2018 Annual Planning Assessment Meeting

April 13, 2018

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Welcome

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Host Introduction

- Peter Thomas, P.Eng., MBA
- Transmission Planning Specialist
- Newfoundland and Labrador System Operator

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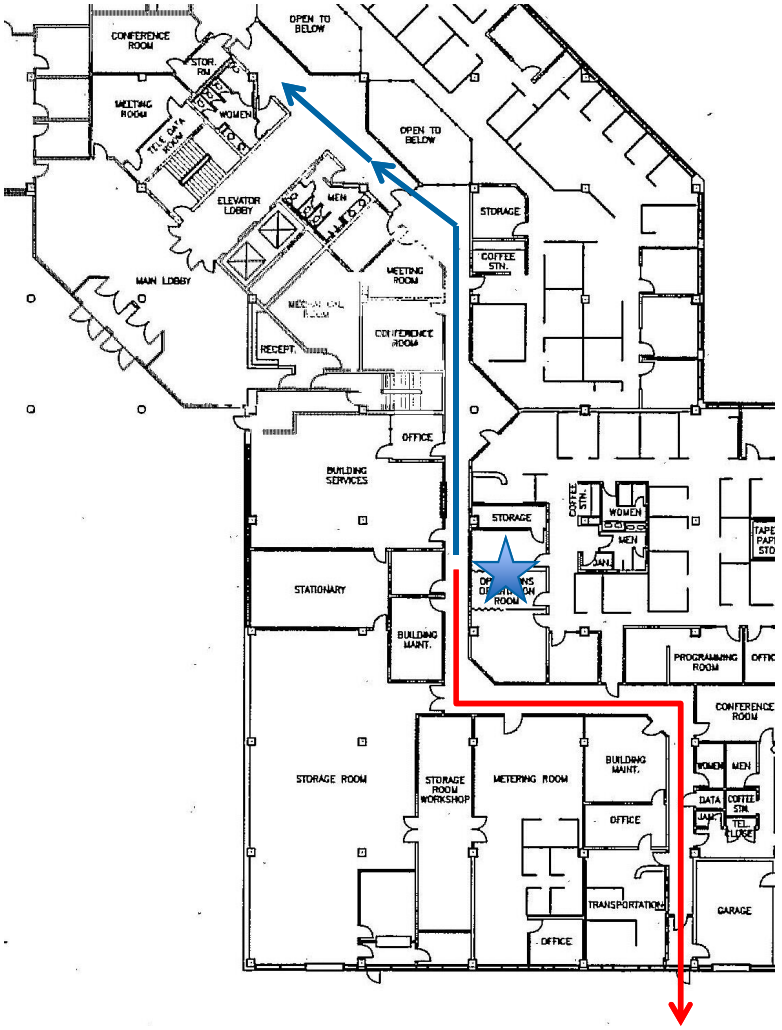
Housekeeping

- Washrooms
- Fire alarm



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Agenda

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Agenda

- 1:10 pm Safety Moment
- 1:15 pm Draft Transmission Plan Overview
- 2:45 pm Break
- 3:00 pm Open Discussion
- 5:00 pm Adjourn

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Safety Moment

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Presentation Outline

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Outline

- The NLSO
- Definitions
- The NLSO Planning Process
- The NLSO Transmission Planning Criteria
- 2018 Annual Planning Assessment
  - Selection of cases
  - Steady state analysis
  - Short circuit analysis
  - Stability analysis
- Resultant 2019 Transmission Plan
- Questions

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The NLSO

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Newfoundland and Labrador System Operator - NLSO

- the entity responsible for the safe and reliable operation of the bulk electric system within the province
- Includes the administration and provision of transmission on the NL system
- Is a part of Newfoundland and Labrador Hydro
  - Has a Code of Conduct governing information sharing

