Impact of Representing Hydrological Information in Power System Model Files (Steady-state and Dynamic)

In Collaboration with V&R Energy

Soumyadeep Nag, S M Shafiul Alam

Pacific Northwest NATIONAL LABORATORY

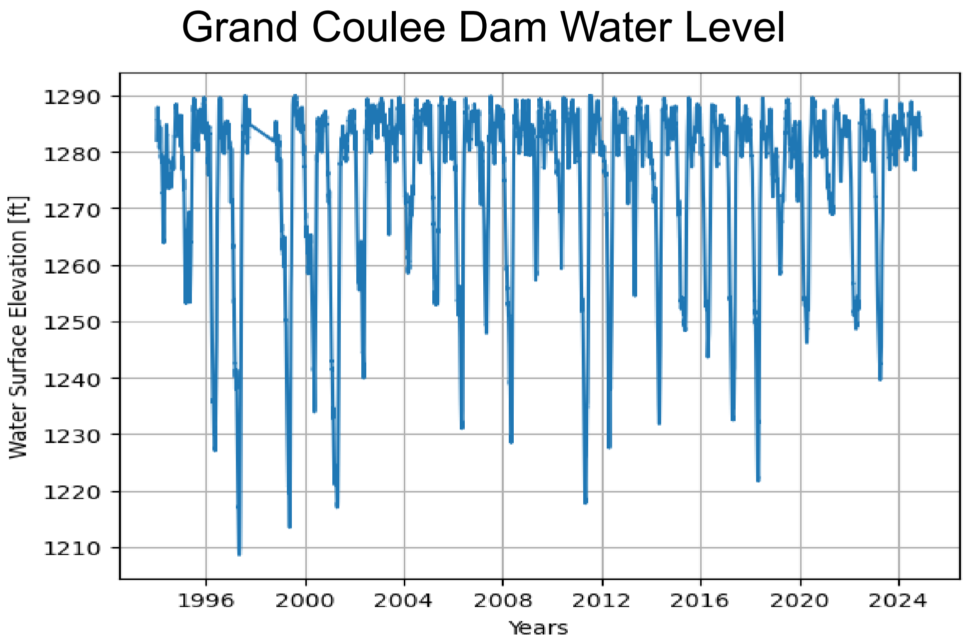
NREL NATIONAL RENEWABLE ENERGY LABORATORY

HydroWIRES U.S. DEPARTMENT OF ENERGY

Presentation prepared by Battelle Energy Alliance, LLC under Contract No. DE-AC07-05ID14517 with the U.S. Department of Energy. Work supported through the U.S. Department of Energy Water Power Technology Office HydroWIRES Lab Call.

INL Idaho National Laboratory

Representing Water Level Information in Power System Files



- Water levels change seasonally, annually and are diverse across geographic regions
- Maximum power output in power system model files is constant and does not reflect this variation
- For long time planning problems, considering variations in hydropower availability is crucial

