Pacific Northwest NATIONAL LABORATORY

Idaho National Laboratory

NREL Transforming ENERGY

HydroWIRES

U.S. DEPARTMENT OF ENERGY

Possible impact of hydrological data on frequency response

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U.S. DEPARTMENT OF ENERGY BATTELLE

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Problem Statement

Context: TPL-008 Transmission System Planning Performance Requirements for Extreme Temperature Events

- Establish requirements for Transmission system planning performance for extreme heat and extreme cold temperature events
- Select one extreme heat benchmark event and extreme cold benchmark event for performing Extreme Temperature Assessments

1. Type of Extreme Temperature Assessment	1. Extreme Cold Temperature Event	1. Extreme Heat Temperature Event	1. Total
Benchmark Planning Case Analysis	A minimum of one extreme cold temperature benchmark planning case assessment	A minimum of one extreme heat temperature benchmark planning case assessment	Total Minimum: Two benchmark planning case assessments
Sensitivity Analysis	A minimum of one sensitivity study case for one of the following: 1. Changes in generation availability, or 2. Changes load level (real and reactive), or 3. Changes in transfer level	A minimum of one sensitivity study case for one of the following: 1. Changes in generation availability, or 2. Changes load level (real and reactive), or 3. Changes in transfer level	Total Minimum: Two sensitivity cases analysis
Total			A minimum total of four Extreme Temperature Assessments

Problem Statement

Hydro generation not adequately and inaccurately represented in planning and operation studies:

- Water availability not updated seasonally or modeled in basecases
- No interdependencies between resources, environmental constraints ignored

The six-turbine Edward Hyatt Power Plant was taken offline after the water level in the Oroville Dam reservoir that feeds it sank to an historic low

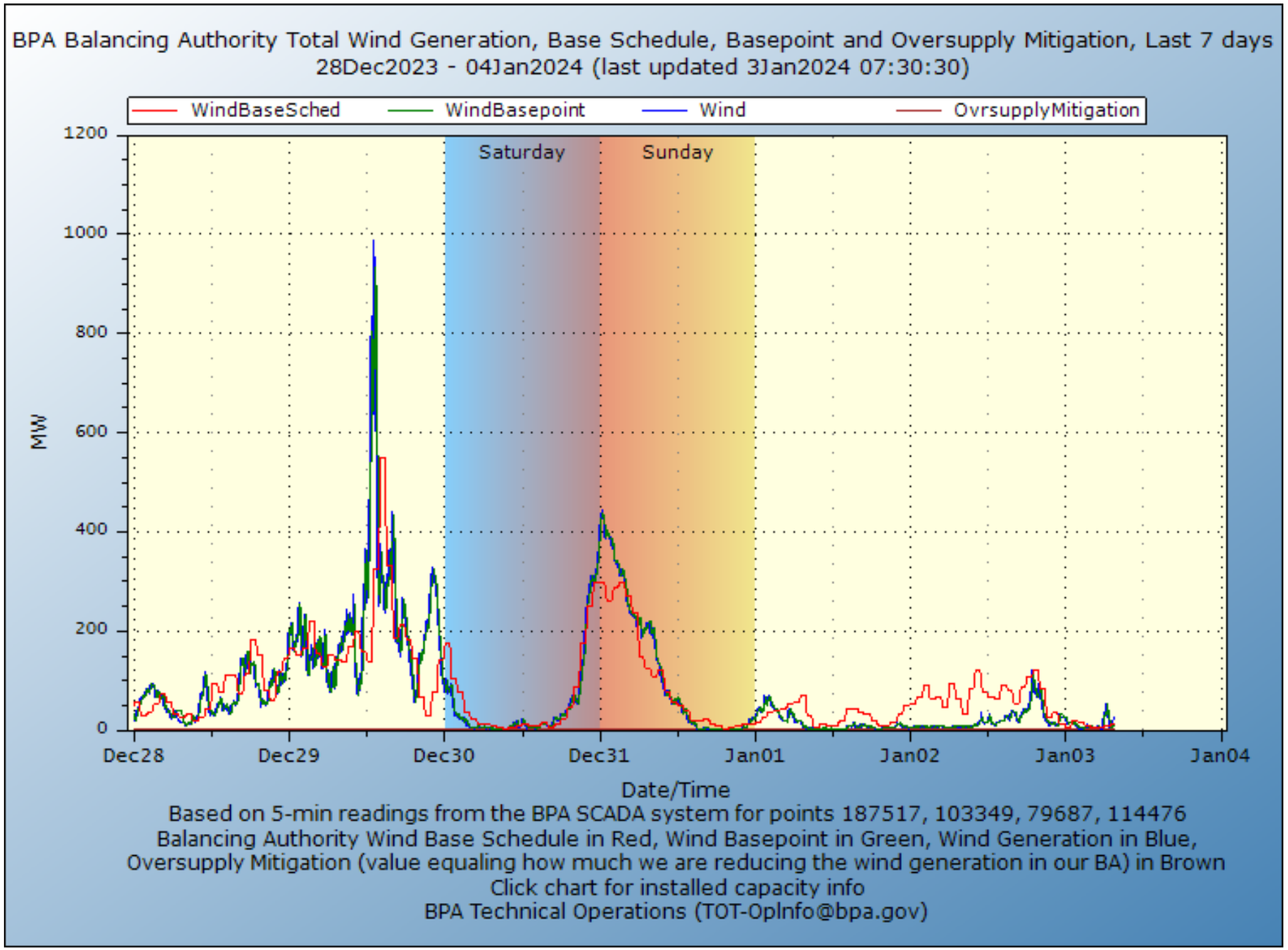
https://www.cnbc.com/2021/08/06/california-shuts-down-major-hydroelectric-plant-amid-severe-drought.html

