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Hydrological Modeling Impact on Western Interconnection Frequency Response Studies

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Introduction

- With the evolving dynamic grid, the need for hydropower resources to help the system increases other than being a base load –
  - System Inertia
  - Primary frequency response

- In the current hydropower modeling being considered in the planning studies, only the electromechanical aspects are taken into consideration
  - Variance of water levels across different seasons is not getting reflected accurately
  - For example, in summer, for low water conditions, the hydropower units in the plant need to be derated

Objectives of this work:

1. Represent the varying hydropower conditions in both steady-state and dynamics accurately
2. Conduct a sensitivity study to understand the impact of the considered varying hydropower conditions on system stability
3. Impact of wind curtailment, under low hydro conditions, on system stability has been analyzed
4. The frequency response from various fuel types has been studied in detail under these critical conditions

Model Preparation: Parameter consideration +Algorithm

WI System with various loading conditions

- ✓ 2022 light spring case has 22800+ buses and 1850+ generators with 79 GW total generation (lightly loaded)
- ✓ 2030 high summer case has 23600+ buses and 2700+generators with 163 GW generation

Hydro Parameters + Wind Contingency Updates

$$Pmax_{new,i} = Pmax_{old,i}H^{3/2}$$

$$Pgen_{new,i} = (1 - HR)Pmax_{new,i}$$

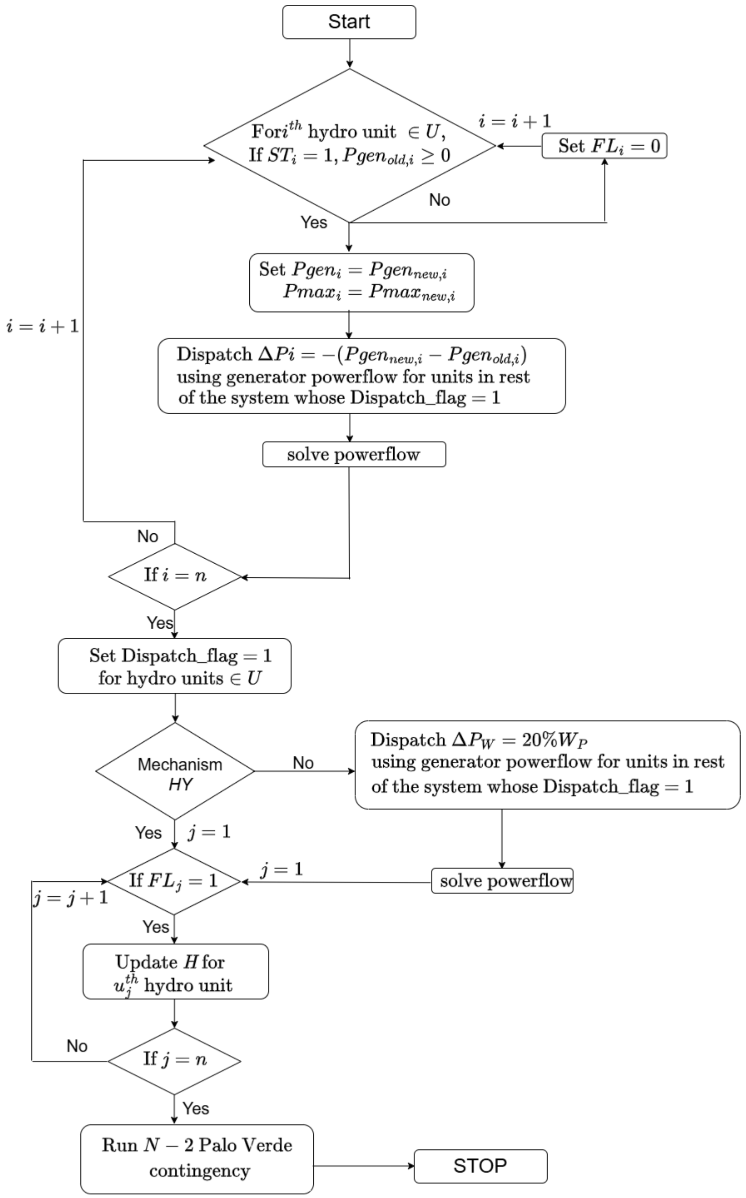
$$HR \in \{10\%, 20\%\}$$

$$H \in \{0.75, 0.9, 1\}$$

Wind Contingency: 20% of the total wind in the Northwest + California regions has been curtailed