- **Procedures for model update**

Input data
- New head

↓

Model update –
- Pmax estimation

↓

Redispatch –
- Reserve proportional redispatch

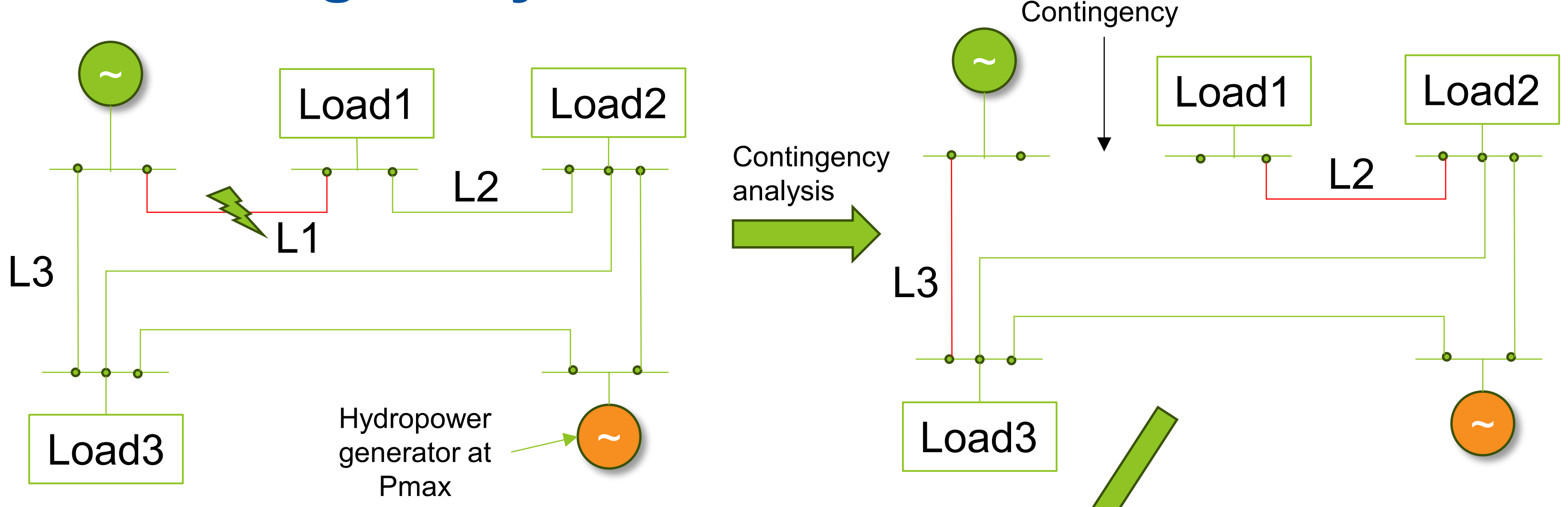
↓

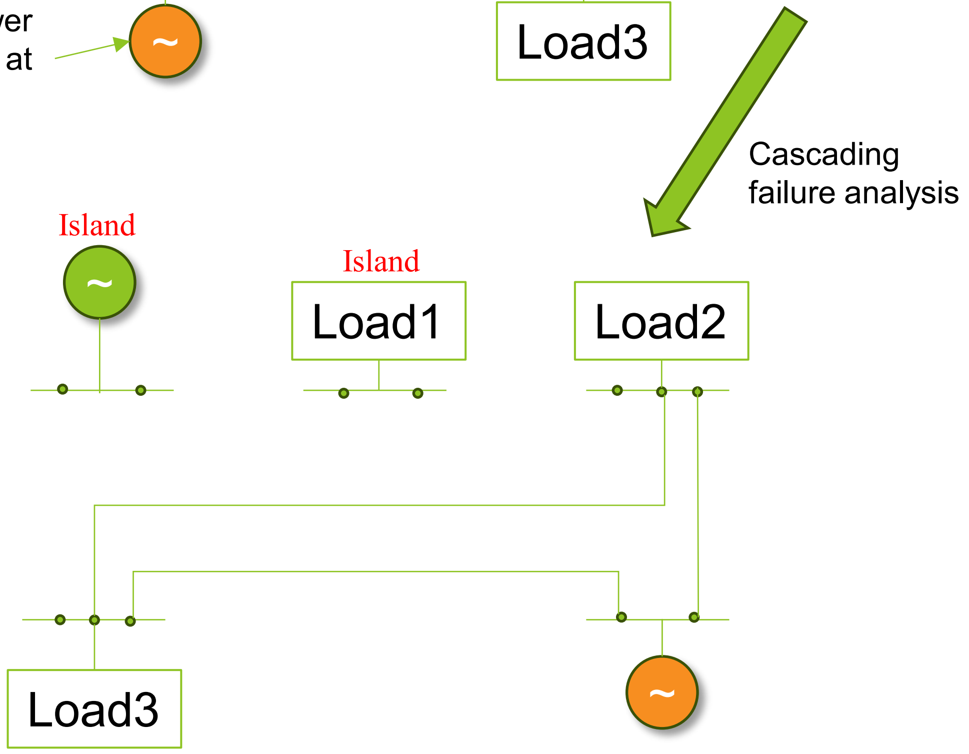
Check for load flow convergence

↓

File update –
- Steady-state and dynamic model files

Reliability estimation using N-1 Contingency analysis and Cascading analysis





N-1 Contingency analysis
- # critical contingencies

Cascading Failure analysis
- # Events leading to Cascading,
- # Formation of Islands,
- # Cascading instabilities

