MARKET OPERATIONS AWARENESS SESSION: WINTER OPERATIONS RECAP

Udayan Nair, Manager – Control Room Support, IESO

June 10, 2019

Agenda

- Weather and Demand profile
- Energy Production
- Extreme Conditions
- Cold Weather Operational Impacts
- Wind Capacity Factor and Production

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Winter 2018/19 –Weather & Demand Profile

- There was considerable weather volatility over the Winter period

Month	Peak-Day Temperature (°C)	Peak Demand (MW)	Energy (TWh)
December	-1.4 °C	19,891 MW	11.9 TWh
January	-11.8 °C	21,525 MW	12.8 TWh
February	-10.1°C	20,500 MW	11.3 TWh

- Winter Peak of 21,525 MW occurred on January 21
- The forecasted normal weather peak for the winter period was 21,506 MW and extreme weather peak was 22,434 MW

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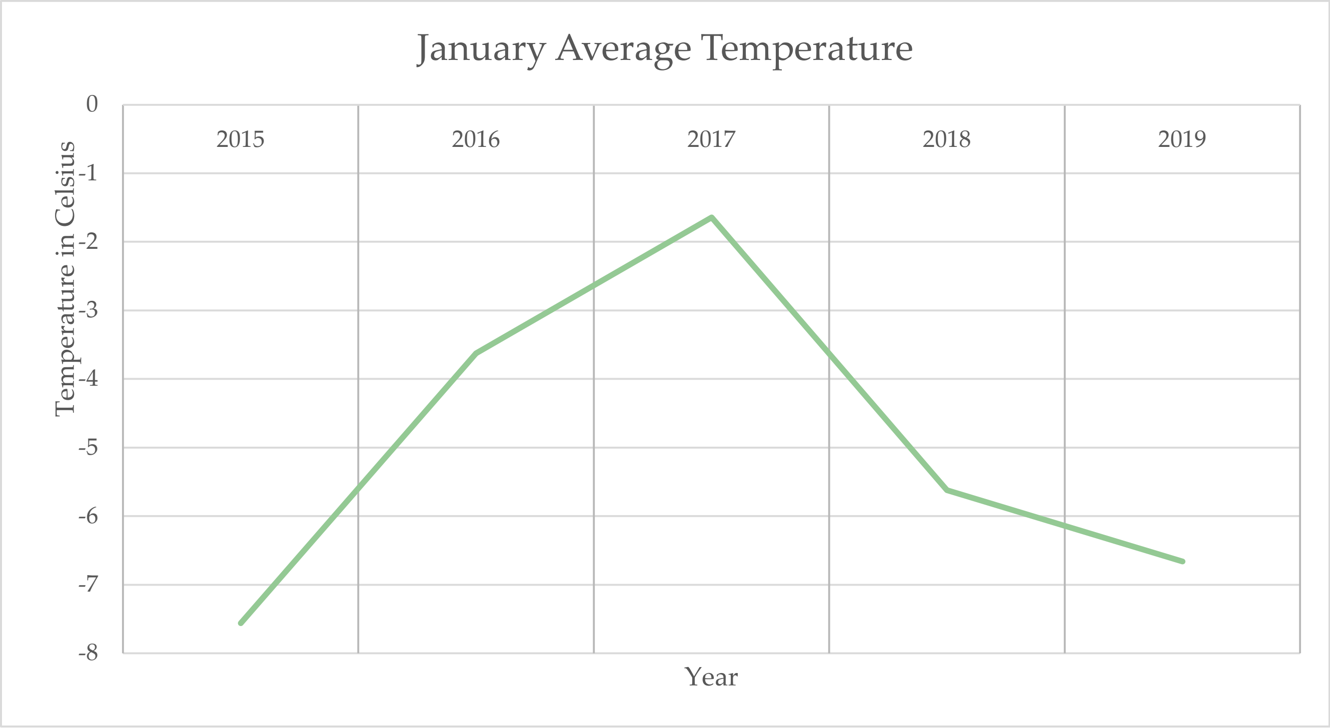
Winter Operations – January 2019

- January was the coldest month this winter
  - Slightly colder than the 5 year average.



Energy Production (GWh): January 2015-19

Timeframe	Nuclear	Gas	Hydro	Wind	Solar	Biofuel	Total Output
Jan '15	8,489	1,846	3,567	950	1	34	14,888
Jan '16	8,459	1,079	3,413	1,198	14	37	14,200
Jan '17	8,388	554	3,231	1,045	18	35	13,271
Jan '18	8,011	1,089	3,389	1,505	19	38	14,051
Jan '19	8,058	941	3,422	1,435	25	31	13,913

Winter Operations – Extreme Conditions

- Extreme conditions advisory notices were published for 8 days during the winter months:
  - 7 of 8 advisory notices were published in January alone

- Extreme Conditions alerts are a transparent mechanism to take actions outside of normal market mechanisms to mitigate reliability issues, they include:
  - Deferring/recalling transmission outages that would bottle capacity/energy; having additional transmission lines in service also improves system resiliency
  - Committing resources in advance to prepare the fleet
  - Other actions appropriate for the circumstances

Winter Operations – Cold Weather Impacts

- On January 21, we experienced approximately 2,100 MW (over a couple of hours) of generator capacity loss due to cold weather related issues
  - Frazil ice buildup at nuclear plants blocking cooling water intakes (same impact as the algae issues in the summer months)
  - Cut outs or icing at wind facilities
  - Frozen sluice gates at hydroelectric facilities
  - Cold or frozen equipment at gas generator facilities
  - Non-firm gas transport curtailments at gas facilities
    - These were reported in the planning timeframe
- Transmission system impacts can include icing conductors, air blast breaker issues and flashover