As the river's biggest reservoirs, Lakes Powell and Mead, fall to one-third of their capacity, the dwindling flow threatens electricity generation.

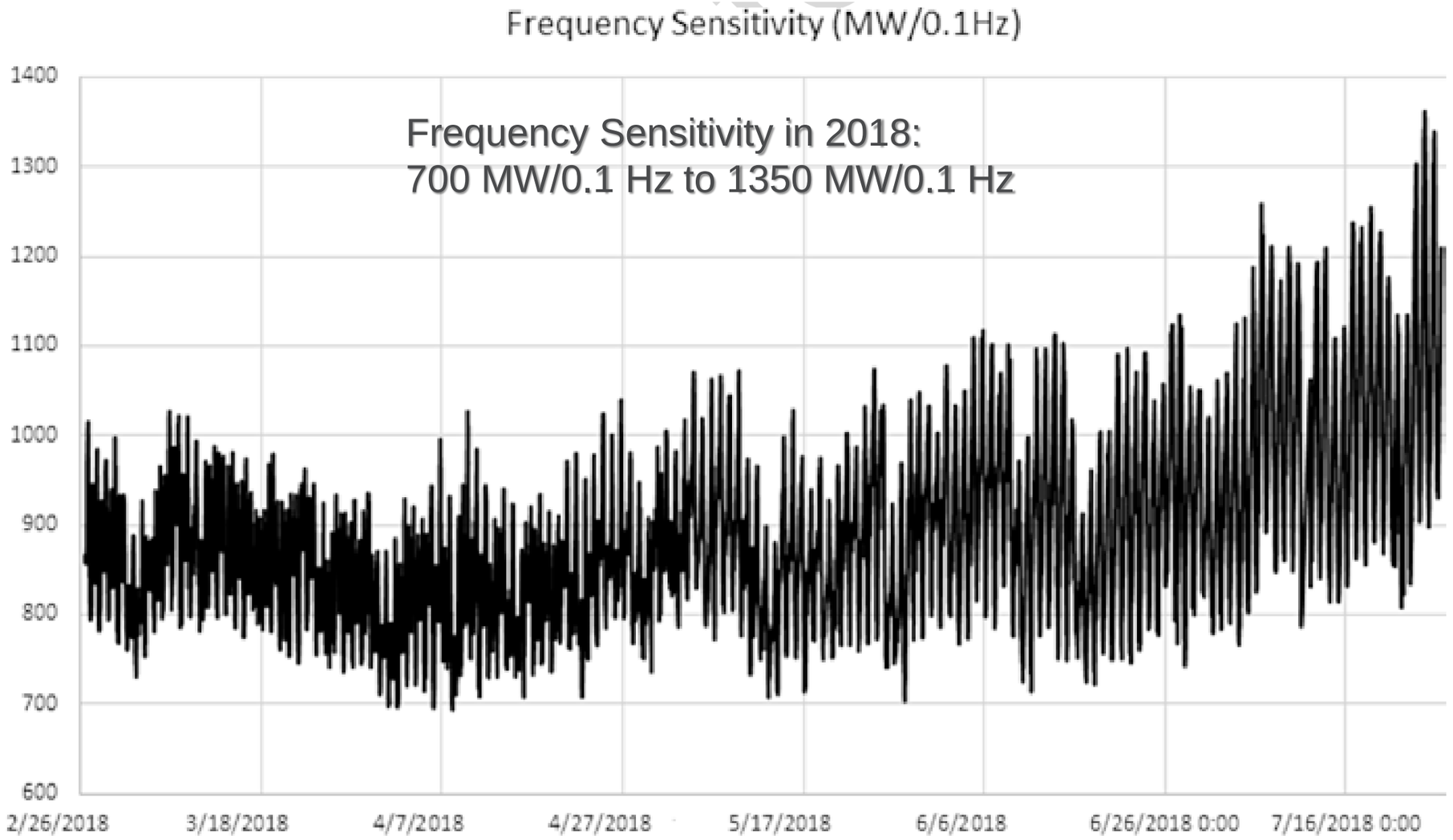
https://insideclimatenews.org/news/08082021/colorado-river-water-power/#:~:text=The%20Colorado%20River%20is%20tapped,government%20will%20declare%20a%20shortage.