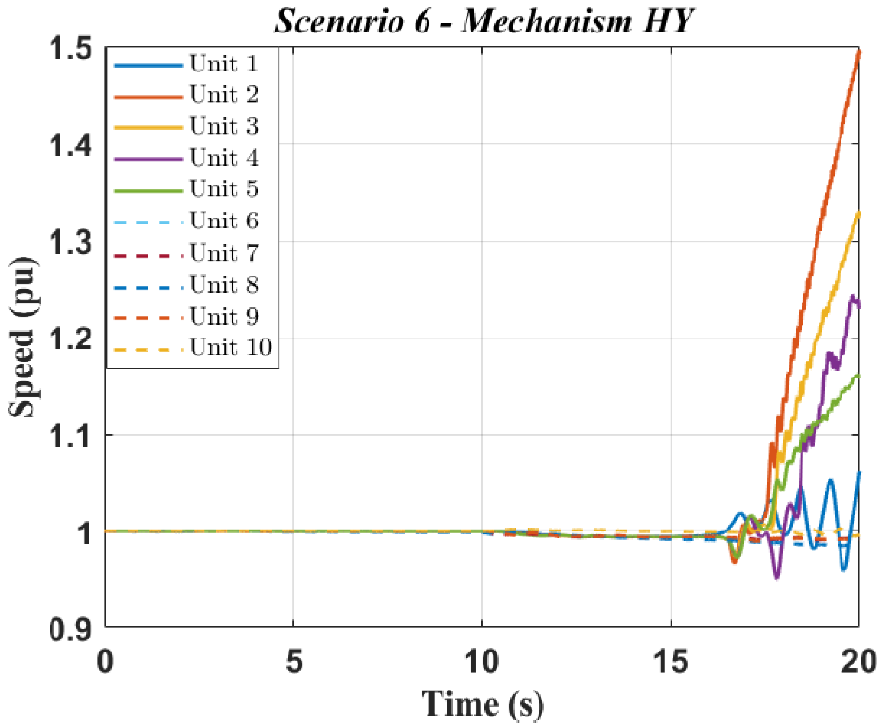
- ✓ Governor powerflow algorithm has been used to redispatch rest of the units in the system for each hydro unit Pgen change and the wind curtailment in that order respectively
- ✓ It is important to represent the hydro conditions in both steady-state and dynamics appropriately –
  - Steady-State: Adjust the Pgen based on derated Pmax (head and headroom are the critical parameters)
  - Dynamics: Adjust the nominal head
- ✓ Considered Double Palo Verde contingency