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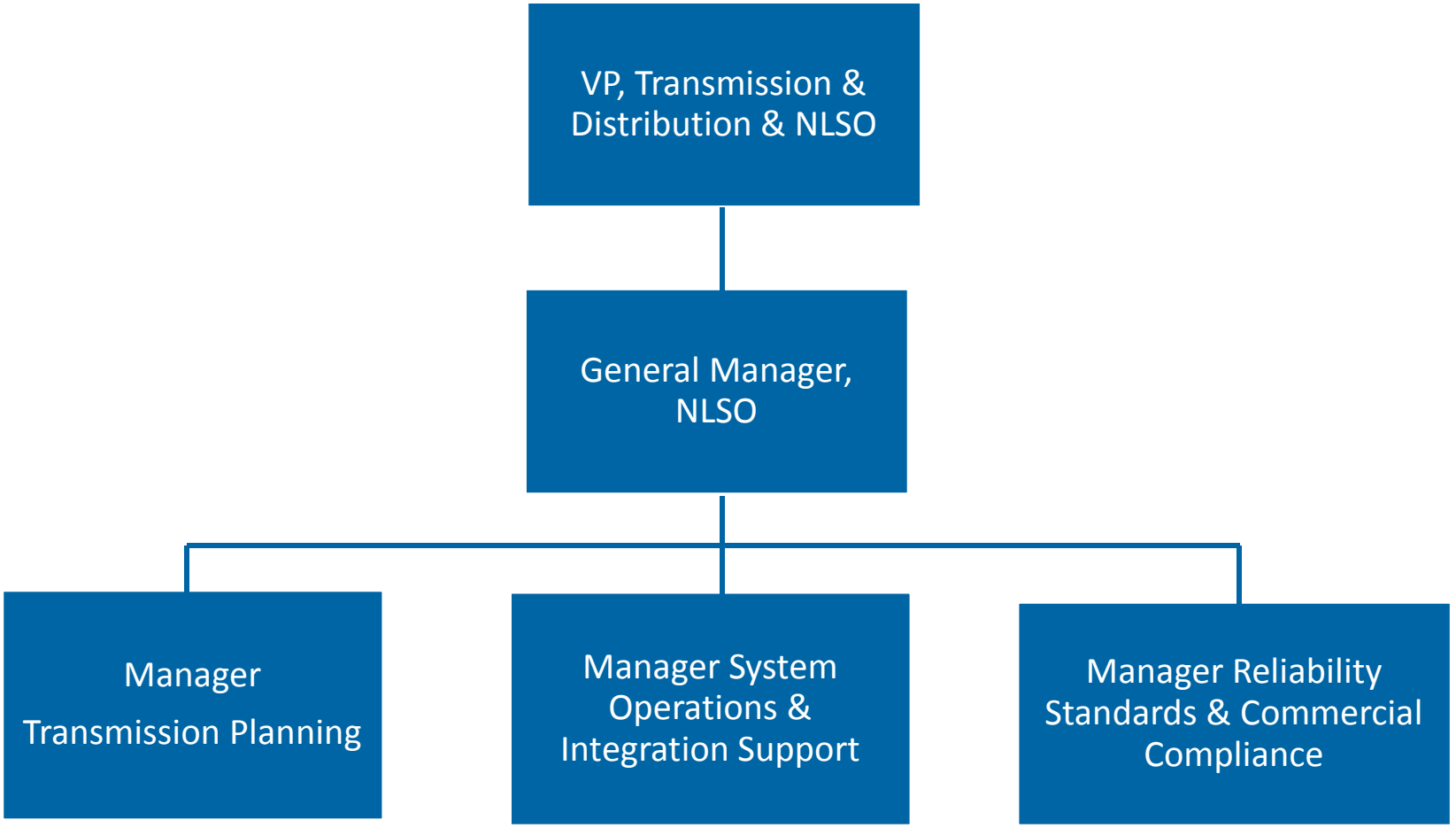
NLSO Structure



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Definitions

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Definitions

- **NL Transmission System:** The transmission facilities located in NL, primarily operating at a voltage level of 230 kV or higher, including, without limitation, the Labrador-Island Link, the Labrador Transmission Assets and Island Interconnected System but excluding the high voltage direct current portion of the Maritime Link transmission line owned by NSP Maritime Link Incorporated.
- **NL Subtransmission System:** Those transmission facilities located in NL, operating at a voltage level above 66 kV but below 230 kV.
- **NL Transmission Study Area:** All transmission facilities located in NL, operating at a voltage level of 46 kV and above.
- **Newfoundland and Labrador Interconnected System**: The interconnected transmission systems in both Newfoundland and Labrador with a rated voltage of 46 kV and above including the Labrador – Island HVdc Link.

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Definitions

- **North American Electric Reliability Corporation (NERC):** A not-for-profit international regulatory authority whose mission is to assure the reliability and security of the **bulk power system** in North America. **NERC** develops and enforces Reliability Standards; annually assesses seasonal and long-term reliability; monitors the **bulk power system** through system awareness; and educates, trains, and certifies industry personnel. **NERC**'s area of responsibility spans the continental United States, Canada, and the northern portion of Baja California, Mexico.
  - At present the NLSO is not a registered member of NERC
- **Northeast Power Coordinating Council (NPCC):** A not-for-profit corporation in the state of New York responsible for promoting and enhancing the reliability of the international, interconnected **bulk power system** in Northeastern North America.

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Definitions

- **Bulk-Power System** or **NERC BPS**: Bulk-Power System:
  - (A) facilities and control systems necessary for operating an interconnected electric energy transmission network or any portion thereof); and
  - (B) electric energy from generation facilities needed to maintain transmission system reliability. The term does not include facilities used in the local distribution of electric energy. (Note that the terms "Bulk- Power System" or Bulk Power System" shall have the same meaning.) (As per NPCC Glossary of Terms)

- **Bulk Power System** or **NPCC BPS**: The interconnected electrical systems within northeastern North America comprised of system **elements** on which **faults** or **disturbances** can have a **significant adverse impact** outside the **local area**. (As per NPCC Glossary of Terms) Note that for NPCC **BPS elements** are determined through application of NPCC Document A-10 "Classification of Bulk Power System Elements".

- For greater clarity, the term **BPS** or **Bulk Power System** (with upper case letters) when used by the **NLSO** is in reference to the **NPCC** definition. The term **bulk power system** (all lower case) is in reference to the **NERC** definition.

