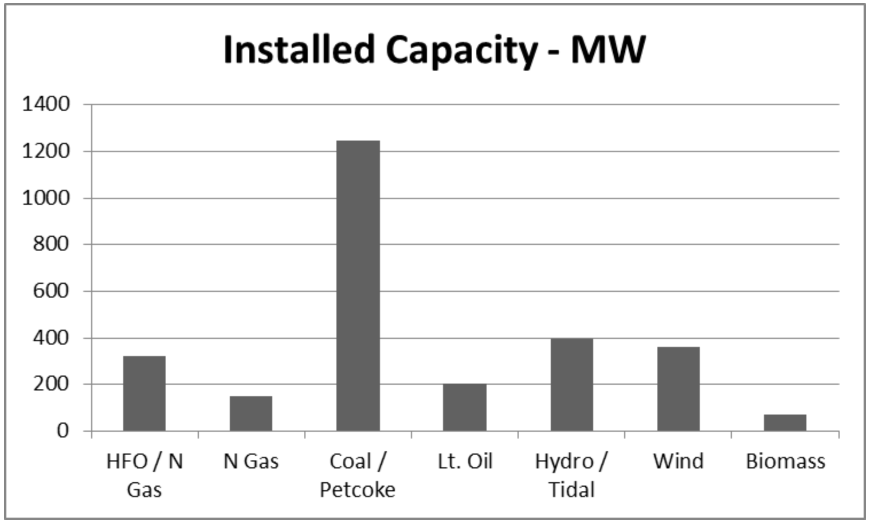
Nova Scotia POWER An Emera Company

PLEXOS 2014 UGM - OCTOBER 1, 2014

Regulatory Approval Process: Fuel Forecasting with Plexos & Modeling Dynamic Reactive Reserve Constraints

About NS Power

- Vertically Integrated, Privately Owned, Regulated
- Serving ~500,000 customers in Nova Scotia
- Annual Energy ~11 TWh
- Peak Demand ~2200 MW (Winter Peaking)
- Diverse Fuel Mix:



Regulatory Approval Process: Fuel Forecasting with Plexos

NSP Regulatory Structure

- Fuel Adjustment Mechanism (FAM)
  - Ratepayers pay the actual cost of fuel, prudently incurred
  - Fuel forecasts are filed with the provincial regulator annually, with updates provided quarterly
  - Independent FAM Audit is conducted every two years

- Plan of Administration (POA) describes fuel forecasting methodology in great detail
  - POA was written when Strategist (Ventyx) was used for system dispatch modeling and fuel forecasting

Selection of Plexos Tool

- NS Power began researching possible tools to replace Strategist as a system dispatch optimization tool in 2008
- Strategist, being intrinsically a resource optimization software, was no longer able to represent the system dispatch complexities caused by decreasing load, increasing variable generation and tightening emissions regulations
  - Researched and tested several tools and selected Plexos in late 2011
- 2010-2011 FAM Audit (Liberty Consulting Group) also recommended that NSP look to replace Strategist for fuel forecasting purposes
- NSP's Plexos model was developed internally, with support from Energy Exemplar, through 2012

Model Validation & Regulatory Update

- Plexos was run in parallel with Strategist internally for two quarterly fuel forecasts, to validate the model
  - Some Plexos results were different from Strategist but could be explained by the addition of chronological constraints or transmission model
  - Strategist remained the tool of record through much of 2013, but some results of the Plexos runs were used to "inform" Strategist to improve forecast accuracy

- Through 2013 NSP fuels and executive leadership teams gained confidence that the Plexos model was accurately forecasting fuel and purchased power requirements

Stakeholder and Auditor Presentations

- Generation Planning group prepared a draft FAM POA document which removed references to Strategist and updated modeling assumptions reflecting Plexos data requirements

- Data from parallel runs and draft POA were presented to FAM stakeholders at two working group sessions; broad approval from stakeholders was received by the end of 2013

- FAM Auditors interviewed several team members to discuss the new tool, and an extensive demo was arranged for the stakeholders and auditors to gain confidence in the new dispatch optimization model

