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Hydro Governor Response

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WECC MVS Workshop

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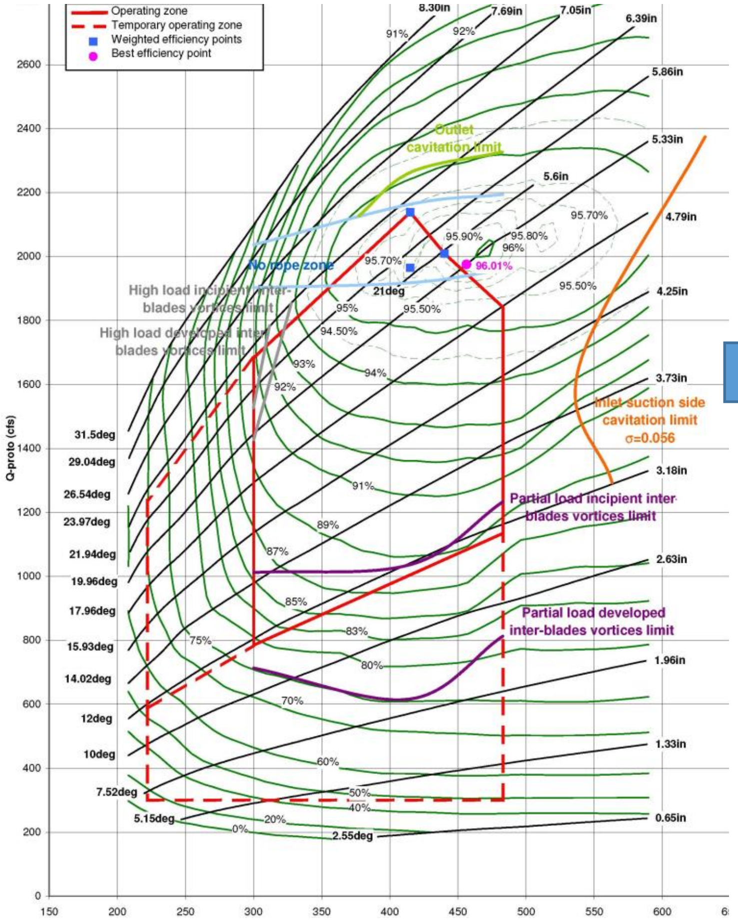
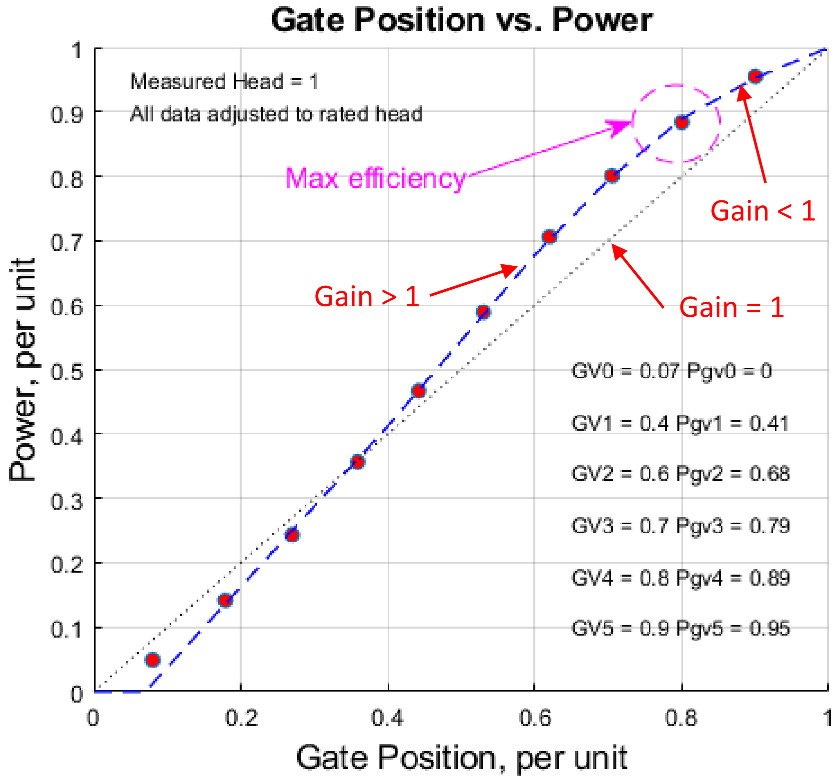
Recap

- Multidimensional characteristic for turbine performance reduced to simple model for power system studies



2 dimensions

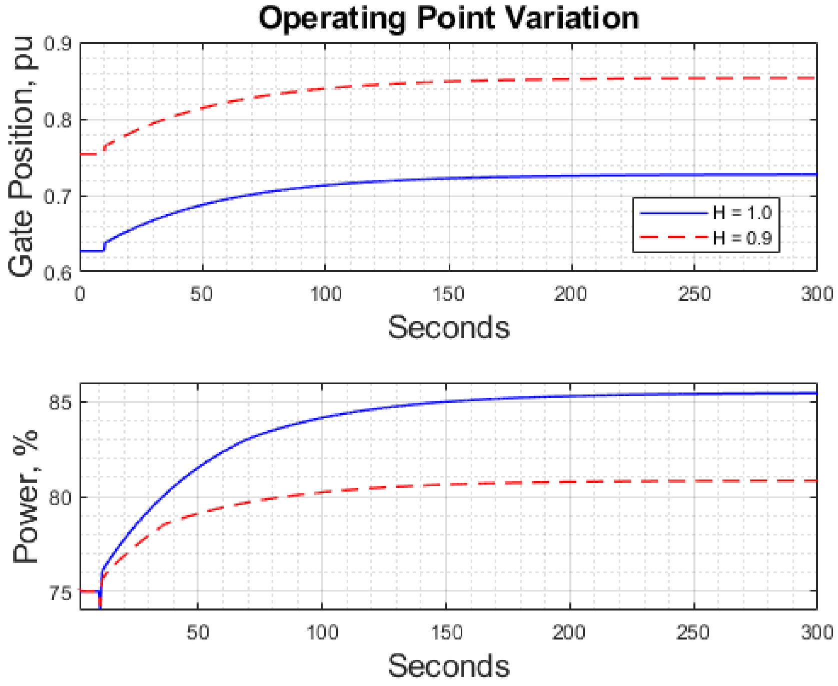


Variable Gain affects dynamic response and amount

More gain, more response

Recap

- Power output varies as $Head^{3/2}$
  - Effect too large to ignore
- Older models don't include head effect
  - change in acceptable models for WECC database