Case Study-Wind Variability

https://transmission.bpa.gov/business/operations/wind/twndbspt.aspx



Frequency Sensitivity



Retirement of generation in WI

2019 Retirements		6581 MW		
Alamitos 1-6	NG	2010	CA	12/31/2020
Boardman	Coal	550	OR	12/31/2020
Centralia 1	Coal	670	WA	12/31/2020
Huntington Beach 1,2 (Potential Delay)	NG	450	CA	12/31/2020
Ormond Beach	NG	1491	CA	12/31/2020
Nucla	Coal	100	CO	12/31/2020
Redondo Beach (Potential Delay)	NG	1310	CA	12/31/2020

2020 Retirements			367 MW
Fort Churchill 2	NG	113	12/31/2021
North Valmy 1	Coal	254	12/31/2021

2021 Retirements		2762 MW		
Oakland	NG	165	CA	10/1/2022
Comanche 1	Coal	330	CO	10/31/2022
San Juan 1,4 (Potential Retirement)	Coal	847	NM	12/31/2022
Naughton 1,2 (Potential Retirement)	Coal	357	WY	2022
Jim Bridger 1,2 (Potential Retirement)	Coal	1063	WY	2022

2022 Retirements		2710 MW		
Diablo Canyon 1	Uranium	1080	CA	11/30/2024
Centralia 2	Coal	670	WA	12/31/2024
Cholla 4	Coal	387	AZ	12/31/2024
Newman 1-3	NG	247	TX	12/31/2024
Scattergood 1,2	NG	326	CA	12/31/2024

2024 Retirements	4242 MW			
Comanche 2	Coal	330	CO	10/31/2025
Diablo Canyon 2	Uranium	1080	CA	11/30/2025
Battle River 4	Coal	148	AB	12/31/2025
Craig 1	Coal	427	CO	12/31/2025
Fort Churchill 1	NG	113	NV	12/31/2025
Harry Allen 1	NG	76	NV	12/31/2025
Intermountain GS 1,2	Coal	1800	UT	12/31/2025
North Valmy 2	Coal	268	NV	12/31/2025

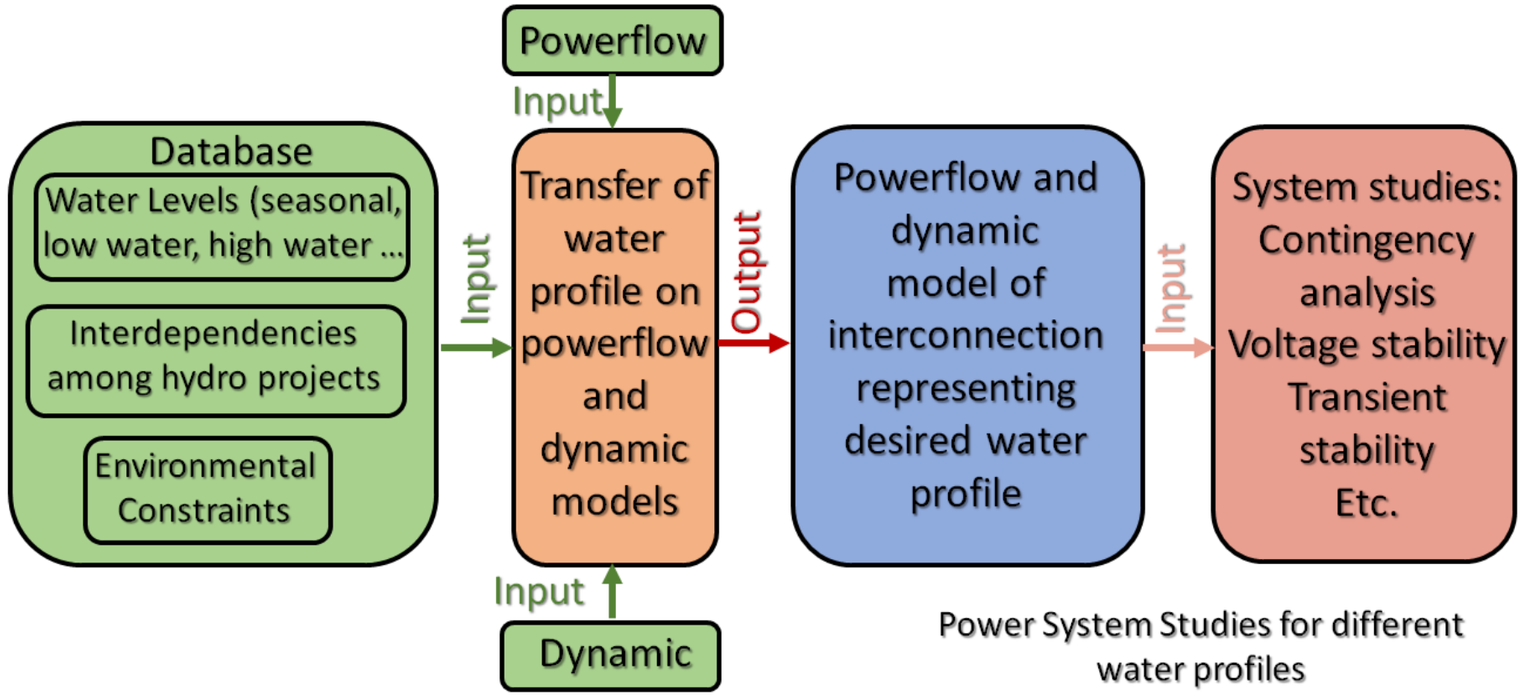
2025 Retirements	910 MW			
Battle River 5	Coal	148	AB	12/1/2027
Dave Johnston 1-4	Coal	762	WY	12/31/2027

