Advanced Governing Algorithms at the Grand Coulee Third Power Plant

American Governor Company - Daniel Londono, Matthew Roberts, Paul Silva, and Reginald Smith

Abstract

- Proportional-Integral-Derivative (PID) control is the most widely used governing methodology for hydroelectric turbine control.
- A fourth order lead-lag governor is used at the U.S. Bureau of Reclamation's Grand Coulee Third Power Plant, one of the largest power producing facilities in the world.
- By constraining certain parameters, a range of PID controllers can be modeled and compared against the Lead-Lag algorithm, exposing performance similarities and differences.
- In May 2010, American Governor Company was awarded a turn -key retrofit project for the Third Power Plant that utilizes this unique Lead-Lag controller.

Brief History

- Traditional industrial controllers are P – I (proportional – integral) or P – I – D (proportional – integral – derivative).
- The Bureau of Reclamation developed and implemented a Double – Derivative control algorithm in the early 1970s for use on all their analog electric governors in the Third Power Plant.

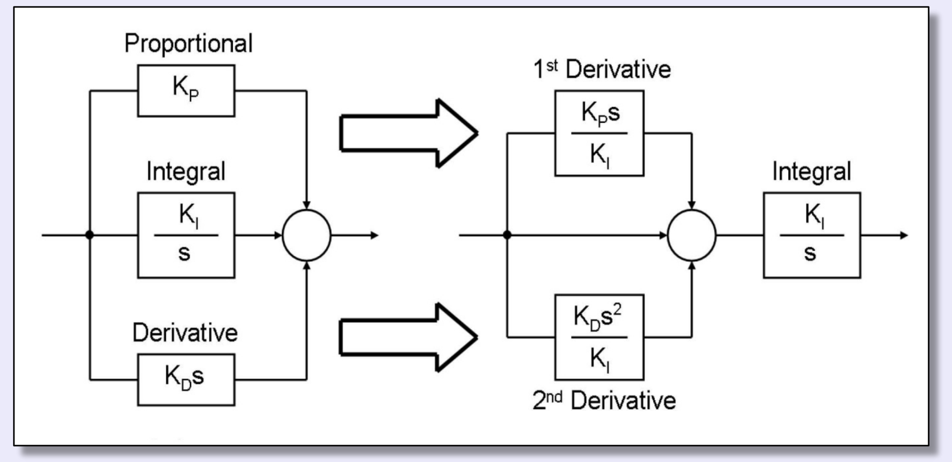

Figure 1. PID (on left) to Double Derivative (on right) transformation.

- In the 1990's the Bureau expanded and improved upon the Double-Derivative algorithm, creating the Lead-Lag-Integral control algorithm.

Figure 2. The Grand Coulee Dam and Hydro-power plant.

- In 2010, American Governor Company began a complete retrofit of Grand Coulee's largest power plant, presenting an opportunity for the Bureau to work with industry to develop and expand the Lead-Lag governor algorithm.
- Two additional Lead – Lag terms were added to compensate for the long water starting times (> 2 seconds) found at the Third Power Plant