Voltage violation index:

$$\%violation = \frac{Measured - Limit}{Limit} \times 100\%$$

Thermal violation index:

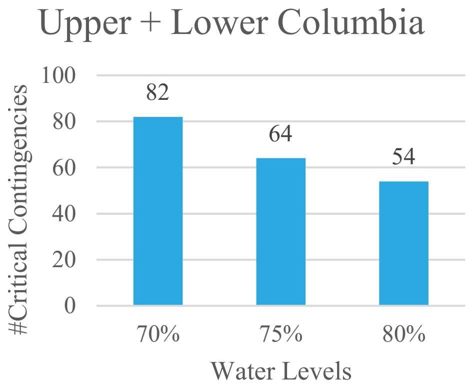
$$\%violation = \frac{Flow - Rated\ capacity}{Rated\ capacity} \times 100\%$$

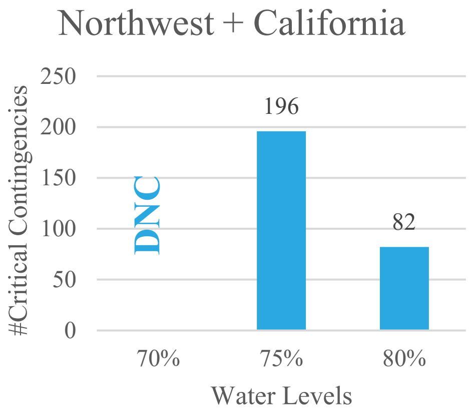
Case files

Water Level Sensitivity Analysis WECC

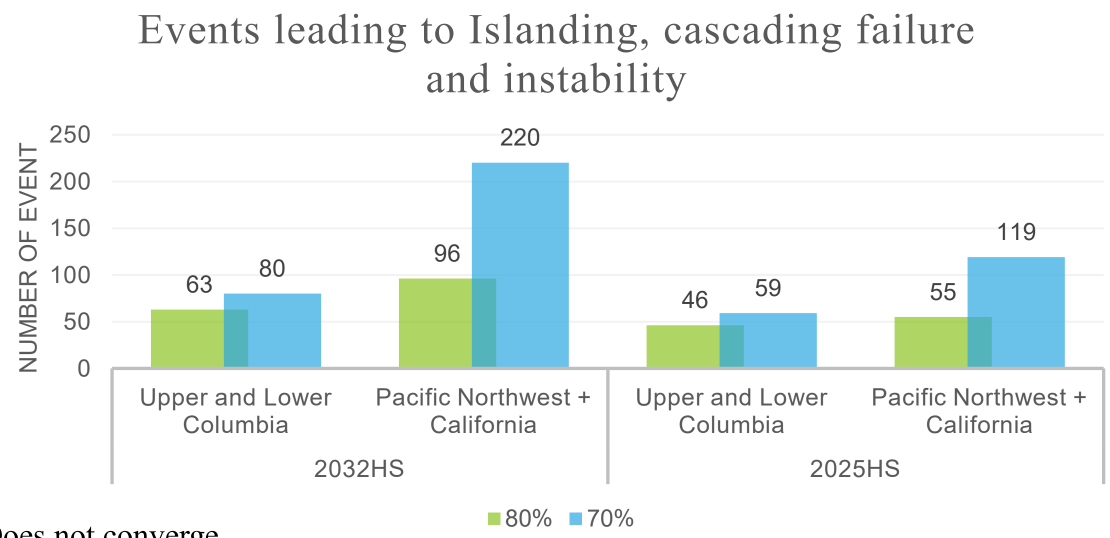
Impact of representing low water conditions (70%, 75%, 80%) over regions of the WECC system (V&R Energy POM)

