Information Session:

Learnings and Actions in Response to Recent System Events

March 9, 2021

Notice

In accordance with its mandate to operate in the public interest, the AESO will be audio recording this session and making the session recording available to the general public at www.aeso.ca. The accessibility of these discussions is important to ensure the openness and transparency of this AESO process, and to facilitate the participation of stakeholders. Participation in this session is completely voluntary and subject to the terms of this notice.

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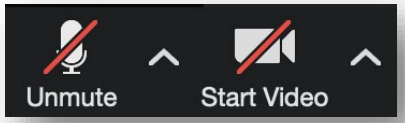
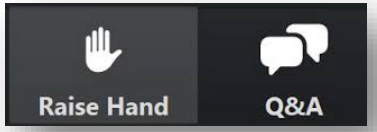
How to ask questions

Using Zoom – asking questions

- All attendees join the webinar in listen-only mode. Cameras will be disabled, and microphones muted



- Two options to ask questions via computer or smartphone:
  1. Click the “Q&A button” at any time
     - Type your questions into the Q&A window. You’re able to up-vote questions that have been already asked
  2. During the Q&A session
     - Click the icon to raise your hand and the host will see that you have raised your hand
     - The host will unmute your microphone and you, in turn, will need to unmute your microphone and then you can ask your question
     - Your name will appear on the screen, but your camera will remain turned off



- When asking a question, please state:
  - Your first and last name, and the organization you work for
  - If you are a landowner, your first and last name

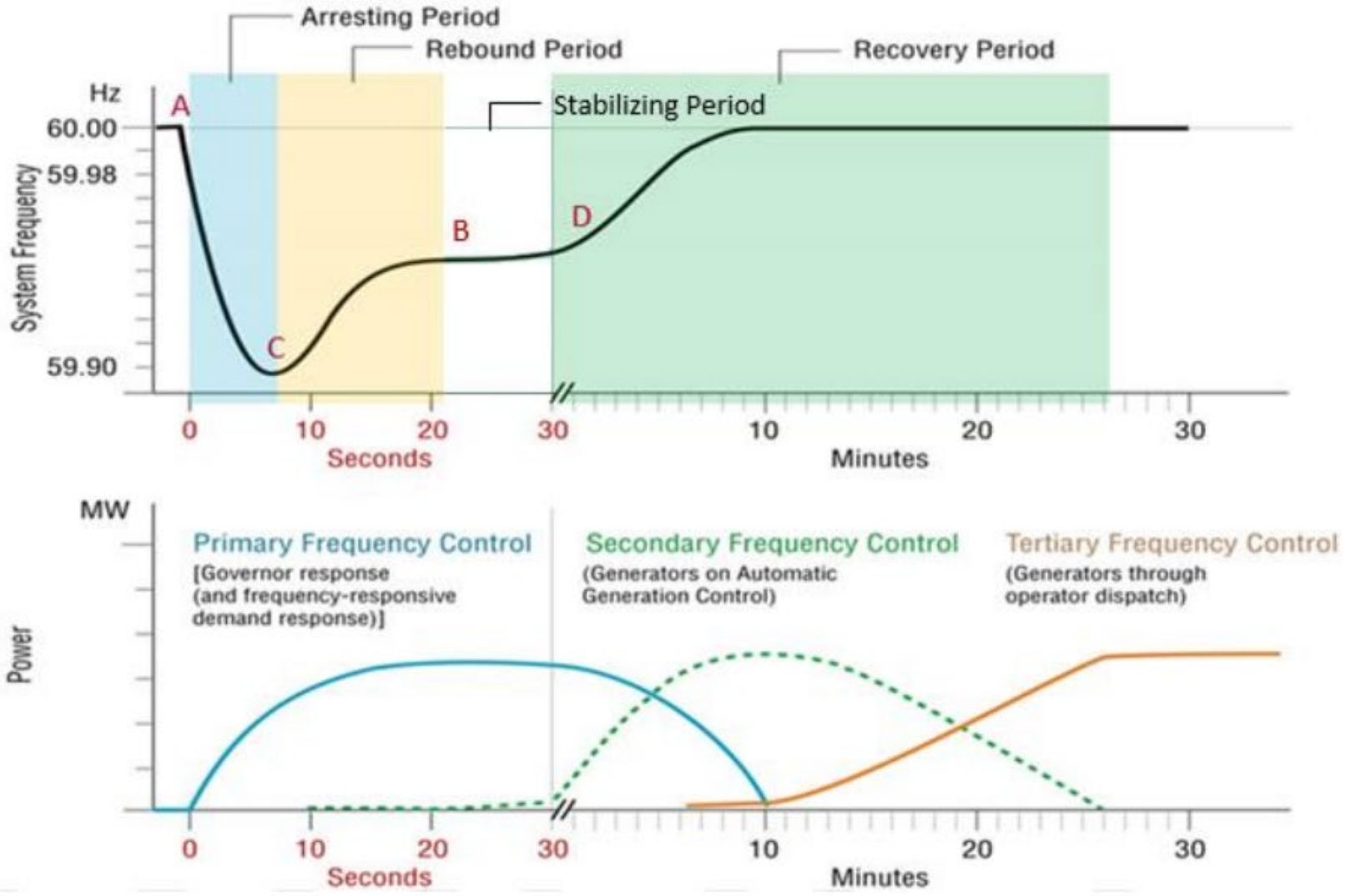
Using Zoom – access controls

2-in-1 / PC / MAC Computer	Smartphone	Telephone/ Conference Call
Hover your cursor over the bottom area of the Zoom app and the Controls will appear		
Click/tap “Raise Hand” and the host will be notified that you would like to ask a question		To raise your hand, on your phone’s dial pad, press *9; the host will be notified
Click/tap “Lower Hand” if your question has been answered		To toggle between mute and unmute, on your phone’s dial pad, press *6
or Click/tap the “Q&A” button and type questions		
If your question (or similar) has already been asked, click/tap “Up-vote” – the question will be prioritized, i.e., shifted to the top of the queue		

Scope of Presentation

- Frequency response characteristics
- System event overviews:
  - June 7, 2020
  - October 16, 2020
  - February 21/22, 2021
- Historical system response during events
- Stakeholder engagement process
  - Discussions with Generation Facility Owners (GFOs)
  - Jurisdictional reviews / engagement with other ISOs/RTOs
- AESO findings
- Recommendations
  - Short, Medium and Long-term
- Conclusion / next steps