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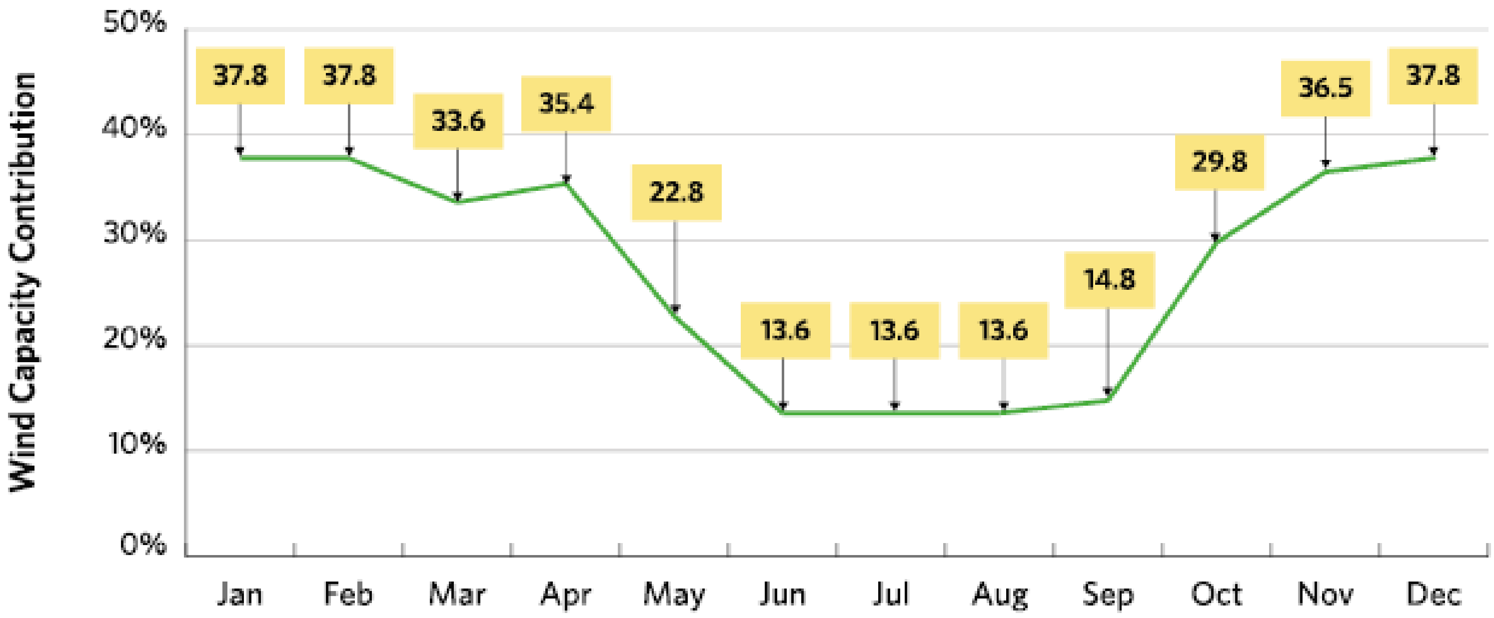
Winter Operations –Wind Capacity Factor



Source: Figure 4-1 Reliability Outlook From April 2019 to September 2020

- Highest hourly peak wind output ever of 4,091 MW observed on March 9
- Wind accounted for 22.3% of Ontario generation and gas accounted for only 3% on March 10

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Winter Operations – High Wind Operation

- As a result of high wind forecast, Operating Reserve is increased in advance to provide flexibility due to potential forecast uncertainty
- This flexibility is to ensure that there is sufficient spare energy to respond to intra-hour differences which could be a result of:
  - Wind generation schedule uncertainty, significant wind generation ramp, system wide weather events, and demand forecast error
- Events are published on our Advisory Notices page

Notice	Issued	Updated
Flexibility Event Forecasted Start: 2019/02/20 06:00 End: 2019/02/20 22:00	2019/02/20 03:27	2019/02/20 03:27

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Thank You!

MARKET OPERATIONS AWARENESS SESSION: PREPARING FOR EXTREME EVENTS

Joseph Ricasio, Market Forecasts & Integration, IESO
Jordan Cope, Real-time Operations, IESO

June 10, 2019

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Agenda

1. How does IESO ensure we have the lights on?
2. Extreme Event Examples
   - Impact Concerns
   - Preparation and Operating Considerations
3. Other Preparation and Operating Considerations

How does IESO ensure we keep the lights on?

- We make sure there is adequate generation for Ontario electricity demand, and sufficient reserve for probable loss of generation.

- We make sure that the Ontario's electricity system will remain secure for probable loss of transmission or generation.

- This is ensured through the development of instructions and guidelines on how to operate the system (i.e. the Operating Plan).

- In Extreme Events, there is increased uncertainty to prepare for.

Agenda

1. How does IESO ensure we have the lights on?
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3. Other Preparation and Operating Considerations

Extreme Events Example #1:
Ice Storms

Freezing Rain: Icing on insulators could cause unintended electricity connections.

Flashover: Conditions on insulators (dirt, salt, or ice) and the air cause unintended electricity connections.

Impact concerns: There is uncertainty in how many number of transmission elements (e.g. circuits, transformers, breakers) would trip.

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Extreme Events Example #1:
Ice Storms (preparation considerations)

Weeks/Days ahead:

- Ensure that generation has been tested if not active in the past month.
- Receive continuous weather updates.
- Re-evaluate outage plans (i.e. defer or recall if necessary).
- Establish conservative system operating limits (e.g. limit electricity flow).

Day-ahead:

- Send out public advisory notice (i.e. Extreme Conditions Alert).
- Plan to have additional generation in-service.
- Request for electrical stations to be staffed to allow for prompt actions.

Real-time:

- Approve equipment owners request to clean insulators (i.e. short notice outages).
- Implement particular system operating limits (e.g. limit electricity flow).
- If transmission elements trip, re-evaluate security operating limits, and support restoration efforts.

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Extreme Events Example #2:
Tornadoes

Effect of tornado on Merivale TS

Impact Concerns:

- There is uncertainty in how many number of transmission elements (e.g. circuits, transformers, breakers) would trip.
- Following equipment is lost, how do we restore the system the quickly.

Actual Impact:

- 33 breakers, 12 circuits, 2 auto-transformers.
- 600MW of load (i.e. 200,000 customers)

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Extreme Events Example #2:

Tornadoes (preparation considerations)

Day-ahead:

- Receive continuous weather updates.
- Send out public advisory notice (i.e. Extreme Conditions Alert).
- Re-evaluate outage plans (i.e. defer or recall if necessary).
- Establish conservative security operating limits (e.g. limit electricity flow).

Real-time and Days-after:

- Implement conservative security operating limits (e.g. limit electricity flow).
- Contact key market participants including government staff.
- After transmission elements were lost, frequent communication with Hydro one and Hydro Ottawa in coordinating restoration efforts (i.e. providing specific system operating limits).

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Extreme Events Example #3:
Extreme Heat

The peak Ontario demand day from 2016-2018 was in Sept.

Impact Concerns:

- Harder to forecast demand (i.e. Will we have enough generation available in time?)
- Scheduled generation (e.g. wind) or imports may not be available.
- Operating Plan instructions may have assumed lighter temperatures conditions (e.g. reduced load demand, reduced thermal ratings)

Extreme Events Example #3:
Extreme Heat (preparation considerations)

Weeks/Days ahead:

- Ensure that generation has been tested if not active in the past month.
- Receive continuous weather updates, and conduct adequacy assessments.
- Talk to neighbouring jurisdictions (e.g. NYISO, MISO).
- Re-assess outage plans (defer or recall if necessary).

Day-ahead:

- Send out public advisory notice (i.e. Extreme Conditions Alert).
- Defer or recall outages.
- Commit to have additional generation in-service.

Real-time:

- Activate Hourly Demand Response.
- Implement 5% Voltage Reductions.
- Curtail firm load.