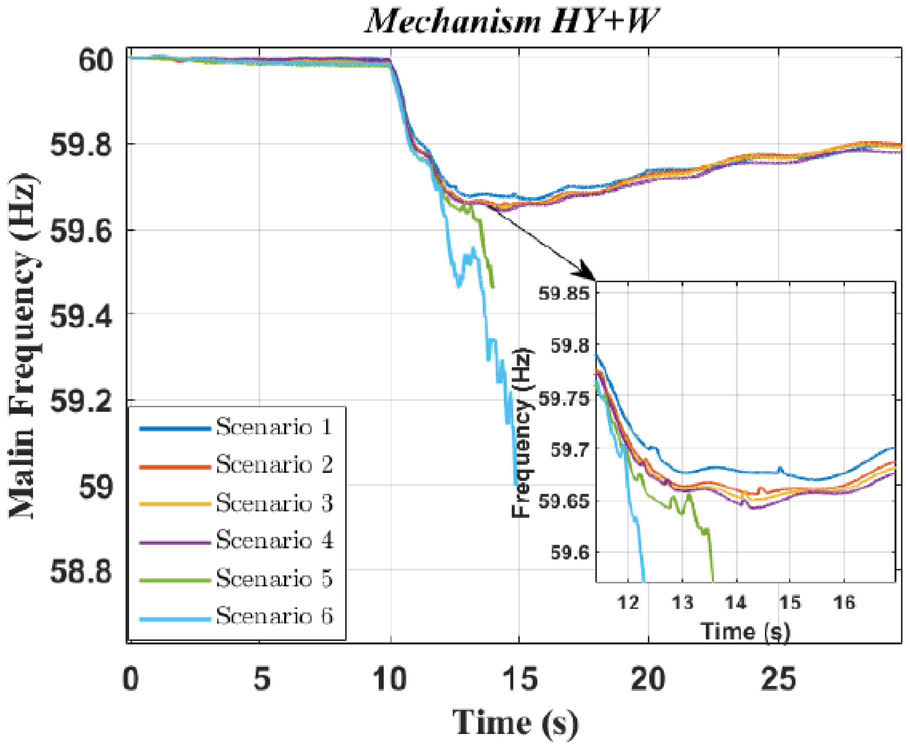
Algorithm: Flowchart



- ✓ Redispatch of the units during governor powerflow is done based on Pmax of the units for only units that are online and is actually generating (Pgen > 0)
- ✓ The list of hydro units that are identified to make the hydro updates are not involved in the redispatch process

Simulation Results & Discussion





- Under heavy loading conditions, system experiences steady-state power flow solution issues under low hydropower conditions
- For lightly loaded conditions, under low hydropower conditions the system experiences potential transient stability issues
  - Wind curtailment contingency exacerbates this issue
  - Units that were observed to be unstable were all hydro units (in other areas in which hydro updates are not made) and are operating close to their peak capacity. Protection for these units are not modeled in the base case

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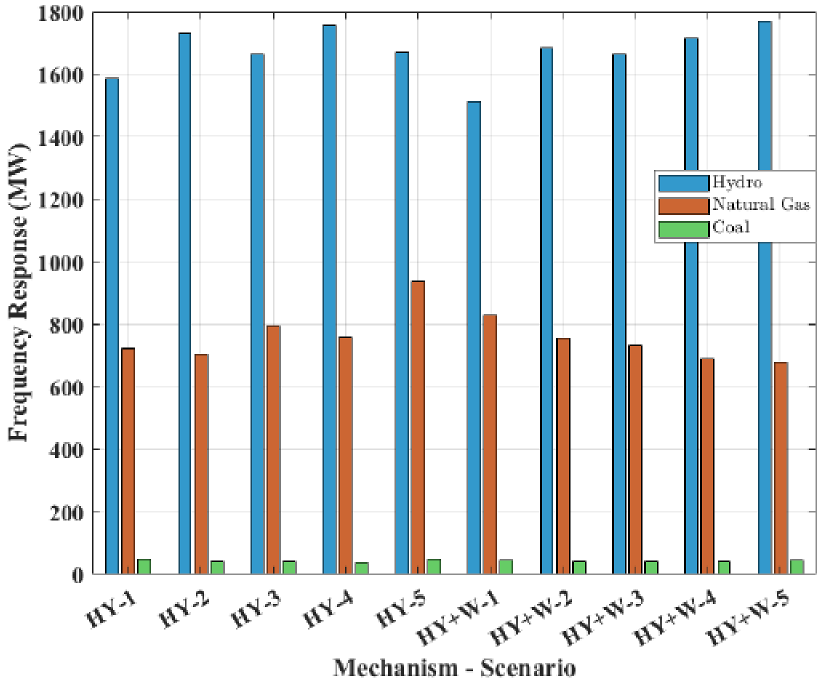
Simulation Results & Discussion: Summary