Lead-Lag Governor Controls

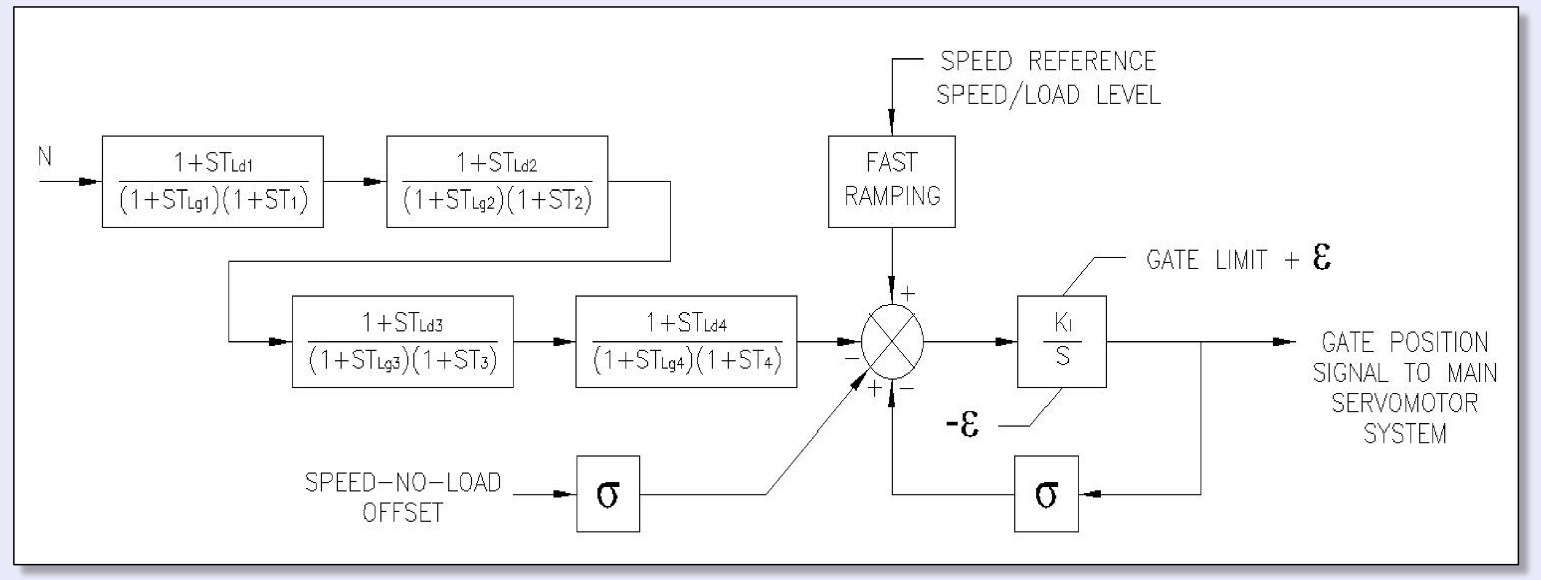

Figure 3. The Lead-Lag governor control diagram.

- The advanced fourth order control algorithm compensates for precise transients (i.e. penstock oscillation) that have the potential to affect the tuning of other algorithms.
- The third and fourth terms require advanced modeling and monitoring of system characteristics during actual operation to properly implement.
- This controller requires advanced knowledge of the control algorithms involved and substantial resources to gather the information necessary for optimization

PID Governor Controls

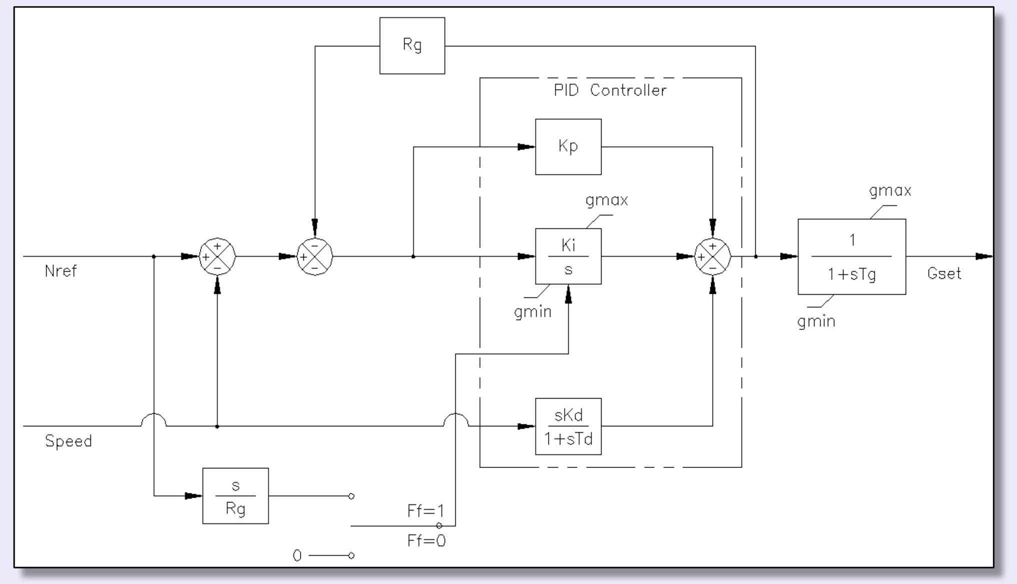

Figure 4. The PID governor control diagram.