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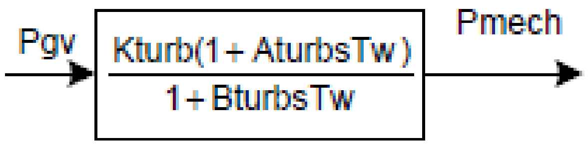

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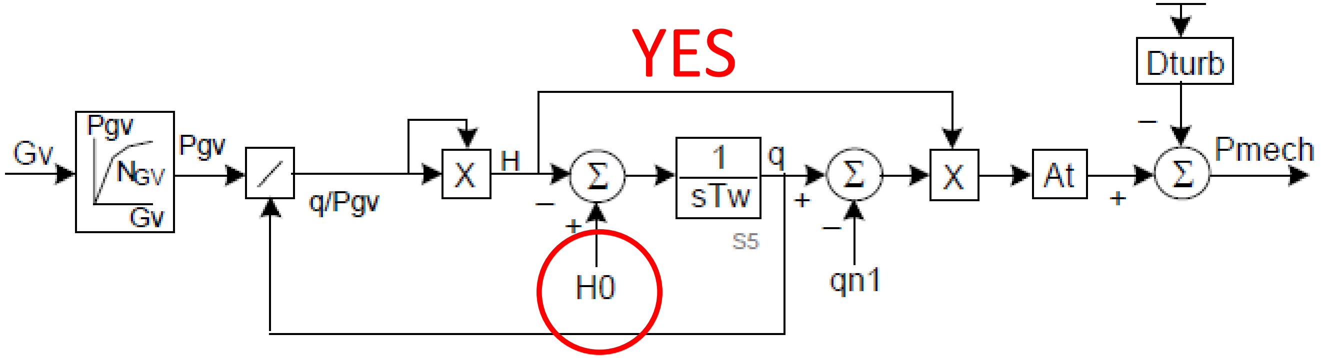


Remaining work

- Base case operating conditions of generators must be reasonable
  - Zones of normal operation should be defined using Pmin, Pmax
  - Zones of forbidden operation should be documented
  - Plants with multiple units, redispatch to maintain Pmin-Pmax range
  - When representing synchronous condensing, governor models should be removed

- Per unit head must reflect conditions to be studied
  - Normal seasonal variation
  - Longer term drought trends

Remaining work

- Secondary Control
  - Other governor control setpoints (flow, MW)
  - Plant control setpoints (MW, efficiency optimization)
  - AGC, SCADA system dispatch
  - Code is being written without regard to primary control
  - Can be overly aggressive, not allow for frequency control
- If secondary control interferes with primary control
  - Change it or model it
  - NERC BAL-003

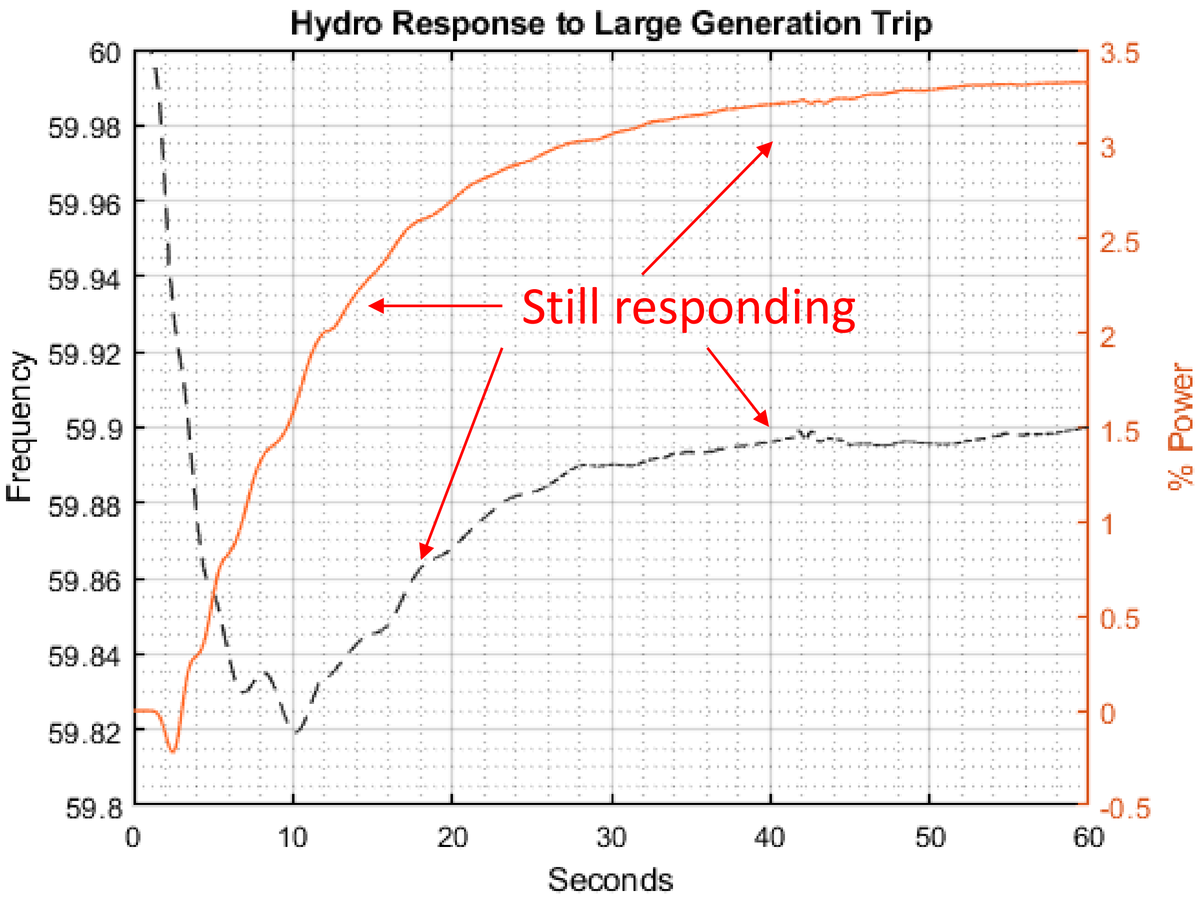
Why is this important

- 40% of total number of generators
- 1/3 of total capacity
- >1/2 of responsive capacity
- Hydro units have dominant effect on the response characteristic