Frequency Response Characteristics

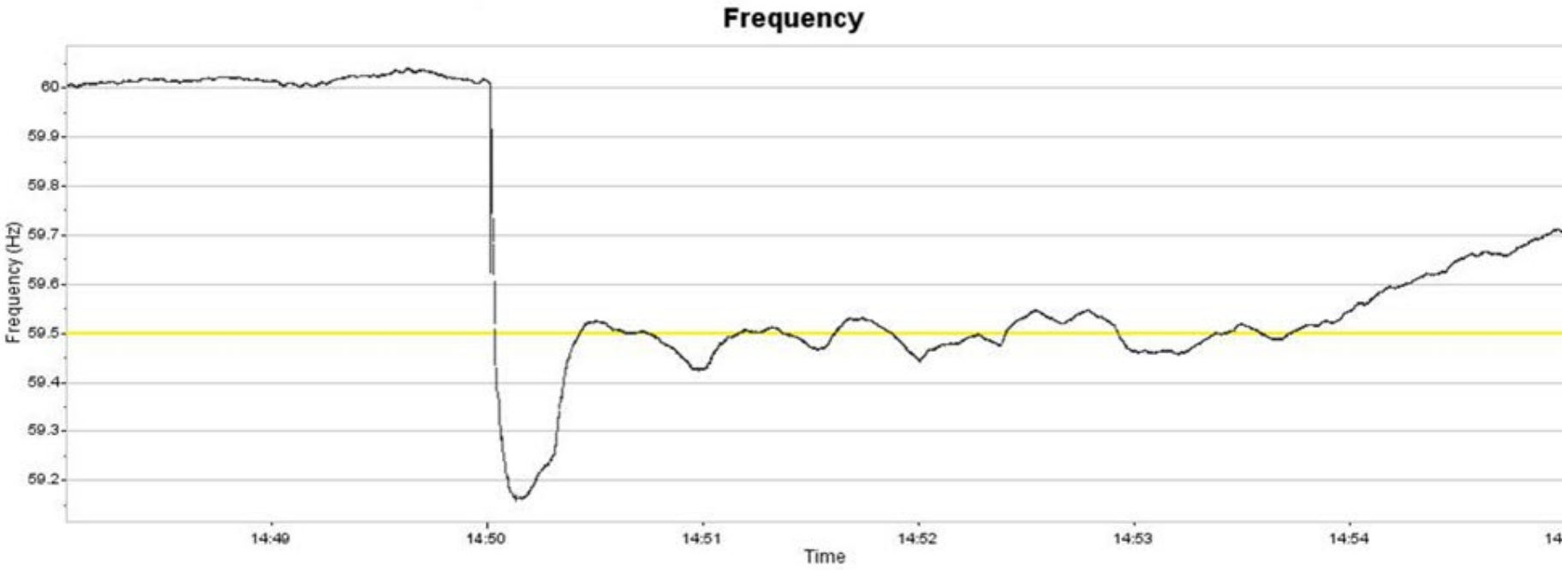


June 7, 2020 Event

Event Overview: June 7, 2020

- Prior to the event – lightning strike on BC side of 1201L @ 2:50pm
  - Scheduled import: 909 MW
  - Alberta Internal Load (AIL): 8,764 MW
  - Actual flow on the intertie: 923 MW
  - Wind generation output: 930 MW
  - Load Shed Service for imports (LSSi) Armed: 181 MW
- Post event:
  - Frequency dropped to 59.15 Hz (nadir “C” point)
  - Under Frequency Load Shed (UFLS): ~ 235 MW
    - **D1** (59.3 Hz, 15 seconds), **D2** (59.5 Hz, 30 seconds) and **D3** (59.5 Hz, 60 seconds) UFLS blocks tripped
  - 188 MW of LSSi tripped

