Bipole III: Past, Present and Future

David Jacobson, Section Head- Interconnection Planning,
System Planning, Manitoba Hydro

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Outline

- Introduction
- Early Planning Studies
- Bipole III Need
- Bipole III Project Scope
- Bipole III Future
- Video
- Q&A

Introduction

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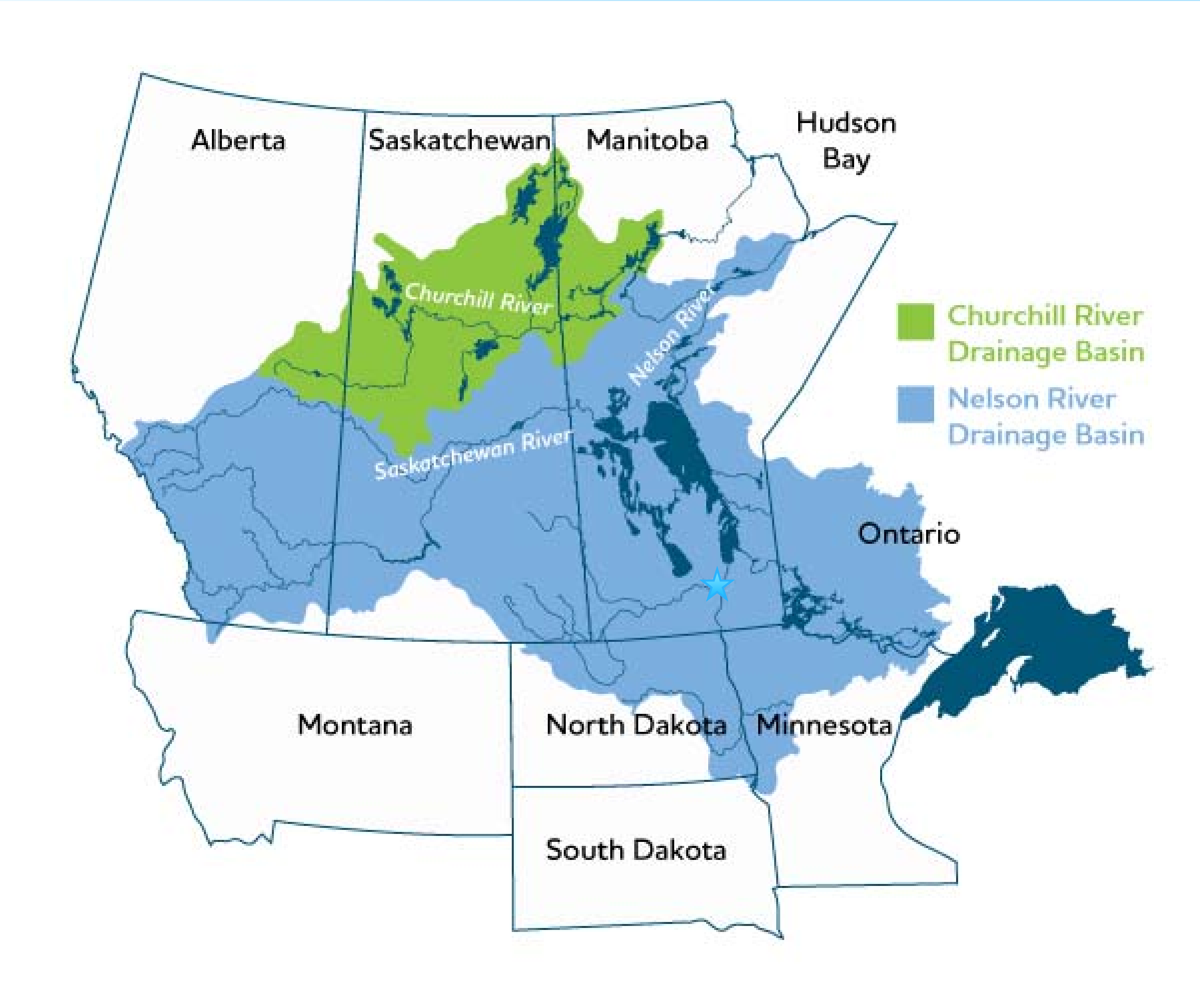

- Crown Corporation (owned by Prov. MB) with head office at Winnipeg.
- Services for over 580,000 electricity and 280,000 gas customers.
- A total generating capacity about 5700 MW produced mainly by 15 hydroelectric stations, 2 wind plants and 2 thermal stations.

https://www.manitobahydropower.com/who-we-are/

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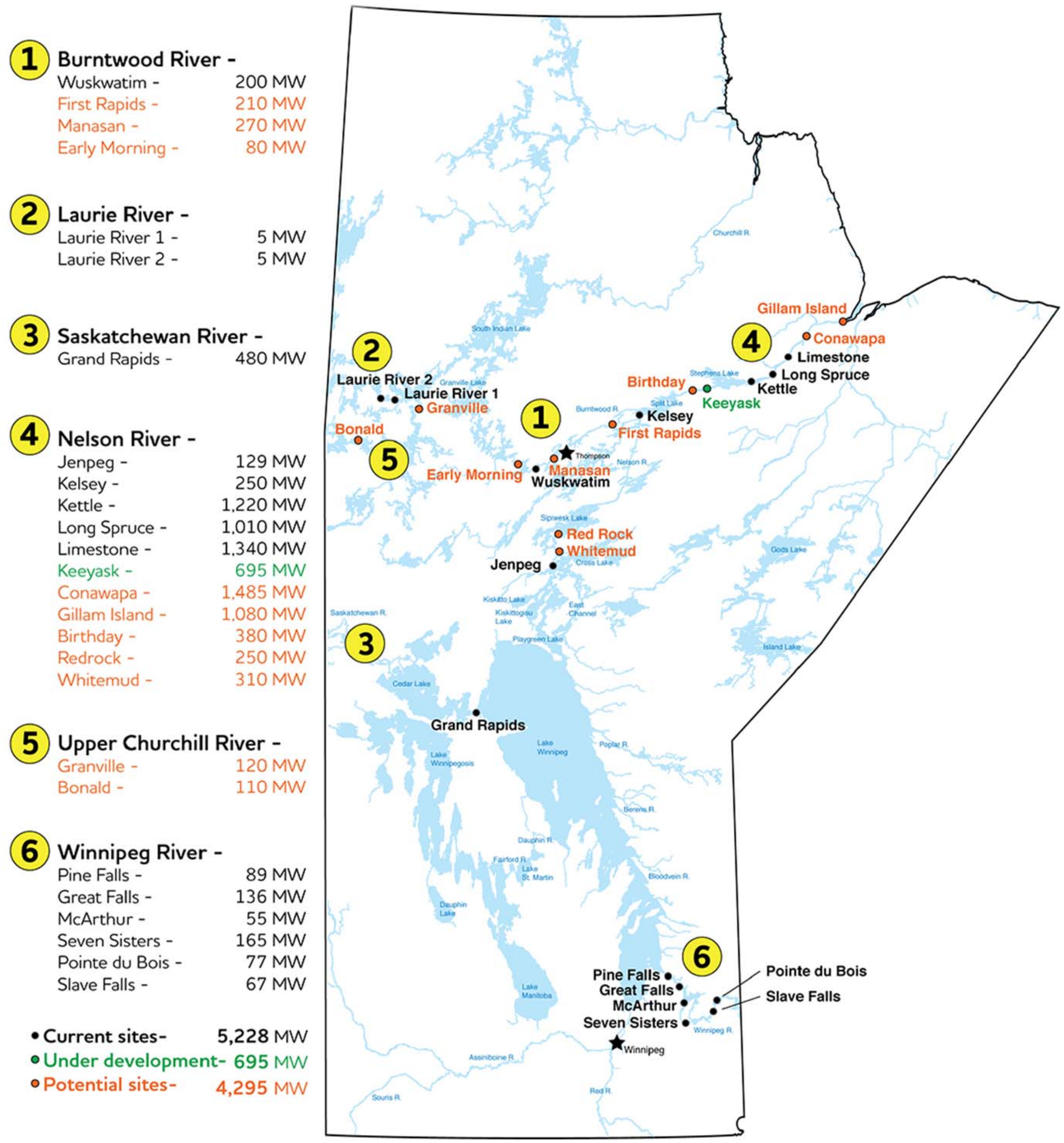

- Current Hydro sites: 5228 MW
- Under development (Keeyask) 695 MW
- Potential 4300 MW