- This is the typical third order control algorithm implemented by American Governor Company in our hydro governors.
- Because it is the most common control algorithm, many industry professionals understand and can easily tune the parameters.
- The three terms are easily tuned in the field, without complex modeling.
- This algorithm is very capable of compensating for system transients.

Comparison of Lead-Lag vs. PID

Lead-Lag and PID controllers are capable of achieving the same response under certain parameters. The following graphs show the mapping of each Lead-Lag controller term to the proportional and derivative gains of the PID controller.

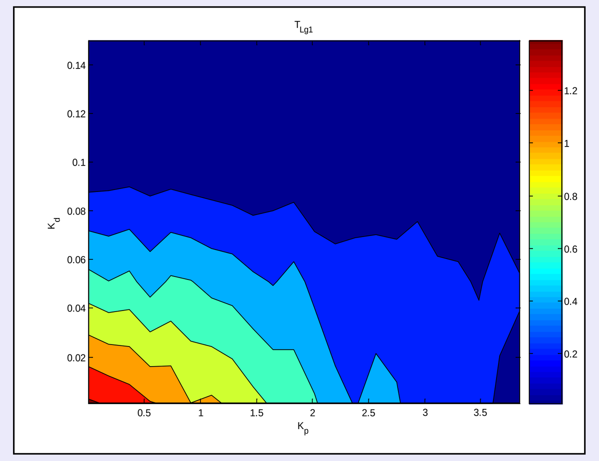

Figure 5. The first lag term of the Lead-Lag controller mapped vs. the proportional and derivative gains of the PID controller

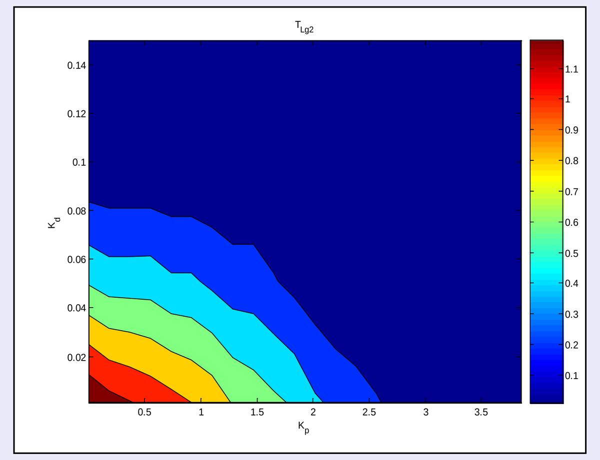

Figure 6. The second lag term of the Lead-Lag controller mapped vs. the proportional and derivative gains of the PID controller

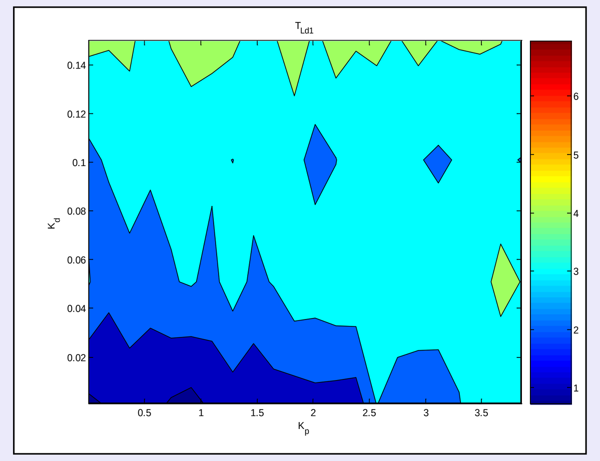

Figure 7. The first lead term of the Lead-Lag controller mapped vs. the proportional and derivative gains of the PID controller

