

Nalcor Energy – Lower Churchill Project



Operations and Maintenance Philosophy for Design

LCP-PT-ED-0000-EN-PH-0005-01

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Inter-Departmental / Discipline Approval (where required)

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TABLE of CONTENTS

1.0 Purpose.....4

2.0 Scope4

3.0 Definitions4

4.0 Abbreviations and Acronyms4

5.0 Reference Documents4

6.0 Responsibilities5

7.0 Design Philosophy.....5

 7.1 General..... 5

 7.2 Health and Safety..... 6

 7.3 Environment..... 8

 7.4 Operations and Maintenance 9

 7.5 Efficiency and Reliability 12

 7.6 Hydro Plant Specific 12

 7.7 Converter Station Specific..... 14

 7.8 Transmission Specific..... 14

 7.9 Strait of Belle Isle Specific..... 15

 7.10 Ground Electrode Specific..... 15

8.0 Activity Flowchart (Excel Format).....15

 N/A..... 15

9.0 Attachments/Appendices.....15

 N/A..... 15

1.0 Purpose

The purpose of this Design Philosophy is to provide guidance for the design of the project facilities to address Nalcor's goals and objectives for long term operation and maintenance of the facilities. Generally, Nalcor requires that these facilities be designed and constructed in accordance with Nalcor standards, legislated and referenced requirements and good utility practice to provide many decades of safe, reliable and least life-cycle cost service.

2.0 Scope

This philosophy concerns all components of the LCP, including but not limited to two hydraulic power plants, converter and terminal stations, marine crossing and transmission lines, but does not include the Maritime Link. The guidelines and requirements contained herein describe goals and objectives for operation and maintenance. Within the context of this document, operation and maintenance should be interpreted to include aspects of health and safety, environment, efficiency and reliability.

3.0 Definitions

Refer to Project Dictionary

4.0 Abbreviations and Acronyms

Refer to GEN-IM-001 Acronyms and Abbreviations List

5.0 Reference Documents

CSA-Z462 – Workplace Electrical Safety Standard

Nalcor Energy Work Protection Code

LCP-PT-ED-0000-EN-RP-0001-01 Lower Churchill Project – Basis of Design

LCP-PT-ED-0000-EN-PH-0021-01 Design Philosophy for HVac Transmission Lines

LCP-PT-ED-0000-EN-PH-0022-01 Design Philosophy for HVdc Transmission Lines

LCP-PT-ED-0000-EN-PH-0026-01 Design Philosophy for Emergency Repair of Overhead
Transmission

Nalcor Standard for Colour Coding and Labeling

LCP-PT-ED-0000-EN-PH-0042-01 Life Cycle Cost Design Philosophy for Equipment,
Structures and Other Assets.

LCP-PT-ED-0000-EN-PH-0018-01 Design Philosophy for LCP Communication Systems

LCP-PT-ED-0000-EN-PH-0014-01 Design Philosophy for Gull Island Plant Layout

LCP-PT-ED-0000-EN-PH-0019-01 Design Philosophy for LCP Converter Stations

LCP-PT-ED-0000-EN-PH-0028-01 Design Philosophy for Muskrat Falls Plant Layout

LCP-PT-ED-0000-EN-PH-0041-01 Design Philosophy for Facility Security

6.0 Responsibilities

Project Director - is ultimately responsible for the allocation and expenditure of the project budget to support the Project.

Project Manager (Generation + Island Link) - is responsible to ensure that The Engineering Management Plan conforms with the substance and intent of the EPCM agreement and to ensure that the relationship between Nalcor Energy and the EPCM contractor is managed in accordance with this plan.

Project Manager (Marine Crossings) - is responsible to ensure that activities of the Marine Crossings Project Team and its relationships with the Nalcor Energy Generation and Island Link Team and the NE-LCP Engineering Team are conducted in compliance with the spirit and intent of the Engineering Management Plan.