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Extreme Events Example #4:
Wildlife

Cow got stuck to a 500kV transmission tower

Impact concerns: Safety of the cow. However, this is not considered an Extreme Event.

Agenda

1. How does IESO ensure we have the lights on?
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3. Other Preparation and Operating Considerations

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Other Preparation Considerations

IESO Readiness Programs

- Voltage Reduction Test
- Simulation of Load Shedding
- Hourly Demand Response (HDR) Test
- Operating Reserve Activation Test
- Reactive Capability Test

Operating Plan Assessment

- Perform capacity and energy assessments daily
- Issue Adequacy Report
- Discontinue commissioning tests

Communications

- Monthly satellite phone tests
- NPCC conference calls (daily & weekly)

Other Preparation Considerations (cont.)

Same-Day Horizon

- Request capacity export from Quebec.
- Reconfigure transmission system.
- Constrain on imports or constrain dispatchable loads down.
- Expand Net Interchange Scheduling Limit (NISL).
- Disregard High-Risk limits.

Real-Time Horizon

- Issue General or Public Appeal to conserve energy.
- Issue Energy Emergency Alerts.
- Warn/Request/Implement Environmental Variances (Thermal and Hydro Electric units).
- Operate to Emergency Condition limits.
- Purchase Emergency Energy.

Real-Time Operations Objectives

[Prevent]

Take all available actions to protect the ICG.

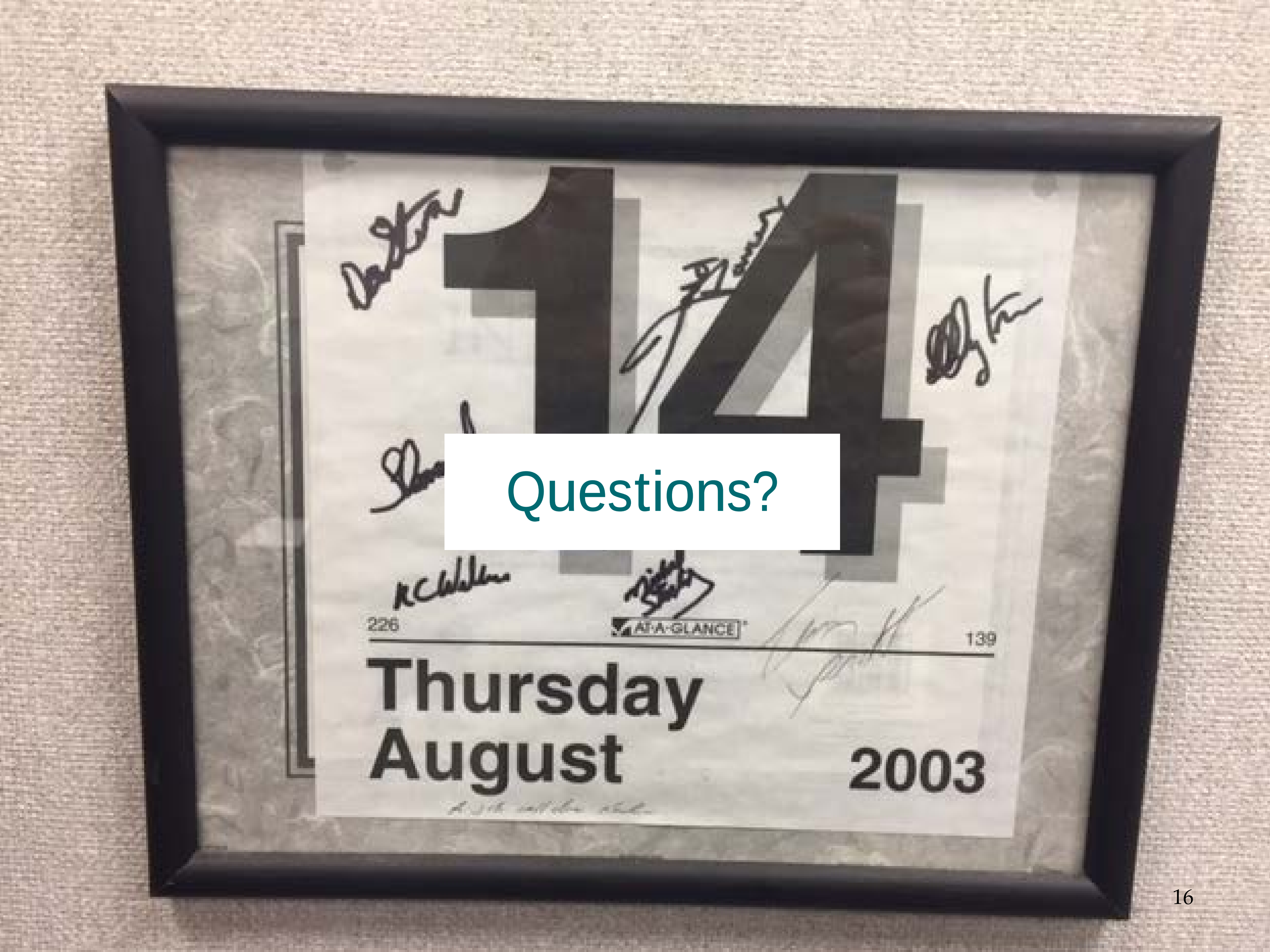
[Contain]

Ensure that the ICG is not susceptible to cascading outages and to contain the issues impacted by extreme conditions.

[Minimize]

The impact to the ICG and return the ICG to a known state.

Questions?



MARKET OPERATIONS AWARENESS SESSION: 2019 SUMMER OPERATIONS OUTLOOK

Frank Peng, Senior Power System Specialist,
Market Forecast and Integration, IESO

June 10, 2019

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Background

- Reliability Assessments
  - Adequacy
    - Do we have enough capacity/energy to meet demand?
  - Security
    - Have we postured our system, with different variables considered, in such a way that the impact of credible contingencies are kept localized?