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Definitions

- **Bulk Electric System** or **NERC BES**: Unless modified by the lists shown below, all **Transmission Elements** operated at 100 kV or higher and **Real Power** and **Reactive Power** resources connected at 100 kV or higher. This does not include facilities used in the local distribution of electric energy. (This definition has five inclusion clauses and four exclusion clauses.)
- **Primary Transmission System** or **PTS**: Given that **Hydro** is not a registered entity within **NERC** and/or **NPCC**, it would be inappropriate to describe **elements** within the **Newfoundland and Labrador Interconnected System** as **BES** or **BPS**. As a result the term **Primary Transmission System** is used to define the bulk transmission facilities within the **NLSO** jurisdiction to which the **NLSO** transmission planning criteria will be applied to ensure reliable operation of the **bulk power system**. The **PTS elements** form the basis of the **NLSO's** future **BES**.

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Definitions

- **Radial systems:** A group of contiguous transmission **elements** that emanates from a single point of connection and:
- Only serves load. Or,
- Only includes generation resources that are not:
  - Including the generator terminals through the high side of the step-up transformer(s) connected at a voltage of 100 kV or above with:
    - Gross individual nameplate rating greater that 20 MVA. Or,
  - Gross plant/facility aggregate nameplate rating greater than 75 MVA.
  - Blackstart resources identified in the Transmission Operator's restoration plan.
- Dispersed power producing resources that aggregate tot a total capacity greater than 75 MVA (gross nameplate rating), and that are connected through a system designed primarily for delivering such capacity to a common point of connection at a voltage of 100 kV or above.
- Where the radial system serves load and includes generation resources, not identified above, with an aggregate capacity of non-retail generation less than or equal to 75 MVA (gross nameplate rating).

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Radial Systems

- Happy Valley
- Great Northern Peninsula
- Bonne Bay
- White Bay & Baie Verte
- Doyles – PAB
- Stephenville*
  - Underlying 66 kV loop with limited transfer capacity
- Ramea
- Connaigre Pen
- Fogo – Change Islands
- Vale

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Definitions

- **Local Network (LN):** A group of contiguous transmission **elements** operated at less than 300 kV that distribute power to load rather than transfer bulk power across the interconnected system. **LN**'s emanate from multiple points of connection at 100 kV or higher to improve the level of service to retail customers and not to accommodate bulk power transfer across the interconnected system. The **LN** is characterized by all of the following:
- Limits on connected generation:
  - The **LN** and its underlying **elements** do not include generation resources that:
    - The high side of the generator step-up transformer(s) are connected at 100 kV or above with:
      - Gross individual nameplate rating greater than 20 MVA. Or
- aggregate capacity of nonretail generation greater than 75 MVA (gross nameplate rating);
    - Blackstart Resources identified in the Transmission Operator's restoration plan
- Real Power flows only into the **LN** and the **LN** does not transfer energy originating outside the **LN** for delivery through the **LN**; and
- Not part of a transfer path: The **LN** does not contain any part of a monitored Facility included in an **Interconnection Reliability Operating Limit (IROL)**.

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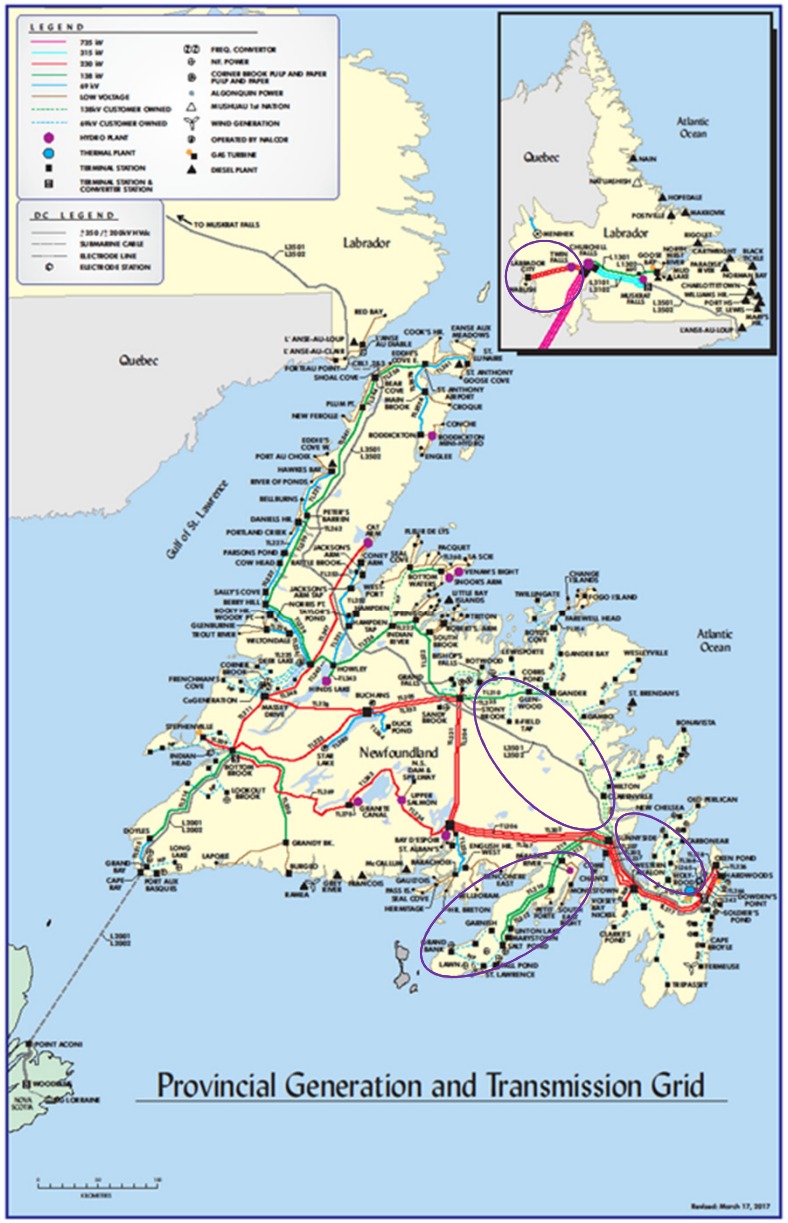
Local Networks