- Hydro model fidelity is important for frequency event simulation

Hydro Response

- **Fast** hydro unit response, 5% droop
- At frequency nadir, only about 1/3 of final response has been delivered
- Final response takes more than 60 sec
- Frequency Response shape in WECC reflects hydro

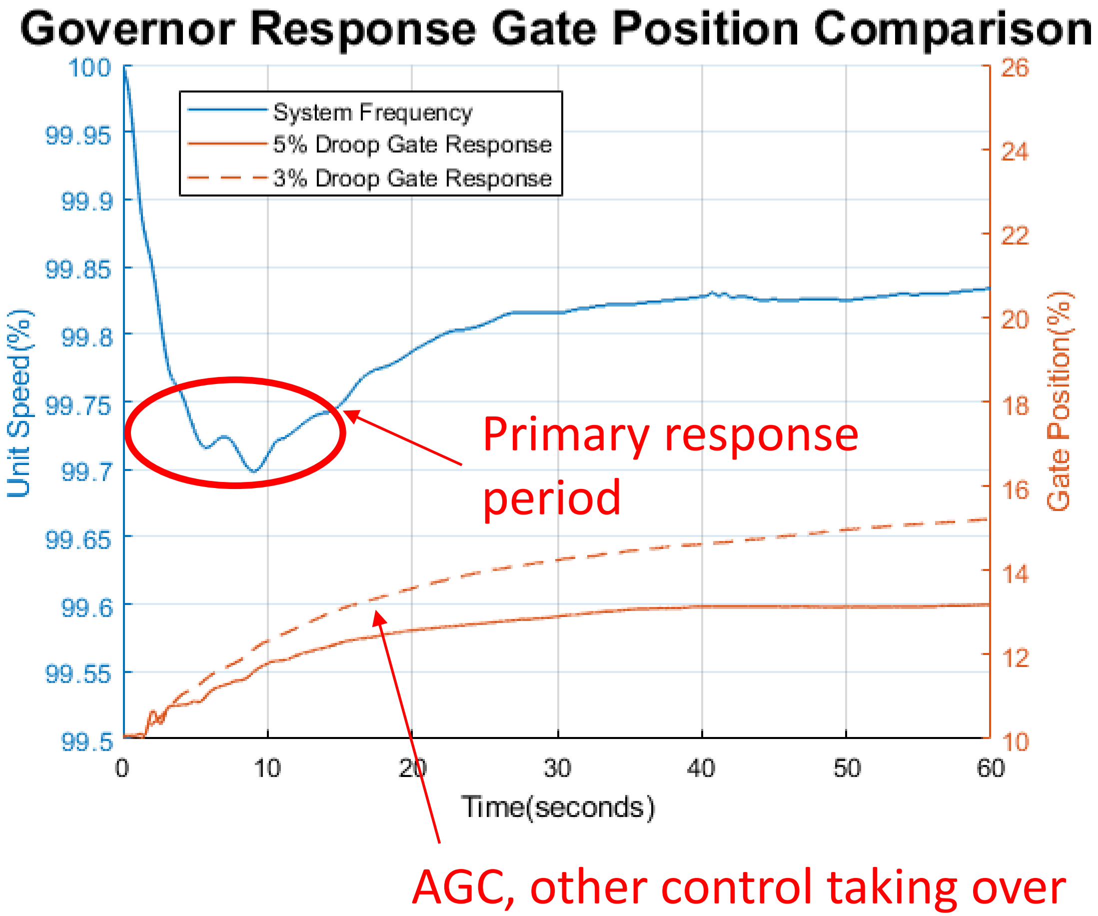


Frequency Control

- Some BAs are discovering that their best (only) frequency responsive assets are hydro facilities
  - Hydro units are in a position to become even more impactful
- If an increase is necessary, one of the first solution attempts is to decrease the droop setting
- Less droop, more response…