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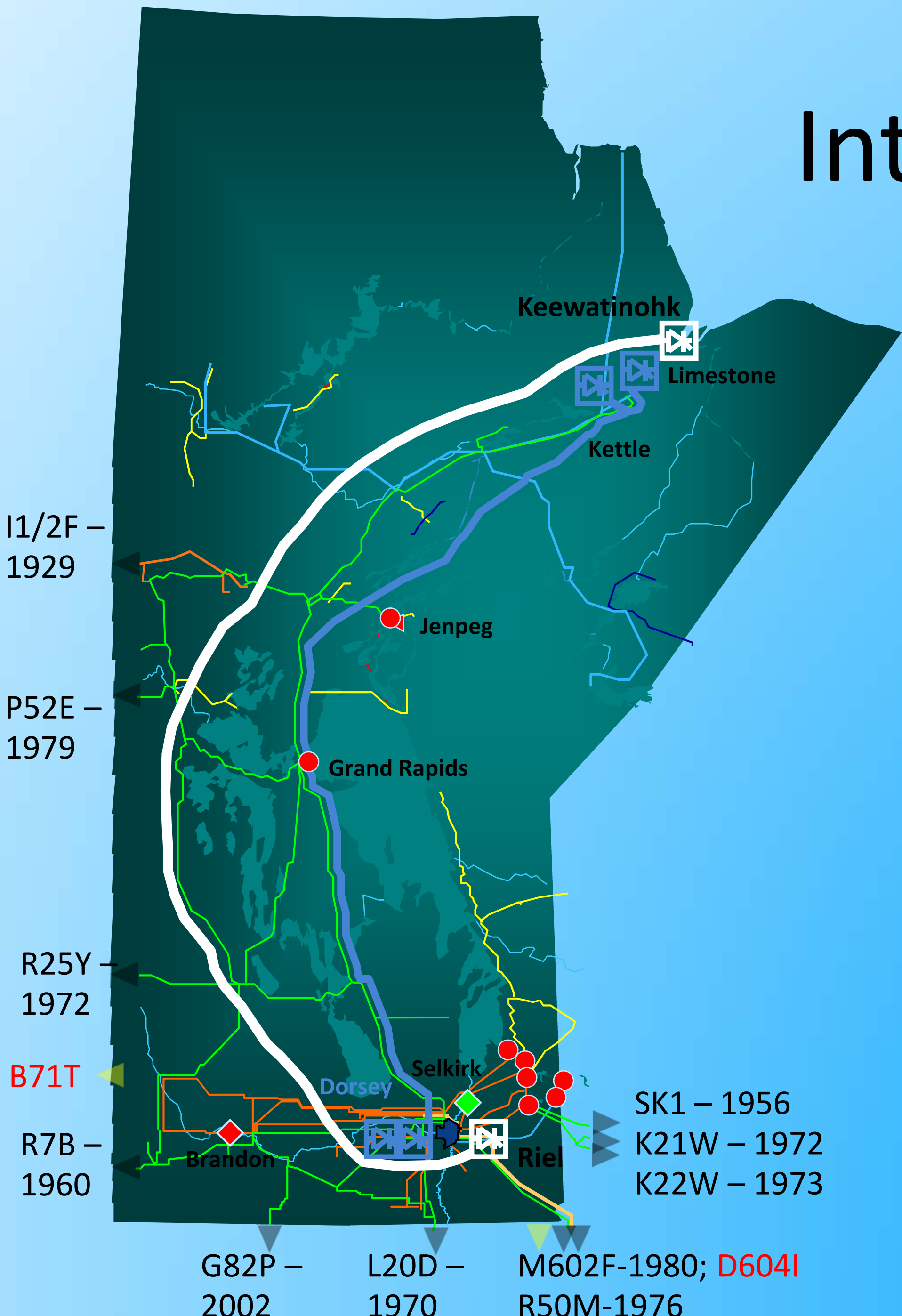
Interconnections



- B71T - Birtle to Tantallon 2021
- D604I – Dorsey to Iron Range 2020 (MMTP/GNTL)

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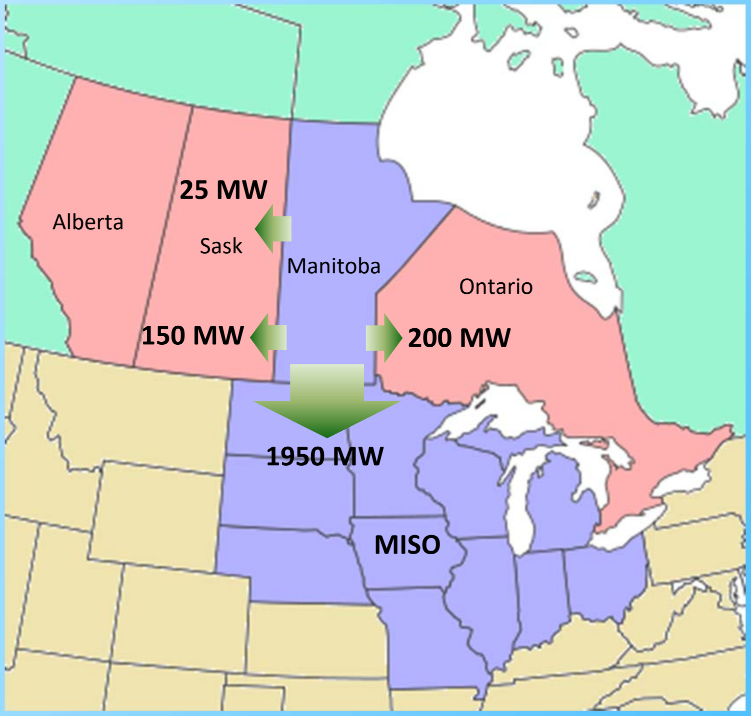
Firm Export/Import Capability



https://www.oasis.oati.com/woa/docs/MHEB/MHEBdocs/2016_Transmission_Interface_Capability_Report.pdf

	Export	Import
U.S.*	1950 MW 2833 MW	700 MW 1398 MW
Ontario	200 MW	0 MW
Sask-south Sask-north	150 MW 290 MW 25 MW	0 MW 0 MW 60 MW

*** Excludes 150 MW CRSG**

Early Planning Studies

1960's

- 1963 – Government of Canada/Manitoba shared cost of study looking at development of the Nelson River.
- 1966 – Agreed to jointly develop Phase 1 – "Birth of HVDC in Manitoba"
- Phase 1 – 1272 MW Kettle (ISD 1974), two 900 km HVDC lines, Bipole I (ISD June 1972),

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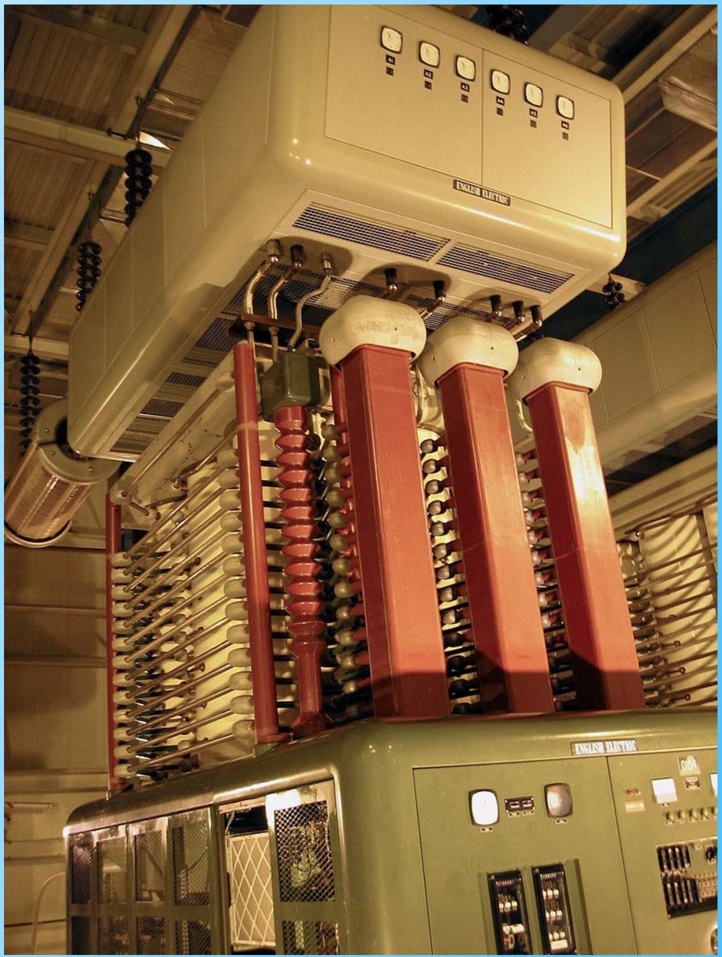
AC vs DC Decision



https://en.wikipedia.org/wiki/Nelson_River_DC_Transmission_System

- 500 kV AC with 70% series compensation was compared with HVDC. Series comp had about 15 years of history.
- HVDC selected – lower cost, lower losses and better performance.
- Four bids – one mercury arc only, two thyristor only and one mercury arc and thyristor. ASEA's first thyristor project (30 MW) only went into service in 1970.
- IEEE Milestone in EE – At 150 kV, they were largest mercury arc valves ever developed.