Background

- Reliability Assessments
  - Performed all year round
  - Different seasons have different types of concerns
  - Summer/Winter are “peak” seasons where we’re focused on higher amounts of demand
  - Spring/Fall are “shoulder” seasons where we’re focused on higher amounts of baseload generation

Executive Summary

- Operational outlook positive for summer 2019
  - Sufficient capacity and energy supply, with no anticipated reliance on support from external jurisdictions
  - Quarterly outage assessment did not highlight any operational concerns
  - Surplus Baseload Generation (SBG) conditions are expected to be manageable with existing market mechanisms

Summer 2019 – Demand Forecast

Forecast peak demand (Source: Reliability Outlook – April 18, 2019 release)

Season	Normal Peak (MW)	Extreme Peak (MW)
Summer 2019	22,105 (Week ending 07-Jul-19)	24,478 (Week ending 07-Jul-19)

- Summer peaks are affected by the load modifying impact of embedded generation
- Majority of embedded generation are solar-powered facilities that have high output during the summer peak period and low output during the winter peak period
- This mean a reduction in the summer peaks as well as a shift of the peak to later in the day

Summer 2019 – Available Resources

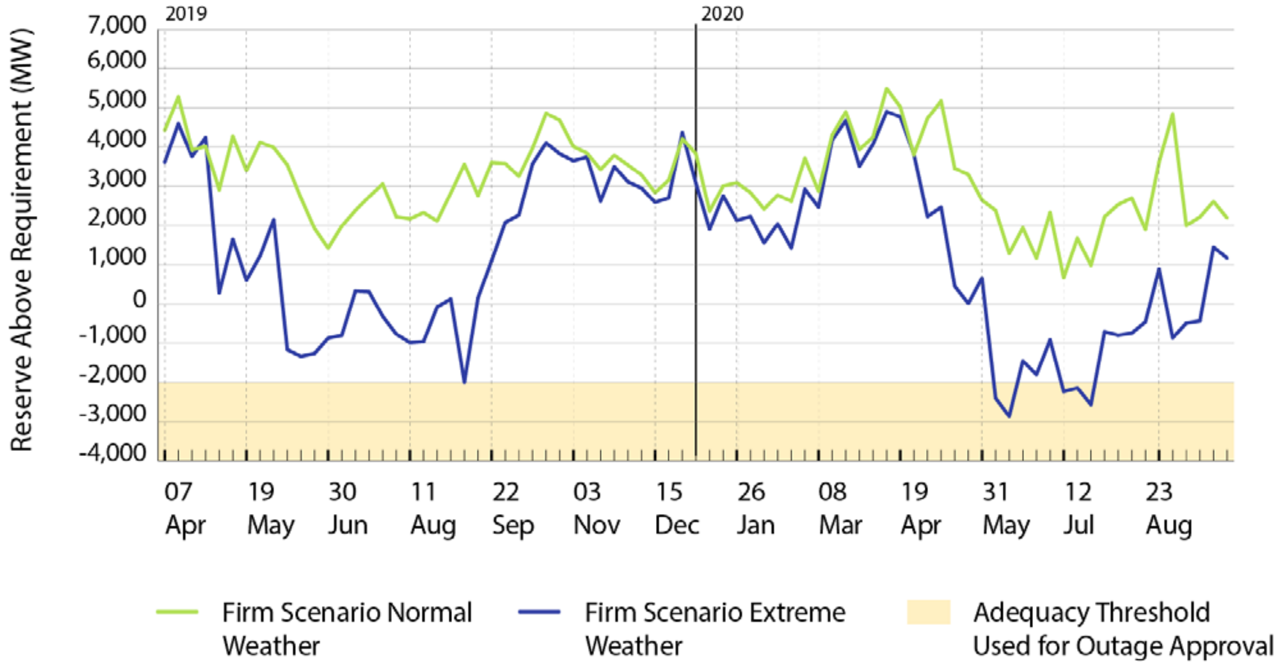
Summary of Available Resources (Source: Reliability Outlook – April 18, 2019 release)

Description	Summer Peak 2019 Firm Scenario
Installed Resources (MW)	36,872
Total Reductions in Resources (MW)	10,329
Demand Measures (MW)	790
Firm Imports (+) / Exports (-) (MW)	0
Available Resources (MW)	27,333

- Demand measure such as dispatchable loads and demand response procured through the 2019 demand response auction are treated as resources.

Summer 2019 – Adequacy Outlook

Firm Scenario Adequacy Outlook(Source: Reliability Outlook – April 18, 2019 release)



- New outage approval methodology implemented for outage that extend past or begin after May 1, 2019. This new methodology uses the extreme weather scenario with up to 2,000 MW of imports.
- For the Summer 2019 period, the Resource Above Requirement (RAR) levels are adequate.

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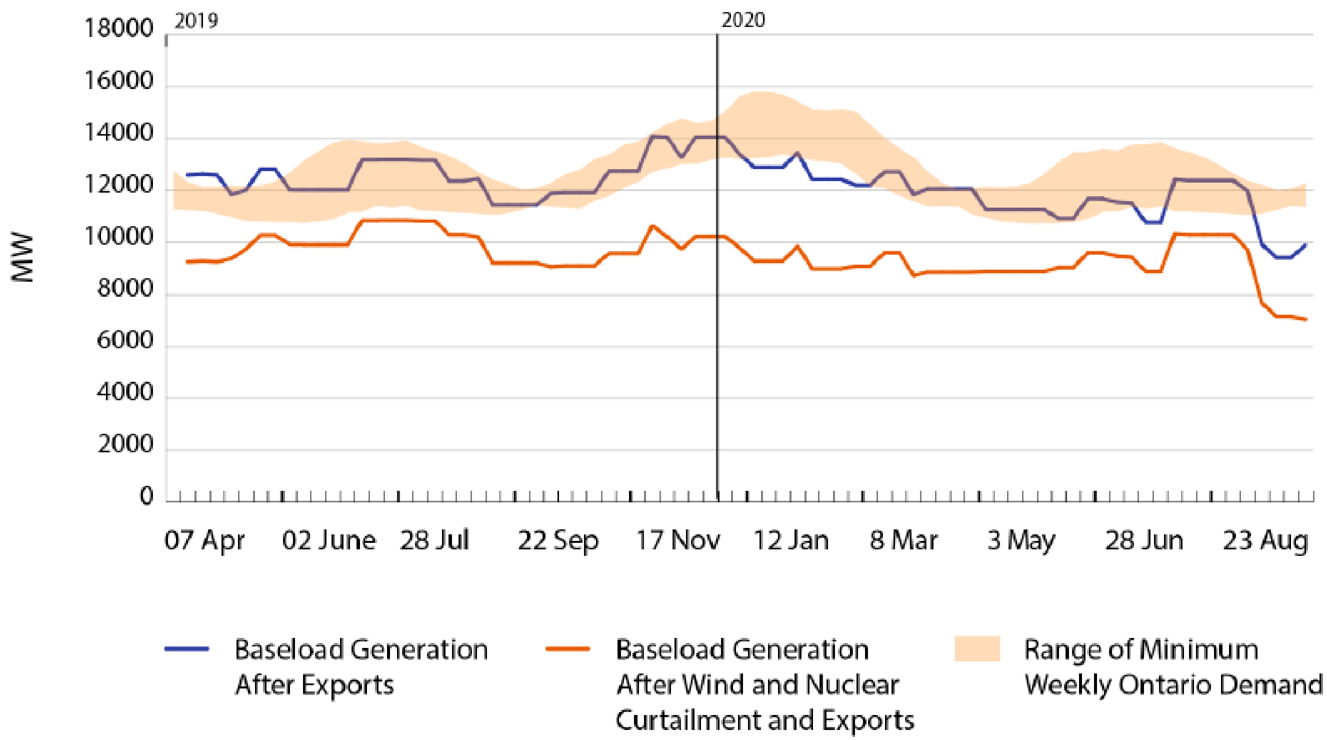
Summer 2019 – System Security

- System security studies are conducted as part of the quarterly outage assessment process to highlight any operating concerns and system constraints.
- Outage approval is based on satisfying the adequacy, system security, and re-preparation criteria.
- Q1-2019 quarterly outage assessment looked at outages during the period of March 2019 – September 2019.
- No adequacy or security concerns were identified in the quarterly outage assessment for Summer 2019.