Engineering Manager – The Engineering Manager has ownership of the Engineering Management Plan and is responsible to ensure the technical and design integrity of the Lower Churchill Phase 1 Development

7.0 Design Philosophy

7.1 General

Hydro electric generation and transmission facilities by their very nature have much longer useful operating lives than most other industrial facilities and there are many hydro electric installations in operation around the world which are over 100 years old. Nalcor expects that the Lower Churchill Phase 1 Development facilities will have similarly long operating lives and requires that they be designed appropriately to provide safe, reliable, low maintenance service based on the principle of least life cycle cost. All facilities will be designed with safety of Nalcor employees, contractors and the general public given paramount importance, following the principals of safety by design. All facilities will be designed in compliance with current environmental legislation and in accordance with the conditions of the EA approval documents. The overall design and selection of equipment and materials will follow the least life cycle cost methodology described in LCP-PT-ED-0000-EN-PH-0042-01 Life Cycle Cost Design Philosophy for Equipment, Structures & Other Assets. This philosophy is part of the Nalcor asset management philosophy which is based on achieving least overall life cycle cost while providing safe, reliable service with due concern for the environment.

The Lower Churchill facilities will be designed to be normally unattended and remotely controlled, requiring particular attention during design and construction to ensure high reliability of all equipment and the selection of equipment which requires infrequent routine maintenance, adjustment and replacement. Equipment and materials should be

selected and installed in such a fashion that routine maintenance, adjustment and replacement can be performed safely, quickly and easily using minimum personnel. The facilities shall be instrumented to provide remote monitoring of equipment performance and condition to facilitate early detection and correction of anomalies and defects. Parameters to be monitored shall be selected in accordance with Nalcor, manufacturers and good utility practice to ensure that Nalcor's performance and reliability goals are attained.

Nalcor requires that the facilities, where appropriate, comply with the requirements of a Silver Standard under the Leadership in Energy and Environmental Design (LEED) rating system as documented by the Canada Green Building Council.

7.2 Health and Safety

Facilities, systems, equipment and materials will be designed, selected and installed to eliminate health and safety hazards wherever possible and to ensure a healthy and safe work environment. Nalcor's preference is to design out any risks and exposures and to utilize controls and extraordinary PPE only if the risk or exposure cannot be designed out.

The facilities shall be designed in accordance with all relevant legislation, codes and standards.

All facilities shall be equipped such that during the performance of inspections, tests and maintenance, personnel can be conveniently protected from energized equipment in accordance with Nalcor's work protection code.

Wherever possible *arc flash* hazards shall be reduced to minimum exposure levels by, in descending order of preference:

1. relay and fuse protection settings
2. selecting appropriate equipment or enclosures
3. through the use of rapid action detection and isolation equipment
4. by providing spatial separation between equipment and personnel
5. the use of PPE.

The design of facilities shall avoid the creation of confined spaces to the greatest extent possible. Where a confined space is unavoidable, sufficient space shall be provided for the provision of confined space supervision and extraction.

The design of facilities shall provide for the protection of personnel from falls to the greatest extent possible. Where the risk of a fall exists, provision shall be made for fall protection and restraint in compliance with legislation and current Nalcor standards.

Safety barriers shall be of a rigid type and, where required, easily removed for maintenance purposes. Where openings are created during maintenance and inspection activities, the perimeter shall be provided with rigid safety barriers which fit into

permanent receptacles which surround the opening, before the opening covers are removed.

Facilities shall be equipped with appropriate fire detection, alarm and suppression equipment. The extent and type of such equipment will follow good utility practice, in consultation with Nalcor and its insurer. Fixed total flooding CO₂ fire suppression systems shall not be used because of the risk to personnel.

Walkways and storage areas shall be indicated using paint striping. Stairs shall be provided with non skid surfaces and handrails. All treads shall be identified using reflective surfaces or bright colors which are visible when normal lighting is out of service and the only sources of light are fixed emergency lights.

Facilities and equipment shall utilize Nalcor's color coding and labeling standard.

Where hazards to employees, contractors and the general public cannot be avoided, they shall be identified using signage and isolated using barriers.

Appropriate controls shall be incorporated in areas where potential liquid leaks and spills could create slipping hazards

An Emergency Response Plan shall be prepared to address emergencies which may be expected at the facilities during operation. The plan will describe immediate actions which must be taken to safeguard people and property. The plan shall be implemented before the facilities are placed in operation.