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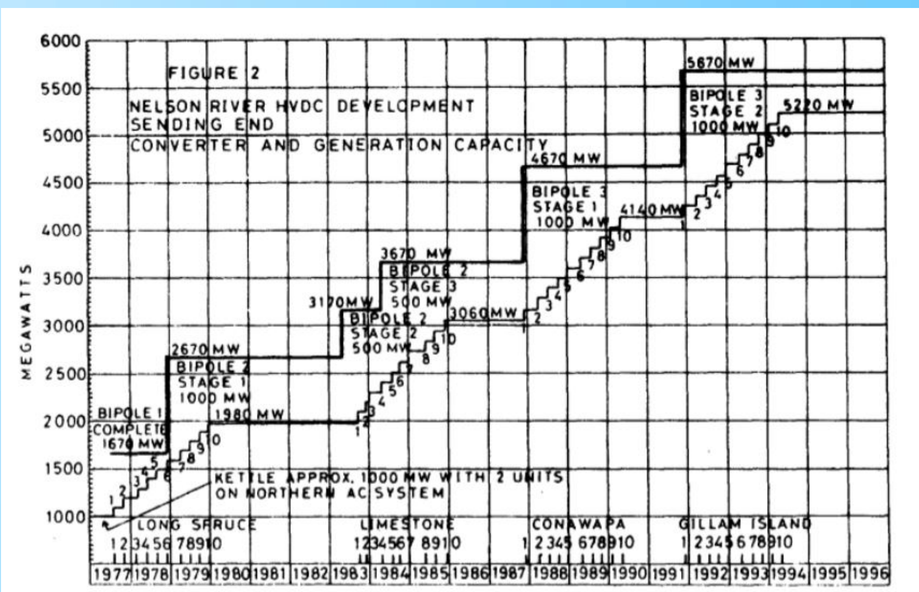
1970s Projections



C.V. Thio, "Nelson River HVdc Bipole-Two Part 1-System Aspects, IEEE Trans. PAS, Vol. PAS-98, No. 1, Jan/Feb 1979.

- High load growth projected need for Bipole III as early as 1988.
- A nuclear engineering department was formed in 1974.

Bipole I

Bipole II

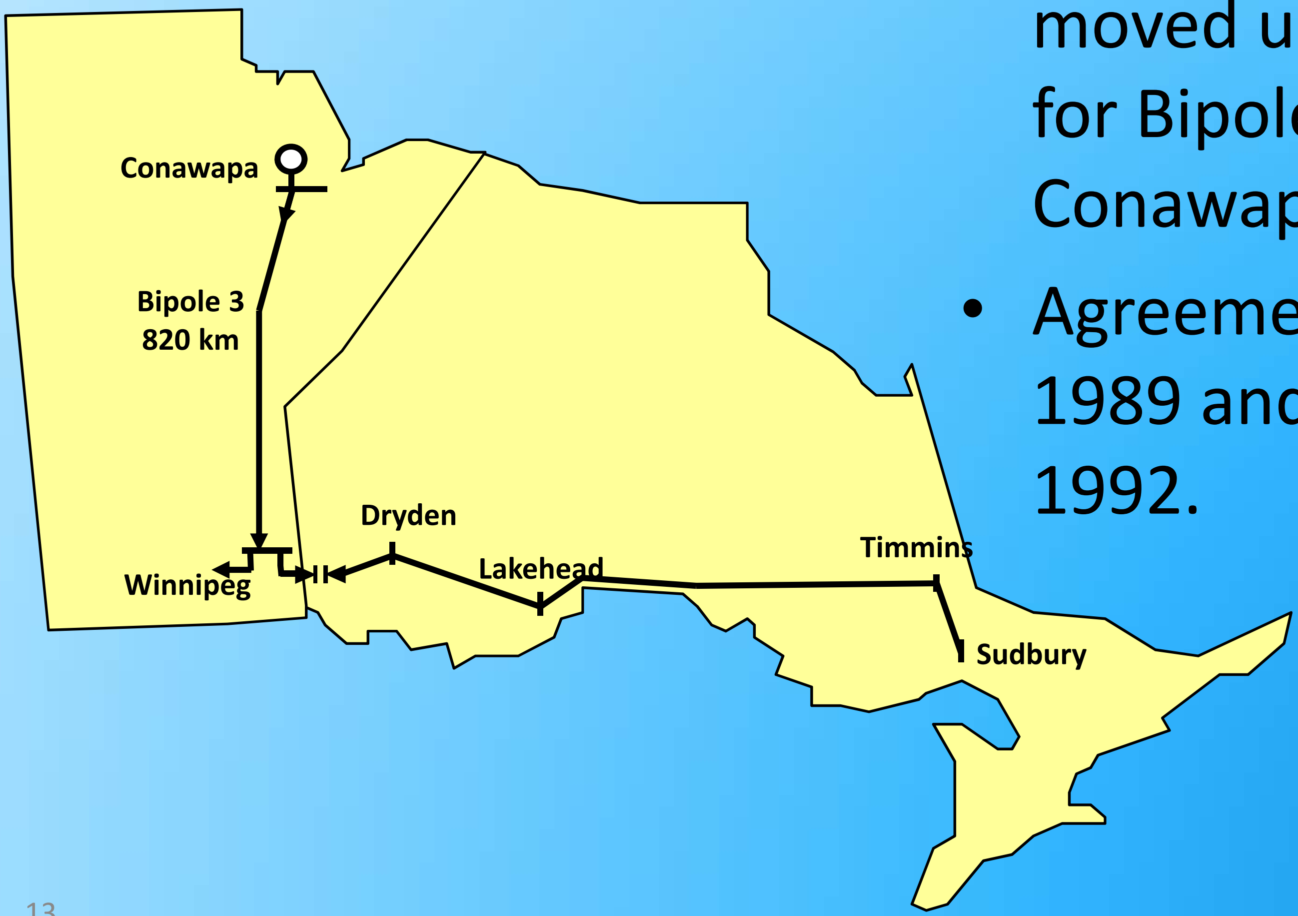
Bipole III

1980's

https://en.wikipedia.org/wiki/Nelson_River_DC_Transmission_System

- Load growth slowed
- Completed development of Bipole II in June 1985.
- 2000 MW, 500 kV thyristor technology
- Long Spruce completed 1979.
- Limestone's original target year was 1983 – deferred to 1990.

Early 1990s



- Potential for a 1000 MW to sale to Ontario moved up the schedule for Bipole III and Conawapa.
- Agreement signed in 1989 and cancelled in 1992.

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Features of the Bipole I and II System

- Link to 70% of the Province's generating capacity
- Bipole I and II HVdc lines constructed on the same Right-of-way
- 900km overhead lines, difficult terrain and access in the north
- Terminated at a common station – Dorsey (inverter)
- Highest percentage of power concentrated in a single facility - "Too many eggs in one basket"

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External Asynchronous Resource (EAR)

- Bipoles I and II allows for hydro to look like a battery. Allows for hydro-wind synergy. Very fast ramping capability.
- EAR is a market-designated resource separated from the main MISO market by a DC tie.
- EAR is very flexible and can provide energy, spinning, supplemental regulating reserves, regulation, ramp products, capacity.
- Currently, EAR is bidirectional and limited to 375 MW. Available since ~2010.

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Bipole III Need

Why is Bipole III required now?

- Bipole III is required for reliability
  - Bipole I & II DC transmission line corridor loss
  - Only one southern converter station (Dorsey)
  - Long restoration times
- We've experienced loss of corridor before and near misses (downbursts, ice, forest fires and etc.).
  - *Real risks, not theoretical*

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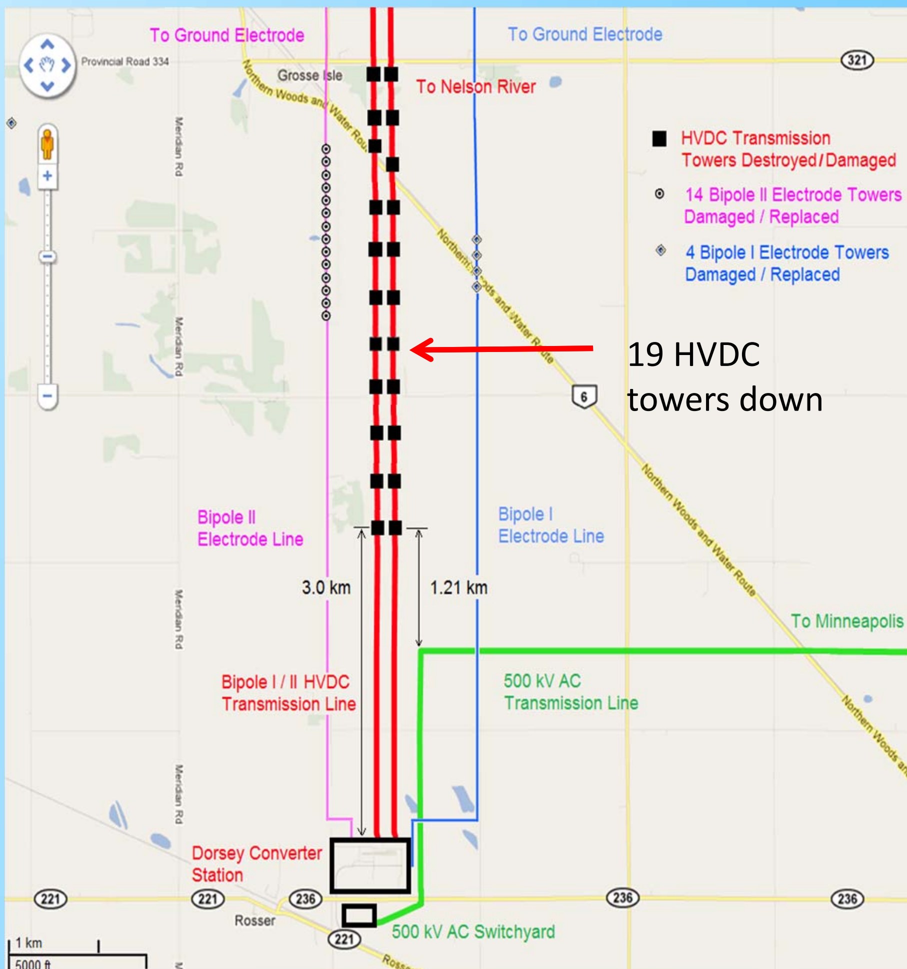
Reliability Risk – Sept. 5th 1996 Wind Event
1.5 miles away from Dorsey Converter Station



- Public appeal for power reduction
- All generation units on maintenance returned to service
- Rotating blackout planned

Reliability Risk – Dorsey Converter Station

Elie F5 Tornado

Storm hits portions of Dorsey, Aug. 10, 2007;
Lost BPI followed by D602F 60 seconds later

- Dorsey is a single terminus point for HVDC system
- Significant weather events (tornados, etc.) in the vicinity of Dorsey in the past
- A complete loss at Dorsey could mean loss of connection to northern generation for up to 3 years.