Current Status and Ongoing Work

- Plexos is now the tool of record for Fuel Forecasting at NSP (as of 2014-Q1)
- FAM Auditor commended NSP for the implementation of Plexos during 2013-14 FAM Audit
  - Requested that a "backcast" study be undertaken to validate the additional Plexos assumptions not required for Strategist; this work is in progress
- FAM POA changes are being finalized with the regulator and stakeholders
  - The approval process has not held up the use of the tool, as the value was recognized by all concerned

Nova Scotia POWER
An Emera Company

Modeling Dynamic Reactive Reserve at NS Power

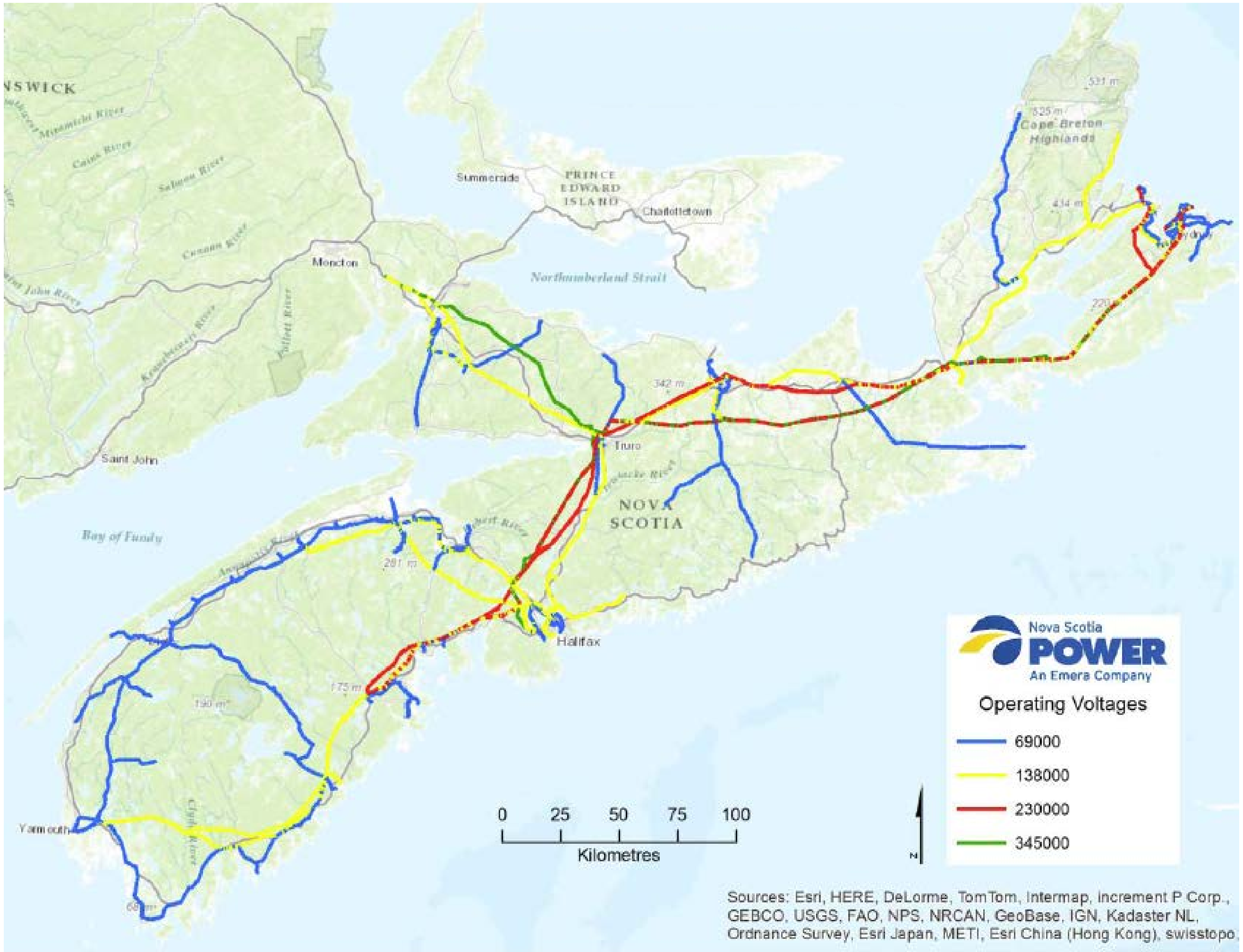