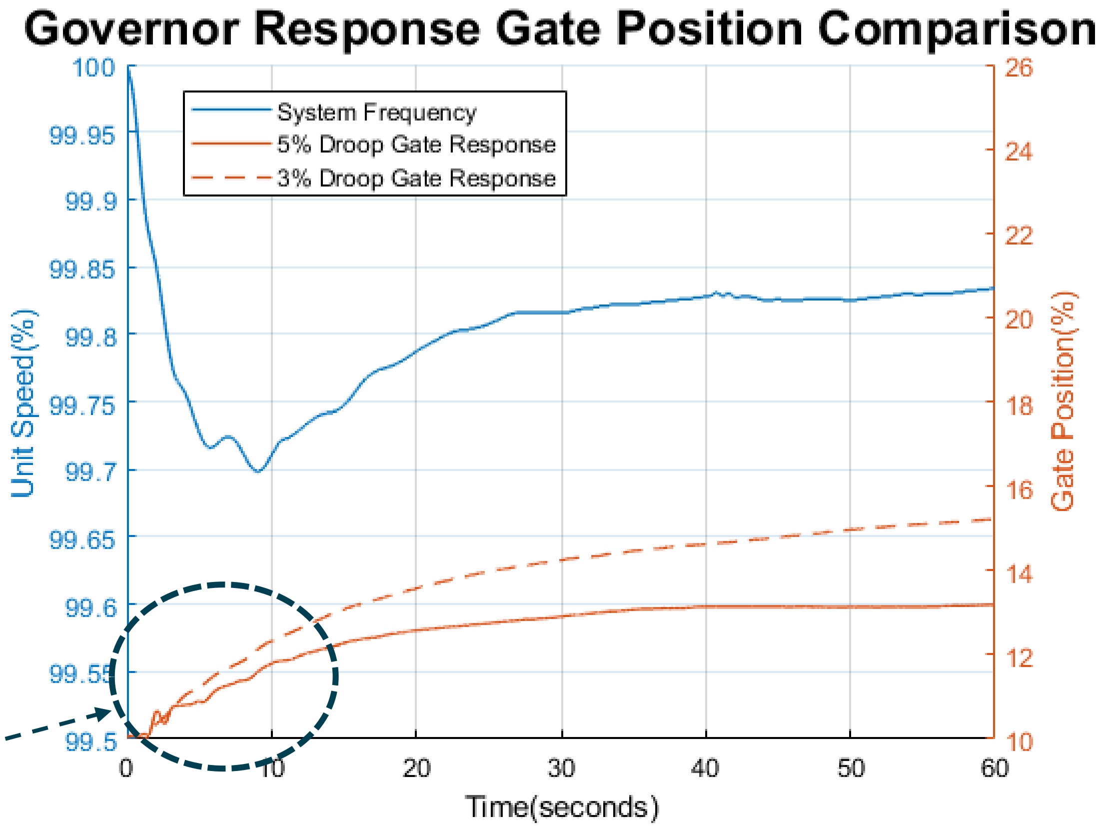
Frequency Control

- 3% droop provides more response (ultimately)
- During the transient, the decreased droop doesn't provide proportional increase
- Takes longer to reach final value



Frequency Control

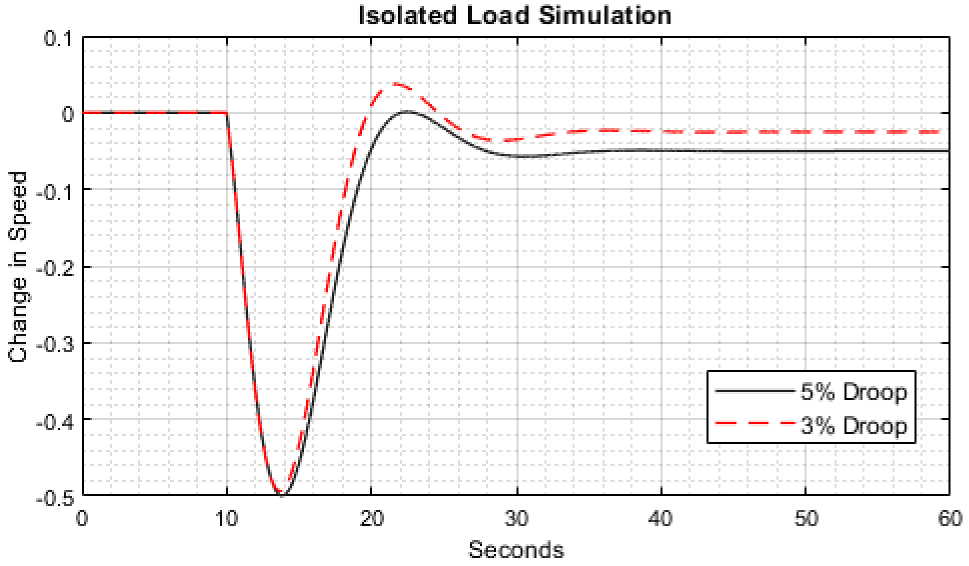
- Secondary control systems are active before droop reaches expected amount
- Real goal is to increase response in < 20 seconds



Time frame of importance for Primary Response

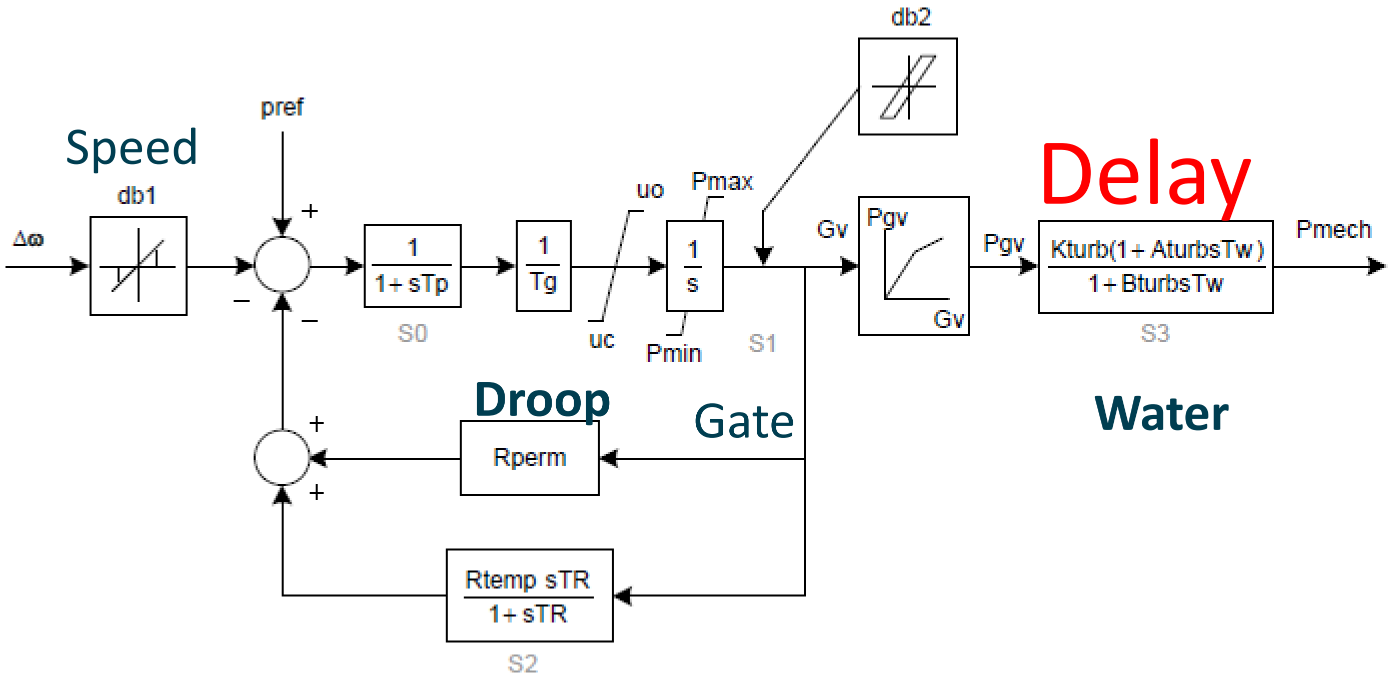
Stability

- A hydro governor is tuned with 5% droop assumed
- Reducing droop can decrease stability margin
- At the very least, a droop change require tuning analysis



How about a faster response?