Permanent emergency shower and eye wash stations shall be supplied from the heated domestic water system. They shall be provided with inlet water filters and actuation detection which alarms in the control room. Temporary and portable eyewash station shall not be used.

Facilities shall be equipped with first aid kits, fire blankets, stretchers and backboards, SCBAs, fire extinguishers, fire hose stations and other emergency response equipment in accordance with relevant legislation, standards and Nalcor practice.

Where practical, noise levels shall not exceed:

- 80 dB(A) within the equipment operating
- 60 dB(A) within workshops
- 50 dB(A) within offices, control, lunch, locker, meeting and washrooms

To achieve this, equipment producing high noise levels shall be located in separate rooms or within noise attenuating enclosures.

All facilities, equipment and materials shall be designed and selected to be inherently safe in accordance with legislation and good utility practice. The physical layout, access and egress to all areas shall be configured to permit the safe and rapid movement of

personnel, tools, equipment and materials. Power plants shall be equipped with elevator(s) which access all floor levels from draft tube access to highest deck to assist employees with handling of materials, tools and equipment. Similarly, all levels of converter station buildings shall be serviced by elevators. To the greatest extent possible, all areas shall be accessible by wheelchair and material cart.

To the greatest extent possible, equipment shall be located to minimize the use of scaffolding or ladders for access to perform routine inspection, adjustments, testing and maintenance. Where it is necessary to climb to an area to access equipment to perform such duties, permanent stairs or other access means shall be provided. Where fall protection harnesses must be employed, readily accessible permanent tie off points shall be provided.

The facilities and equipment shall be electrically grounded as required by the applicable electrical code. Additional grounding shall be provided to reduce step and touch potentials below annoyance levels.

Electrical equipment, fixtures and cabling within battery rooms shall be explosion proof.

7.3 Environment

Nalcor requires that the facilities, where appropriate, comply with the requirements of a Silver Standard under the LEED rating system. The facilities shall be constructed such that they can be operated and maintained in accordance with those aspects of the Silver LEED standard which are practical to adopt.

Generally, facilities and equipment shall minimize environmental impact during construction and operation, shall be of the most efficient type for that service to minimize energy consumption, shall have a long service life to minimize replacements, shall require a minimum of maintenance and shall be manufactured of materials which can easily be recycled, while following the principle of least life cycle cost. Any and all releases from the facilities must comply with all applicable laws and regulations, with all permits issued for the facilities and in compliance with environmental approvals.

Oils (including waste oils, new oil in containers, within bearings, transformers, reactors, etc), fuel and other hazardous products shall be stored in self dyking tanks, double wall vacuum monitored tanks or single wall tanks within dyked areas. Outdoor dyked areas shall be designed to facilitate rainwater, ice and snow removal or shall be enclosed to prevent the accumulation of rainwater, ice and snow. Drainage from dyked areas shall be processed to remove hazardous products with the exceptions of dyked areas for batteries, which shall not be drained. Tanks shall be instrumented and monitored. The storage and monitoring of fuels shall comply with the Province's Gasoline and Associated Products regulations. Monitoring equipment for fuels shall be suitable for reconciliation purposes.

Babbited bearings shall be lead free.

Self lubricating bushings, permanently sealed bearings and environmentally friendly lubricants and other fluids shall be considered for use where equipment has the potential to leak to the environment. Notwithstanding the desire to eliminate oils where possible, all non lubricated devices shall be of proven design and acceptable to Nalcor.

All facility drainage (with the exception of roof and storm drains which cannot contain hazardous materials), shall pass through grease traps and oil interceptors before being discharged. The fluid level within containment compartments of traps and separators shall be monitored and alarmed.

When specifying and selecting equipment, consideration shall be given to minimizing the volumes and types of hazardous substances which will be present on site.

7.4 Operations and Maintenance

The facilities shall be designed to be normally unattended and remotely operated from ECC via Nalcor's SCADA system; refer to LCP-PT-ED-0000-EN-PH-0018-01 Design Philosophy for LCP Communication Systems. Sufficient local controls, instrumentation, data acquisition and storage shall be provided to permit local operation, performance monitoring, trending and basic diagnosis. Automated equipment shall be fitted with manual controls to permit local operation.