Nova Scotia POWER An Emera Company

NSP Dynamic Reactive Reserve Requirement

- Due to distance between major generators and load centre, reactive power and generation are required in Halifax (Metro) to support system voltage and provide adequate fault current for the system protection to operate
  - In many hours, this is provided by SVC and capacitor banks
  - During certain system condition additional generation in the load centre is required to be dispatched out of economic merit

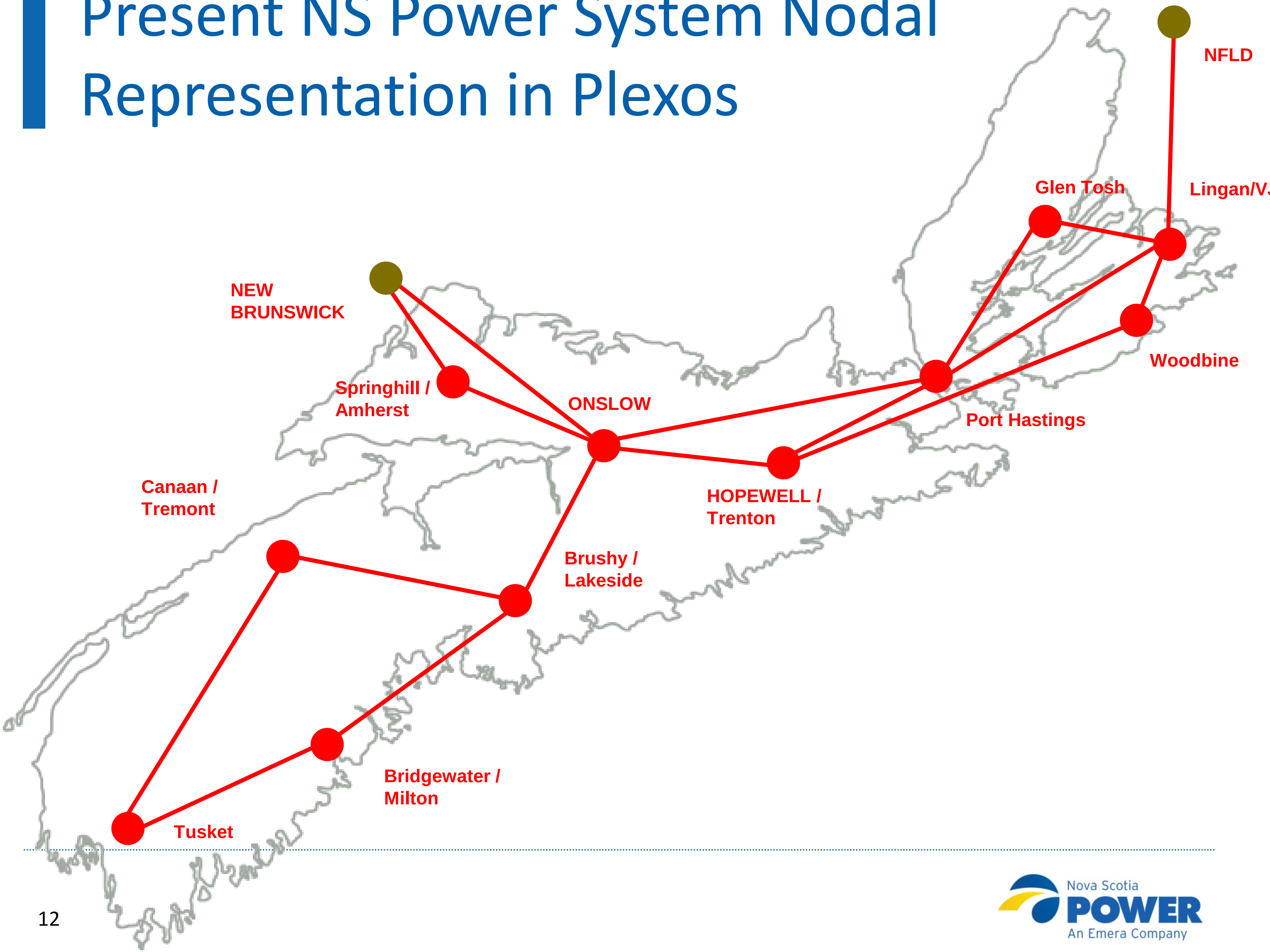
- Reactive reserve must also be maintained to cover SVC, cap bank, and generator contingencies