- More response during large transients needed
- Normal governor tuning provides the fastest stable response
- Water column delays power and speed changes by seconds

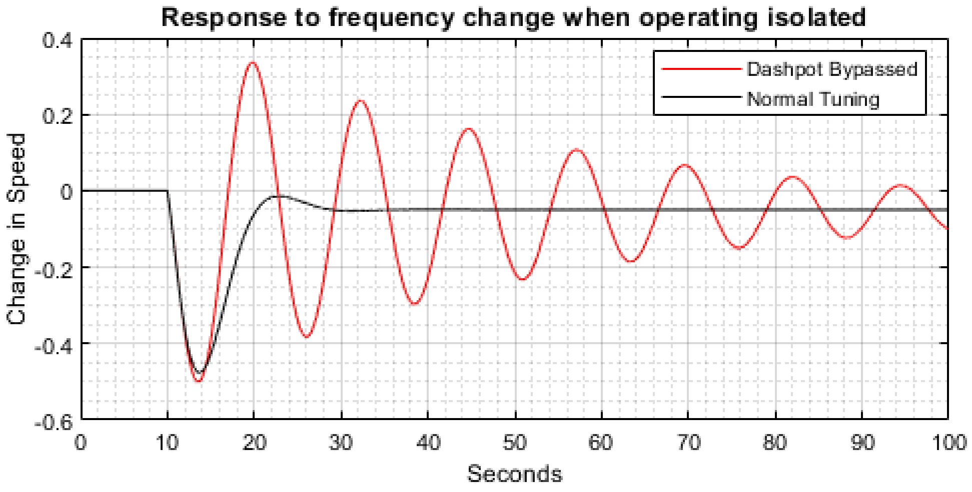


Simple mathematical model for a mechanical turbine/governor

Stability

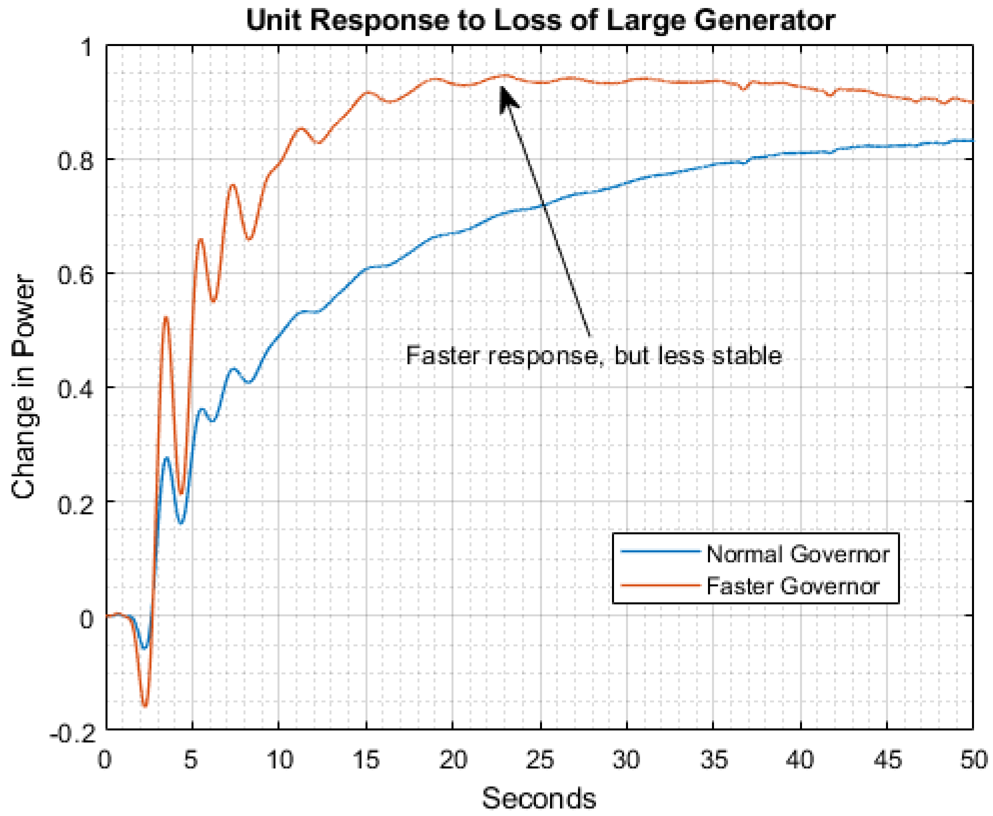
- Delay due to inertia of water column (and rotor) result in speed changes that will be out of phase with normal power system and unit oscillations
  - Governor must be non-responsive to these oscillation frequencies

- Faster tuning will lead to instability when isolated



Stability

- Faster tuning (such as operating with dashpot bypassed) will result in making system oscillations worse
  - Will not be obvious when connected to the grid



