Digital Governor Systems

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Digital Governor Systems

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Background

- BSEE University of Wisconsin-Platteville
- MSEE Wichita State University
- Joined Idaho Power 2011
- Main Responsibilities
  - WECC Generator Model Development and Validation
  - AVR/PSS Commissioning and Tuning
  - Governor Commissioning and Tuning

Digital PLC Governor Drivers (1)

- Lack of parts availability on Analog and older Digital governors
- Good comfort level with PLC technology and development
- Technical Personnel Participation and Buy-in
- Better handling of license flow requirements
- Set-point control
- Flow matching for spill gates and free discharge valves
- Elimination of many SCADA hard points (same points plus more, over communication)

Digital PLC Governor Drivers (2)

- Improved Amenities
  - More and better information about current unit and control state (Not just Speed Adjust, Gate Position and Gate Limit)
  - Set-point control
- Better control loop
  - Better feedback devices
  - Tighter control loop
  - IEEE C50.12 synchronization limits of +/- 67 mHz now very achievable
  - Using same hydraulic components, performance of Digital PLC vs. Woodward Mod II is “astounding”.
- Parts obsolescence

Digital PLC Risk Factors

- Parts availability
  - Using commercial off-the-shelf components (PLC, Proportional Valve, Speed Sensors), many with multiple manufacturers and multiple industry applications
- Manufacturer Support
  - Purchase “unlocked” PLC software
  - In-house develop PLC software
- PLC obsolescence
  - Expect to replace PLC in 5-10 year time frame, more from ability to access PLC than functionality concerns
  - Fairly easy to replace PLC, compared to complete install/retrofit
  - In-house and unlocked software
- Technical Personnel
  - Both in-house and unlocked PLC software encourage deeper understanding of operation and troubleshooting
  - PLC part of standard education for technicians
  - Use in-house personnel for install/retrofit

Idaho Power
Hydro Governor Fleet (1)

	2013	2015	2017	?
Woodward Mechanical	29	29	29	
Woodward Mod II Analog	3	1	0	
Woodward 501/505 Digital	6	5	0	
L&S Digital	4	6	6	
IPCo Digital	1	2	6	
Emerson Digital			1	
Other	8	8	8	

Idaho Power
Hydro Governor Fleet (2)

- Woodward Mechanical
  - Reliable
  - Some control concerns, better after improving tuning procedures
  - Some parts concerns, but most parts can be machined if necessary
  - Some personnel experience issues, resolved with training and experience
  - Low flexibility for advanced control
- Woodward Mod II
  - Mostly reliable
  - Some control concerns
  - Serious parts concerns, particularly with analog cards
  - Serious personnel experience issues, complex mechanical and analog equipment, low number of units in fleet
  - Low flexibility for advanced control
- Woodward 501/505 Digital
  - Reliability concerns
  - Control concerns
  - Serious parts concerns
  - Serious personnel experience issues, locked-down digital equipment, low number of units in fleet
  - Low flexibility for advanced control

Idaho Power
Hydro Governor Fleet (3)

- L&S Digital and Digital PLC
  - Some control concerns
  - Depending on vintage, some parts concerns, but most parts are commercial off-the-shelf.
  - Depending on vintage, low to medium flexibility for advanced control
  - Manufacturer support available
- IPCo Digital PLC
  - High flexibility for advanced control
  - Parts are commercial off-the-shelf
  - Some long-term personnel experience risks, as no manufacturer support
  - New to fleet, so personnel developing experience. In-house development provides deep expertise.
- Emerson DCS
  - High flexibility for advanced control
  - Most parts are commercial off-the-shelf
  - New to fleet, so , so personnel developing experience.
  - Manufacturer support available

Governor Tuning

- There is a range of settings that will work, and even a range of settings that will work well. There is also a range of settings that appear to work, but can contribute to frequency instability (particularly under stressed, islanded or black start conditions)
- There is too little compensation (hunting), too much compensation (stable, but sluggish control) and just enough compensation (stable, responsive control). We always want just enough.
- Historically (even recent history), most governor tuning was done by varying settings and choosing “best” response at speed no load.
  - With straightforward calculations, specifications for tuning a particular unit can be developed, and tuning the governor becomes a matter of entering numbers (digital), or selecting a compensation crank setting and adjusting the dashpot for a particular time constant (adjust the screw for a particular measured time, do not adjust for particular screw position)