NS Power Transmission System Map



Nova Scotia POWER An Emera Company

Present NS Power System Nodal Representation in Plexos



Volt Amperes Reactive - Definition

- Mega Volt Ampere Reactive **MVAr**
- A feature of AC Power Systems
  - Does not apply to DC power
  - Cannot be efficiently transmitted across long distances
  - Primary role is to support system voltage

$$S = P + jQ$$

$$\text{MVA} = \text{MW} + \text{MVAr}$$

- ***Disclaimer - IANAEE!***

Nova Scotia POWER
An Emera Company

Engineer's Definition

Changes to NSP System Dispatch

- Historically, MDRR was not a major concern for NSP
  - System load used to be higher; gas and HFO prices were flatter
  - Halifax units would be dispatched economically before MVAr constraints became binding
- Lower system demand and increased variable generation have created the opportunity to serve Halifax load with remote units even under high load conditions
- Dispatch models would economically dispatch coal units ahead of Halifax generators, to the point that an infeasible dispatch was created and our models would under-forecast the Natural Gas / HFO fuel requirement
  - Minimum generation constraints were an initial solution
  - A more detailed model of this constraint was required

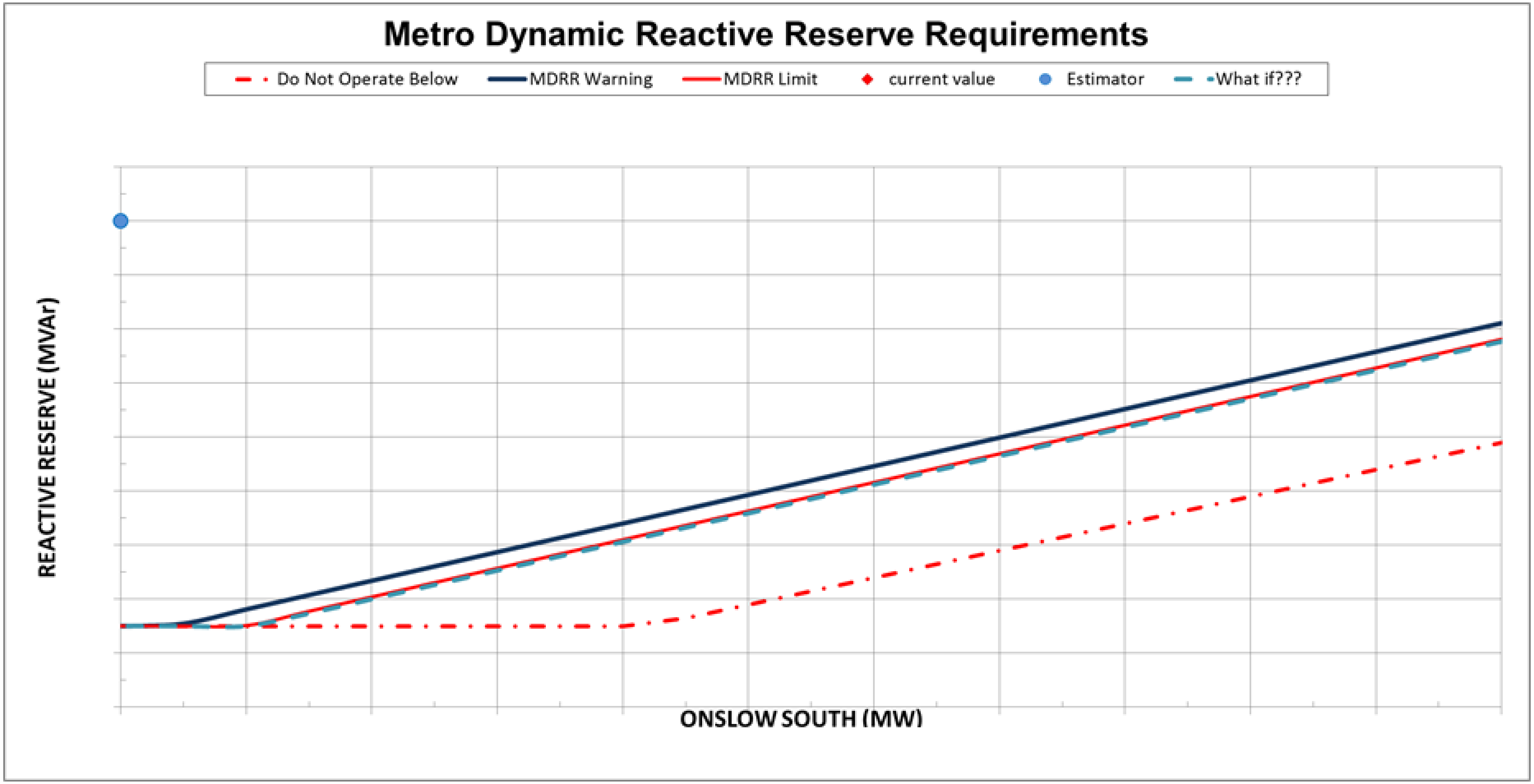
Model of MVAR Requirement

- The hourly Metro MVAr requirement is a factor of ONS corridor flow, SPS arming levels, and load

- MVArs can be provided by online generators and CTs operating in sync condenser mode
  - Reactive Capability Curves describe available MVAr from a generator by shifting its power factor; more MVArs are available at lower MW dispatch levels

- Difficult to model because:
  - No transmission line complex impedances in the model
  - NSPI nodal model is a transport model at this time (no impedances)

Sample MDRR Curves



Nova Scotia POWER An Emera Company

Plexos Constraints

- Plexos model assumes that our SVC is always in service; reserve requirement above that level is modeled using a curve similar to the one shown