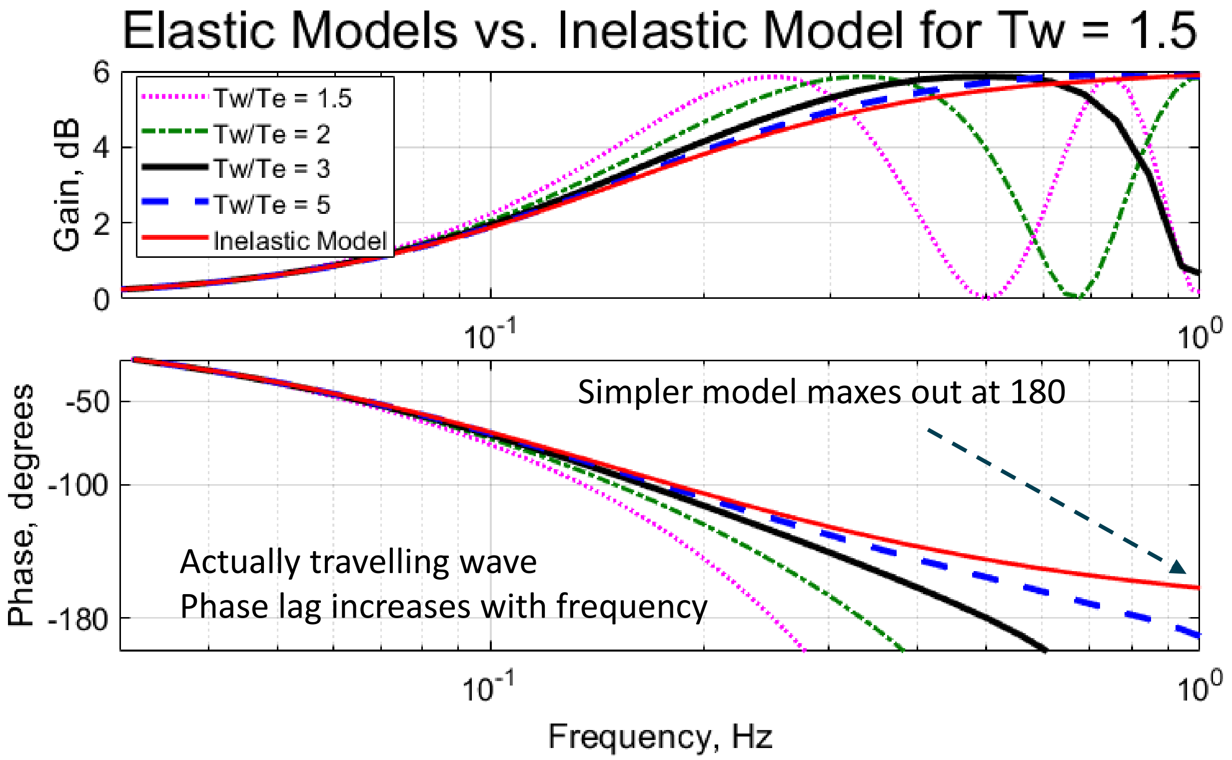
Fast governor responds more (and undesirably) to system oscillation

Simplified model

- The water column model used in all standard models is simple

- The simple model is valid as long as the response is limited to the accurate bandwidth

- Increasing bandwidth of controller invalidates the simplified model



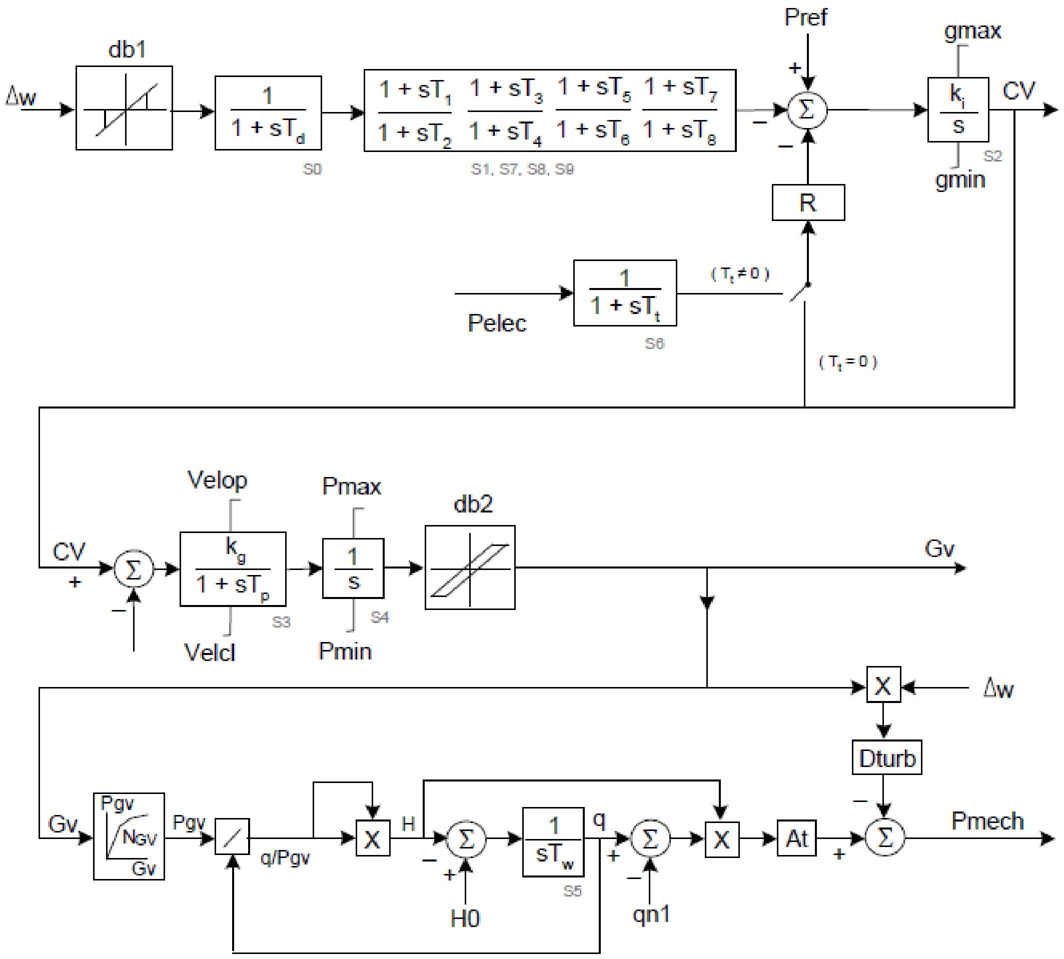
Faster tuning may result in stable model of unstable governor

Travelling wave model required for accurate simulation

Frequency Control

- Stability issues with modern digital governors are similar to old mechanical governors