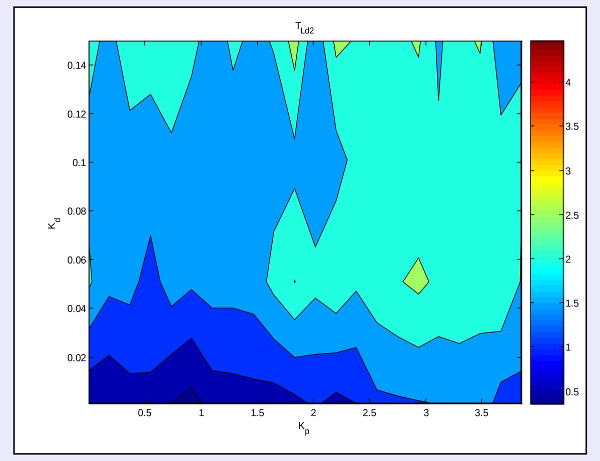

Figure 8. The second lead term of the Lead-Lag controller mapped vs. the proportional and derivative gains of the PID controller

- The Lead-Lag controller is capable of achieving true ramping, fast system response to transients, and derivative response to speed changes.
- The Lead-Lag controller is well suited to compensate for lower frequency and higher order transients. It also exhibits quick response during load transients.
- The PID controller with Setpoint Feedforward, as implemented by American Governor Company, is able to compensate for speed changes in a manner similar to the Lead Lag controller.

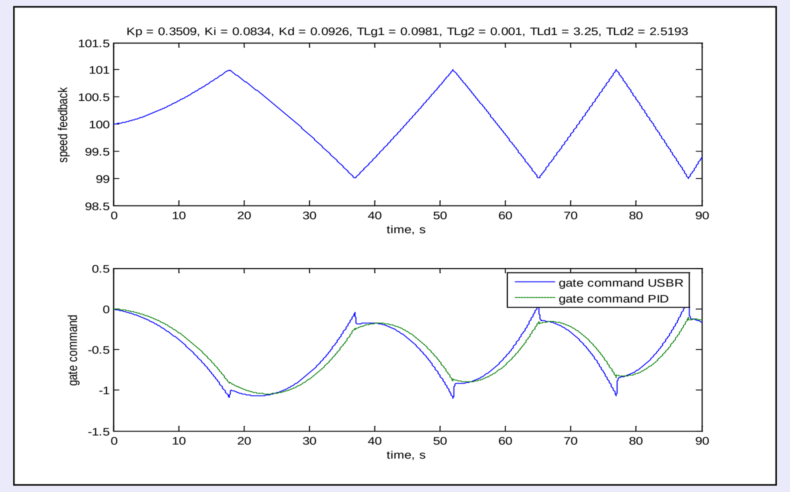

Figure 9. A PID and Lead – Lag – Integral (titled "USBR") controller compensating for speed deviations. Note the smoother response of the PID controller.

- PID algorithms are better understood and easier to tune than multiple Lead-Lag algorithms.
- Both the PID and Lead-Lag controllers can manipulate the integrator to allow for rapid loading and other feed-forward or predictive control in specific situations (i.e. during online operation).
- A balance must be struck between unit response and system stability. Many hydro governors in the Northwest U.S. are being considered for detuning, which may nullify the performance benefits that originally drove the development of the Lead-Lag controller.

Grand Coulee – Third Power Plant

- The Grand Coulee Dam was constructed between 1933 and 1941 on the Columbia River in Washington State. Originally outfitted with two power plants, Left and Right, (looking downstream), a third and much larger power plant was constructed in 1974.
- With an installed capacity of 6,809 MW, the Grand Coulee project is the largest power complex in North America.
- The Third Power Plant has 3 x 750 MW Francis turbines and 3 x 805MW Francis turbines.

Figure 10. The Grand Coulee Third Power Plant (Center). The Right Power plant and the main dam spillway are shown on the right.

- American Governor Company implemented the Lead-Lag control scheme in its comprehensive retrofit project , begun in 2010.

Figure 11. The Third Power Plant Unit G-23 governor, installed by American Governor Company, utilizing the Lead-Lag-Integral control scheme.

Figure 12. Unit G-23 distributing valve, as modified by American Governor Company.

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About American Governor

American Governor Company (AGC) (www.americangovernor.com) is a key company in the hydroelectric industry, providing critical support for hydro turbine governors and control systems for hydroelectric power plants. Since its founding in 2000, AGC has supported more than 1500 hydro plants with governor conversions, parts, field service, repairs, engineering services, and training. AGC has emerged as the leading company for governor support and digital governor design and conversions.

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