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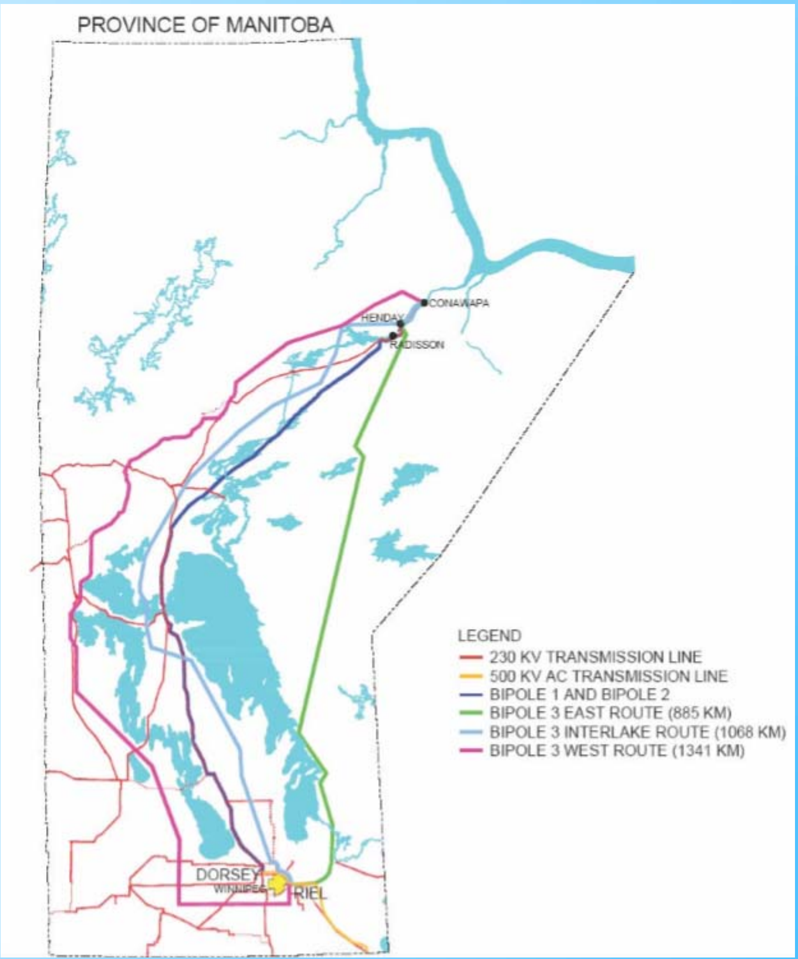
Probabilistic Analysis – Weather Hazards



Manitoba Hydro has worked closely with field experts/consultants to evaluate weather hazards (Tornados, wide front wind, ice) and other risks of losing the HVDC system after the 1996 event.

Events	Return Period of Failure (years)	
	Pre-Bipole III	Post-Bipole III
Tornados	17	3700
Synoptic Wind (wide front)	90	560
Combined Wind and Ice	20	200+

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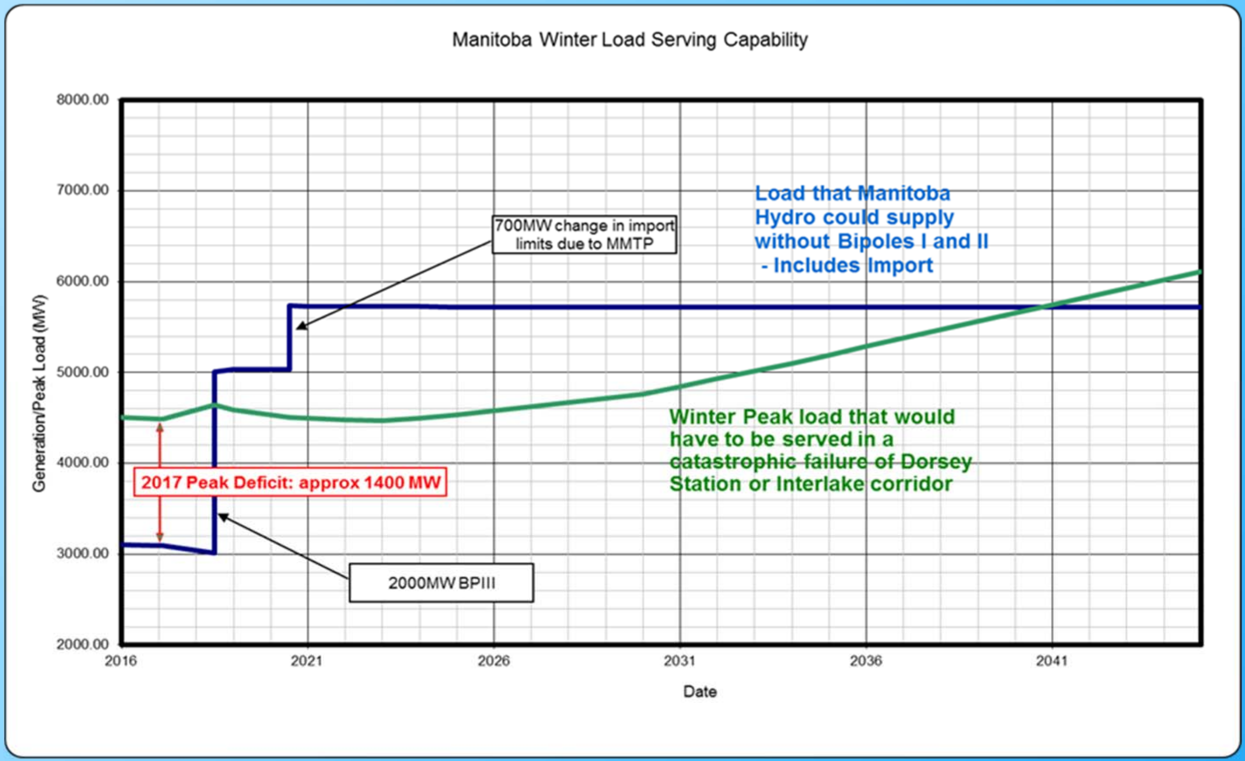
Deterministic Analysis – Supply Deficit



- Manitoba Hydro assesses the reliability risk of low-probability high-impact events according to NERC Standard TPL-001
- Supply deficit of about 1400MW for the loss of existing Bipole I/II system in the winter of 2017 (pre-Bipole III).

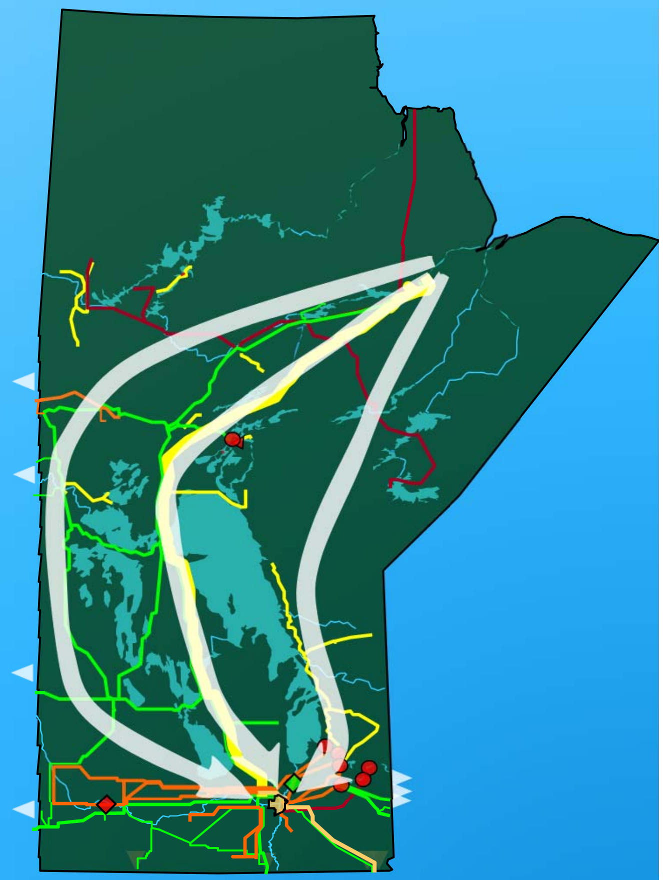
Additional Benefits of BPIII

- Aging BP I and BPII converters (>30 years in service) require life extension upgrades: $1B.
- BPIII offers adequate DC transmission spare to facilitate & optimize BPI/II refurbishment and save outage costs.
- Reduce HVDC transmission loss: about 80MW
- Provide HVdc capacity for future renewable energy development

Pole1 refurbished with thyristor valves -1992

2000's

- 2001: Internal report recommends:
  - Building 800 km East side HVdc line by 2010
  - Sectionalization of D602F at Riel in 2008.
  - Bipole I and II lines would be paralleled on BP I. Bipole III line would terminate at Dorsey on BP II.
- In 2005, East side becomes unavailable as an application to designate area as a UNESCO world heritage site in progress.
- Decision made in 2007 to proceed with Western route. New DC converters added to scope as impedance of 1388 km route expected to be difficult for Bipole II analog controls.