2027 Retirements	871 MW			
Harmac Biomass	BIO	55	BC	8/12/2028
Sheerness 1,2	Coal	816	AB	12/31/2028

Total: 18,433 MW

Software

The software will update the existing steady state and dynamic model based on desired historical hydro conditions, allow modification while respecting interdependences and impose desired hydro profile, including dispatch constraints on hydro plants, as illustrated in Figure below:



Power System Studies for different water profiles

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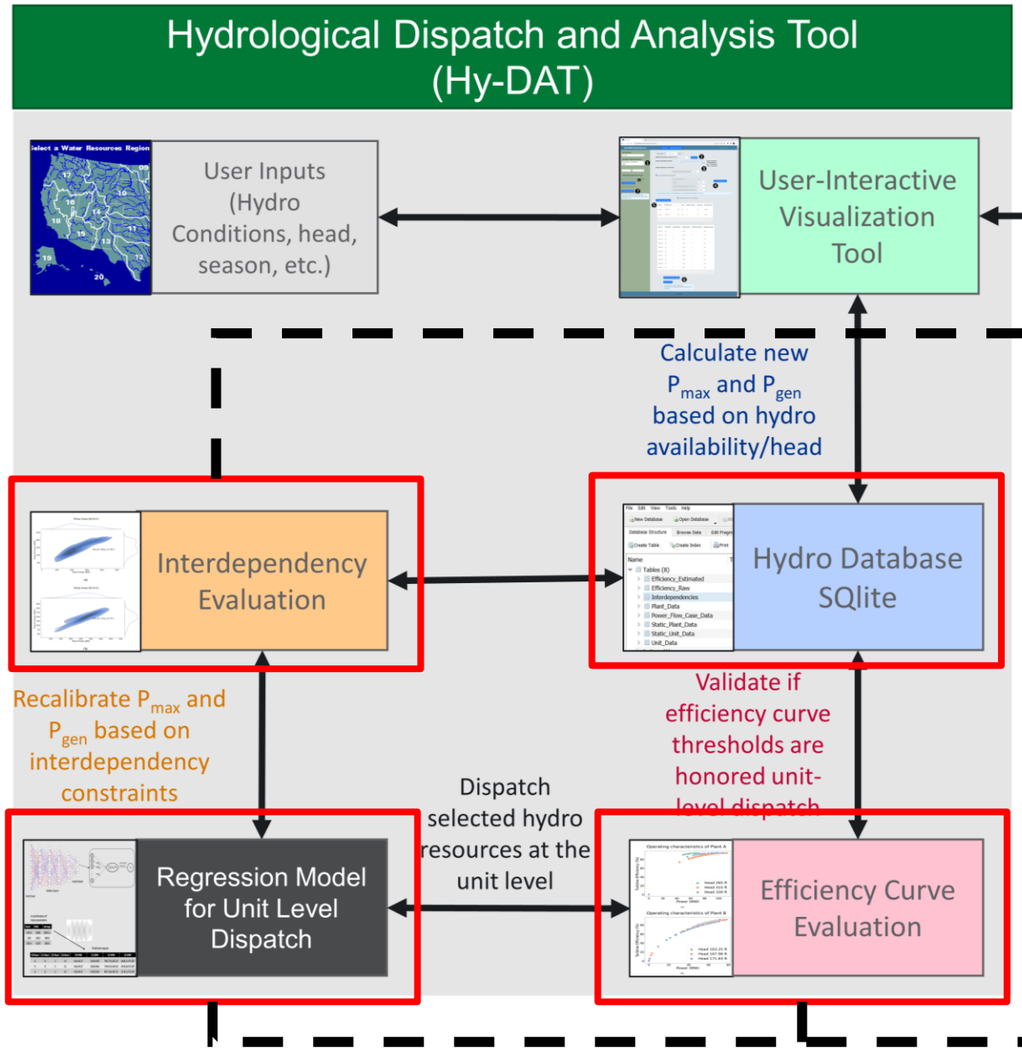


- **Interdependency**
  - This module uses seasonal hydrological information from upstream plant to limit the output of the plants downstream below the allowable limit.

- **SQL based database**
  - Static Hydro data containing plant information like nominal head, turbine rating, # of units, etc.
  - Historical Hydrology data containing plant head, flow, MW output, spillage, etc.
  - SCADA output – hydro unit level generation data from actual operations

- **Regression Model**
  - Merges SCADA data and hydrological data
  - An ML technique is used to learn the historical unit-level dispatch of hydro resources based on available head, flow, season, etc.