2032 Heavy Summer: Base case Total Critical Contingencies = 35





2032 Heavy Summer: Base case = 43 , 2025 Heavy Summer: Base case = 37

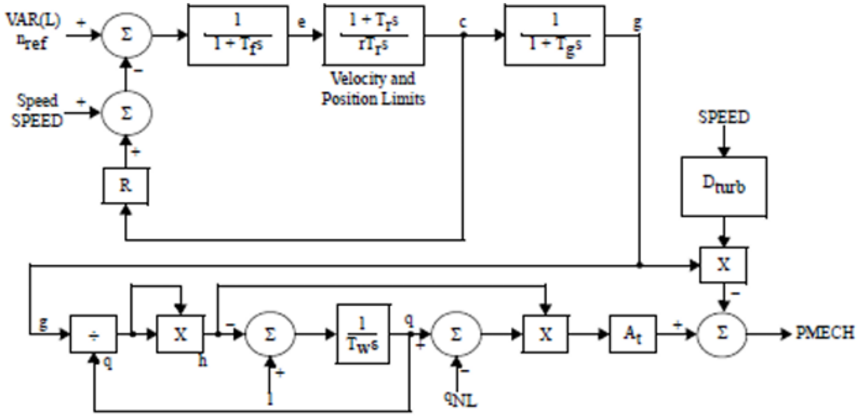


DNC – Does not converge

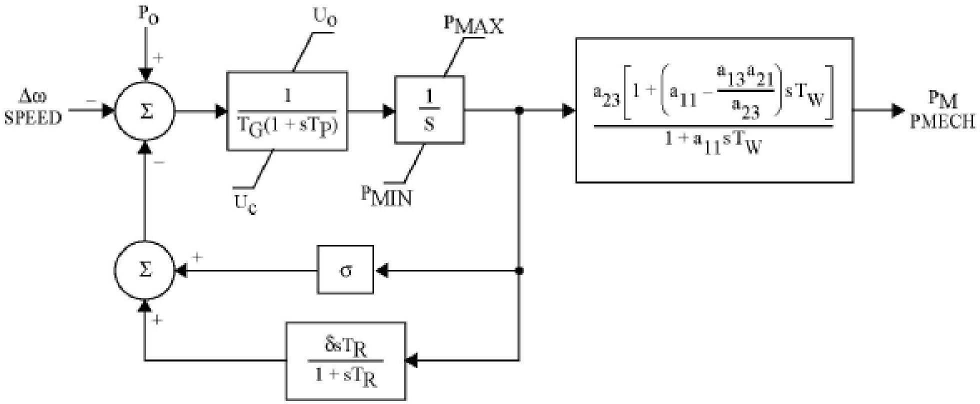
Gap in Dynamic Model for Water Head

Commonly used governor structures that do not allow head variation and/or turbine non-linearities (PSS/E v35.5)