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Bipole III Project Scope

Bipole III Planning Studies

- Power flow studies
- Fault studies
- Stability studies
- Ac and DC harmonic studies
- Small signal stability assessment
- Feasibility studies of VSC technology

Outcome of Bipole III Planning Studies

- Determine BPIII size and operation modes
- Ac system reinforcement for integration of BPIII (new lines/stations, location, upgrades, etc.)
- Static/dynamic reactive power requirements
- Determine equipment rating (breakers, switches, grounding and etc.)
- Estimation of ESCR and MIESCR for dc performance and determine mitigation
- Determine impact on the nearby systems (ac and dc in multi-infeed schemes)
- Determine special requirements (supplementary damping /fast dc reductions)

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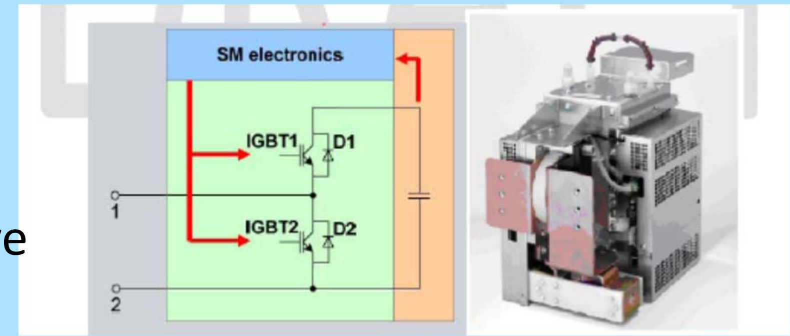
Feasibility Study - VSC Option

- No synchronous condensers
  - Cost savings : Capital /O&M
  - Reduce system fault levels
  - VSCs can provide voltage and reactive power support, but not inertia that synchronous condensers do



- No commutation failure

  - Large infeed of HVdc schemes in proximity: If all LCC links fail commutation at the same time, it can lead to potential (although very short) loss of significant power to southern system.

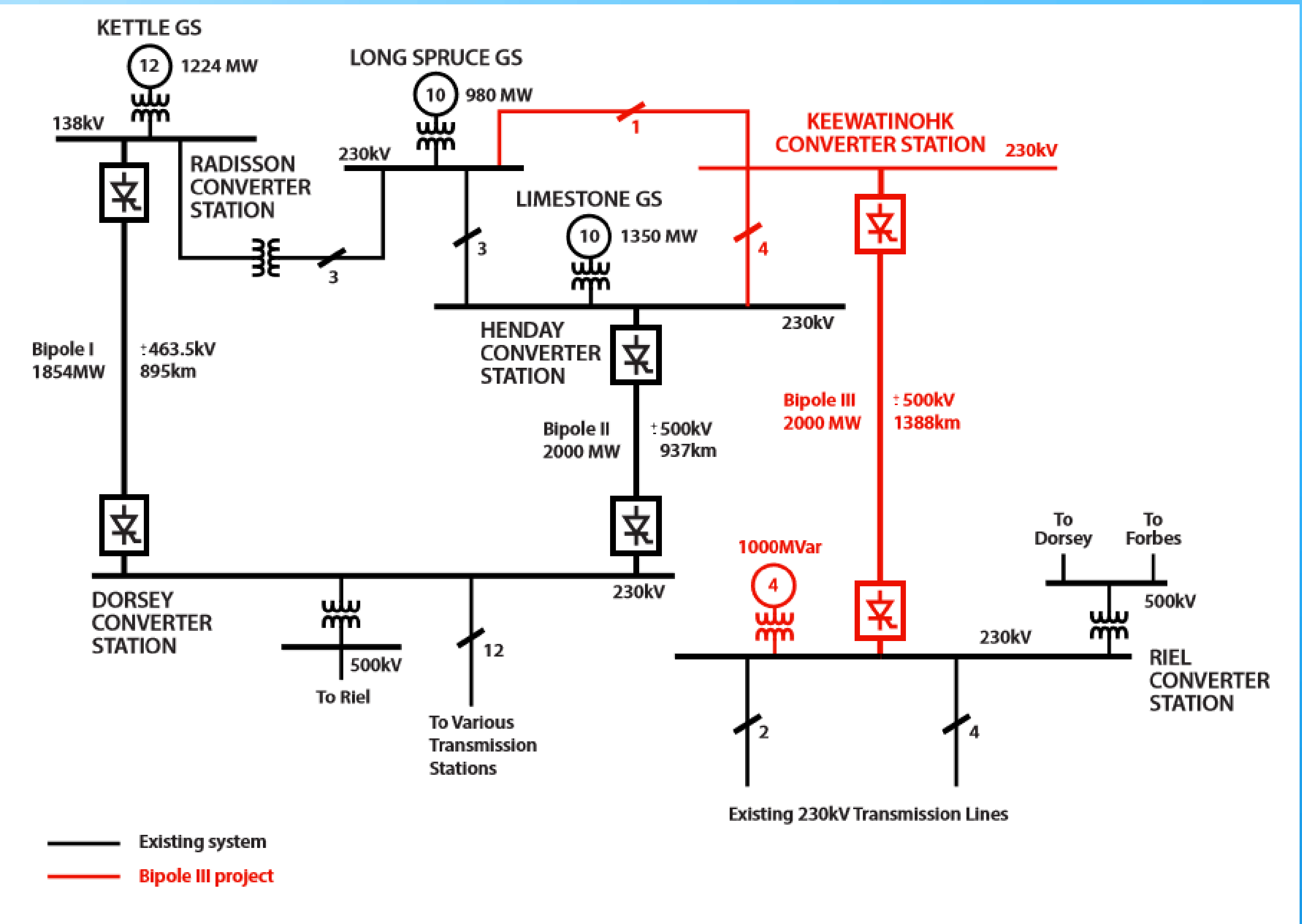
  - VSC improves this situation by not failing commutation and ability to maintain power flow.

Feasibility Study - VSC Option

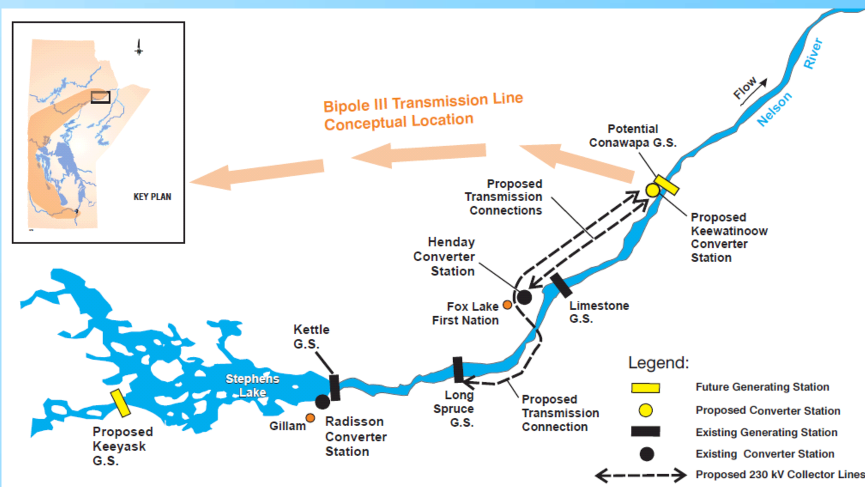
- Disadvantages
  - Not implemented at 500 kV and 2300 MW; Skagarak 4 planned for 2014
  - Limited number of vendors
  - Dc fault clearing requires ac breakers (half bridge technology)
  - Converter losses slightly 1% vs 0.7%

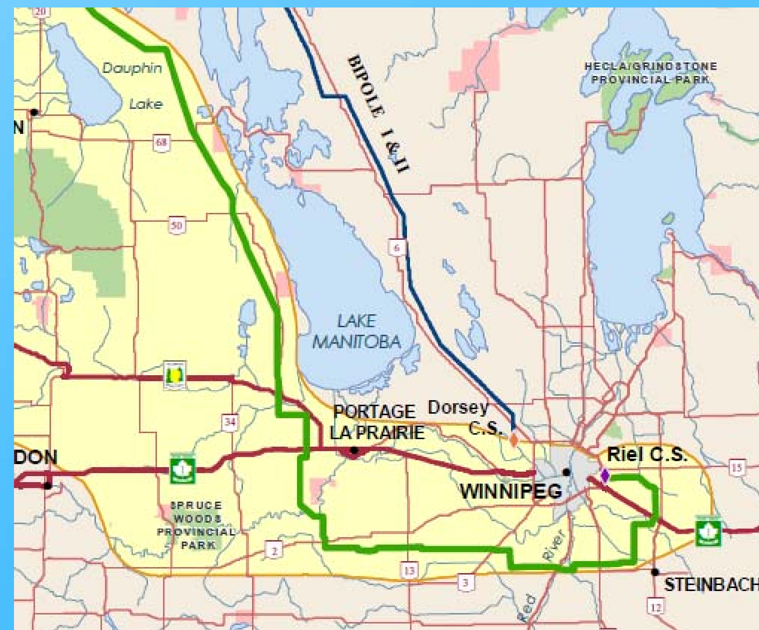
- Decision
  - Permit VSC bids as an option
  - Included price break as 4x250 MVAr synchronous condensers not required.
  - Required dc faults to be cleared on dc side (full bridge or dc breaker needed).