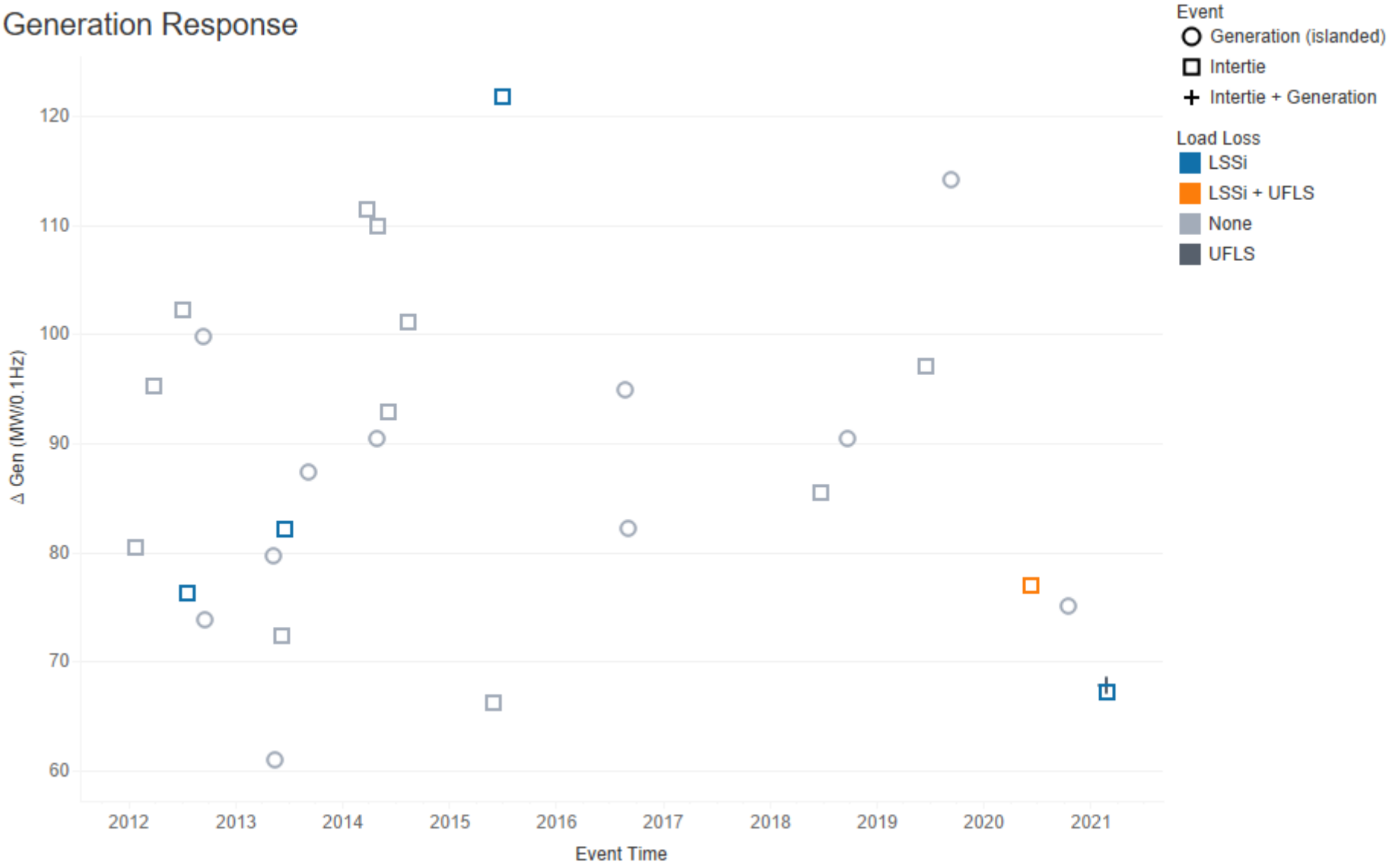
Frequency Dip – 59.15 Hz



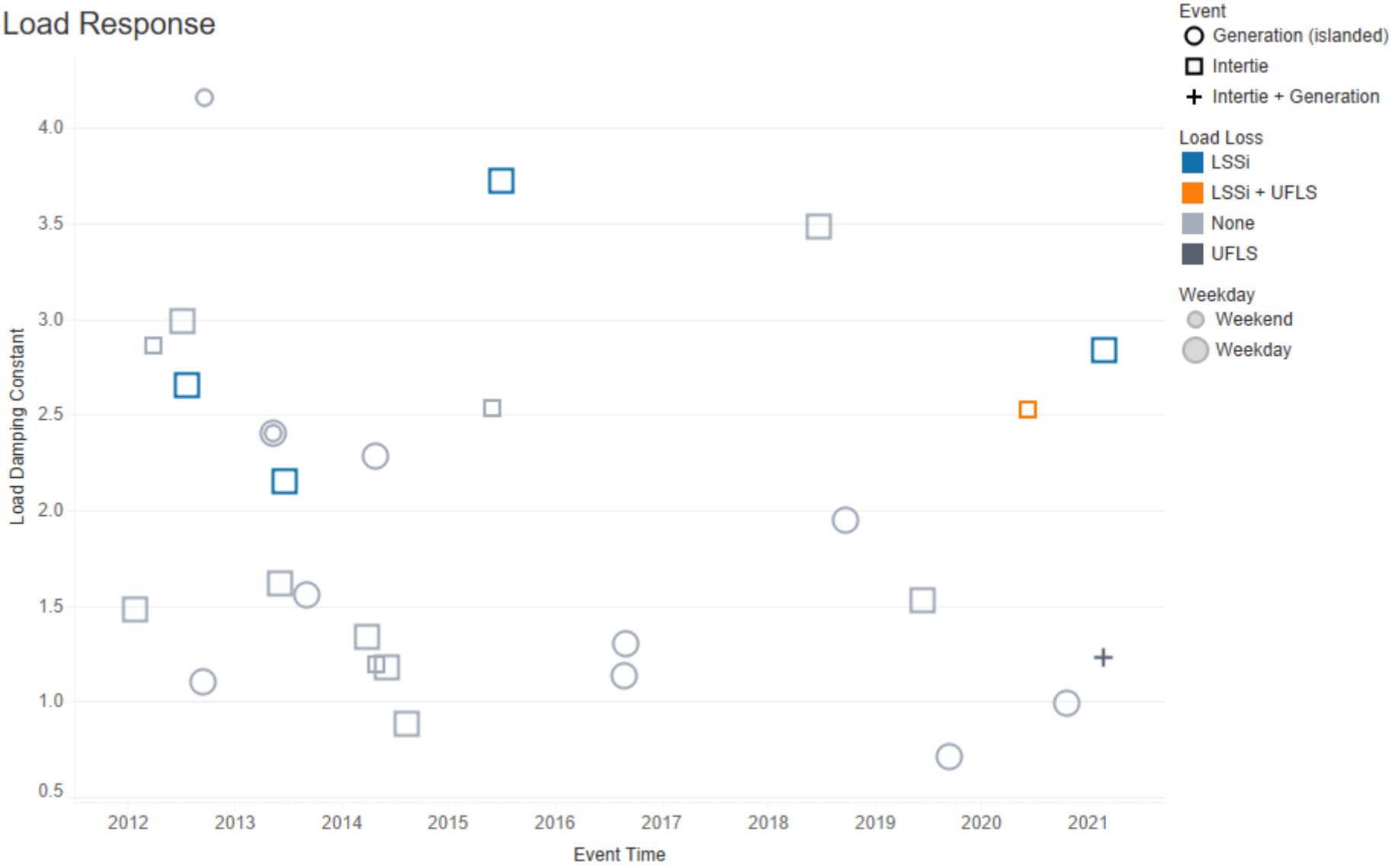
System – Under-performance Reasons

- Low inertia
  - Caused by high renewables and high intertie flow
  - Studied range was between 50 and 60 GVA.s
  - Actual pre-contingency inertia was 47.1 GVA.s
- Generator governor response
  - Change in generator response per 0.1 Hz change in frequency
  - Studied was between 88 MW/0.1 Hz and 102 MW/0.1Hz
  - Observed was around 77 MW/0.1Hz which dropped to 40 MW/0.1Hz
- Load frequency response
  - Average load response at ~ 2.5% (load damping constant)