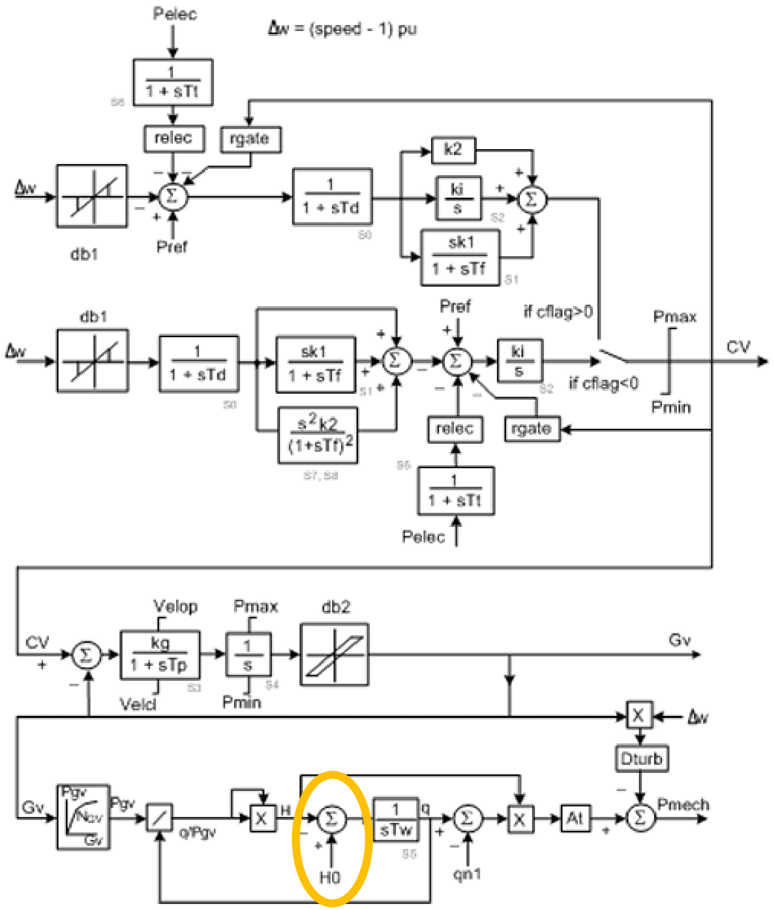
HYGOV (WI: 26.7%, EI: 64.3%)



IEEEG3 (WI: 7%, EI: 2.2%)



HYG3 (WI: 26.7%, EI: 64.3%)



Code modifications for representing hydrological conditions – Pmax estimation

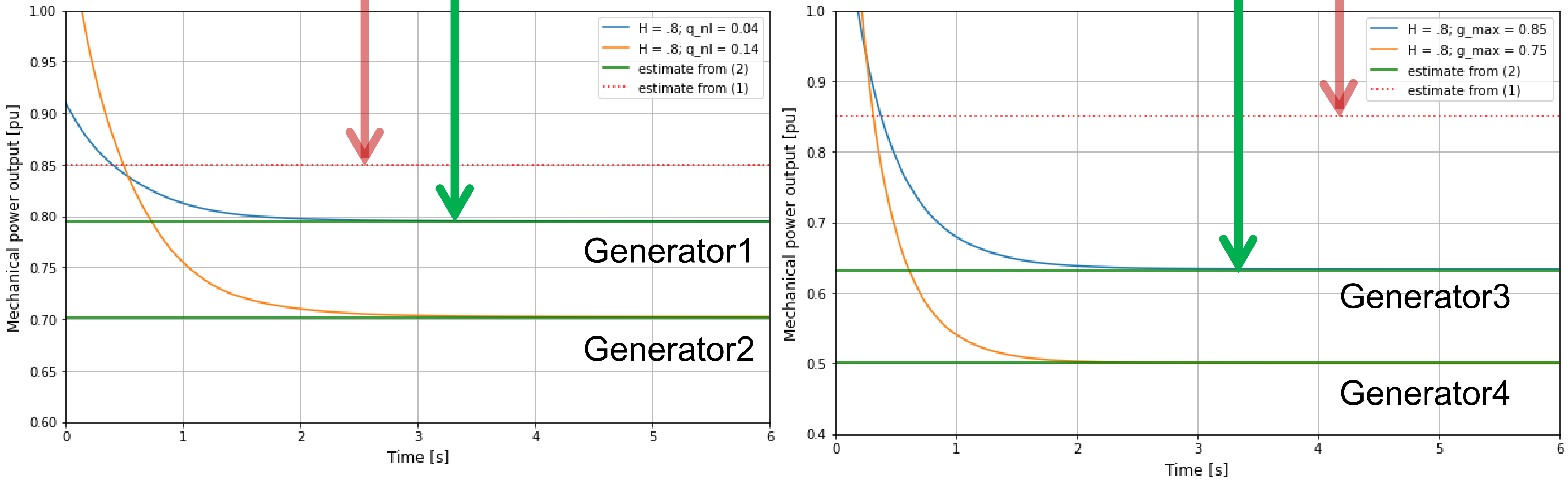
Milestone: Identify additional code modification beyond Pgen, Pmax and H_0 derating. Develop codes to integrate tailrace and other hydrological conditions in updating the standard hydropower plant steady-state and dynamic models.