- Western Labrador
- Burin Peninsula
- Stony Brook to Sunnyside 138 kV Loop
- Western Avalon to Holyrood 138 kV Loop



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Definitions

- **Open Access Same-Time Information System (OASIS):** The real time information sharing system used to communicate with Transmission Customers, provide transmission system information, process requests for Transmission Service and post certain Code of Conduct requirements.

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NLSO Planning Process

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Planning Process Overview

- NLSO wishes to execute a coordinated, open and transparent transmission planning process in consultation with:
  - Network Transmission Customers
  - Firm Point-to-Point Transmission Customers
  - Interconnection customers
  - Other interested parties

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Planning Process Objective

- to ensure the Newfoundland and Labrador Interconnected System is planned:
  - to meet applicable reliability standards
  - to serve native load within the Province
  - to fulfill service commitments to Network and Firm Point-to-Point Transmission Customers and Interconnection Customers on a comparable and non-discriminatory basis

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Planning Process Principles

- Coordination
  - transmission customers and interconnected systems will be included in the development of the Transmission Plan.
- Openness
  - the NL Transmission Planning Process will be open to transmission customers and other stakeholders via planning meetings and public comment periods.
- Transparency
  - the data, study methodology, basic criteria and assumptions required for the development of the Transmission Plan will be made available via OASIS.
- Information exchange
  - information exchange guidelines and schedules for the submittal of transmission planning information
- Comparability
  - the Transmission Plan will evaluate use of the transmission system on an equal basis for all customers. The same criteria and planning processes will be applied to the same types of projects, regardless of customer.

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Planning Process Principles

- Dispute resolution
  - a dispute resolution process will be defined.
- Regional participation
  - coordination with interconnected systems will be considered with respect to regional planning.
- Economic planning studies
  - will economically meet reliability requirements.
- Cost allocation
  - the types of new projects not covered under existing cost allocation rules will be identified.