Summer 2019 – SBG Outlook

SBG Outlook (Source: Reliability Outlook – April 18, 2019 release)



Questions?

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MARKET OPERATIONS AWARENESS SESSION: JANUARY 11TH POWER SYSTEM OSCILLATION EVENT

Ahmed Rashwan, P. Eng, Engineering Manager – Power System Limits, IESO

June 10th 2019

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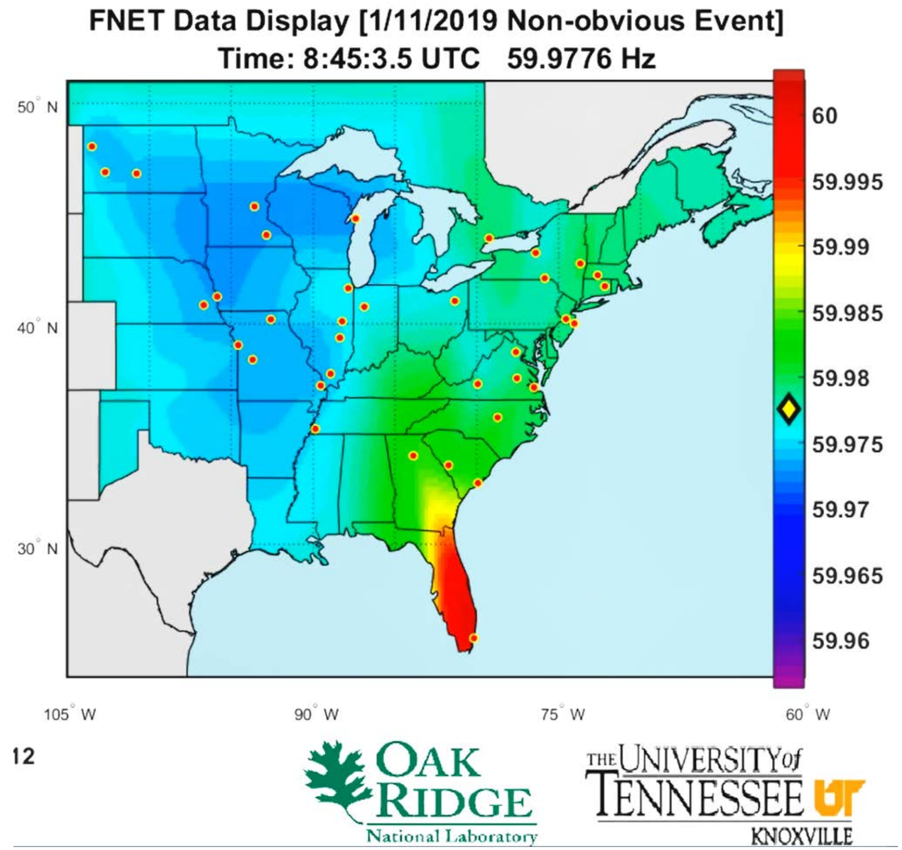
Agenda

- The January 11th 2019 Oscillation Event
- Oscillation and Resonance Phenomenon Explained
- Why Oscillation Resonance is Critical
- Real-Time Monitoring Technology – SCADA vs PMU
- The Ontario Phasor Measurement Unit Initiative

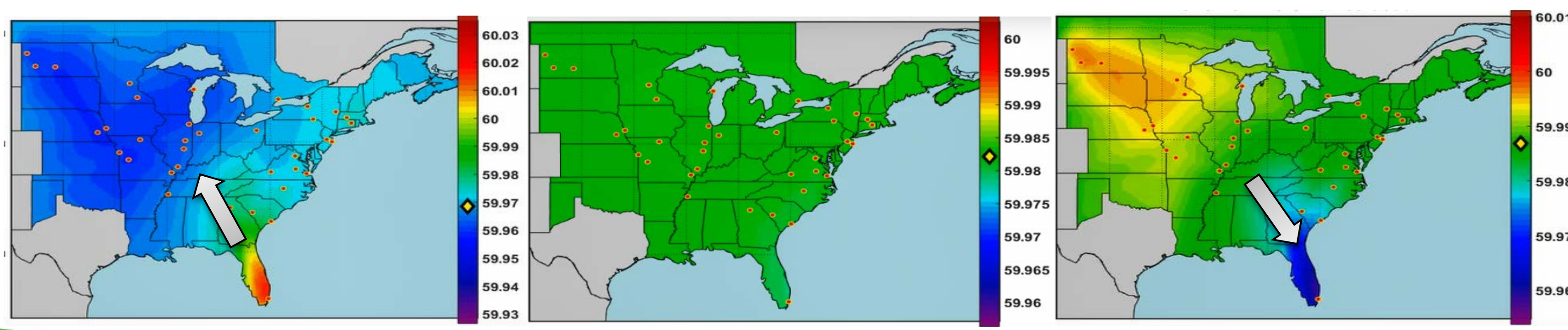
January 11th 2019 Event

- Power and frequency oscillations observed across entire Eastern Interconnection (EI) from 03:44 to 04:02am
- Bruce and Darlington reported power swings of 10-20 MW
- IESO's tools did not detect any system issues
- Other jurisdictions with Phasor Measurement Unit (PMU) based tools confirmed the oscillations
- Oscillations lasted until a generator in Florida was manually disconnected
- NERC initiated event analysis the next day



What are Oscillations?

- The power system experiences changes throughout the day, including load changes, generation changes and system disturbances
- Like **a pendulum or a swing**, system changes result in exchanges of energy, or **oscillations**, between the part of the system experiencing the change and the broader system
- System oscillation occur roughly every 4 seconds for the North/South direction of the EI – or at its natural response frequency (0.25 Hz)
- The magnitude of the oscillations gradually dampen out