Additional factors for code modification:

- no-load flow
- turbine rating
- maximum gate opening

$$P_{max}^{new} = P_{max}^{old}\left(\frac{H}{H_{nom}}\right)^{1.5}$$

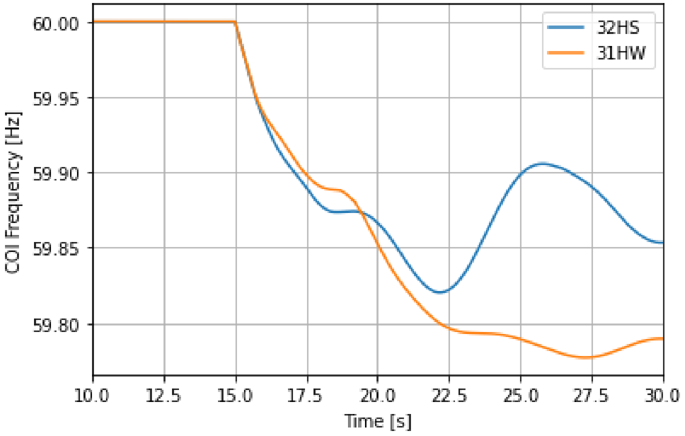
$$P_{max}^{new} = A_t(\overline{G}H^{1.5} - q_{nl}H)$$



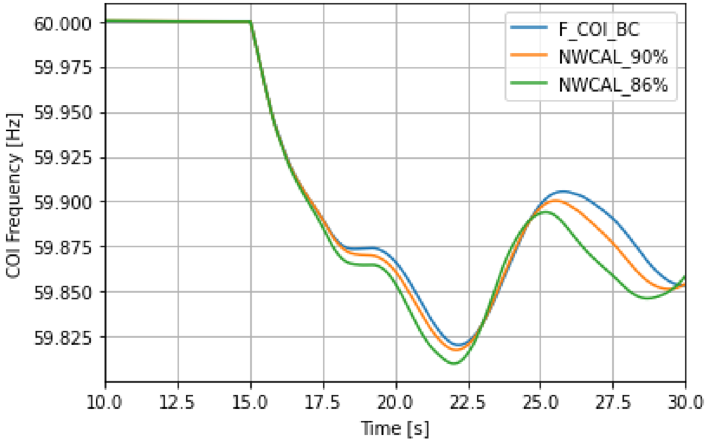
Center of Inertia Frequency for summer and winter cases

Results showing system center of inertia frequency after disconnection of 2 Palo Verde units **(PSS/E v35.5)**