Bipole III Project Scope - ISD 2018
LCC, ±500 kV, 2000 MW



Locations of BPIII Converters





- Rectifier KCS: The location is physically separated from existing Bipole I and II converter facilities at Radisson and Henday stations
- Inverter RCS: about 40km away from Dorsey Station
- Considerations of separation to eliminate the common mode failure

Bipole III Project Implementation

Turnkey Contracts:

- Keewatinohk and Riel converter stations & HVDC equipment (> $800M)
- Keewatinohk ac switchyard (~ $112M)
- 4x250MVar, Riel Synchronous Condensers (>$200M)

Managed by MH:

- 1388 km transmission line
- AC system upgrades (north/south)
- Other interface components

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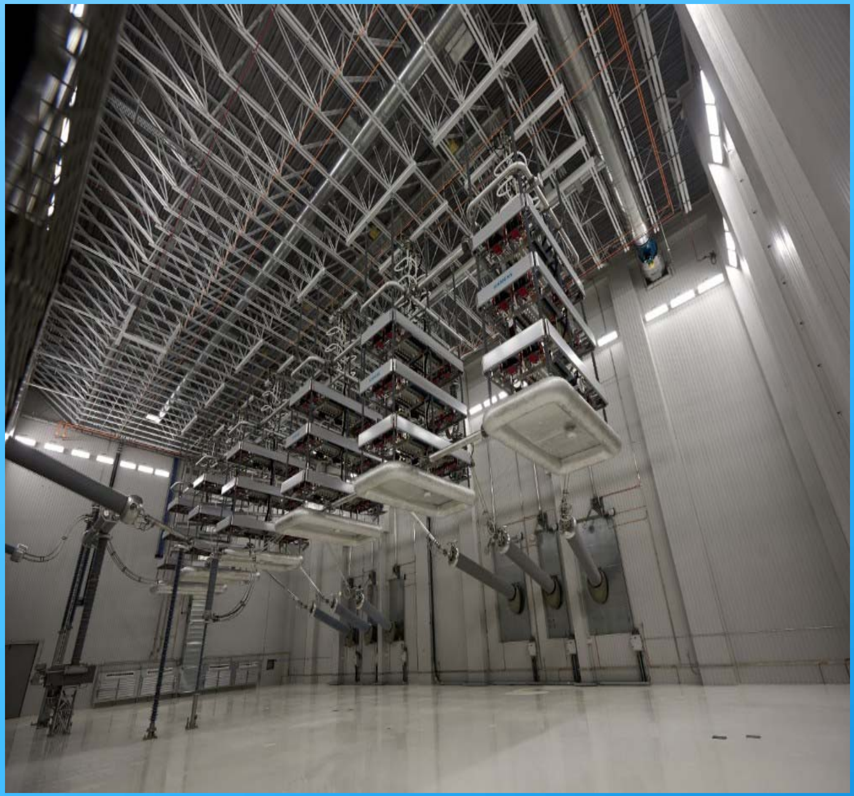
Project Scope - Converter Stations

- LCC technology with Direct-light Triggered Thyristor (LTT)
- High levels of availability & reliability
  - Two series connected 12-pulse valve groups (VG) per pole
  - physical separation of valve group & pole controls on a per-pole basis
- -50C to +40C outdoor equipment design



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Project Scope - Converter Stations

- Nominal power transfer capacity of 2000 MW with 115% continuous overload
- Transient overload capability of 1.27pu for damping purposes
- Reduced (0.8 pu) dc voltage operation for forest fires conditions.
- De-icing operation : 2 poles transmit power in opposite directions (P6 in forward & P5 in reverse) to allow high DC current flow for melting ice on the HVdc line
- Paralleling with BPII – control capability tested
- Up to 80Hz frequency excursions at the rectifier – permits HVDC reduction

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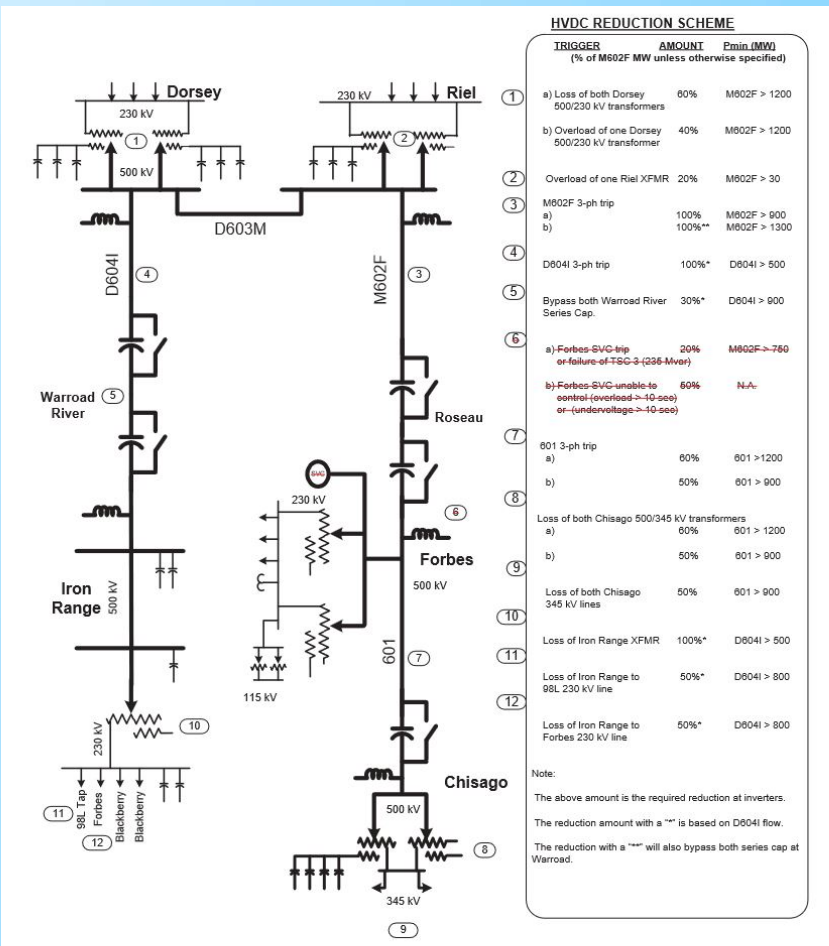
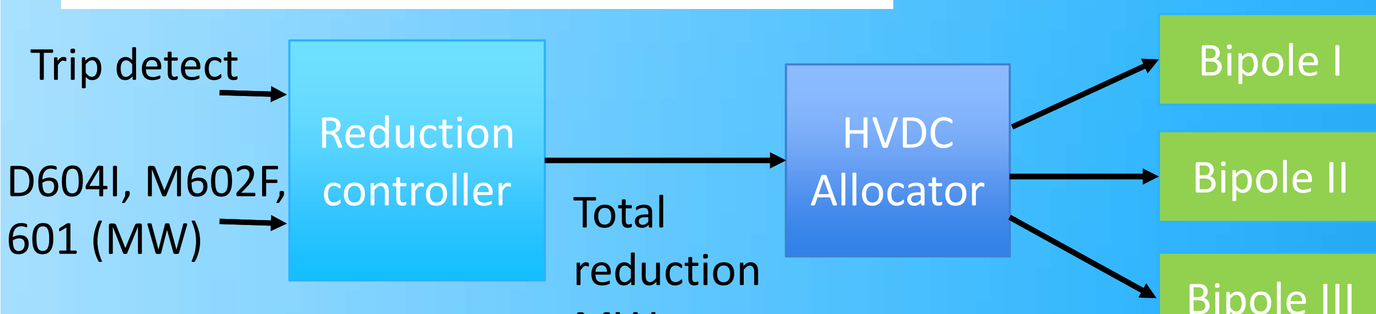


DC reduction

- Monitors status of key components of 500 kV tie lines
- Monitors pre-contingency MW flow at key locations
- Calculates dc reduction required
- Changes power order at rectifier of each Bipole
- Total time delay around 50-100 ms. Modelled as 200 ms



Project Scope - Converter Stations

- Total of 20 converter transformers including spare units
- Controlled switching for energizing two parallel converter transformers (3-phase 5-limb): Pre-insertion resistors at Rectifier and Point-on-Wave (POW) controllers at Inverter (world first!).
- Both POW and PIR can meet the requirements of mitigating transient inrush (typically less than 0.1pu, 1.5 kA base)
- Controlled switching reduced inrush current such that they could be released for operation in 2 minutes rather than 10 minutes.