Nalcor requires that the facilities, where appropriate, comply with the requirements of a Silver Standard under the LEED rating system. This requirement should be considered in conjunction with the principal of least life cycle cost. For example, generally it is expected that electric motors will be of the high efficiency type.

The severe weather conditions at the Lower Churchill facilities shall be considered during design. Where possible all equipment requiring adjustment and routine maintenance shall be located inside heated buildings or enclosures. Equipment and materials which must be located outdoors shall be selected to provide long service life, infrequent adjustment and minimal maintenance. The deterioration, wear and failure modes of such equipment should be gradual and provide sufficient notice to operators so that maintenance, adjustment, repairs or replacement can be scheduled to when the weather is more clement and to minimize any interruption to facility operations. To facilitate this process, adequate provisions and access shall be incorporated into the design to permit convenient inspection by operating staff to assess the condition and performance of equipment and materials.

Repair shops, lunchrooms, offices, locker rooms and warehouse shall all be located within, or attached to, the powerhouse, to minimize the requirement to go outdoors.

All equipment shall employ proven technology; prototype equipment shall not be used.

Locker rooms shall be provided with large individual lockers for Nalcor personnel. The lockers shall be adequately sized to accommodate bulky winter clothing, including coveralls, winter and summer boots and other PPE.

Plants shall be equipped with a laundry area, containing heavy duty washing machine and dryer.

All facilities shall be equipped with access ways, doors, hatches, shafts and hoisting equipment to facilitate safe and rapid access for operation, adjustment and maintenance of equipment. The size of such access shall minimize the requirement for dismantling equipment for removal. Equipment of such dimensions or mass which require hoisting equipment to service or dismantle and which are not accessible by the facility crane(s) shall have local hoisting equipment provided. Where it is not possible to install permanent hoisting equipment, permanent attachment points shall be provided for chain falls, or sheave blocks for portable hoists. Attachment points shall be load tested.

Redundant systems and equipment shall be provided to ensure reliability as required by Nalcor's performance and reliability goals and good utility practice. Facilities and the equipment contained therein shall be configured and located to provide redundancy and minimize any disruption which may be caused by an equipment failure or major occurrence such as fire or flooding. Redundant devices shall be powered from a different source than the principal device such that, for example, a failure or fire in one MCC does not disable both the primary and redundant backup equipment. Equipment controls shall be configured to permit rapid and convenient transfer to and operation of, equipment in manual mode should a control system fail. Adequate local instrumentation and devices shall be provided to permit local monitoring and control. Equipment and systems shall be configured to permit the performance of maintenance on auxiliary equipment without affecting the facility performance.

All equipment and systems will be *fail safe design*, preventing harm to employees, contractors, the general public, other equipment and systems. The specific interpretation of fail safe design for each system and piece of equipment will be developed with Nalcor during the design process.

To facilitate the ease of maintenance, staff training, reliability and to reduce the spare parts inventory, equipment conforming to Nalcor standards shall be selected to the greatest extent practicable. Where no Nalcor standard exists equipment of a common type shall be selected.

Concrete floors shall be hardened and colored to enhance longevity, maintenance and appearance and shall employ a wax free finish.

All surface finishes shall be durable, easily cleaned, resistant to peeling, pitting and flaking and where appropriate, abrasion resistant, resistant to water, oil and chemicals. All floors, stairs and platforms shall have a slip free finish.

Sealing surfaces shall be made from corrosion resistant materials.

Strainers shall be equipped with backwash or flushing devices. Strainers on critical service systems shall be equipped with automatic backwash devices of the rotary type.

Flow meters shall be of the non intrusive type.

All lighting shall be of low energy consumption, long life type, provided with safe and easy method of lamp replacement. Lighting levels shall be appropriate for each area and shall comply with relevant standards and legislation. Facility interior main lighting shall be controlled from a switch near the main entrance so that lights, other than minimal security lights, can be turned off when the facility is not occupied. Exterior security lighting shall be controlled by photocells.