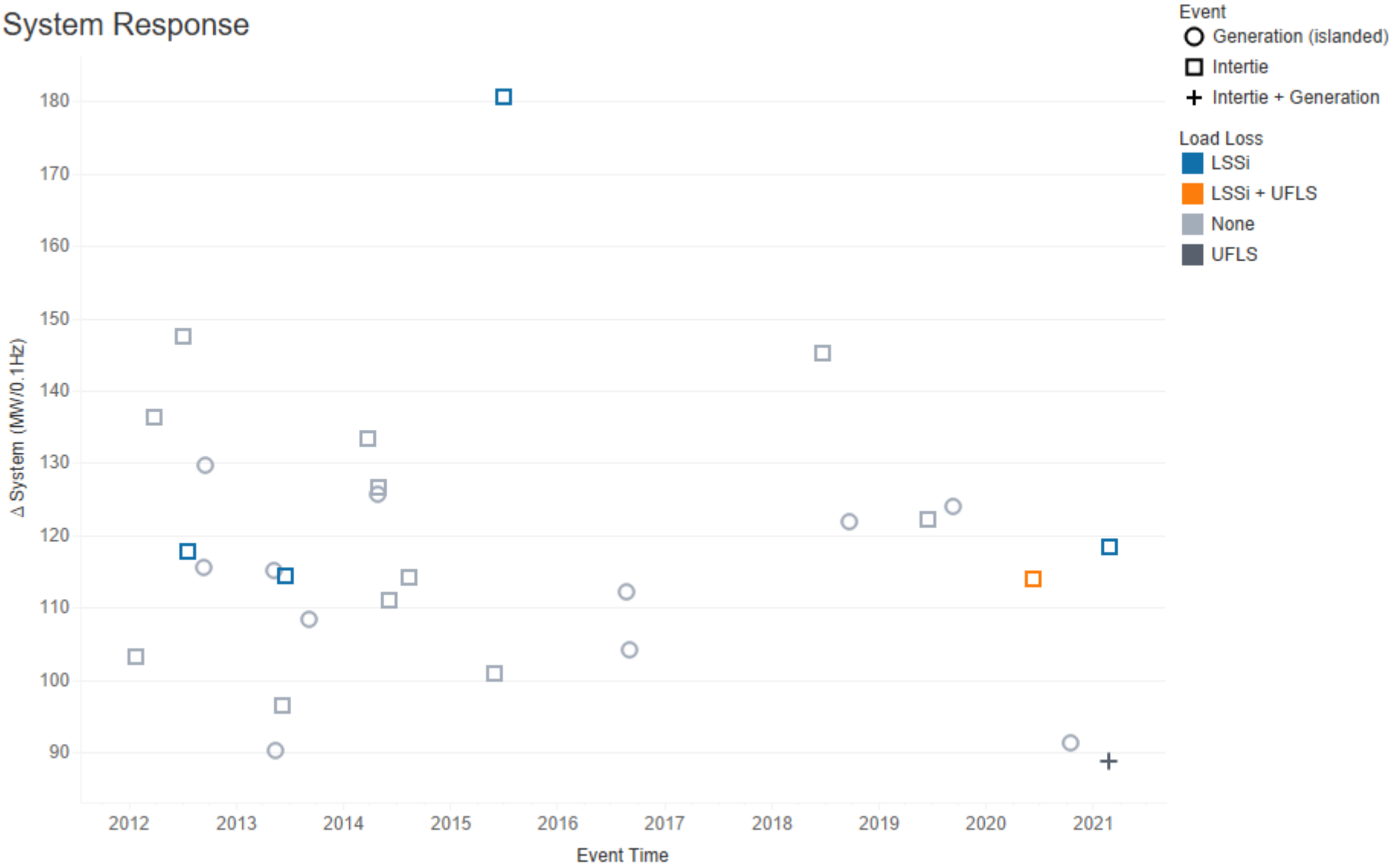
Historical Events – Generation Response



Historical Events – Load Response



Historical Events – System Response



Mitigation Measures

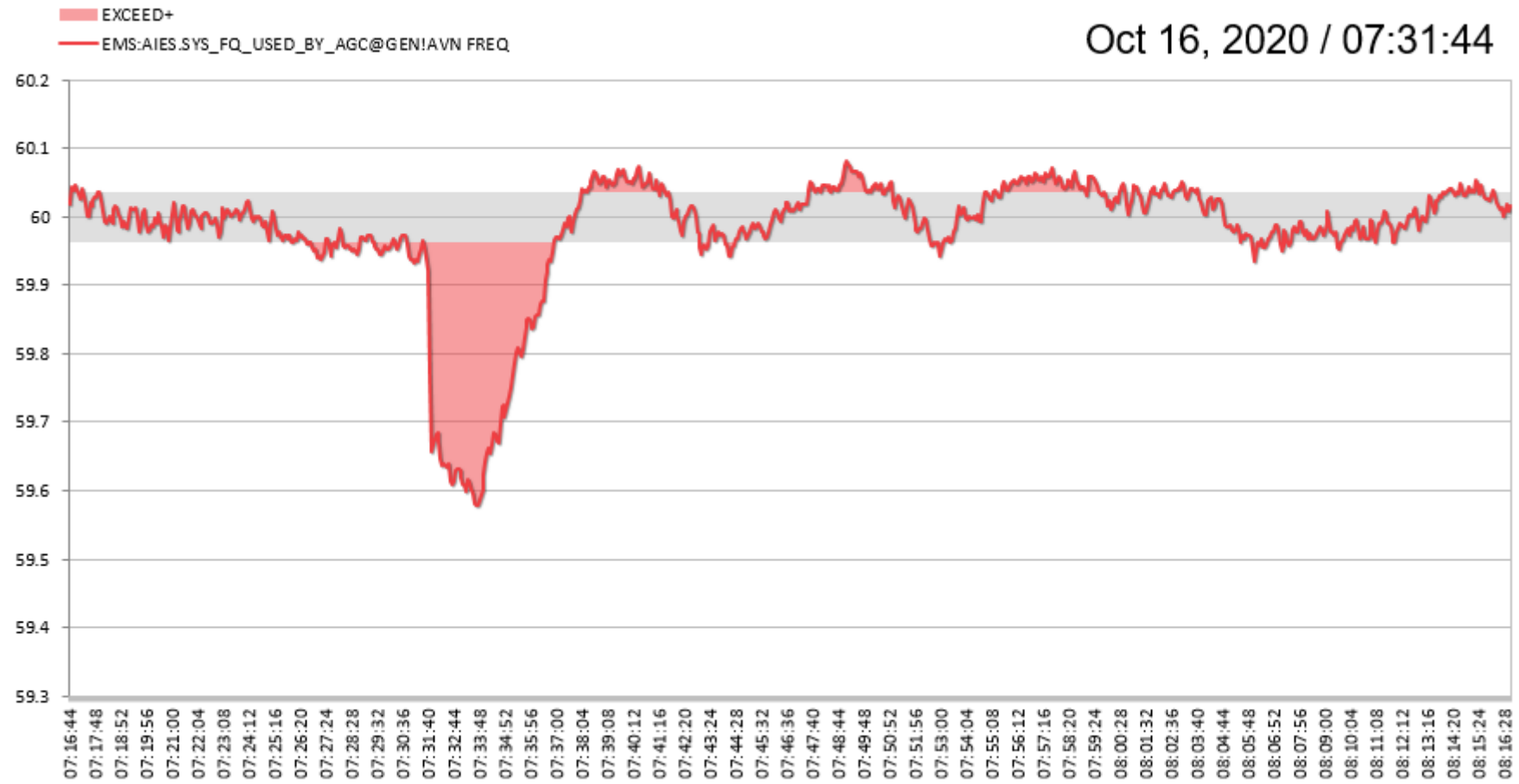
- Available Transfer Capability (ATC) was held at 550 MW until additional mitigation measures were implemented
- Mitigation measures effective June 22, 2020
  - **Step 1:** Load Shed Service for imports (LSSi) arming
    - Updated study results
      - *Lower response from generators and loads from the previous study*
      - *Generator response @ 90 MW/0.1Hz*
      - *Load damping constant @ 1.9%*
    - Additional arming table volumes to achieve 90% confidence level [Table 7a – ID# 2011-001R] based on system performance in historic events
    - A severe weather table was implemented to achieve 95%+ confidence level under higher risk of tie line tripping, based on system performance in historic events [Table 7b – ID# 2011-001R]
  - **Step 2:** System inertia calculations incorporated into operating protocols/ procedures
    - Calculates ratio of contingency to system inertia
      - *Ratio needs to be lower than 0.0135*
    - System controllers reduce ATC if ratio is above the threshold

October 16, 2020 Event

Event Overview: October 16, 2020

- Keephills Unit #1 tripped at 267 MW output while the AIES was in an islanded mode of operation
- Prior to the event:
  - Total Generation and Load prior to the event: 9,780 MW
  - Total wind on the system: 955 MW
  - Inertia: 54.1 GVA.S
- Post event:
  - Frequency dropped to: ~59.6 Hz
  - System response: 91 MW/0.1Hz
    - Governor response: 75 MW/0.1Hz
    - Load response: 16 MW/0.1Hz
    - Low system response (around 95%+ confidence level)
  - No UFLS was triggered

Frequency Dip – 59.57 Hz



- Phasor Measurement Unit (PMU) recorded as low as 59.57Hz, 180 seconds after first dip