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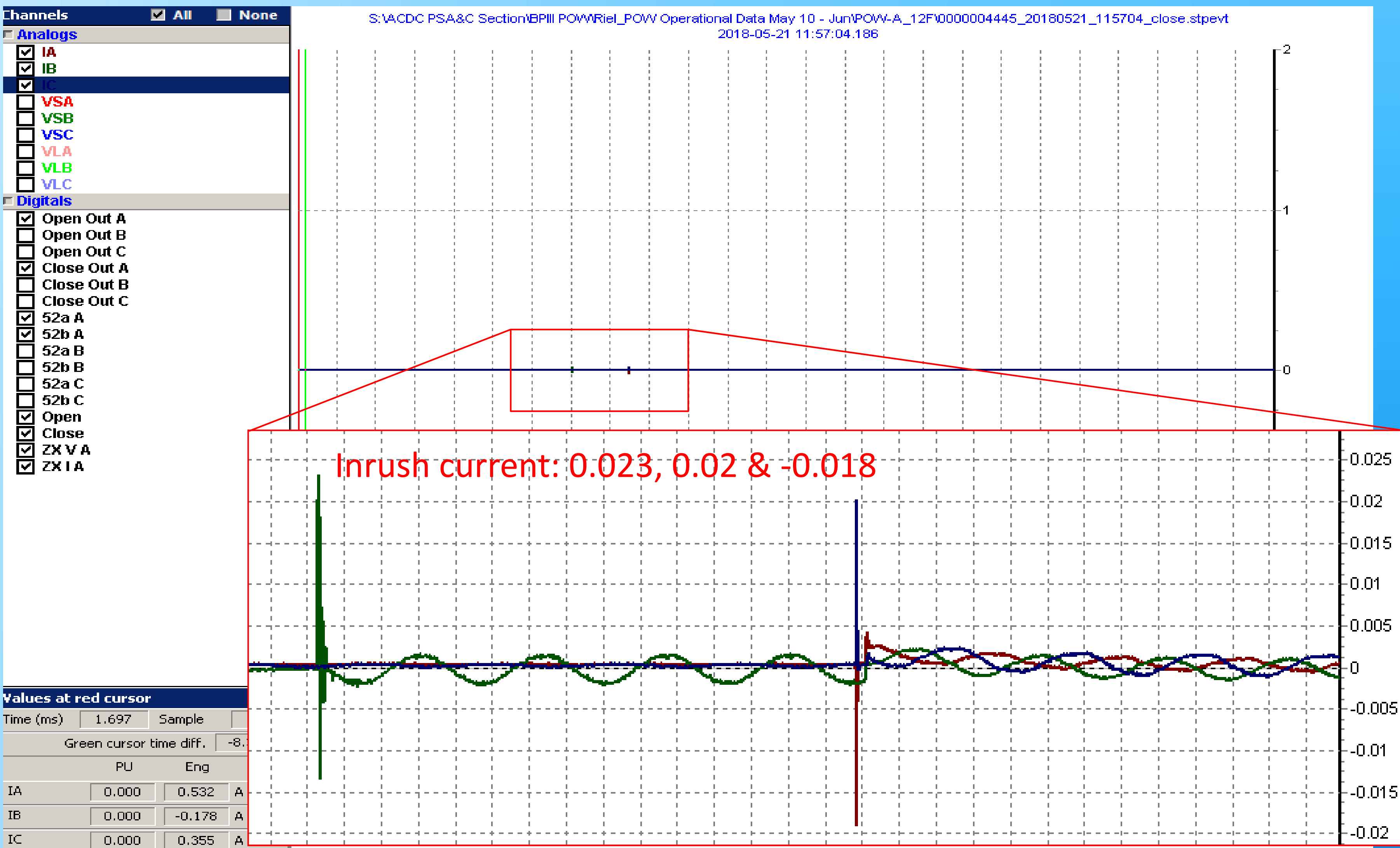
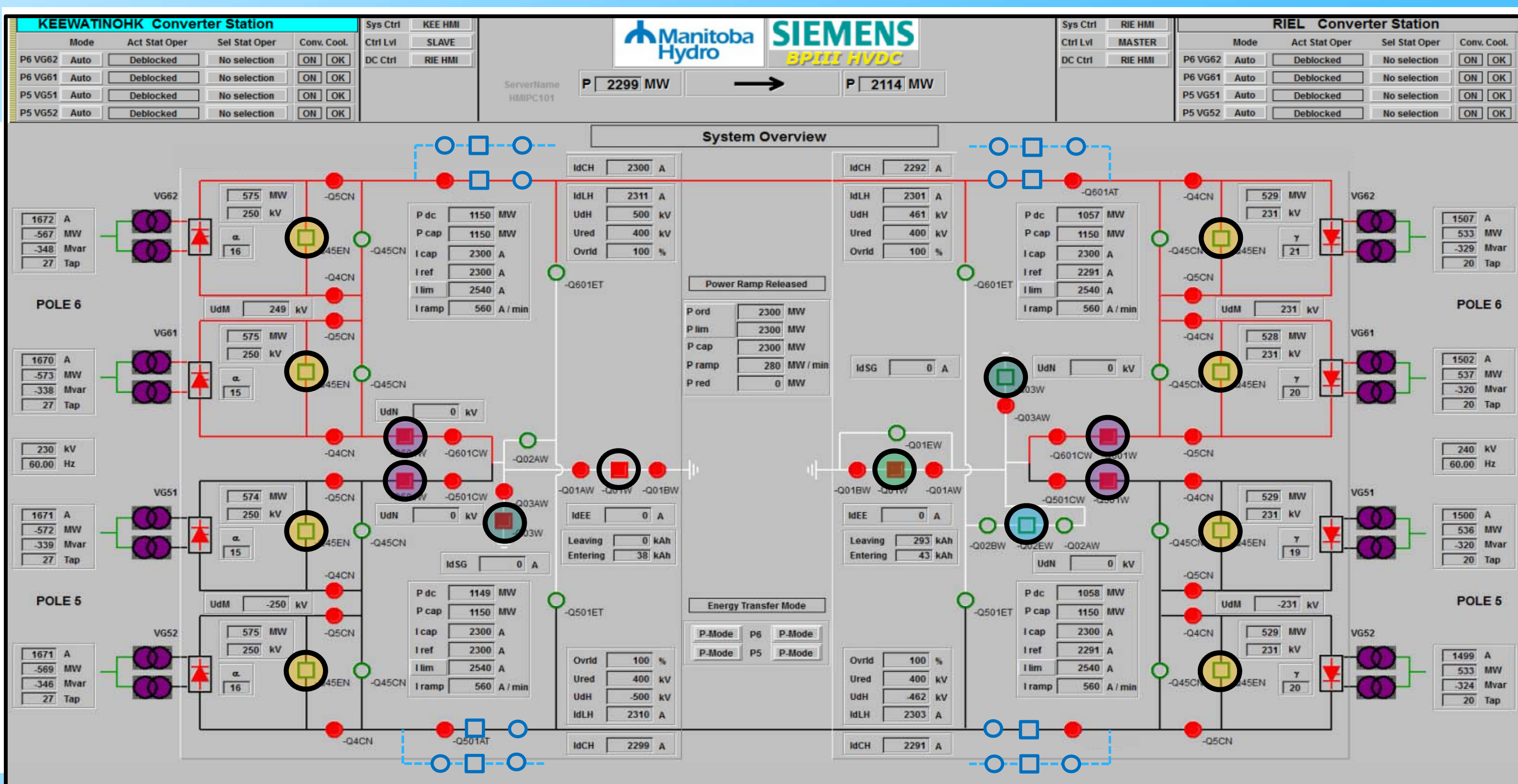
Field Commissioning & Results

Riel CS Operation: Optimal Scenario



Project Scope - Converter Stations

- Highly flexible operation modes (bipolar, monopolar ground return, monopolar metallic return, combinations of different VGs) achieved with dc yard design



- MRTB (1)
- GRTB (1)
- NBGS (2)
- NBS (4)
- ELTS (1)
- BPS (8)

Project Scope - Converter Stations

- DC switchyard
- DC filter banks (multi-turned, N-1)
- Smoothing reactors (two individual units for redundancy)

Project Scope - Converter Stations

- 230 kV Air Insulated Switchyard (AIS)
- New 230 kV bays & apparatus at KCS
- Expansion of 230kV yard at RCS
- Four AC filter banks at each station (with controlled switching)

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Project Scope - Riel Synchronous Condensers

- Four +250/-125 MVAr synchronous condensers; hydrogen cooled.
- Each synchronous condenser requires a unit transformer
- Provide voltage , reactive support and system inertia: critical for HVDC operation in Manitoba southern weak ac system
- Minimum MIESCR of 2.5 at Riel
- Multi-infeed Effective Short Circuit Ratio (MIESCR) – considers the closeness of converters via an impact factor. If the inverters are on the same bus, the factor is 1; if they are infinitely far away the factor is 0.