Lubricants and other consumables shall be standardized to minimize inventory and reduce the possibility of error.

Interior piping containing fluids below the ambient dew point shall be insulated to prevent condensation. Insulation on piping which must be removed to maintain piping or equipment shall be of the replaceable jacket type.

Liquid filled process piping shall not be located above electrical panels and equipment.

Workshops shall be provided to facilitate the repair and maintenance of equipment in a safe, comfortable and expeditious manner. The shops will be located to be easily accessible to the facility, outdoors, warehouse, washrooms and shall be equipped with an assortment of tools and equipment required to maintain the facility. Workshops shall be provided with compressed air, water and electricity, safe storage for volatile materials, storage for consumable parts and materials and workbenches suited to the nature of work which will be performed in that shop.

Electric motors shall be TEFC with sealed bearings, unless explosion proof construction is required.

Rotating and sliding components shall be fitted with lubrication systems requiring minimal maintenance. Self lubricating bushings and pads and sealed bearings shall be used wherever possible.

Equipment and materials shall be selected to be resistant to damage caused by and to prevent the entry of, insects and animals.

Facilities shall be designed to be inherently safe from vandalism, theft and intrusion. Fencing with controlled access shall be provided and a security camera system shall be provided. Refer to LCP-PT-ED-0000-EN-PH-0041-01 Design Philosophy for Facility Security.

7.5 Efficiency and Reliability

Equipment and materials should be selected and installed in such a fashion that frequency and scope of routine maintenance, adjustment and replacement is minimized and that such actions can be performed safely, quickly and easily using a minimum personnel, tools and equipment.

Where practical, equipment waste heat shall be used to heat facilities. Facilities shall be equipped with appropriate HVAC equipment to maintain air, temperature, humidity and quality within comfortable limits for personnel and equipment. Remote locations, confined spaces and lower levels shall be provided with positive ventilation systems to prevent accumulation of moisture, vapors, or gasses. An adequate supply of consumables and spare parts will be identified, procured, catalogued and placed in the warehouses prior to facilities being placed in service, to ensure early reliable operation. Special consideration shall be given to provide additional spare parts to address early "burn in" period equipment failures.

7.6 Hydro Plant Specific

To differentiate each generating unit and associated auxiliary equipment, all equipment, enclosures, panels, etc. for each unit shall be number coded and the walls at all levels shall be number coded.

Turbine shafts shall be equipped with replaceable stainless steel seal sleeves.

Each governor system shall be equipped with a kidney loop oil filtration system to maintain governor hydraulic oil cleanliness.

Spiral cases and penstocks shall be equipped with pressure tapping points for performance and index testing, piped to a common location on each unit. This instrumentation is vulnerable to damage during construction and shall be adequately protected to ensure its availability for acceptance testing and performance monitoring throughout the life of the plant.

Intake trash racks shall be equipped with a trash cleaning device that can remove trash from above and below the water surface and over the entire height and width of the trash racks. The intake access roads shall accommodate a dump truck to facilitate the removal of trash. Trash racks shall be equipped with a differential pressure monitoring system, which is indicated and recorded in the control room.

Each turbine unit shall be equipped with an easily installed and removed maintenance platform below the runner incorporating a beam and roller positioning system or similar arrangement. To further facilitate runner maintenance, sources of compressed air, water and electricity, including a welding receptacle, shall be located near each draft tube door.

Gate hoists shall utilize wire ropes, not screw stems.

Generator brakes shall be equipped with a dust collection system.

Oil filled bearings shall be constructed to prevent leakage and the release of mist and vapor.

Plant shall be equipped with frazil ice detection systems and intake and tailrace cameras.

Powerhouse shall be provided with a method of removing transformer windings, Acceptable methods include providing sufficient height in the repair bay under the crane or by providing a transformer pit elsewhere in the powerhouse. Crane capacity shall be sufficient to handle the largest transformer or reactor at the power plant and nearby converter and terminal stations.

Hydro electric plant intake canal shall be protected by trash booms during ice free periods. Convenient shoreline access shall be provided for the removal of the boom and material captured by the boom.

Sufficient land shall be acquired around the power plant and sound attenuation methods (including retention of trees) shall be employed such that the normal operating noise level at the property line does not exceed 45 dB(A).