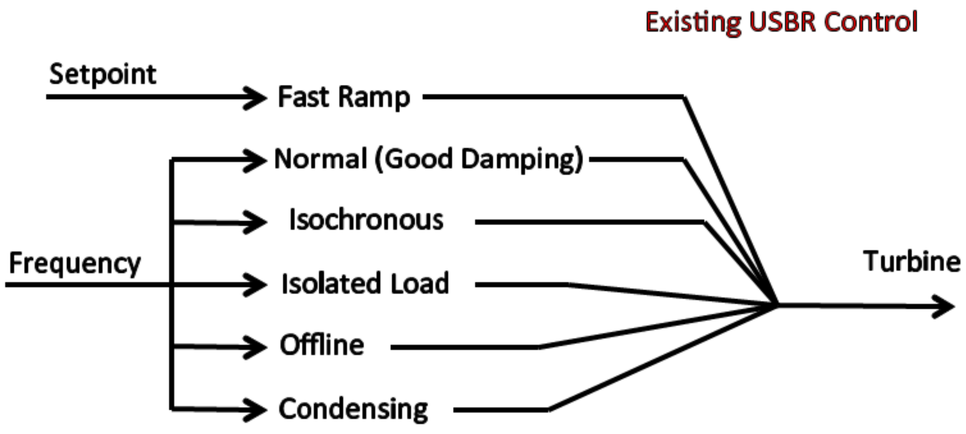
- However, the USBR designs operating in many plants are more flexible



USBR digital governors

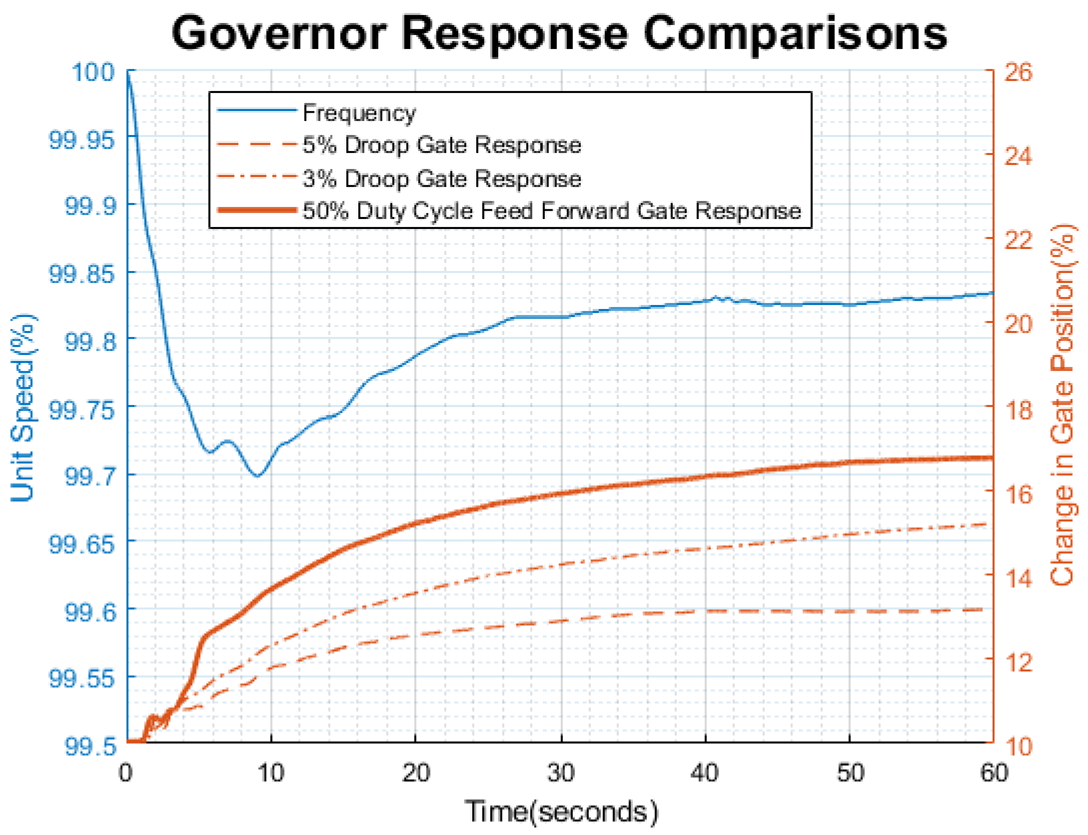
- Designed with a ramp loading function
  - Gate setpoint is fed forward to the gate position control
  - Independent of the speed feedback path

- The single closed loop path must be slow to regulate frequency, but the wicket gate maximum travel speed is relatively very fast
  - Full travel in around 10 seconds