Mitigation Measure for Islanded Operation

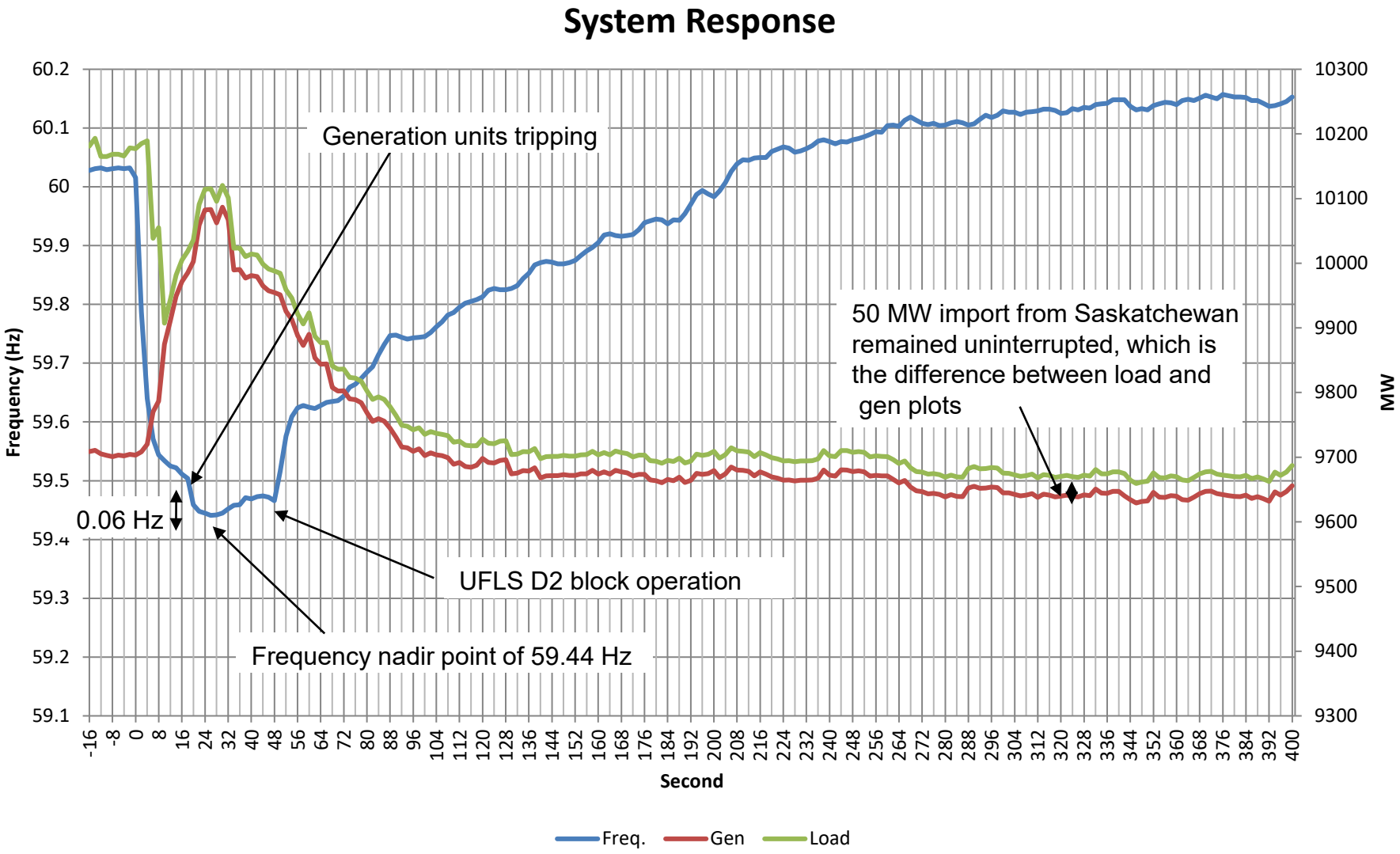
- Arming LSSi currently not an option
  - Service contracted only for interconnected operations
- Two options were considered to mitigate risks for the remainder of the islanded operation period:
  - Curtailment of the MSSC
  - Additional headroom through OR conscription directives
- Effective solution implemented:
  - Curtailment of the MSSC to 400 MW
    - Curtailment is more effective than increasing headroom on multiple generating units
    - Allocation concerns related to headroom management
    - Uncertainty if increasing headroom would help address Primary Frequency Response (PFR)

February 21/22, 2021 Events

Event Overview: February 21, 2020

- Prior to the event – caused by high wind speeds leading to a permanent line-ground fault, 150 kms from Bennett (@ 9:13 PM)
  - Alberta Internal Load: 10,173 MW
  - Actual BC/MT import flow: 440 MW
  - Wind generation: 1,270 MW
  - Inertia: 53.9 GVA.S
  - No LSSi was armed per lower import levels
- Post event:
  - Generation trips during the event (transmission and distribution connected); due to the frequency disturbance
    - About 120 MW
  - UFLS Block D2 trip: ~125 MW