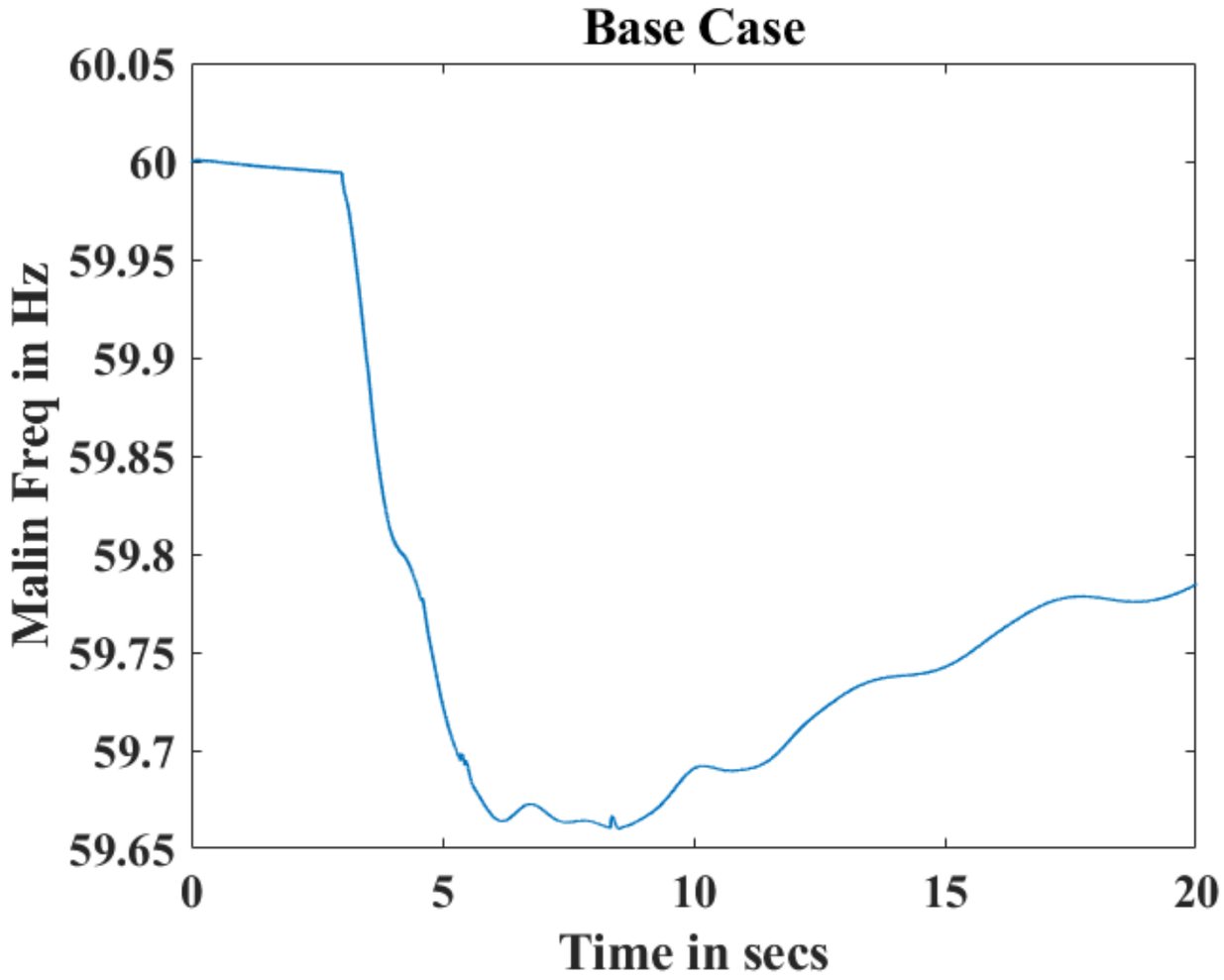
- **Efficiency Curve**
  - The tool uses historical hydrology data to generate a database for efficiency curves for various hydro units.
  - This is used when dispatching an unit based on user inputs making sure efficiency threshold is met.

[Hosted online: Hy-Dat.pnnl.gov](Hy-Dat.pnnl.gov)