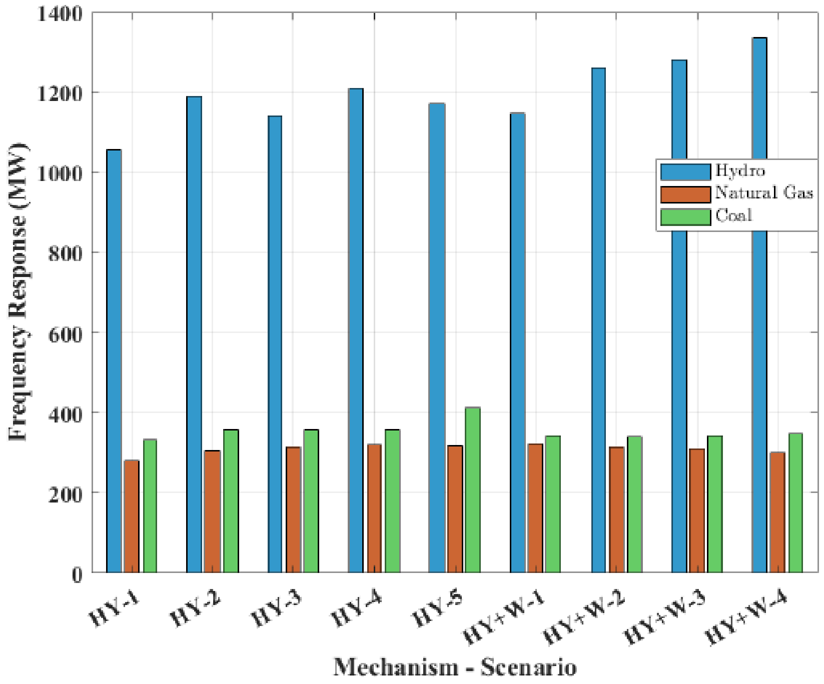
Scenario	Head Adjustment	Headroom Adjustment
1	H=1	HR=10%
2	H=1	HR=20%
3	H=0.9	HR=10%
4	H=0.9	HR=20%
5	H=0.75	HR=10%
6	H=0.75	HR=20%

Scenario	2022 Case Mechanism *HY*	2022 Case Mechanism *HY+W*	2030 Case Mechanism *HY*	2030 Case Mechanism *HY+W*
1	Stable	Stable	Stable	Stable
2	Stable	Stable	Stable	Stable
3	Stable	Stable	Stable	Stable
4	Stable	Stable	Stable	Stable
5	Stable	Unstable (Dynamics)	Stable	Stable
6	Unstable (Dynamics)	Unstable (Dynamics)	Unstable (Steady State)	Unstable (Steady State)

At lower head values, potential stability issues is observed to be increasing

Frequency Response: Based on Fuel Type





- ❑ Frequency response from IBRs is negligible as most of them are grid-following in nature
- ❑ Aggregated frequency response from hydro units increases for both mechanism *HY* and *HY + W* as headroom is increased
- ❑ As head is decreased, the aggregated frequency response from natural gas units significantly increases marginally and significantly respectively for the 2022 and 2030 cases for both mechanisms *HY* and *HY + W*
- ❑ As headroom is increased, the aggregated frequency response from natural gas units significantly decreases marginally and significantly respectively for the 2022 and 2030 cases for both mechanism *HY* and *HY + W*

Conclusions and Future Work

- Sensitivity studies to represent varying hydropower conditions for various planning scenarios with different loading conditions has been presented
- Under low hydropower conditions (and especially in the presence of a wind curtailment contingency) current planning WECC cases experience significant potential stability issues (both steady-state and dynamics)
- This highlights the need to improve existing hydro-governor models to account for these instabilities
- As part of future work, the developed algorithm would be integrated into HYDAT-tool* to utilize the tool's existing historical hydrological data to chose appropriate H and HR values to set a more realistic dispatch for the hydro units

*D. Wang *et al.*, "Hy-DAT: A Tool to Address Hydropower Modeling Gaps Using Interdependency, Efficiency Curves, and Unit Dispatch Models," *2024 IEEE Green Technologies Conference (GreenTech)*, Springdale, AR, USA, 2024.

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Thank you