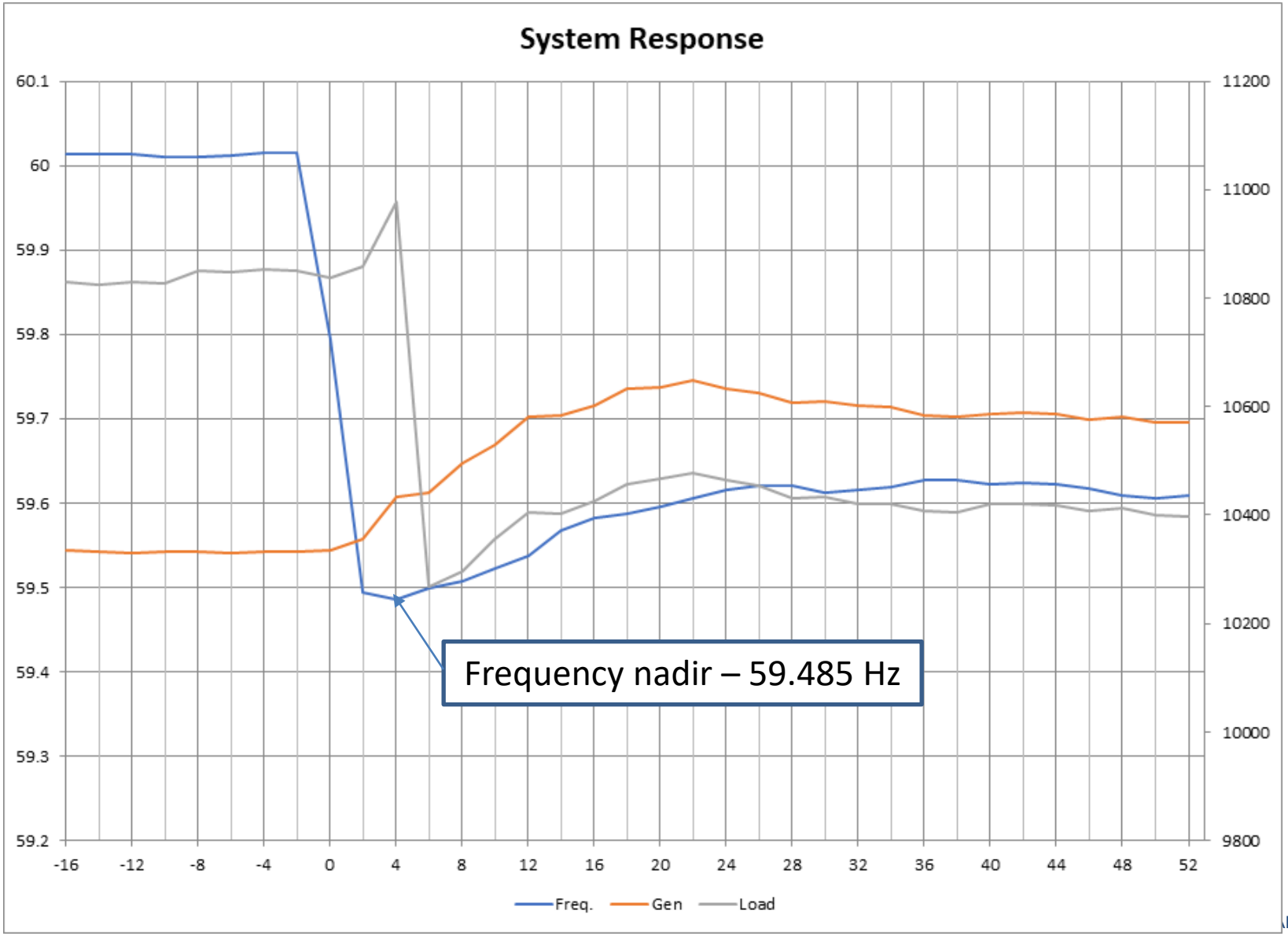
System Response – February 21, 2021



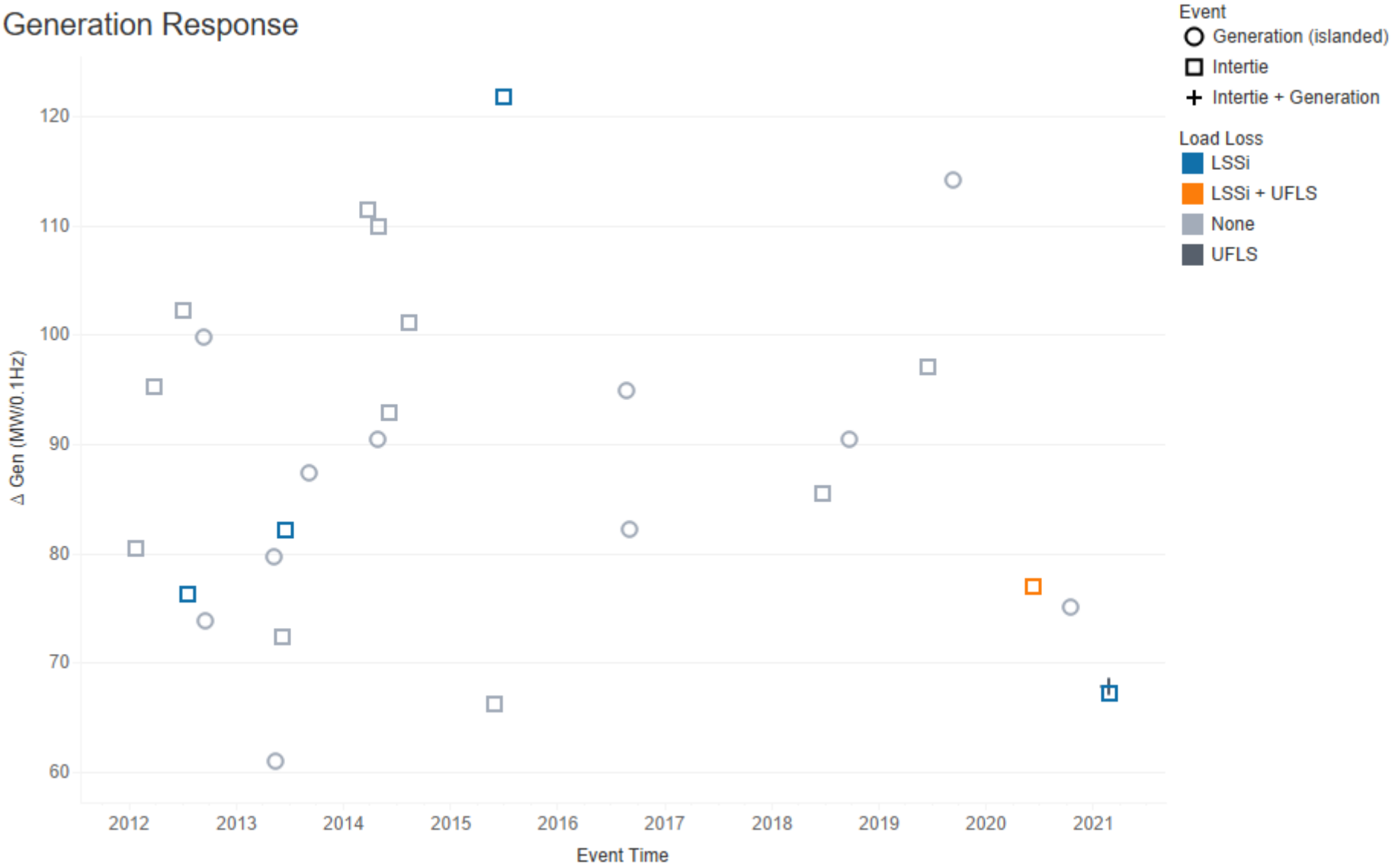
Event Overview: February 22, 2021

- Alberta was islanded from WECC as 5L92 (Selkirk – Cranbrook) tripped out of service @ 6:22 pm
  - Icing at higher elevations led to phase-to-phase sustained fault, about 35 kms from Selkirk, in the mountains (per BC Hydro)
- Prior to the event:
  - Alberta Internal Load: 10,850 MW
  - Actual 5L92 + MT import flow: 673 MW
  - Wind generation: 789 MW
  - Inertia: 54.3 GVA.S
  - ~201 MW LSSi armed per the severe weather LSSi table
- Post event:
  - About 30 MW of generation tripped (distribution connected)
  - ~208 MW shed LSSi, no UFLS operation