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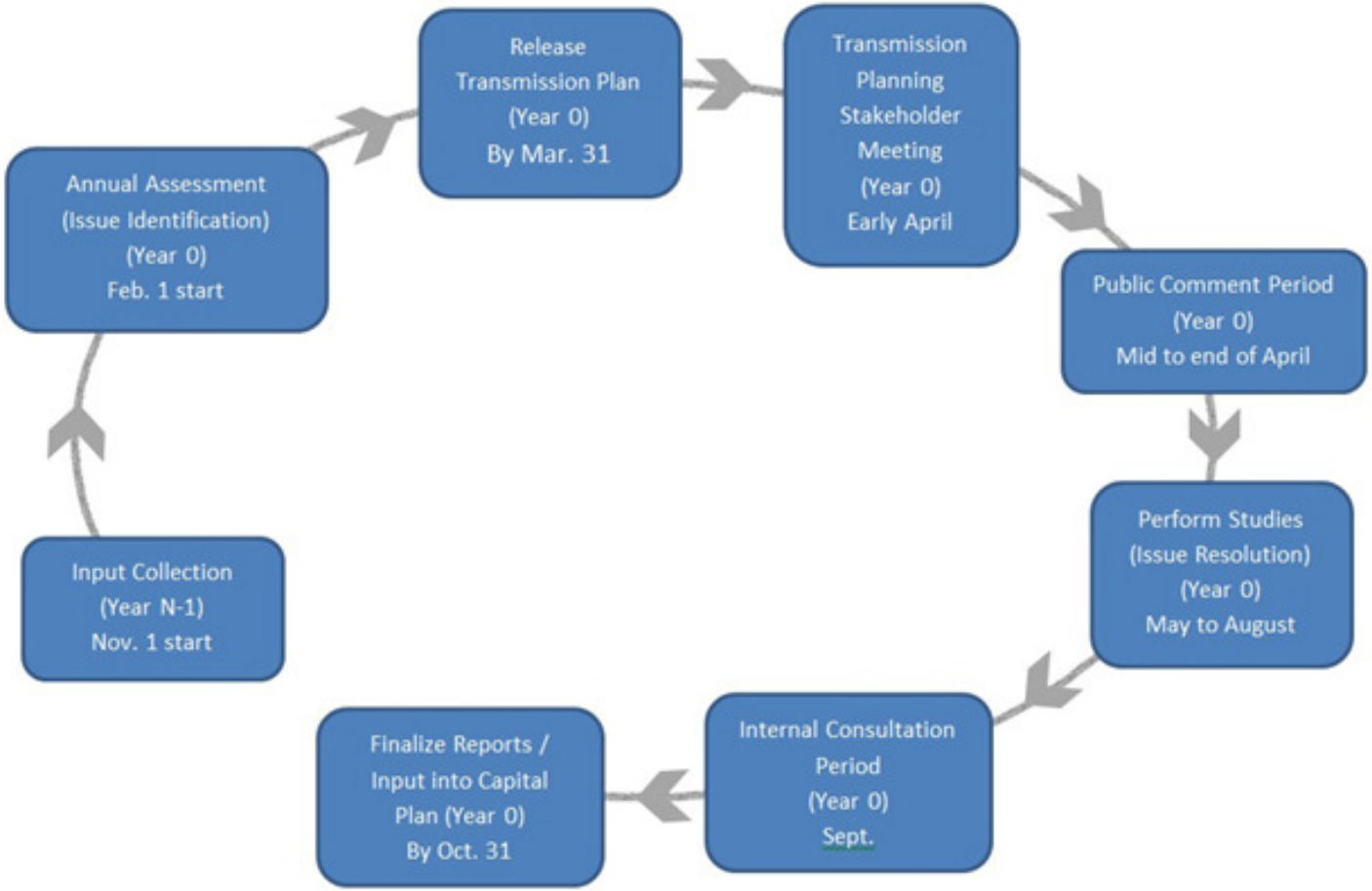
Transmission Planning Schedule



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Transmission Planning Criteria

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NLSO Transmission Planning Criteria

- TP-S-007 NLSO Standard – Transmission Planning Criteria
- Posted on the OASIS
- Summarized as per the following slides

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Steady State Criteria

- With a transmission element (line, transformer, synchronous condenser, shunt or series compensation device) out of service, power flow in all other elements of the power system should be at or below normal rating
- Transformer additions at all major terminal stations (i.e. two or more transformers per voltage class) are planned on the basis of being able to withstand the loss of the largest unit
- For normal operations all voltages be maintained between 95% and 105%
- For contingency or emergency situations all voltages be maintained between 90% and 110%
- Analysis will be conducted with one high inertia synchronous condenser out of service at Soldiers Pond

Stability Analysis Criteria - Contingencies

- System response shall be stable and well damped following a disturbance
- System disturbances include:
  - Successful single pole reclosing on line to ground faults
  - Unsuccessful single pole reclosing on line to ground faults
  - Three phase faults except a three phase fault on, or near, the Bay d'Espoir 230 kV bus with tripping of a 230 kV transmission line
  - Loss of the largest generator on line on the Island System with and without fault
  - Line to ground or three phase fault with tripping of a synchronous condenser
  - Fault and tripping of a series compensated 230 kV transmission line with the series compensation device out of service on the in service parallel 230 kV transmission line
  - Temporary pole fault
  - Permanent pole fault
  - Temporary bipole fault

Stability Analysis Criteria – Stable Response

- From the NPCC definition for Significant Adverse Impact:
  - an unacceptable system dynamic response is an oscillatory response to a contingency that is not demonstrated to be clearly positively damped within 30 seconds of the initiating event.

Stability Analysis Criteria - Voltage

- Post fault recovery voltages on the ac system shall be as follows:
  - Transient under voltages following fault clearing should not drop below 70%
  - The duration of the voltage below 80% following fault clearing should not exceed 20 cycles

Stability Analysis Criteria - Frequency

- Post fault system frequencies shall not drop below 59 Hz
- Under frequency load shedding
  - shall not occur for loss of on-island generation with the HVdc link in service
  - shall not occur for permanent loss of HVdc pole
  - shall not occur for a temporary bipole outage
  - shall be controlled for a permanent bipole outage
- There shall be no commutation failures of the HVdc link during post fault recovery.