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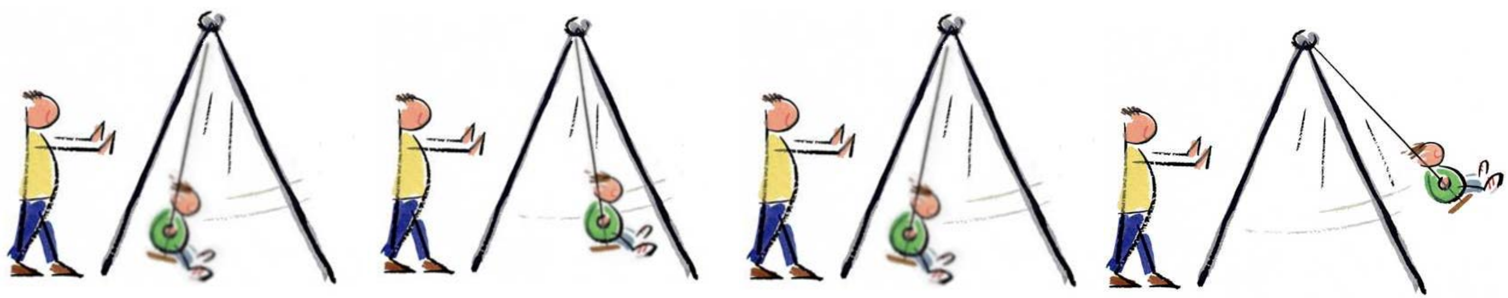
Oscillation Resonance

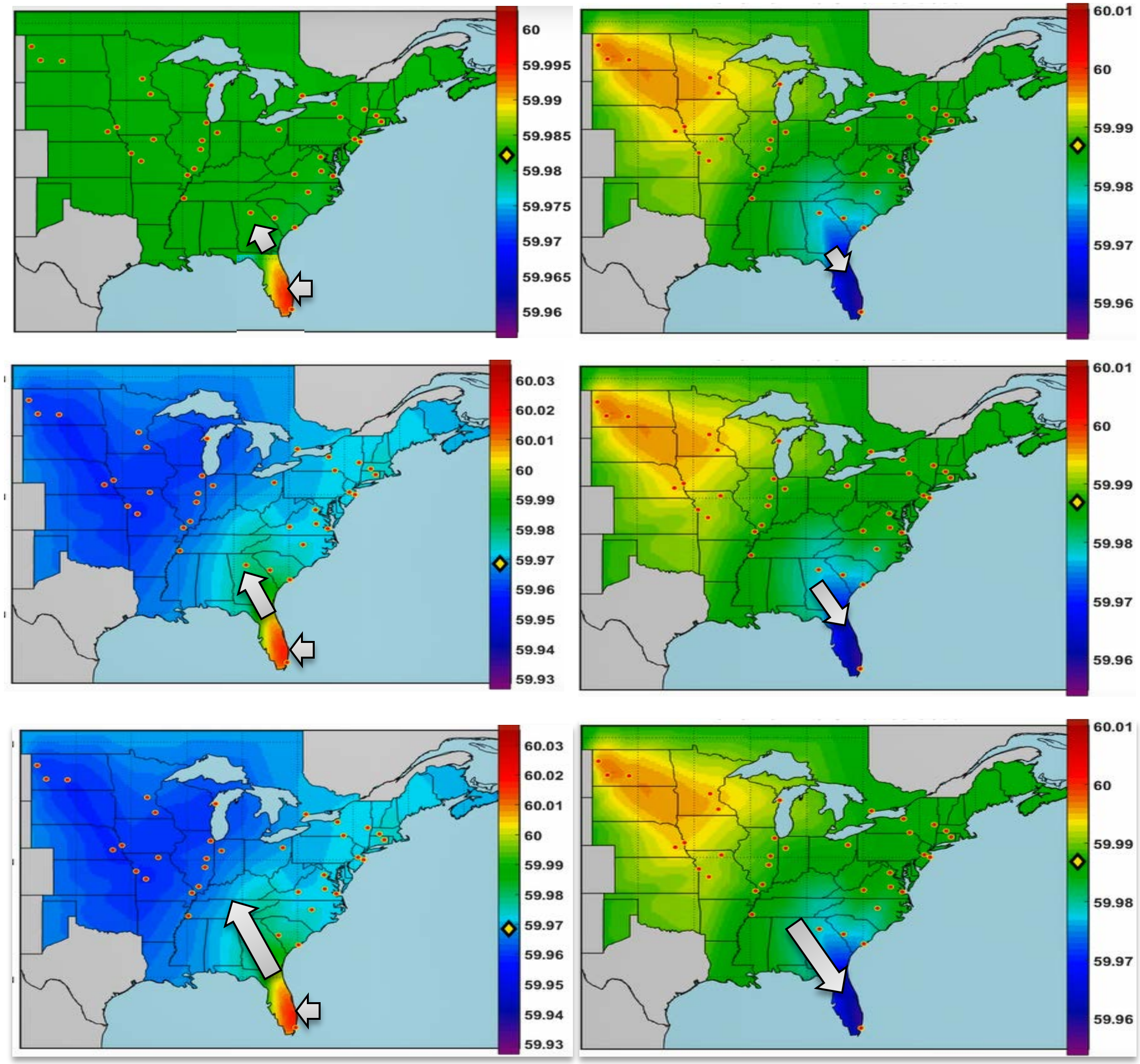
- The oscillations can be amplified by a **periodic** forced input
- If the periodicity (frequency) of the forced input matches the system natural frequency, it could produce **resonance** and amplify the oscillations

Example

Child in swing: Pushing a child in a swing at a frequency that matches the swing's natural oscillation period, the size of the swing's oscillation grows.



Power System Oscillation Resonance – Jan 11



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Why Oscillation Resonance is Critical

During instances of oscillation resonance, the grid is **at risk**

In this case, the oscillation was sustained but was **held at 600 MW** due to the damping strength of the Eastern Interconnection (EI)

If a disturbance were to have occurred during the event, there could've been cascading outages **and the loss of parts of the system**

Power System Oscillation Resonance

Factors for Resonance with Inter-area Natural Frequency:

- **Forced oscillation frequency** (e.g., uncontrolled generator) is near the system natural frequency
- **Forced oscillation location** is near the end with stronger effect (participation) to the system natural frequency
- System natural frequency is **poorly damped**

All three conditions are satisfied → **Blackout Event**

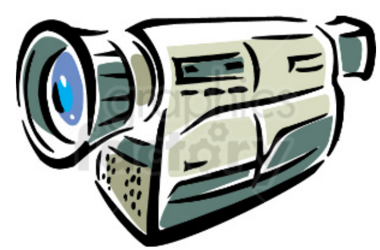
Only two conditions are satisfied → **Sustained Oscillation Only Event**

Why Our Tools Didn't Capture the Oscillatory Phenomena

- Our online tools take **snapshots of the system** to monitor critical parameters, like current flows and system voltages

  - IESO's real-time tools are based on conventional Supervisory Control And Data Acquisition (SCADA)
  - SCADA reads data every 2 to 4 seconds from the field – **similar to the oscillation frequency** on January 11th
  - SCADA readings are not time-synchronised

- In order to capture and detect real-time oscillations, we need the **power system equivalent of a video feed**
- The power system video feed can be provided by Phasor Measurement Units (PMU)



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How PMUs Work

Phasor Measurement Unit (PMU) is a device that provides **time stamped** voltage, current and angular measurements at a high sample rates – **30 to 60 samples/second**