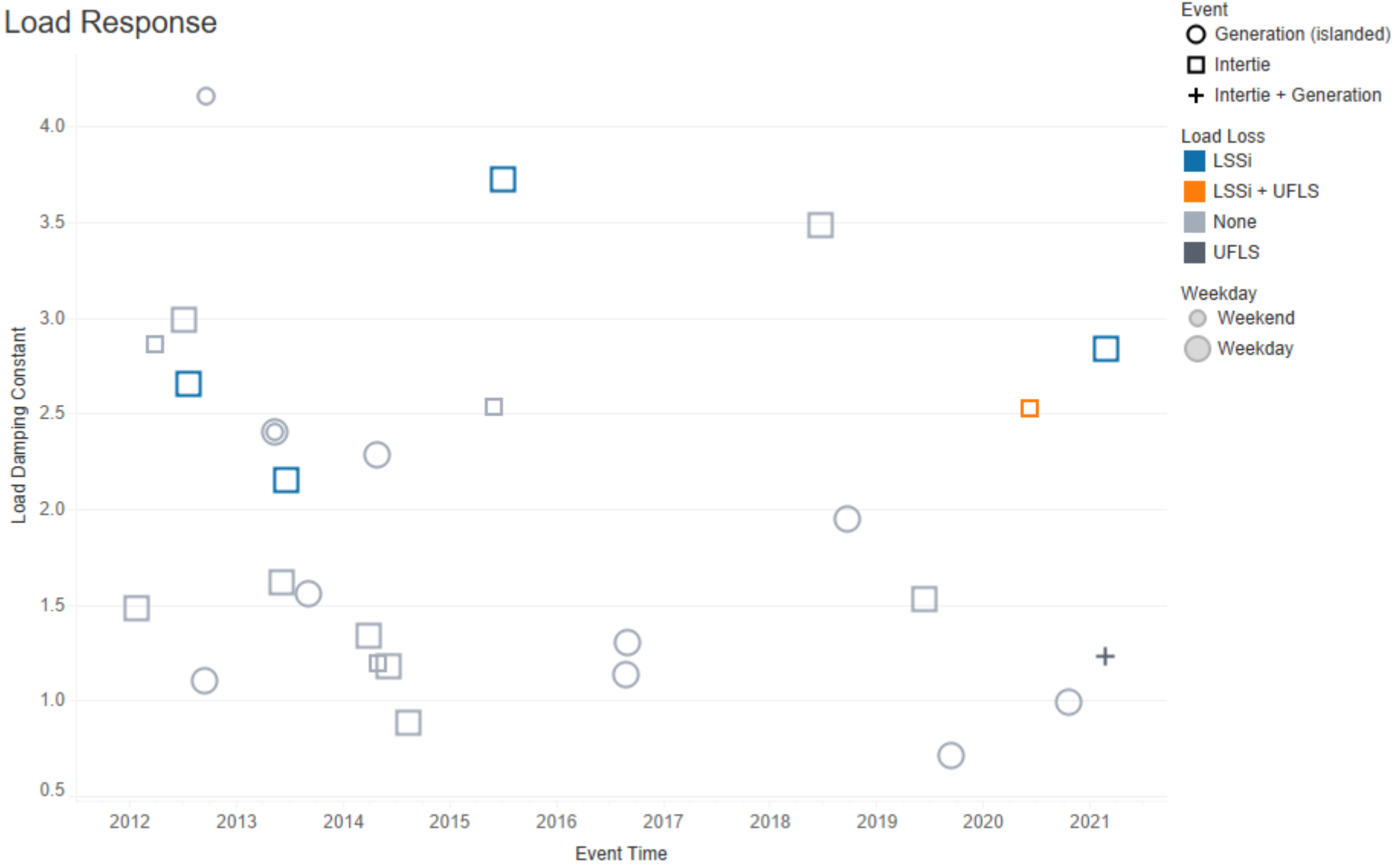
System Response – February 22, 2021



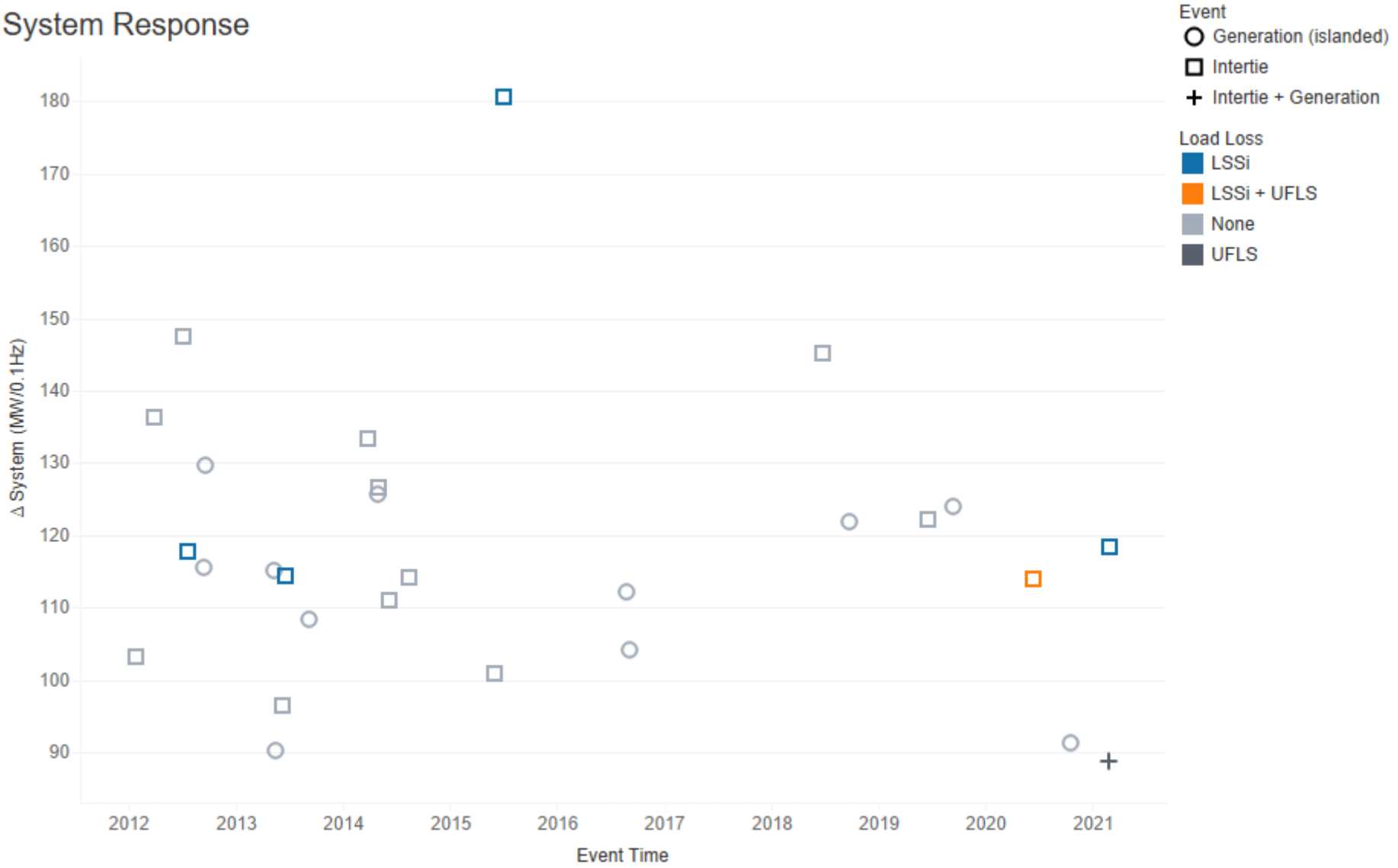
Historical Events – Generation Response



Historical Events – Load Response



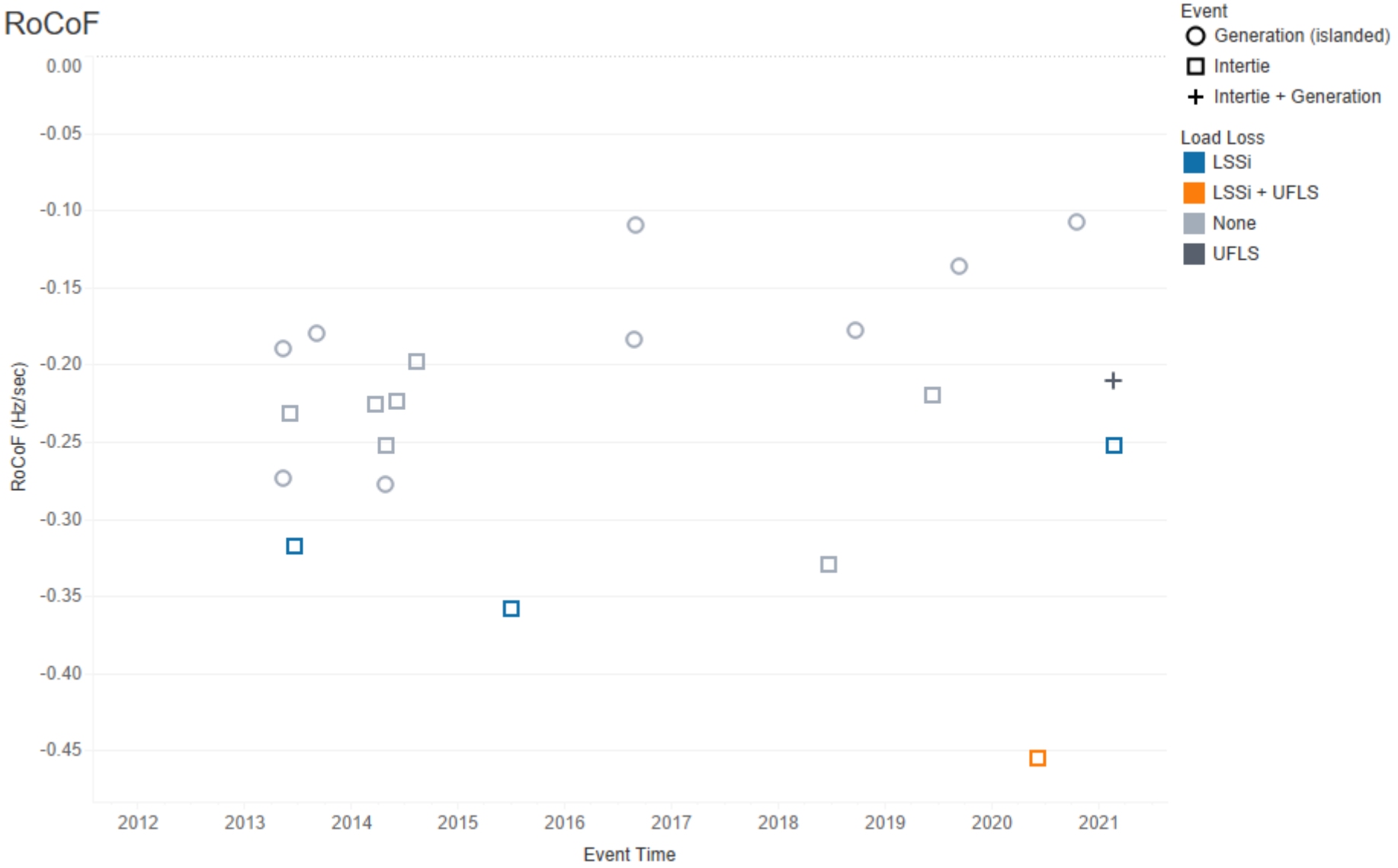
Historical Events – System Response



Mitigation Measures

- Use of severe weather table as a short-term relief measure to reduce risk during high wind/icing conditions
  - Table 7b, ID #2011-001R, Available Transfer Capability and Transfer Path Management
  - Effective February 22, 2021 until March 4, 2021 HE11
- Use of revised table, for normal operations, effective March 4, 2021 @HE12
  - Addition of incremental volumes to LSSi (50 MW)
  - Arming below 500 MW
  - Based on system studies / simulations

Historical Events – Rate of Change of Frequency (RoCoF)



Stakeholder Engagement Process

- The AESO has been proactively engaged in collaborative discussions with GFOs
  - Multiple discussions were held at all levels with the generator community in the province
    - Executive, Technical, Commercial, and Markets
  - Technical reports submitted by GFOs in Q4 2020
- Worked with TFOs and LSSi service providers to identify concerns and mitigating measures
- Engaged other ISOs/RTOs and regional reliability organizations such as the WECC and NWPP
- Review of global actions by other system operators such as EirGrid and the Australian Energy Market Operator (AEMO)
- Review of NERC literature

Various AESO Findings from Engagement with GFOs

- GFOs were highly engaged to understand the reasons for lower PFR from generators
- No compliance concerns from the AESO
- Engagement with GFOs led to the following findings:
  - Distributed Control Systems (DCS) operation not fully understood at plant level
    - DCS operation inadvertently interfering with the generating unit's frequency response
  - Typical mode of operation for most Gas Turbine units
    - Baseload operation unless participating in the Operating Reserve (OR) market
    - Sensitivity to ambient temperature
    - Lack of visibility at unit level for the AESO

AESO Findings - Continued

- Findings Continued
  - Plant level controller overriding Units' droop response
    - Net output control at the plant level
  - Sliding pressure controls
    - Mode of operation specific to some coal assets
  - Cap on Droop response
    - Some assets had a limit on how much the asset is able to respond during system events
  - Suspected Automatic Generation Control (AGC) signal mismatch
    - Suspected conflict between AGC signals and a certain class of assets leading to response withdrawal
  - Ramp rate control in Gas Turbine units
    - Control logic implemented by specific Original Equipment Manufacturer (OEM)

AESO Recommendations – Approach

- Recommendations developed based on detailed system event analysis, engineering studies, discussions with GFOs, jurisdictional reviews, and recommendations by NERC
- Recommendations are holistic in nature
  - These address the entire frequency continuum spectrum