Case Study

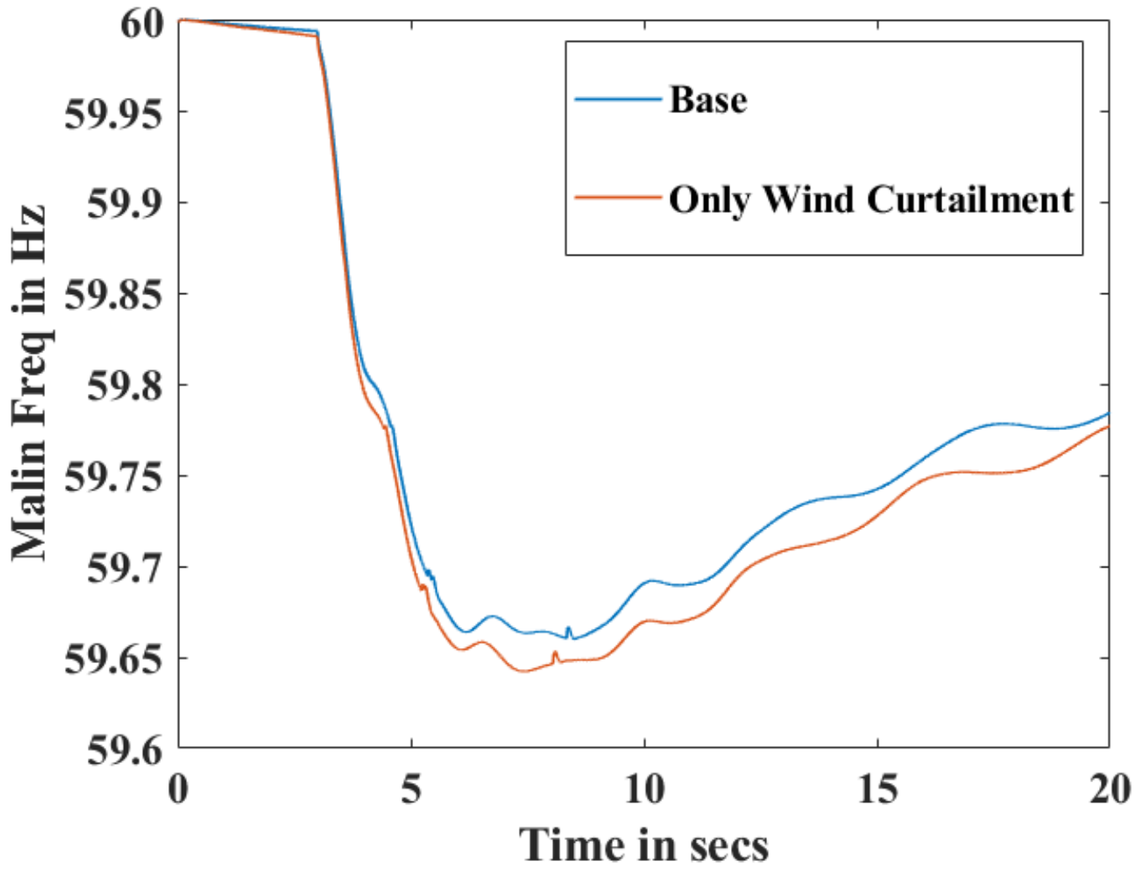
- 2022 Light Spring Case has been used as the base case
- Four scenarios have been simulated:
  - Scenario1: ‘Base Case’
  - Scenario2: ‘Only Wind Curtailment’
  - Scenario3: ‘Only Hydro Update’
  - Scenario4: ‘Wind Curtailment + Hydro update’
- Governor powerflow option in PSLF has been used to redispatch the changes in the generation made in the different scenarios considered using other resources throughout the system
- ‘N-2’ Palo Verde Trip Event has been simulated
- Wind units has been curtailed in the NORTHWEST area