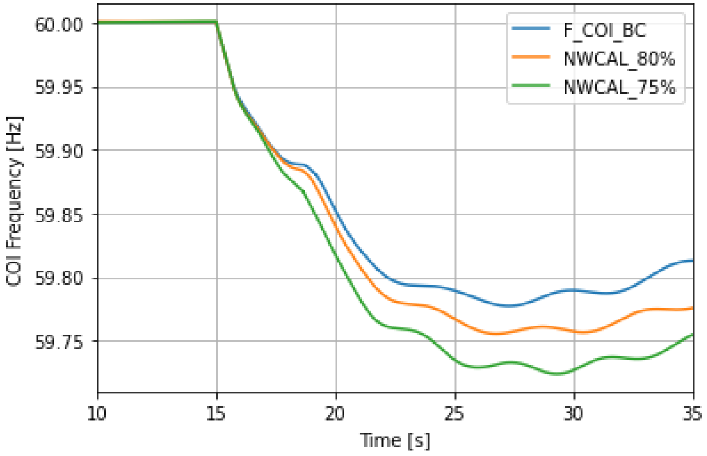
Base cases

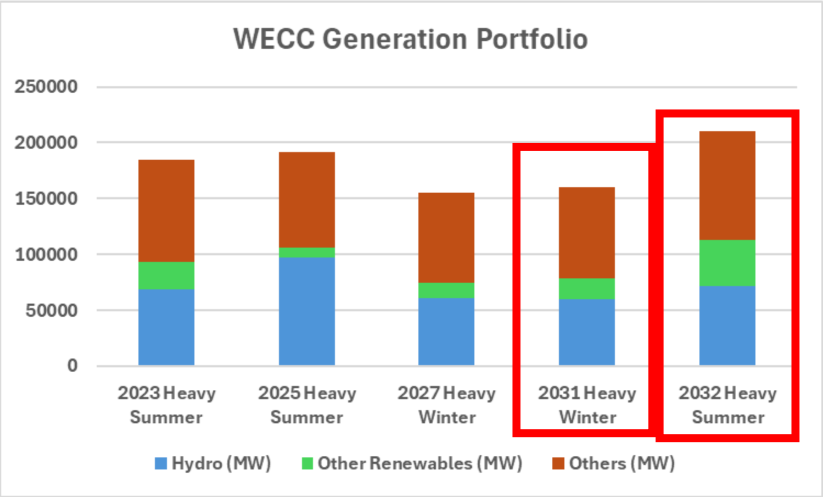


2032 Heavy Summer



2031 Heavy Winter



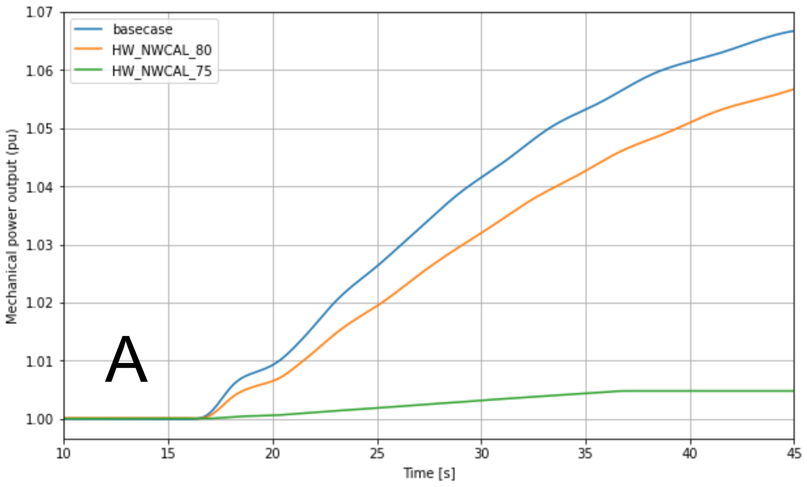


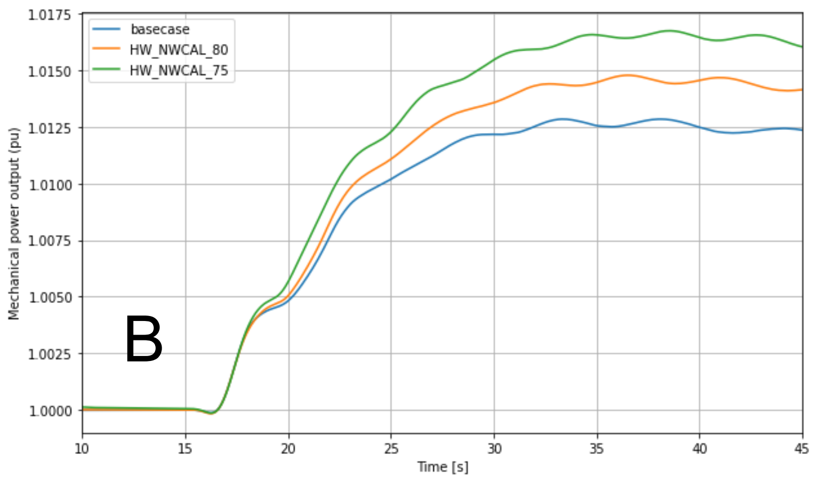
Key take aways:

