

LOWER CHURCHILL PROJECT
MUSKRAT FALLS HYDROELECTRIC DEVELOPMENT
SELECTION OF TURBINES AND POWER TRANSFORMERS
Technical Note

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1. Purpose

The purpose of this technical note is to explain the selection of the type of turbines and power transformers for the Muskrat Falls Hydroelectric Development.

2. Turbines

The 1998 Final Feasibility Study for the Muskrat Falls Hydroelectric Development by SNC/AGRA, recommended a combination of 3 generating units with fixed type propeller runners and 1 generator unit with a Kaplan type runner. As noted in the report, SNC/AGRA's main focus was to determine the viability of the project using a conservative approach. In the report, as well as during a presentation on January 20, 1999, it was emphasized that optimization of runner selection combination was to be completed during final design. At the time of the report, Nalcor's mode of plant operation was not yet determined.

1998 SNC Study – 3 Propellers, 1 Kaplan

The 1998 cost estimate for the supply, transport and installation of 3 propeller turbines and 1 Kaplan turbine, including the governors, was:

3 propeller turbines and governors	\$54,744,000
1 Kaplan turbine and governor	\$20,531,300
Total	\$75,275,300

Using the 1998 SNC cost estimate from above, the cost difference for the supply, transport and installation of 3 additional Kaplan turbines and governors was \$6,849,900.

Since a Kaplan turbine requires a deeper setting than a propeller turbine, civil costs must also be included to obtain the total cost difference. The excavation and concrete placement has been estimated by Lower Churchill Project (LCP) civil engineering to be approximately \$5.4 million (in 1998 dollars) for the additional 3 Kaplan turbines. In addition, the generator cost will also increase by approximately \$500,000 per unit (total \$1.5 million).

The total cost difference is therefore \$13.8 million in \$1998.

2010 Nalcor Study – 4 Kaplan Turbines

Prior to Decision Gate 2, Nalcor considered the merits of using 4 Kaplan units rather than 3 propeller units and 1 Kaplan, and concluded that a 4 Kaplan plant was an appropriate choice for the following reasons:

1. Optimization of plant efficiency and operational flexibility

Maximizing plant unit efficiency, in concert with the mode of operation, was the main reason behind turbine selection. SNC/AGRA's proposal of maintaining peak plant efficiency depended heavily on having one single Kaplan unit always being in operation. This reliance on having only one Kaplan unit to ensure maximum plant efficiency at all times was not practical from an operational perspective.

Since propeller units typically have a narrow operating band (80% + of rated capacity) compared to Kaplan units (50%+ of rated capacity), matching plant output to varying inflows is challenging given the environmental objective to maintain the Muskrat Falls reservoir within a range of 38.5 to 39.0 m ASL.

It is recognized that the startup of generating units requires careful planning and organization. One of the key goals of the LCP is to operate the plant remotely. Greater control and response times can be achieved by having an all Kaplan unit plant as a result of their wide operating efficiency range.

During the winter, maintaining a stable ice cover on the reservoir is important; this will require repeated stopping and starting the propeller units during the winter period in order to maintain a stable reservoir level. This is avoided with all Kaplan units, as units can operate efficiently over a much wider unit loading range.

2. Availability of Capacity Reserve

Based on an operating range of 80% to 98% of rated capacity, a fixed propeller unit can offer approximately 40 MW of spinning reserve per unit. With an efficient range between 50% and 98% of unit loading, a Kaplan unit can offer approximately 100 MW per unit. On a plant basis, the maximum reserve would be 220 MW with 3 propeller units and 1 Kaplan unit compared to 400 MW with 4 Kaplan units.

3. Wind Integration Opportunities

Kaplan turbines provide for high operating efficiency over a wide output operating range. The selection of 4 Kaplan units enables all 4 Muskrat Falls units to provide flexibility for integrating non-dispatchable and variable generation sources, such as wind, on the Newfoundland and Labrador system.

Wind integration was not an important consideration during the 1998 feasibility studies, but wind energy development is an objective for Nalcor after development of the Lower Churchill Project. The wide operating band for the Kaplan units enables the plant to respond quickly to variations in wind generation on the system.

4. Other Benefits

a. Reduction of civil plant complexity

Installing two different type turbines in the same plant increases the complexity of the civil design due to elevation differences in the distributor centerlines. The civil design of the plant would not be symmetrical which would create an elevation difference on the turbine floor for different type units. Four Kaplan turbines would not only ensure simplicity in the civil aspect of the powerhouse design but also ensure consistent access for equipment maintainability.

b. Elimination of one model test

The use of a single turbine type eliminates the requirement for model testing for a second turbine design.

c. Transportation cost of runners

SNC's 1998 estimate of \$1.4 million for transportation of propeller turbines was considered to be underestimated. A propeller turbine is approximately 160 tonnes and 9 meters in diameter; the transportation of such a large mass is considered problematic and costly. The transportation logistics of road and bridge upgrades were not studied in 1998 and were not a part of the cost estimate. On the other hand, the Kaplan runner can be dismantled for transport and would drastically reduce transportation cost of the runners.

The capability of being able to dismantle the Kaplan runners prior to transportation eliminates the runners as the critical components, in size and weight for transportation over the Trans Labrador Highway to the Muskrat Falls site. Each runner can be transported in at least 7 sections, reducing the maximum size to less than 4 meters and the largest weight component, the hub section, to less than 75 tonnes.

d. Fish Mortality Reduction Rate.

Kaplan runners provide laminar flow over a greater range of loading conditions than propeller runners and, therefore, can contribute to a reduction in fish mortality rates.

Conclusion

In considering overall capital cost, operational advantages, cost savings related to doing one turbine model test, objectives for remote operation, future wind generation, potential energy gain and long term maintenance costs, an all Kaplan unit generating plant has been selected as the approach that best meets these requirements.

3. Power Transformers

The 1998 Final Feasibility Study for the Muskrat Falls Hydroelectric Development by SNC/AGRA recommended the use of 2 - three winding power transformers for conversion from unit voltage to line voltage for the entire 4 unit plant. With each of the 2 low voltage windings connected directly to the output of a generator, any issue with one power transformer would directly impact the operation of two units; that is half of the Muskrat Falls plant.

During the development of the Basis of Design for the LCP, a unitized approach was selected for the hydroelectric developments in consideration of appropriate reliability and operational flexibility. Overall, this approach minimizes the impact of any equipment or system failure of a single unit as it relates to operation of the remaining units. In order to meet this criteria, a two winding power transformer dedicated to the output of each generator was selected. Consequently, the failure of a power transformer would result in the loss of operation of only one unit.

This unitized approach, using two winding power transformers, is common practice. The use of three winding transformers is infrequent and usually considered for powerhouses with a very large number of units. Design and construction of three winding power transformers is more challenging and their use makes the field connections and protection schemes more complex.