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Annual Planning Assessments

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Assessment Requirements

- Industry Best Practices
- NERC Transmission Planning Standard
  - TPL-001-4 Transmission System Planning Performance Requirements
    - R2 sets out the requirement for each transmission planner and planning coordinator to prepare an annual Planning Assessment of its portion of the BES
      - Must complete for near-term and long-term horizons
    - R3 defines the requirements for steady state analysis
    - R4 defines the requirements for stability analysis

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Assessment Requirements

- TPL-001-4 Transmission System Planning Performance Requirements
  - R5 through R8 provide the requirements for:
    - Stated criteria
    - Document criteria and methodology
    - Determine each entity's responsibility
    - Distribution of results

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Selection of Cases

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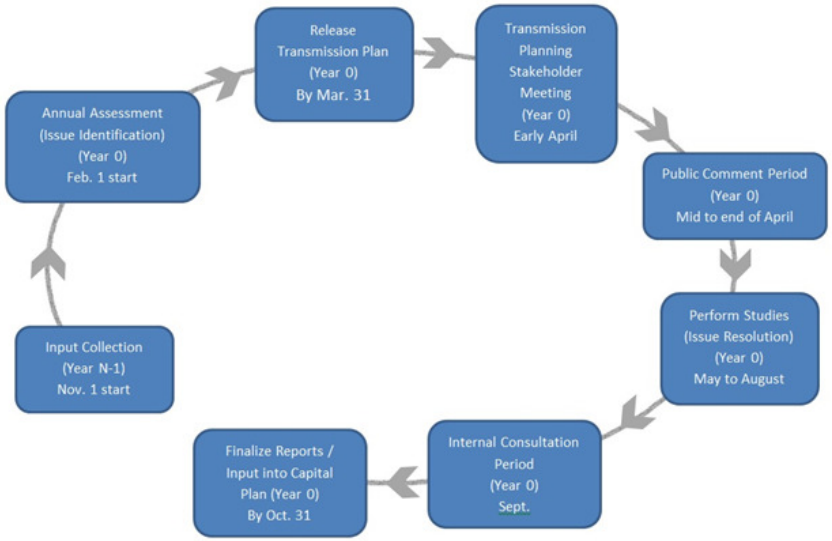
Cases for Near-Term Horizon

- Near-term covers Years One to Five
  - i.e. 2018 to 2022
  - Year One (2018) cases prepared for operational planning
  - Other years studied to identify required capital additions
  - End of planning process coincides with start of Hydro's Capital Budget cycle



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Near-Term Year Two (2019)

- Transitional year
- Maritime Link completed
  - Firm transfer set at 0 MW
  - Nova Scotia Block begins flowing when third unit at Muskrat Falls is commissioned
- 315 kV transmission in service between Churchill Falls and Muskrat Falls
- Labrador – Island HVdc Link is in operation in monopolar mode
  - Delivering available recapture energy to Island
- Holyrood generation on line
- Soldiers Pond synchronous condensers in service
- Rebuild of TL266 between Soldiers Pond and Hardwoods is complete

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Near-Term Year Five (2022)

- Muskrat Falls Generating Station complete
- Maritime Link completed
  - Firm transfer set at 157 MW at Bottom Brook
- Labrador – Island HVdc Link is in operation in bipolar mode up to 900 MW capacity
- Holyrood thermal generation off line
- Hardwoods and Stephenville gas turbines out of service

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Cases for Long-Term Horizon

- Long-term covers Years Six to Ten
  - Must study at least one year in long-term horizon
  - Select Year Ten (2027)

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Load Forecast

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Load Forecasts

- Island Interconnected 10 Year P50 and P90 Peak Demand Summary – Summer 2017 dated August 2017
- Labrador Interconnected 10 Year P50 and P90 Peak Demand Summary – Summer 2017 dated July 6, 2017
- Peak load cases use P90 forecast
- Light load cases use P50
- Provides load forecast extremes

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Special Considerations

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Special Considerations - Labrador

- Capacity limitations are a concern for the transmission system in western Labrador
  - NLSO is completing a comprehensive study
  - To be submitted to Regulator in Fall, 2018
- Hydro had proposed interconnection of eastern Labrador 138 kV transmission to Muskrat Falls
  - PUB Order No. P.U. 9(2018)
  - Hydro will be addressing eastern Labrador separately

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Special Considerations– Labrador Island Link

- recent changes in the approach to implementing the Lower Churchill Project
  - Phased approach
  - Requires rework of stability analysis
  - Analysis for monopolar operation included
  - Analysis of bipolar operation is ongoing and will be included in 2019 assessment

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Steady State Analysis

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Steady State Analysis Findings

- No pre-contingency violations of criteria in either the near or long-term horizons

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Steady State Analysis Line Outs

- The loss of TL235 (Stony Brook to Grand Falls) or TL247/248 (Cat Arm to Deer Lake to Massey Drive) will result in the loss of generation
  - generation deficiency is mitigated by re-dispatch of existing generation
- Loss of TL210 Stony Brook to Cobb's Pond results in low voltages at Farewell Head
  - The low voltages are mitigated by placing the 230/138 kV transformer OLTCs at Stony Brook and Sunnyside in manual and adjusting the 138 kV bus voltages
- Loss of TL219 Sunnyside to Salt Pond results in low voltages on the Burin Peninsula 138 kV system south of Bay l'Argent
  - The low voltages are mitigated by placing the Greenhill Gas Turbine in service at a minimum load of 5 MW

Steady State Analysis Line Outs

- In Year Two, prior to the interconnection of Muskrat Falls generators, the loss of 315 kV transmission lines L3101 or L3102 will result in undervoltages at Muskrat Falls Terminal Station 2.
- The 315 kV, 150 MVAR shunt reactor at Muskrat Falls Terminal Station 2 will be equipped with undervoltage protection to ensure that it is tripped if voltages drop below 0.88 per unit (277.2 kV).