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Project Scope – HVdc Line

- 1388km, 500KV overhead
- Self-supporting and guyed towers
- Base reliability level of 150 year return period for weather loads and increased to 500 year return design at some sections
- Anti-cascading towers (every 5-10 km)

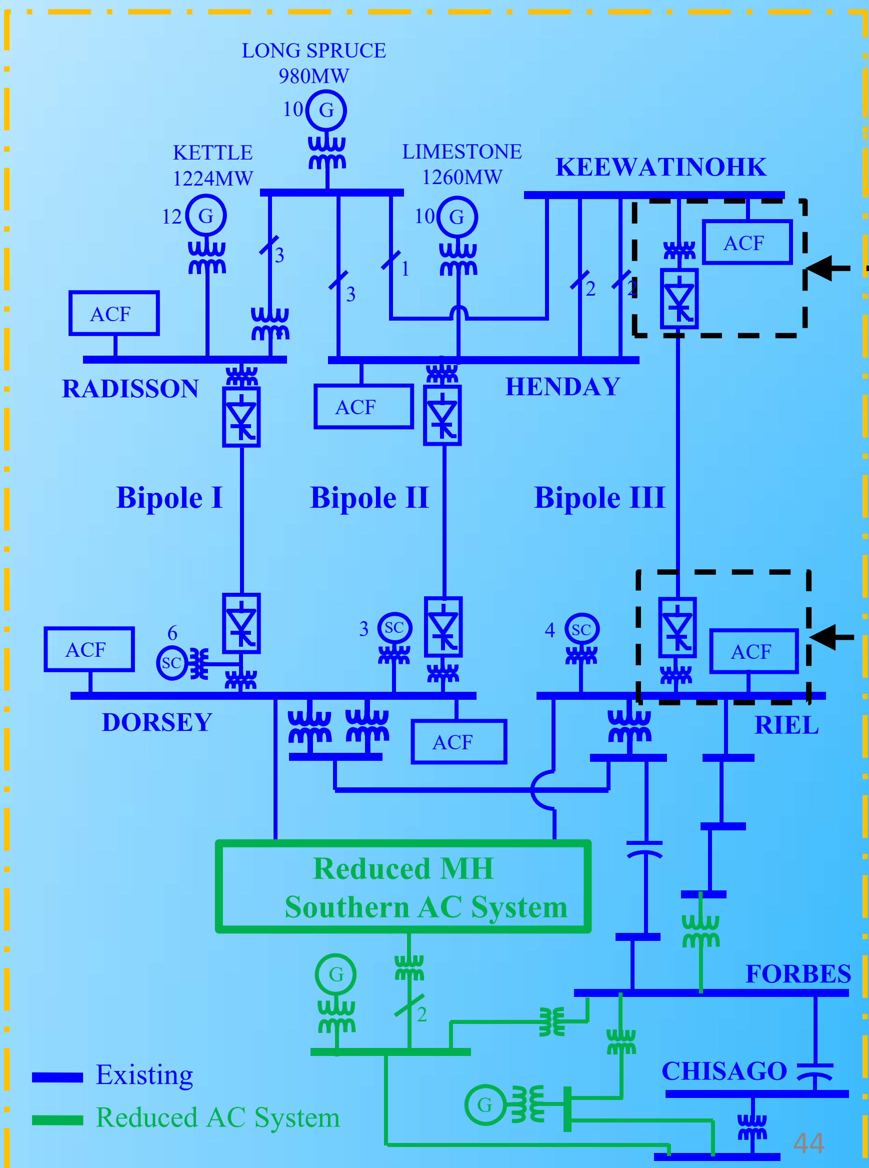
Project Scope – HVdc Line

- 3-bundle Configuration vs. 2-bundle of existing Bipole I&II lines
- Conductor surface gradient less than 23kV/cm.
    - Bipole II is 28 kV/cm. Reduced noise, corona loss and hopefully reduced risk of anomalous (pseudo-random fair weather on negative pole) flashovers.
- OPGW for Lightning protection and communication; 4 repeater stations

Project Scope – AC System Upgrades

- Five new 230kV ac lines (north) and sectionalization of one 230kV ac line in the south
- Upgrades of two existing ac stations for line terminations
- Breaker upgrades at various stations due to fault level increases

BPIII Replica C&P HIL Testing



real-time simulation

RTDS (PB5)

Bipole III C & P Replica

Model Improvements

- In-house Bipole I&II model
- Freq-Dependent TLine
- Transformer saturation & OLTC
- 55 µs time-step; 6 racks

MH SPS & supplementary controls

- HVDC reduction allocator, 500 kV SPTR
- Custom SC exciter & JVC

MH & US ac dynamic equivalent

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Bipole III Project Timeline

- EIS was filed in 2011 for western route and Environmental License was received in August 2013.
- Various RFP packages were released after 2013.
- Line construction started in 2013.
- Converter contract was released and awarded in 2014 . Both VSC and LCC were considered in the HVDC converter station tendering process – only LCC bids received.
- System commissioning tests in 2018 (4 months, ~250 tests, ~400 transformer energizations, 5 staged faults with drone/pendulum)
- ISD of July 2018

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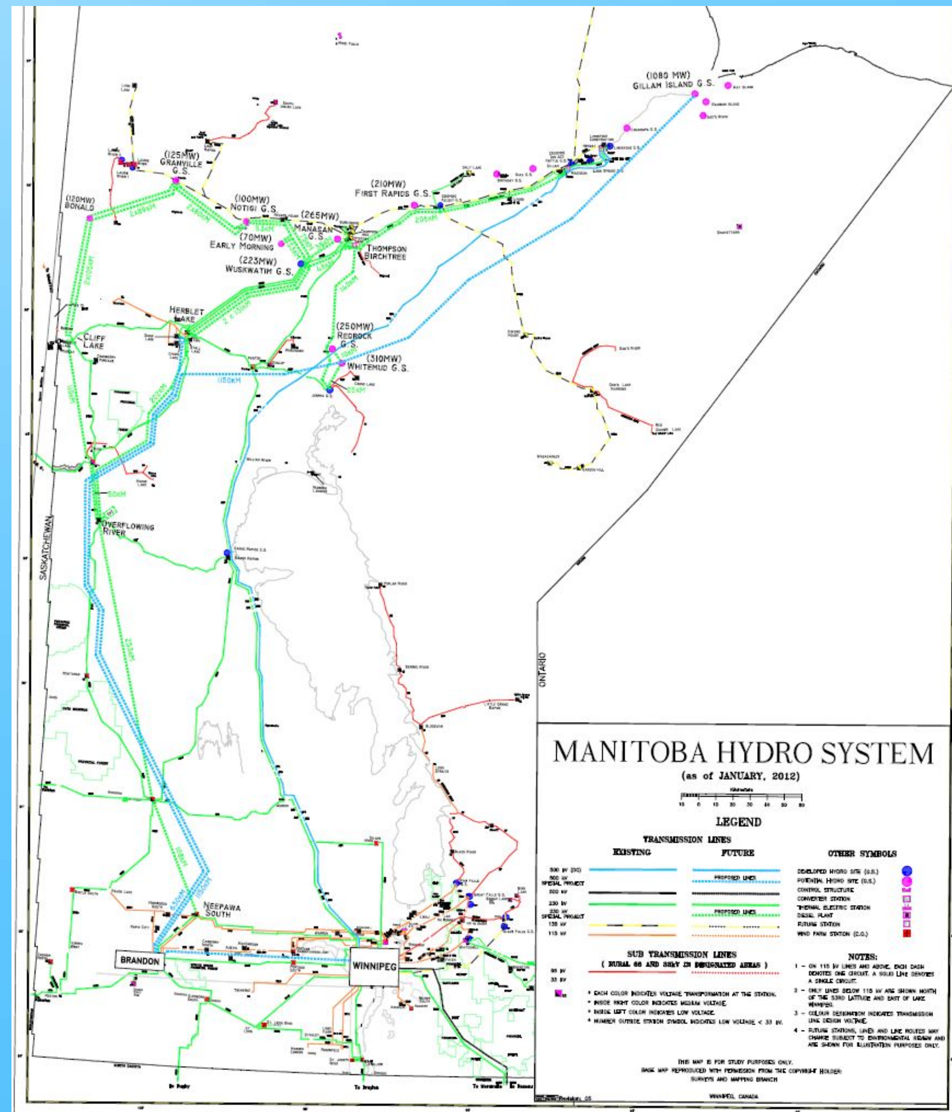
Bipole III Future

Business as Usual

- Conawapa will utilize Bipole I-III. Full 2300 MW rating of Bipole III will be utilized (6x250 MVAr syncs). Maintain a minimum valve group spare above generation.
- Statcom with or without energy storage will be considered instead of syncs.
- After Conawapa, northern generation will be integrated using new north south 230 kV and 500 kV ac.
- Bipole IV (LCC or half-bridge VSC) not permitted.



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With BPIII VSC taps (full bridge)

- Stage 1 – Integrate 680 MW Burntwood River; 700 MW VSC near Thompson plus new collector system (370 km)
- Stage 2 – Integrate 500 MW of Upper Nelson generation; 500 MW parallel VSC tap at Thompson and 500 MW tap at Brandon

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With BPIII VSC taps

- Stage 3 – Integrate 1130 MW Conawapa plant; 700 MW parallel VSC tap at Brandon; Conawapa connects to Riel via east side Bipole. Salvage and relocate DC lines. End up with a 1200 VSC point to point link to Brandon and a 2000 MW LCC link between NCS and Winnipeg, which creates three north-south corridors.

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Summary

- Bipole III has a long history!
- Bipole III is a large investment ($B) by Manitoba Hydro to address the lack of redundancy in the HVdc system and load serving deficiency under catastrophic HVdc contingencies
- The in-service of Bipole III reliability project significantly enhances our system reliability and resilience.
- BP3 offers adequate HVdc transmission spare to facilitate & optimize BPI/II refurbishment .
- Provides additional HVdc capacity for future renewable energy development in northern Manitoba.

Video

Questions?

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