Case Study



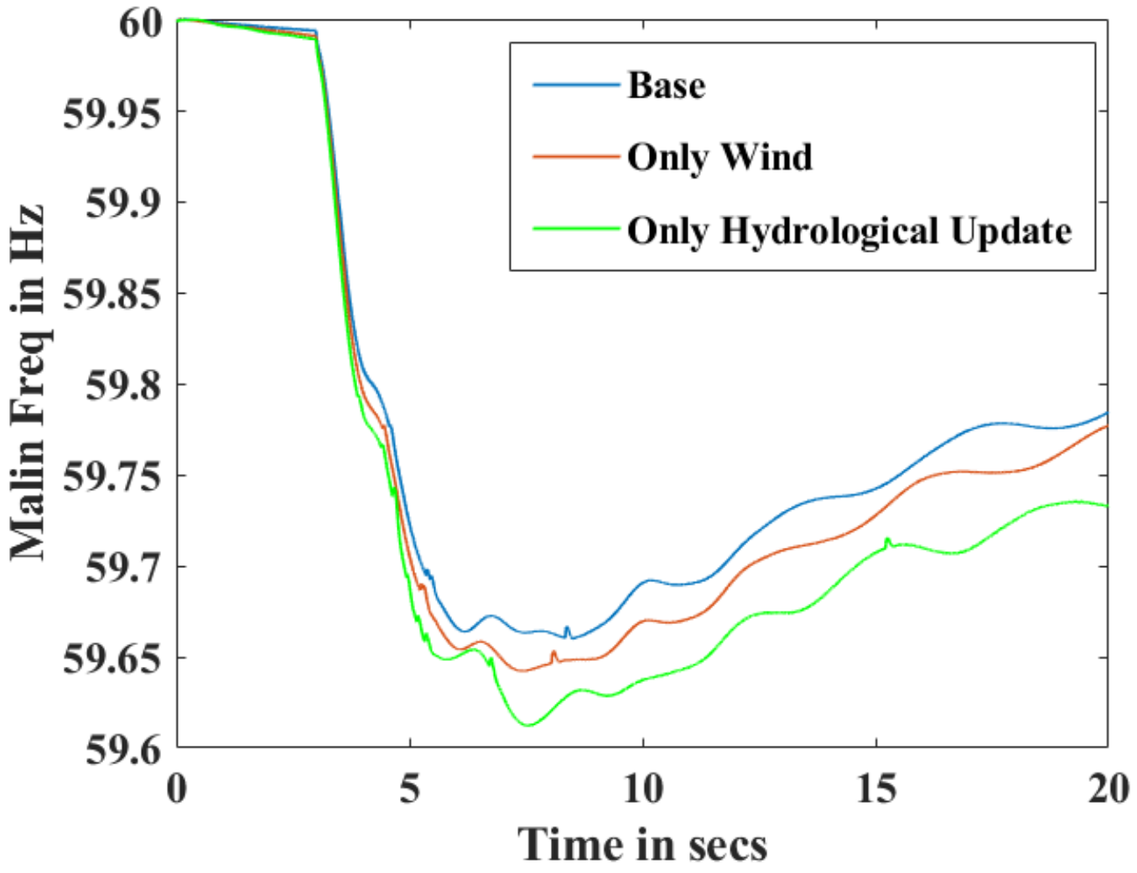
Observation: System recovers well

Case Study



- 20% of the total wind generation in the Northwest and California areas have been curtailed
- Wind units are only tripped in the Northwest area (~1500 MW)
- The hydro units whose generation data needs to be updated based on the new hydrological data are not utilized in the governor powerflow dispatch when wind generation is curtailed.

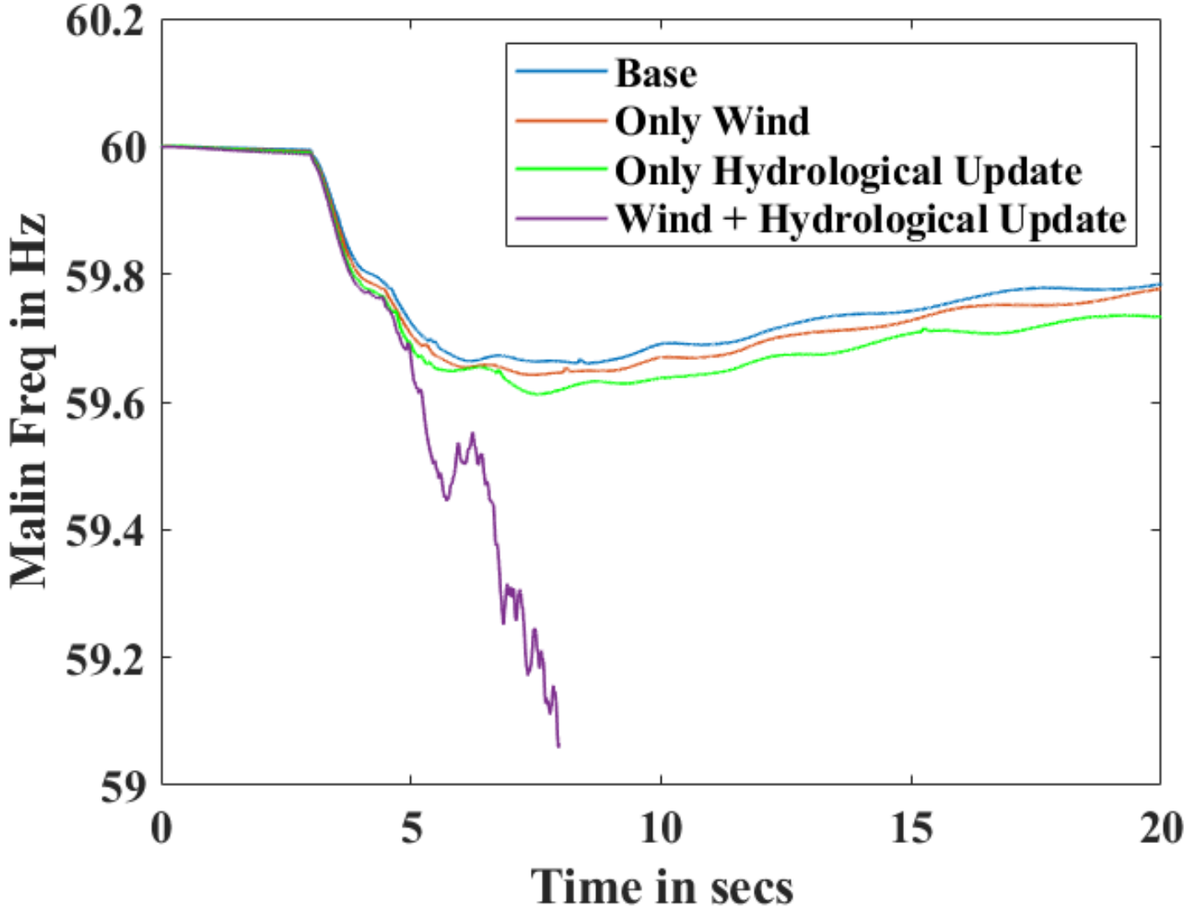
Case Study



- No wind generation has been curtailed
- The Pgen, Pmin and Pmax of the hydrounits have been updated based on the new hydrological data.
- Total of 4720 MW have been updated.
- ‘Head’ value in the corresponding dynamic governor models has been updated to 0.75 pu (default is 1 pu).