Voltage and Current Measurements

PMU Relay

Phasor Data Concentrator (PDC)

PMU Relay … PMU Relay

GPS

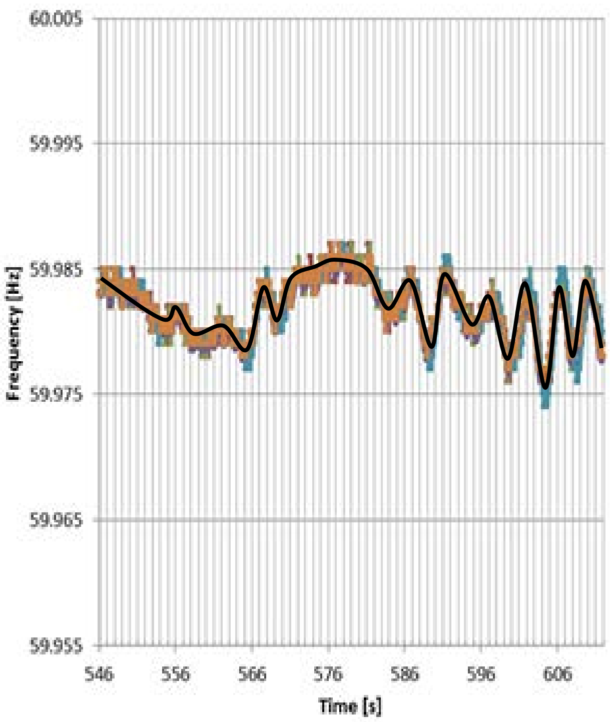
Antenna

GPS Clock

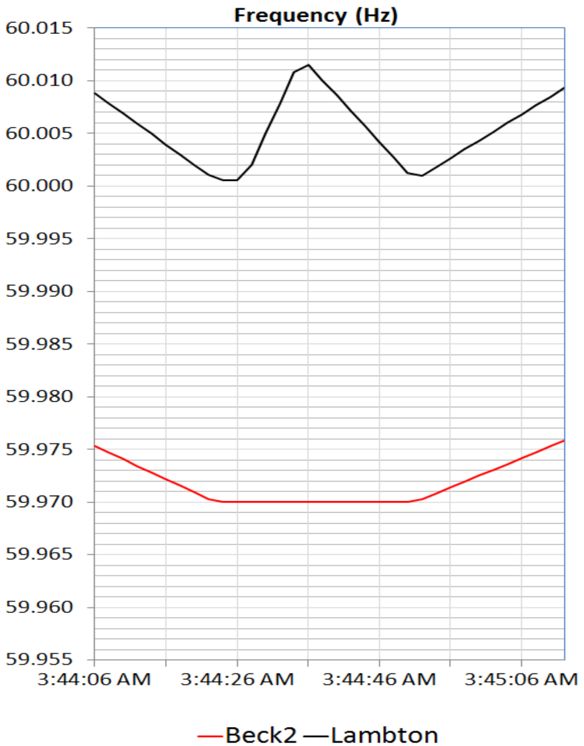
PMU data vs. SCADA data

Frequency for Jan 11 Oscillations for same time period (3.44.06 – 3.45.12 EDT) from PMU data and SCADA data

Hydro One pilot PMU data
(Frequency from Beck2, Scott, Lambton, Keith, St Lawrence)



SCADA data
(Frequency from Beck2, Lambton)



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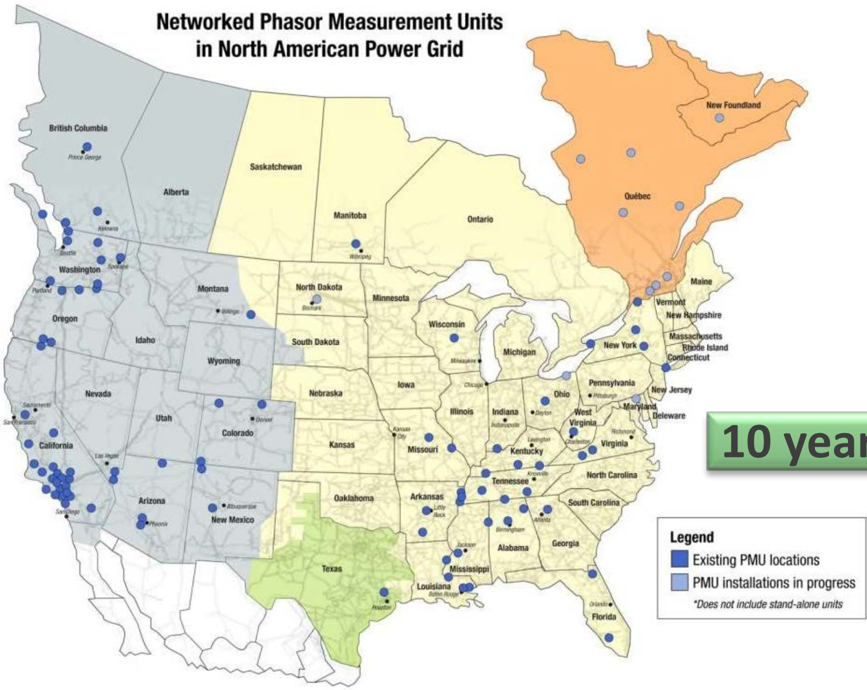
PMUs installed in the North American Grid

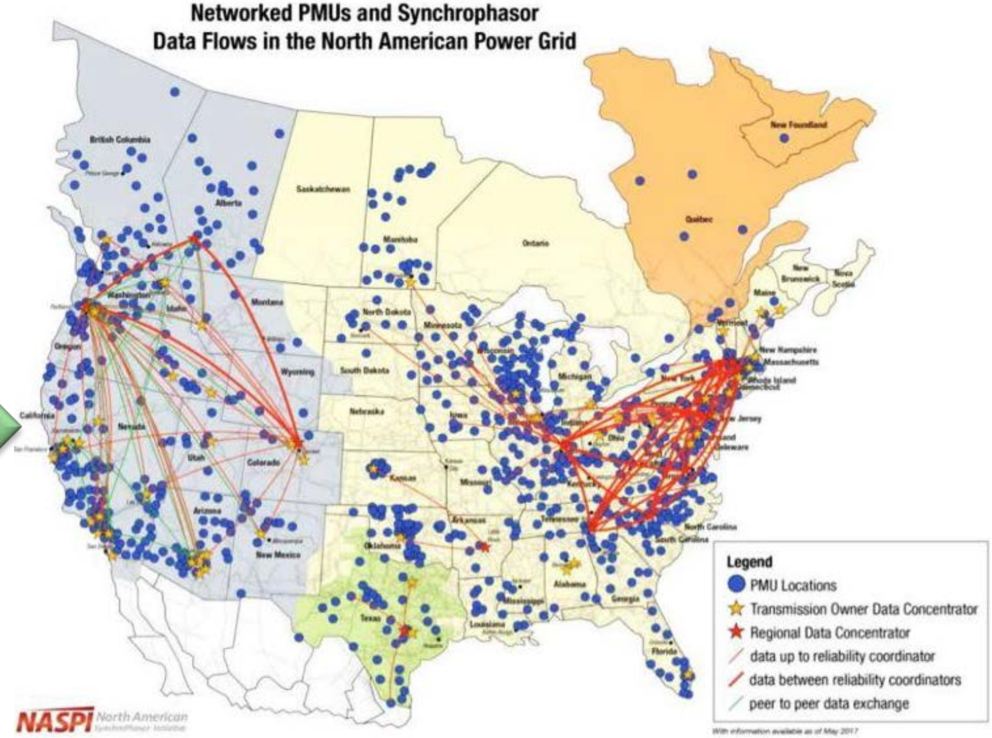
- Over 2500 PMUs in North America
- Most areas receive & share PMU data for real-time wide-area situational awareness