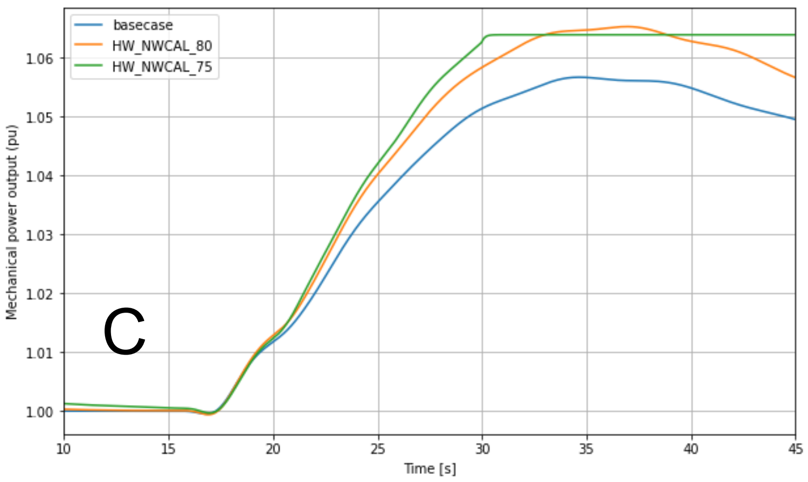
- 32HS and 31HW have different frequency response profiles due to the difference in generation resources
- Frequency nadir decreases with lower water levels
- Winter conditions display lower frequency nadir but higher damping than the summer conditions

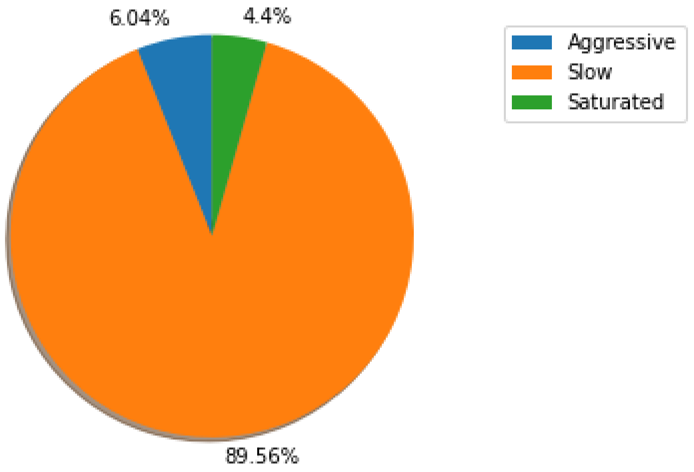
Mechanical power response comparison

All mechanical responses have been normalized with their initial values **(PSS/E v35.5)**









A – Slow controller fails to compensate for the reduction in head.

B – Aggressive Controller responds to excessive frequency dip and overcomes the effect of head reduction. Oscillatory response due to over-active controller.

C – Aggressive controller without reserves saturates

Key take away:

- 89.56% are slow controllers that cannot compensate the response rate for the change in head

Conclusions

- Findings and Impacts
  - Hydrological conditions are not represented in either steady-state or dynamic files
  - Using designed tools, power system files can be modified to represent hydrological conditions in both steady-state and dynamic representations
  - Analysis using both steady-state and dynamic representations show significant deviations from uninformed representations (cascading, contingency and dynamic frequency response analysis)
  - Retired models

GE PSLF	PTI PSS/E*	Number of the models in WECC case	Model Description
ieeeg3	IEEEG3	119	IEEE hydro turbine/governor model. Represents plants with straightforward penstock configurations and hydraulic-dashpot governors
gpwscc	WSHYGP	47	PID governor and turbine.
g2wscc	WSHYDD	4	Double derivative hydro governor and turbine.
pidgov	PIDGOV	48	Hydro turbine and governor. Represents plants with straight forward penstock configurations and "three term" electro-hydraulic governors (i.e. Woodard electronic)