Governor Tuning Calculations

- Tune for optimum response based on Generator Inertia and Water Inertia
  - Highly stable while online
  - Good performance at speed no load for synchronizing
  - Optimized loading rate (generally not fast, but optimum while preserving stability)
  - No need for separate online/offline gains
- Generator Inertia
  - Mechanical Time, Tm [or H, Tm=2H]
  - Does not change with load
- Water Inertia (Water Starting Time, Tw)
  - Changes with load (Tw larger for larger flows)
  - Calculate at full load flows, will result slightly slower response for synchronizing.
- References
  - Hovey, L.M., "Optimum Adjustment of Hydro Governors on Manitoba Hydro System," *Power Apparatus and Systems, Part III. Transactions of the American Institute of Electrical Engineers* , vol.81, no.3, pp.581,586, April 1962
  - Hagihara, S.; Yokota, H.; Goda, K.; Isobe, K., "Stability of a Hydraulic Turbine Generating Unit Controlled by P.I.D. Governor," *Power Apparatus and Systems, IEEE Transactions on* , vol.PAS-98, no.6, pp.2294,2298, Nov. 1979

Governor Tuning and Stability

- Recognize that many schemes that improve online “response rate” or “loading rate” also drastically affect stability. As long as system is strong and frequency is not fluctuating, the problem is hidden
  - For mechanical governors, this scheme is the “dashpot bypass” (both mechanical and electrical versions), and exposes the system to instability
  - For electronic (analog and digital), schemes that have different online and offline gains typically also expose the system to instability
- PI/PID with feed-forward or double-derivative schemes provide greatly improved loading rates without causing stability concerns
- PI/PID with transient feed-forward can greatly improve initial response to a frequency event, without causing stability concerns
- Auto-synchronizer settings may also need to be reviewed (time between jogs, and possible jog rate), and can be calculated

Digital Governor Advanced Control Capabilities

- Speed matching - improves synchronization time
  - Master Start to Breaker Close in 45-60 seconds vs. 3+ minutes (Auto Sync)
- Control based on other variables besides gate position (speed and droop)
  - MW
  - Flow
- Set-point control – simplifies control schemes
- Ramp rates for load changes
  - e.g., flow ramp restriction of 500 cfs/15 minutes, change flow at even rate of 450 cfs/15 minutes vs. periodic step changes
- Blade angle control – eliminates troublesome mechanical schemes

Beyond Advanced Control

- Calculated flows based on gate position (and head)
- In-plant multi-unit coordination
- License restrictions monitored and used to guide/enforce changes in set-points and ramp rates
- Flow-matching control and coordination (spill gates/free discharge valves)
- Modification of primary frequency control to provide additional frequency response from hydro units while maintaining frequency stability

Testing and Troubleshooting Capabilities

- Straightforward translation of model parameters from equipment settings to WECC dynamic models
- Step injection for model validation
- Gate/Blade timing monitoring to detect developing mechanical/hydraulic issues

Design and Implementation Notes (1)

- Non-negotiable
  - Separate over speed sensing and trip (e.g. Tach Pack with proximity sensor), do NOT depend on digital controls for this (if the unit is over speed, something in the digital control path has already failed)
  - Use mechanical/hydraulic means for gate open/close rate limiting (e.g., distributing valve stop nuts, limiting orifices), do NOT depend on digital and electronic controls
  - Parallel/override shutdown means (i.e., shutdown solenoid that overrides electronic valve control)
  - Mechanical/hydraulic energy and position control for lock-outs

Design and Implementation Notes (2)

- Suggested
  - PT speed sensing works well for online speed sensing, but need separate means for low-speed and creep detection (e.g., proximity probes with toothed ring).
  - Kidney Loop Filter to keep oil extra clean, the electric proportional valves are less tolerant of contamination than mechanical pilot valves.
  - MLDT sensors mounted on/close to main servo works well and eliminates restoring cabling. Keep in mind mechanical protection, and interference with service of other components in the turbine pit.

Design and Implementation Notes (3)

- Retrofit issues
  - Unless other issues drive a change, maintain existing hydraulic system from distributing valve to main valve (i.e., maintain existing oil pressure)
  - Use governor for speed matching system speed, but use protection relay/synchronizer technology for breaker close
  - Locate power transducer/synchronizer close to protection relays (rather than close to governor cabinet) to reduce CT/PT wiring

Contact Information

- Questions?

- Contact Info:

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