April 2007



10 years

May 2017



*North American SynchroPhasor Initiative

Ontario PMU Initiative

PHASE 1 ✓

PMU Pilot - Proof of Concept

- Used existing Hydro One PMUs (12)
- Data streaming to and storage at the IESO
- Completed in Q1 2018

PHASE 2 ✓

Analyze and Design - Solution Development

- Engaged industry experts , internal and external stakeholders
- Completed in Q4 2018

PHASE 3

Implement PMU -

Build systems and Deploy Tools

- Collect and process PMU data from across Ontario and from the EI
- Install PMUs at key locations on the system

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Next Steps

- IESO and other system operators will continue to assist NERC with event investigation and implement lessons learned
- Pursue Phase 3 of the Ontario PMU Initiative
- Monitor the progress of NERC’s request to the industry to develop a suite of online tools that leverage PMU data to:
  - Improve situational awareness and online oscillation detection capability
  - Provide an early warning for operators regarding deteriorating conditions
  - Assist in recovery from disturbances

Questions?

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MARKET OPERATIONS AWARENESS SESSION: PROPOSED MARKET RULE UPDATES FOR CONNECTION OF ELECTRICITY STORAGE AND LOAD DISPLACEMENT UNITS

Mahmoud Bayoumi, PhD, P. Eng., Senior Power System Engineer, Connection Assessments, IESO

June 2019

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Terms of reference:

'Electricity Storage' means

- *withdrawing electrical energy from a transmission system, a distribution system, or from a load facility or generation facility,*
- *storing this energy for a period of time, and*
- *injecting back this energy, minus reasonable losses, at the location from where it was originally withdrawn.*

'Load Displacement Unit (LDU)' means

- *generation or storage unit(s) that are installed within a load facility directly connected to the IESO controlled grid (ICG)*
- *strictly used for the needs of the customer, and*
- *don't intentionally inject active power into the transmission system*

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Agenda

- The need to update Market Rules
- Overview of the proposed updates to Market Rules

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Why update the Market Rules

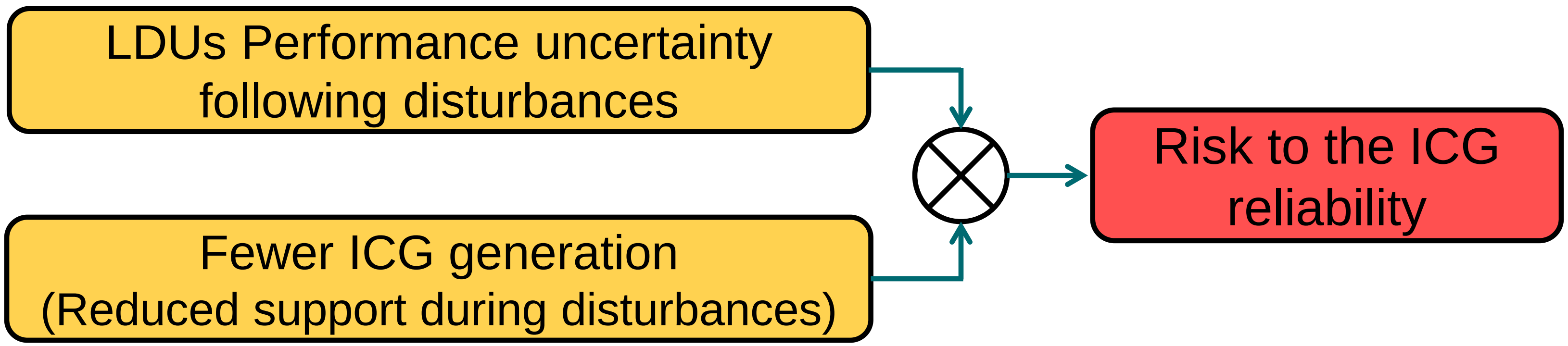
Treatment of Electricity Storage is not discussed in the Market Rules

- There is a lack of clarity on which performance requirements to apply

Why update the Market Rules

Increased penetration of LDUs

– No specific performance requirements for units < 10 MW & facilities < 50 MW



– 2018 IESO Operability Assessment identified the need for these units to ride-through transmission faults

Why update the Market Rules

Clarity on performance requirements

- Inverter-based units can enter into momentary cessation, i.e., stay connected but cease injections following disturbances
  - No support to the grid for fault recovery
  - Can adversely impact IESO-controlled grid reliability
  - Examples: August 16, 2016 California lost 1,200 MW of PV and in October 9, 2017 California lost 937 MW

- NERC is updating PRC-024 to explicitly ban the use of momentary cessation for BES facilities

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Overview of the proposed updates

- Market Rule Chapter 4 Appendices updates:
  - Extend performance requirements of Appendix 4.2 to electricity storage facilities directly connected to the ICG
  - Explicitly specify inverter-based units may not enter into momentary cessation during the ride-through period
  - The following requirements will apply to all generation and storage units regardless of their size or connection point
    - **Off-nominal frequency operation**: ride-through frequency excursions
    - **Freq. control**: change active power in response to frequency variations
    - **Voltage ride-through:** ride-through voltage excursions

Key Messages

– Performance requirements are consolidated together to make applicability clear for Market Participants

Generation and Storage facilities connected to ICG →	Appendix 4.2
LDUs and Embedded Generation (Wholesale & Distributors) →	Appendix 4.3

– Clarity on these performance requirements help ensure these units support ICG reliability

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Resources

- Market Rules Chapter 4 Appendices http://www.ieso.ca/-/media/Files/IESO/Document-Library/Market-Rules-and-Manuals-Library/market-rules/mr-chapter4appx.pdf?la=en
- Market Rules Chapter 11 http://www.ieso.ca/-/media/Files/IESO/Document-Library/Market-Rules-and-Manuals-Library/market-rules/mr-chapter11.pdf?la=en
- Contact: connection.assessments@ieso.ca

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Questions?

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