- Path forward regarding implementation of some of the recommendations will be based on:
  - Clearly identified need and benefits to grid reliability as observed from technical studies and impact assessments
  - Address issues with efficient and effective solutions that align with the Markets framework
  - Coordinated approach with other AESO roadmaps/initiatives
  - Follow the AESO's due stakeholder engagement process

Recommendations – Short Term 2021

- The use of inertia as a third parameter to develop arming tables for LSSi
  - Modification to ID #2011-001R only
- Situational Awareness
  - Expected system frequency response display in the control room for system controllers
- Operational preparedness during islanded operations to ensure frequency stability during system events
- System studies to develop optimized regulating reserve (AGC) volumes to manage net demand variability (NDV)
  - Optimization implemented within the existing OR block procurement structure, on-going
- Work to improve wind and solar forecast accuracy
  - Ramp prediction reports

Recommendations – Medium Term 2021-2022

- Initiate ID revisions to provide additional clarity on expected frequency response during system events - Impacted IDs would be related to:
  - Generating Unit Technical and Operating Requirements
  - Operating Reserve Technical Rules
- Modify AESO's power system modeling processes and assumptions
  - Move away from the maximum authorized real power (MARP) concept as a benchmark
  - Incorporate summer and winter ratings modeling for generation units
- Technical study to determine the potential benefits of deploying synthetic inertia in the AIES
- Explore the feasibility of automatic duct and peak firing with certain generators
- Work with GFOs to modify ramp rates for Gas Turbines during system events, if feasible

Recommendations – Long Term 2021-2023

- Study the technical feasibility of new ancillary service products to address primary frequency response (PFR) from generators or low system inertia
  - Implemented by ERCOT
- Study the technical feasibility of dynamic AGC (slow versus fast AGC) and benefits to system reliability
  - Implemented by other North American ISOs/RTOs
- Work with generator facility owners (GFOs) to ensure natural frequency response of assets do not conflict with AGC signals
- Strengthen compliance monitoring
  - Proactive monitoring during system events
  - Consider a performance metric standard (similar to ERCOT), measuring actual generator frequency response during events
- Share learnings and approaches with ISOs/RTOs and reliability organizations such as WECC and NERC

Conclusion / Next Steps

- Continue to closely monitor system events and system performance
- Continue collaboration with industry stakeholders, other ISOs/RTOs, and reliability organizations
- Technical studies and reviews and impact assessments per AESO timelines and priorities
- Regular updates to the Market and the Industry

Contact the AESO

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Thank you

Appendix - Interconnection Map AB-BC