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Steady State Analysis – Multi-transformer Stations

- Multi-transformer stations are those with more than one transformer in parallel supplying the load
- Loss of Daniels Harbour T1, a 66/12.5 kV, 1.0/1.33 MVA unit
  - overload of the remaining transformer T2, a 66/12.5 kV, 1.0 MVA unit in both the near-term and long-term horizons.
  - overload is mitigated by installation of Hydro's mobile transformer.
  - Hydro is working with the manufacturer of the Daniels Harbor T2 unit to determine if the unit can be upgraded to a 1.0/1.33 MVA rating.
- Loss of Happy Valley T1, a 138/25 kV, 30/40/50 MVA unit
  - overload of the remaining transformers T2 and T3 (138/25 kV, 15/20/25//28 MVA units) in both the near-term and long-term horizons even with the Happy Valley Gas Turbine operating at 25 MW during the T1 outage over peak.
  - Hydro will be addressing the issue in accordance with PUB Order No. P.U. 9(2018).

Steady State Analysis – Multi-transformer Stations

- Loss of Holyrood T10, a 230/69 kV, 15/20/25 MVA unit
  - overload of the remaining transformer T5, a 230/69 kV, 15/20/25 MVA unit in both the near-term and long-term horizons
  - The overload is mitigated by opening Newfoundland Power 66 kV line 52L between Kelligrews and Seal Cove to offload Holyrood T5
  - The mitigation action has no loss of customer load
- Loss of Western Avalon T1, a 230/66 kV, 15/20/25 MVA unit
  - overload of the remaining transformer T2, a 230/66 kV, 15/20/25 MVA unit in both the near-term and long-term horizons
  - The overload is mitigated by opening Newfoundland Power 66 kV line 41L between Heart's Content Substation and Carbonear Substation
  - The mitigation action has no loss of customer load

Steady State Analysis – Looped System Transformers

- Looped Systems are those have multiple supply points and multiple transformers
- Loops Include
  - Hardwoods to Oxen Pond 66 kV Loop
  - Stony Brook to Sunnyside 138 kV Loop
  - Western Avalon to Holyrood 138 kV Loop
  - Stephenville to Bottom Brook 66 kV Loop

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Steady State Analysis – Looped System Transformers

- The loss of Oxen Pond T3 (a 230/66 kV, 150/200/250 MVA unit) in the Hardwoods - Oxen Pond 66 kV Loop will result in the highest loads levels on the remaining transformers.
  - Should Hydro retire the Hardwoods gas turbine in the 2022 time frame, it is expected that there will be a transformer overload within the loop in the long-term horizon.
  - Potential mitigation measures for this potential long-term horizon overload include:
    - Replace the Hardwoods Gas Turbine
    - Add new gas turbine capacity within the Hardwoods – Oxen Pond 66 kV Loop
    - Increase transformer capacity in the Hardwoods – Oxen Pond 66 kV Loop in 2027 to meet the load growth and planning criteria
    - Each of these alternatives is being considered in Hydro's Resource Adequacy Study to be completed in 2018.
- No transformer overloads are expected in the Holyrood - Western Avalon 138 kV Loop in either the near-term or long-term horizon.

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Steady State Analysis – Looped System Transformers

- The loss of a 230/138 kV, 75/100/125 MVA transformer at Stony Brook Terminal Station in the Stony Brook – Sunnyside 138 kV Loop will overload the remaining 230/138 kV transformers in both the near-term and long-term planning horizons.
  - The overload is mitigated in the near-term by opening the 138 kV Loop on the Gander/Gambo region to off load the remaining Stony Brook transformer.
  - Analysis has indicated that with the loop open during the transformer contingency 138 kV bus voltages on the order of 90% can be expected to occur in the Gambo area.
  - Hydro is working with Newfoundland Power to determine an appropriate long-term solution to the issue.
- Long-term transmission mitigation strategies may include:
  - Additional transformer capacity within the loop
  - Construction of additional 138 kV transmission line(s) in the Gander to Clarenville portion of the loop
  - Addition of reactive power support to maintain acceptable voltages during the transformer contingency
  - Each alternative must be assessed for technical viability and a cost benefit analysis completed to determine the least cost reliable alternative

Steady State Analysis – Looped System Transformers

- The Stephenville – Bottom Brook 66 kV Loop
  - Normally operates open at the Bottom Brook end such that all load in the Stephenville area is supplied via 230 kV transmission line TL209 and the Stephenville Terminal Station.
  - For the loss of the single 230/66 kV transformer at Stephenville, the Stephenville gas turbine is operated for 50 MW.
  - Under light load conditions the 66 kV loop can be closed such that the Stephenville is supplied via a 138/66 kV, 15/20/25 MVA transformer, T2, at Bottom Brook and Newfoundland Power 66 kV line 400 L.
  - If Hydro were to retire the Stephenville gas turbine in the 2022 time frame, it would not be able to supply all load in the Stephenville area for loss of the 230/66 kV transformer at Stephenville Terminal Station.
  - Assuming retirement of the Stephenville gas turbine
    - the long-term mitigation strategy to maintain full back up supply to the Stephenville area for loss of the 230/66 kV transformer at Stephenville or the loss of TL209, is to add a 230/66 kV, 40/53/3/66.6 MVA transformer at Bottom Brook to replace the 138/66 kV, 15/20/25 MVA unit.

