suggest the same optimum conductor in this case. However, analysis without the 100°C limit again suggests that a larger conductor would be very close to optimum and small changes in energy costs could change the selection of an optimum conductor.

3.3 Conductor Thermal Ratings

It is useful to compare the capacity of conductors for the typical requested line ratings at 240kV. These are summarized in Figure 3 with location details for the Edmonton International Airport. This is generally representative for most locations in North/Central Alberta, however, this should be revisited for areas at much higher elevations in South Western Alberta.

240kV Line Rating			
Bundle	**Common ACSR Conductor**	**100°C Summer Rating**	
		Current per Sub-Conductor (Amps)*	**Maximum Line Load (MVA)**
Single Conductor	636 kcmil “Grosbeak”	896	**372**
	795 kcmil “Drake”	1032	**429**
	1033.5 kcmil “Curlew”	1185	**493**
	1272 kcmil “Pheasant”	1347	**560**
	1351.5 kcmil “Martin”	1399	**582**
	1590 kcmil “Falcon”	1547	**643**
Two Bundle	397 kcmil “Ibis”	665	**553**
	477 kcmil “Hawk”	747	**621**
	556 kcmil “Dove”	823	**685**
	636 kcmil “Grosbeak”	896	**745**
	795 kcmil “Drake”	1032	**858**
	1033.5 kcmil “Curlew”	1185	**985**
*Notes: Bundle options assume current equally split between sub-conductors Conductors shaded grey may be unusable due to corona at 240kV Latitude and Elevation for Edmonton International Airport			

Figure 3: Summer Rating Capacity for Common ACSR Conductors

So long as the 100°C minimum design criterion is in place, the optimization process will favor the conductor closest to its maximum thermal capacity at the maximum line rating.

3.4 Transmission Line Costs

The transmission line costs shown in the figures are for relative comparison, only. They do not reflect complete costs and should not be used in that context.

4 Conclusions

Conclusions are as follows:

1. Use of the 100^{o}C minimum rating for all conductors reduces the advantage of larger conductors and changes the optimization in favor of the conductor which most closely approaches this thermal limit at the specified line rating.
2. Specification of a 100^{o}C minimum rating circumvents the line optimization process and should be removed as a requirement of the 502.2 Technical Requirements.
3. Incremental costs of applying the 100^{o}C rating after the optimization may be small when expressed in a dollar/km basis in comparison with total line cost but could add substantial costs on a line of significant length.
4. Line optimization for 240 kV projects should be based solely on the load transfer requirements and other data given by the AESO in the Functional Specification for each project. The 100^{o}C rating should be treated as an incremental cost and considered in a separate cost/benefit analysis based on specific project considerations.