Observation: System recovers well similar to base case but has slightly lower nadir and much slower recovery rate compared to Scenario 1 and Scenario 2

Case Study



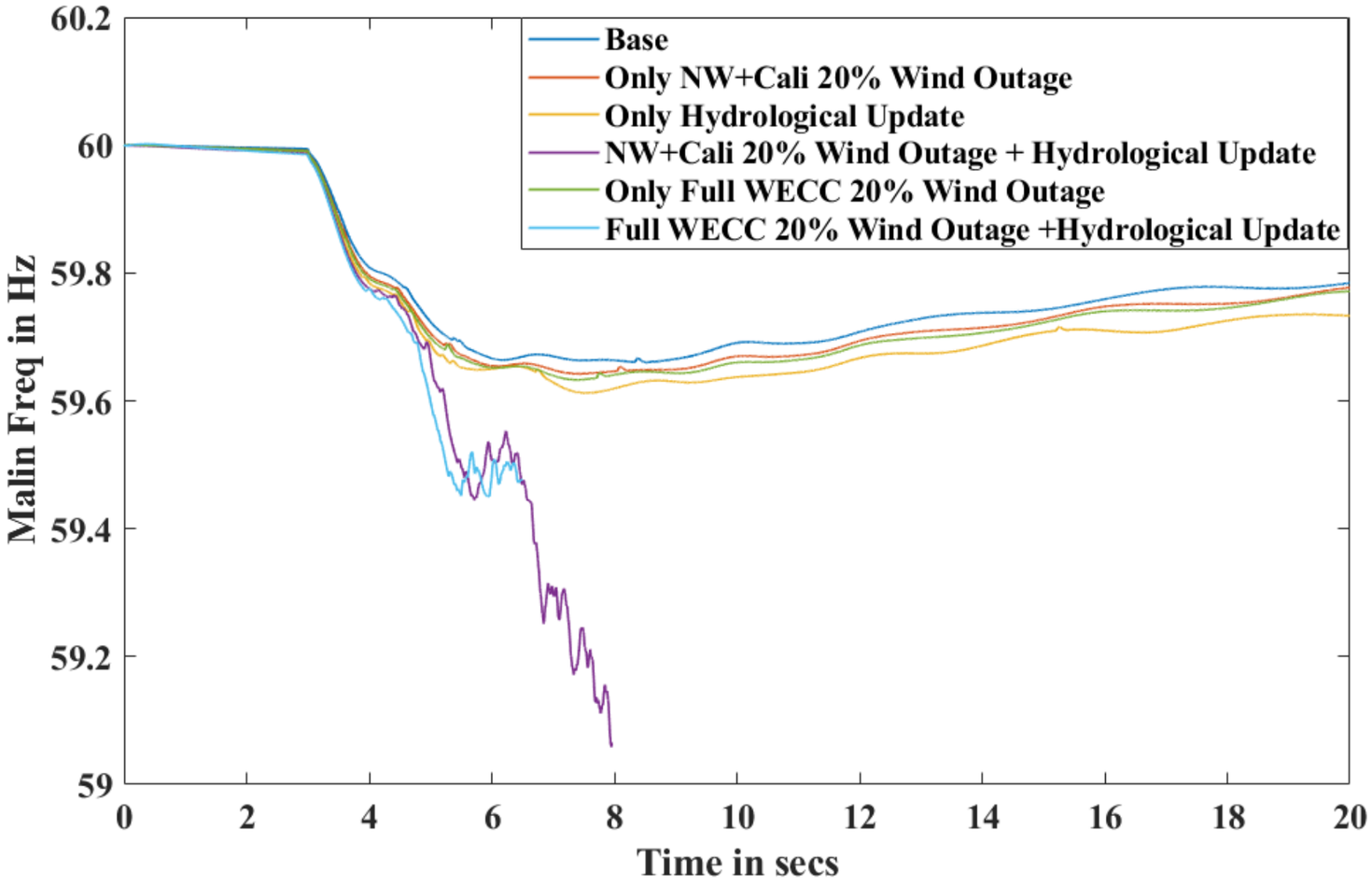
- Updates made in both Scenario 2 and Scenario 3 have been made in this Scenario

It should be noted that these simulations have also been redone by implementing the governor powerflow redispatch considering only units whose baseload flag value is 0.

Noticed almost same behavior, in the results, as shown before without considering baseload flag constraint.

Observation: **System doesn't recover which clearly shows the importance of having an accurate reflection of the hydro units generation based on the hydrological data**

Scenario 6: Result Comparison (20% Wind Curtailment based on Full WECC wind generation + Hydrological update) with Scenarios 1-5



Observation: **System response in this scenario is very similar (does not recover) to Scenario 4 (20% wind outage based on NW & Southern Cali wind generation areas + hydrological update)**