- MVAR available from each online unit is determined using a linearized capability curve

$$\text{Available MVAr} = \alpha(\text{Dispatched MW}) + \beta$$

- CTs dispatched in sync condenser mode have a constant MVAr contribution, γ
  - Issue with non-spin reserve modeling was discovered & resolved

Plexos Constraints

- Dynamic Constraint:

$$\sum_{i=1}^{n} [\alpha_i(Generation\ Coeff) + \beta_i(Units\ Generating\ Coeff) + \gamma_i(Units\ Sync\ Condense\ Coeff)] - \theta(ONS\ Flow\ Forward\ Coeff) \geq c$$

- Fixed Constraint (MVAr floor):

$$\sum_{i=1}^{n} [\alpha_i(Generation\ Coeff) + \beta_i(Units\ Generating\ Coeff) + \gamma_i(Units\ Sync\ Condense\ Coeff)] \geq d$$

Nova Scotia POWER An Emera Company

Effects on System Dispatch

- Sync condenser operation was modeled for the first time at NSP as a part of this work
- It is only with the Plexos model that sync condenser contribution to system load could be considered explicitly
- Metro units are more often dispatched at lower loads, to maximize their reactive power (MVAr) contribution

Model Validation Resulting in Improvement of Actual Dispatch

- During the model validation phase, Plexos showed that optimal dispatch was different from what was seen in reality with respect to natural gas usage

- Extensive review of system stability and security parameters was undertaken to confirm that the system can be securely dispatched in the way it was optimized by Plexos

Current Status and Ongoing Work

- Dynamic Reactive Reserve Requirement model has become our base case for all system studies and fuel forecasts
- This model is being used to justify transmission investments
    - Historically, business cases for transmission system upgrades were difficult to build unless the upgrades impacted system safety, stability and security
    - Now we can justify transmission system upgrades based on fuel cost savings

Nova Scotia POWER An Emera Company