Frequency Response

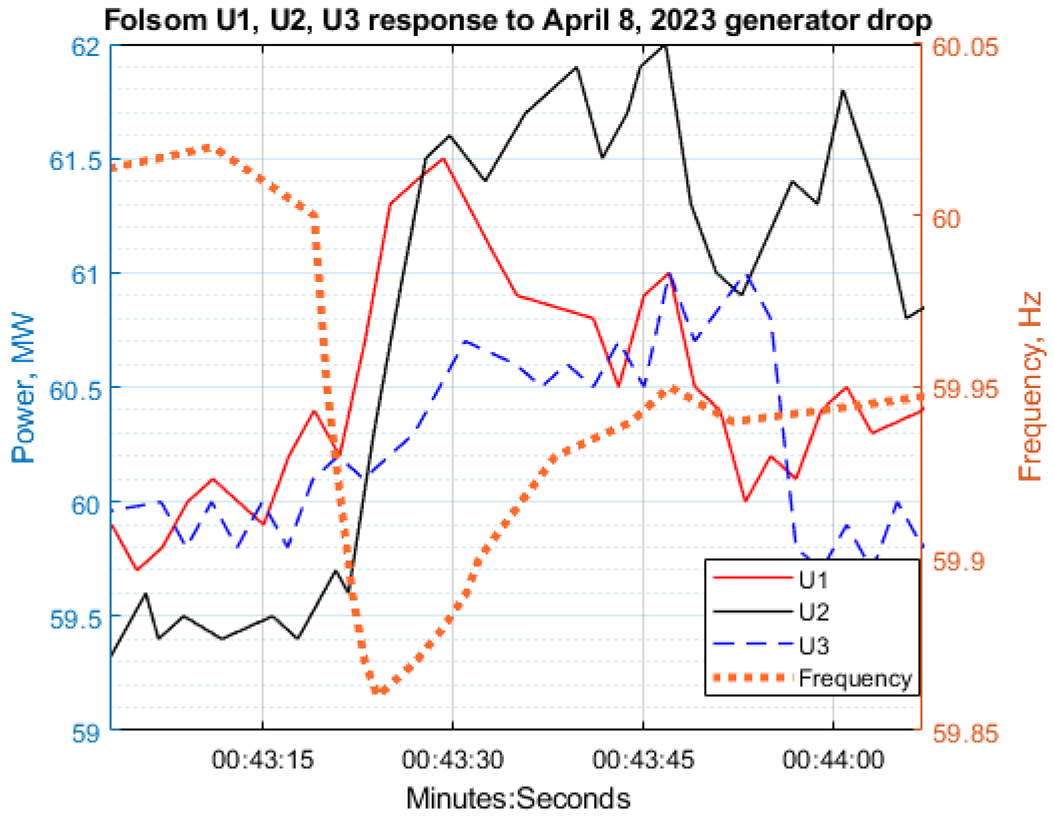
- Folsom response mod
  - Reduction to 3% droop response requested
- Instead, gate ramp is added to normal governor response with 5% droop
- Final response is above 3% droop
- Ramp duration is proportional to frequency dip



3% droop response amount reached during transient

Frequency Response

- Large generator drop
  - April 8, 2023 9:43 pm
- Fast response implemented on Folsom G1 and G2; not G3
- Full G1, G2 responses delivered in about 10 sec



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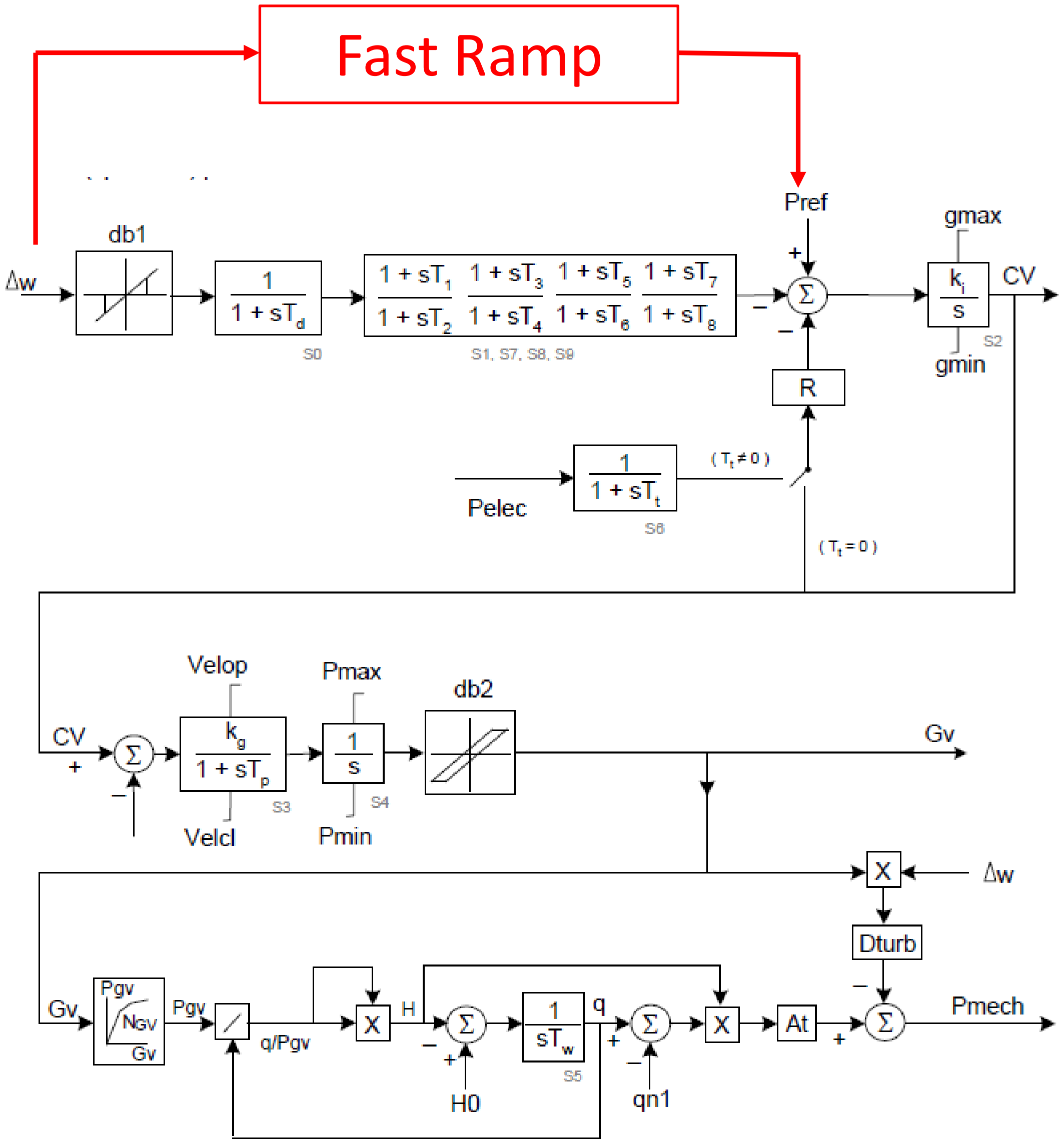
New Model

- hygovr model with ramp loading
- Triggers on low frequency
- Programmable ramp rate and duration



Summary

- Realistic representation of head variation in load flow and dynamic models
- Effects of outer loop controls must be known and represented
  - Better yet, modify to allow for temporary response for frequency control
- Do not attempt to speed up the governor control loop
- Lowering droop is not effective during the critical time period
  - There are better solutions

Thanks

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