Convenient access shall be provided near the intake and tailrace to launch boats for inspection and maintenance purposes and for the removal of trash.

Plant governor and instrument air shall be provided from an independent compressed air system. Service air with air tool connections shall be provided in the service bay and around each generating unit at the generator, turbine and draft tube levels.

Seal and cooling water piping 150 mm in diameter and less shall be fabricated from stainless steel. Cooling coils shall be fabricated from copper-nickel alloy.

Workshops shall be provided off the turbine or generator floors and shall be accessible by wheelchair and hand cart from the main access corridors and elevators. They shall be fully equipped to perform routine maintenance on all facility equipment. Mechanical shop shall be equipped with work benches, vices, welding facilities, including fume extraction equipment, lathe, milling machine, drill press, etc. Electrical and electronics

shop shall be equipped with work benches, electrical and electronics test benches, power supplies and storage for a full range of electrical and electronics test equipment. All shops shall be provided with a complete assortment of hand and powered hand tools required for routine maintenance, adjustment and repair of all plant equipment. All shops shall provide safe storage for portable equipment (pipe threading, chop saws, grinders, jacks, chain falls, oscilloscopes, multimeters, meggers, hipot test equipment, Doble test equipment, etc.) and a selection of consumable parts and materials which are used throughout the facility.

7.7 Converter Station Specific

Sufficient land shall be acquired around the converter station and sound attenuation methods (including retention of trees) shall be employed such that the normal operating noise level at the property line does not exceed 40 dB(A) .

A workshop shall be provided off the main equipment hall and shall be accessible by wheelchair and hand cart from the main access corridors and elevators. It shall be fully equipped to perform routine maintenance on all facility equipment. The repair shop shall be equipped with work benches, vices, welding facilities, including fume extraction equipment, drill press, electrical and electronics test and repair benches, power supplies and storage for a full range of electrical and electronics test equipment. All shops shall be provided with a complete assortment of hand and powered hand tools required for routine maintenance, adjustment and repair of all plant equipment. The shop shall provide safe storage for portable equipment (pipe threading, chop saws, grinders, jacks, chainfalls, oscilliscopes, multimeters, meggers, hipot test equipment, Doble test equipment, etc.) and a selection of consumable parts and materials which are used throughout the facility.

Cooling water piping shall be fabricated from non corrosive material.

7.8 Transmission Specific

The design of transmission structures will facilitate the future maintenance and repair requirements, which are described in the following documents:

- LCP-PT-ED-0000-EN-PH-0021-01Design Philosophy for HVac Transmission Lines
- LCP-PT-ED-0000-EN-PH-0022-01Design Philosophy for HVdc Transmission Lines
- LCP-PT-ED-0000-EN-PH-0026-01Design Philosophy for Emergency Repair of Overhead Transmission

During construction access trails shall be reviewed with Nalcor to identify those which will be retained for future use for inspection and maintenance. Nalcor practice is to regularly patrol lines using helicopters, all terrain vehicles and snowmobiles. During these patrols all components of the lines are visually inspected and potential problems such as danger trees are noted. At regular intervals each structure is climbed for a more detailed visual inspection.

7.9 Strait of Belle Isle Specific

The design of this component will comply with the overall goals of the project to ensure that its reliability and serviceability is consistent with the overall project. Provisions will be made for periodic inspection and testing of all components for condition monitoring purposes. Facilities will be incorporated to permit isolation of any of the cables for maintenance, repair, or replacement and to permit any two cables to be operated in parallel.

7.10 Ground Electrode Specific

The configuration of the ground electrodes shall consider the requirement to periodically replace the electrode elements. Convenient truck access shall be provided to an area immediately adjacent the electrode elements. The electrode elements and attachments shall be configured to be easily handled manually or, if this is not practical, facilities and anchor points shall be provided for the use of chain falls or sheave blocks for portable winches. Facilities shall be provided to permit the inspection and assessment of the electrode elements, cables and related infrastructure.

8.0 Activity Flowchart (Excel Format)

N/A.

9.0 Attachments/Appendices

N/A.