Steady State Analysis - Generators

- The loss of a synchronous condenser at Wabush Terminal Station in western Labrador will result in low voltages and tripping of loads
  - A comprehensive review of the transmission system in western Labrador is underway and will be covered under a separate report
- The loss of the Happy Valley gas turbine in synchronous condenser mode in eastern Labrador will result in low voltages and tripping of loads
  - Hydro will be addressing the issue in accordance with PUB Order No. P.U. 9(2018)
- Hydro is completing a long term resource adequacy analysis to assess the future generator capacity requirements. The report will be completed in 2018

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Steady State Analysis – Shunt Devices

- Loss of the Granite Canal Tap shunt reactor results in a potential for self-excitation of the Granite Canal generator
  - To avoid potential for self-excitation of Granite Canal generator an operating instruction has been prepared to remove TL269 from service when the Granite Canal Tap shunt reactor is out of service.
- The loss of a 46 kV, 25.2 MVAR shunt capacitor at Wabush Terminal Station in western Labrador will result in low voltages and tripping of loads.
  - A comprehensive review of the transmission system in western Labrador is underway and will be covered under a separate report.
- Eastern Labrador Shunts include
  - 11.4 MVAR at the Happy Valley Terminal
  - six 3.6 MVAR cap banks at the Muskrat Falls construction power station (MFATS3
  - Loss of a shunt capacitor bank will result in low voltages and a requirement to reduce transfer capacity on the 138 kV system in eastern Labrador.
  - Hydro will be addressing the issue in accordance with PUB Order No. P.U. 9(2018).
- In Year Two the Muskrat Falls generators are not yet in service. The loss of the 315 kV, 150 MVAR shunt reactor at Muskrat Falls will result in overvoltages due to the charging associated with 315 kV transmission lines L3101 and L3102.

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Short Circuit Analysis

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Short Circuit Results

- no issues with circuit breaker ratings in the near-term or long-term planning horizons

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Stability Analysis

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Stability Near-Term Horizon

- For the addition of the Maritime Link ONLY:
  - a firm import of 108 MW is available at Bottom Brook
  - an additional 192 MW of non-firm import capacity is available at Bottom Brook depending upon the Island Interconnected System load
- The export limit at Bottom Brook is a function of not only the Island load but also the generation dispatch and particularly, the number of thermal units on line at Holyrood.
  - The firm export limit is set at 55 MW at Bottom Brook
  - Up to an additional 70 MW of non-firm export is available at Bottom Brook depending upon the Island Interconnected System load and status of generation at Holyrood

Stability Near-Term Horizon

- For the addition of the Maritime Link and Soldiers Pond Synchronous Condensers:
  - a firm import of 108 MW is available at Bottom Brook
  - Up to an additional 242 MW of non-firm import capacity is available at Bottom Brook depending upon the Island Interconnected System load
- The export limit at Bottom Brook is a function of not only the Island load but also the generation dispatch and particularly, the number of thermal units on line at Holyrood
  - The firm export limit is set at 55 MW at Bottom Brook
  - Up to an additional 70 MW of non-firm of non-firm export is available at Bottom Brook depending upon the Island Interconnected System load and status of generation at Holyrood

Stability Near-Term Horizon

- For the addition of the Maritime Link and Soldiers Pond Synchronous Condensers with the Labrador – Island HVdc Link in monopolar mode, metallic return:
  - LIL transfers are limited as a function of the following parameters:
    - The status of the ML frequency controller
    - The number of SOP synchronous condensers that are in service
    - The Churchill Falls bus voltage

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Stability Near-Term Horizon

- There will be no frequency controller on the LIL in the initial monopolar mode of operation.
  - the import and export limits on the Maritime Link will be dependent upon the number of high inertia synchronous condensers in service and the thermal units on-line at Holyrood
  - A firm import of 108 MW is available at Bottom Brook
  - Up to an additional 242 MW of non-firm import capacity is available at Bottom Brook depending upon the Island Interconnected System load.
  - The export limit at Bottom Brook is a function of not only the Island load but also the generation dispatch and particularly, the number of thermal units on line at Holyrood.
  - The firm export limit is set at 55 MW at Bottom Brook.
  - Up to an additional 70 MW of non-firm export is available at Bottom Brook depending upon the Island Interconnected System load and status of generation at Holyrood and number of high inertia synchronous condensers on-line at Soldiers Pond.

Stability Long-Term Horizon

- The long-term horizon stability analysis is ongoing as part of operational studies
- Will be completed for the 2019 annual planning assessment

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Resultant 2018 Transmission Plan

- No system additions in the near-term
- System additions in the long-term to be based upon the results of the ongoing resource adequacy review
- Near and long-term transmission plan for Labrador under separate review

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Break

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Questions/Discussion

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