

Large Scale Governor System Retrofits – U.S. Army Corps of Engineers, North Pacific Region

Deepak Aswani¹, American Governor Company, Warminster, PA
Gary Rosenberger², American Governor Company, Warminster, PA
Matt Roberts³, American Governor Company, Warminster, PA

Abstract

Throughout the Pacific Northwest the U.S. Army Corps of Engineers owns and operates 21 hydroelectric powerhouses. The mechanical and analog governor systems that control the turbines in these facilities include a wide variety of manufacturers: Woodward, Pelton, Voest-Alpine, and Allis-Chalmers. The turbines are predominately Kaplan type, but also include a number of Francis units. In an effort to enhance operational efficiencies the U.S. Army Corps of Engineers has begun the process of converting all of the 146 governor systems to a standardized digital control platform with a common electro-hydraulic interface. This will help to both simplify future support calls and streamline maintenance efforts if and when such issues arise. Considering the scope of the upgrade project, much focus has been given to the ways in which standardization will provide economies of scale to the Army Corps' operational efforts for years to come. This paper provides a fundamental overview of the project. Inherent to this project profile will be a discussion of standardization strategies implemented across such a wide variety of governor models and types.

Project Background – U.S. Army Corps of Engineers

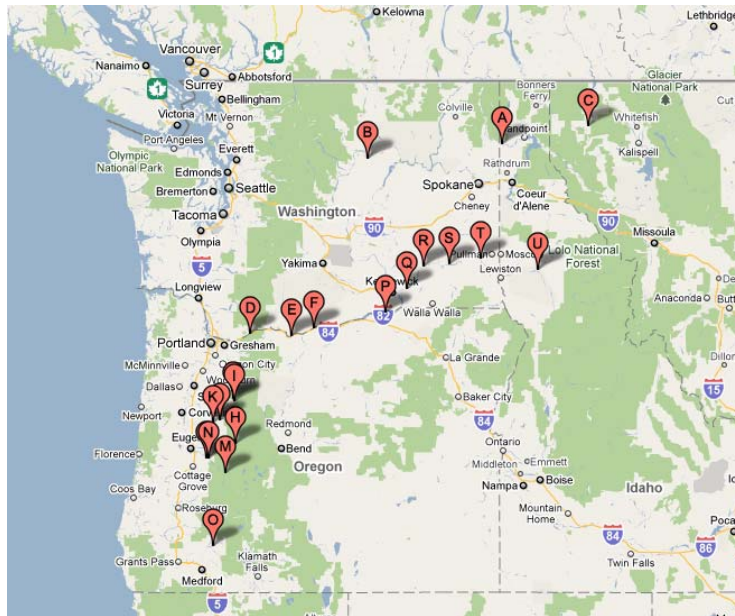


Figure 1: US map showing the 21 plant locations for the 146 units in the project scope

¹ daswani@americangovernor.com
² garyr@americangovernor.com
³ mroberts@americangovernor.com

In September 2008, the U.S. Army Corps of Engineers (USACE) released a Request for Proposals to convert 146 legacy governors in the North Pacific Region to digital control [1]. This Request for Proposal was the culmination of a ten year effort on the part of USACE to define how they wanted to achieve their goal of standardized digital governors. The plants are located in Oregon, Washington, Idaho, and Montana, USA, and Figure 1 shows a map of the 21 plant locations in the project scope. The 146 governor units include both Francis and Kaplan turbines, ranging from small Station Service units to large Main Generator units. Table 1 shows a listing of the plants, number of units, turbine types, and current governor manufacturers.



Figure 2: USACE Bonneville hydroelectric plant in Oregon



Figure 3: USACE Ice Harbor hydroelectric plant in Washington

Plant	Units	Turbine Type(s)	Current Governor Manufacturer(s)
Albeni Falls	3	Kaplan	Woodward
Chief Joseph	27	Francis	Voest-Alpine & Woodward
Libby	5	Francis	Woodward
Bonneville	10	Kaplan	Woodward
The Dalles	24	Kaplan	Pelton & Woodward
John Day	16	Kaplan	Pelton
Big Cliff	1	Kaplan	Woodward
Cougar	2	Francis	Woodward
Detroit	2	Francis	Woodward
Dexter	1	Kaplan	Woodward
Foster	2	Kaplan	Pelton
Green Peter	3	Francis	Woodward
Hills Creek	2	Francis	Woodward
Lookout Point	3	Francis	Woodward
Lost Creek	2	Francis	Pelton
McNary	16	Francis & Kaplan	Allis-Chalmers, Pelton, & Woodward
Ice Harbor	6	Kaplan	Pelton & Woodward
Lower Monumental	6	Kaplan	Pelton & Woodward
Little Goose	6	Kaplan	Pelton & Woodward
Lower Granite	6	Kaplan	Pelton & Woodward
Dworshak	3	Francis	Woodward

Table 1: Listing of U.S. Army Corps Plants Included in the Project

This project requires conversion of governors from four different legacy manufacturers: Woodward, Pelton, Voest-Alpine, and Allis-Chalmers. Figure 4 through Figure 6 show examples of various governor conversion candidates. Through a competitive bidding process, American Governor was awarded the contract for this project based on its experience, past performance, references, and price. American Governor has over 500 years of combined governor experience and regularly provides parts, field service, overhauls, training and digital upgrades for Woodward, Pelton, Allis-Chalmers, Voest-Alpine, Lombard, and other brands of mechanical, analog, and digital governors. American Governor's experience performing numerous digital governor conversions, combined with its expertise with legacy governor equipment, made it particularly well suited for the diversity of this U.S. Army Corps project.



Figure 4: A legacy governor conversion candidate at the USACE Detroit plant (Oregon) - Woodward mechanical cabinet actuator



Figure 5: A legacy governor conversion candidate at the USACE Little Goose plant (Washington) – Pelton mechanical cabinet actuator

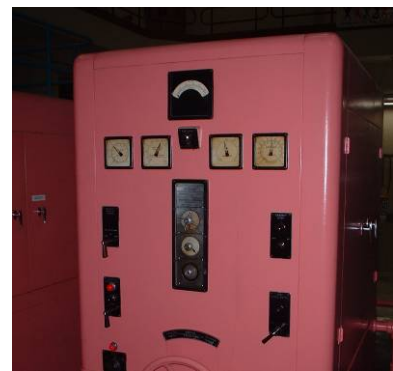


Figure 6: A legacy governor conversion candidate at the USACE McNary plant (Oregon) – Woodward station service unit

Methodology for Cost Control

In addition to the primary goal of commonality in hardware and software, another driver to bid so many units at once was to take advantage of engineering and production economies of scale through a single contractor to better control cost. The U.S. Army Corps demanded a lower price per governor unit than smaller scale projects involving only a few units. Unfortunately, successfully achieving economies of scale is much easier said than done. American Governor has focused its cost control strategy on two methods: design standardization and process innovation.

Cost Control through Design Standardization

With the large scale of this USACE project, significant labor and materials cost savings can be realized through standardization. By aiming to share as much engineering and components for each of the governors, there will be minimal engineering effort required specific to each governor or site. This will help control engineering costs. Sharing components also provides the

additional benefit of lower material costs. Often component suppliers offer a non-linear pricing strategy, where the marginal cost per unit declines with quantity.

American Governor and the U.S. Army Corps of Engineers Hydroelectric Design Center have been in discussion for several months to refine the hardware and design requirements in order to finalize the hardware configuration. The agreed-upon design allows for standardization in three key areas: control cabinet components and layout, field hardware, and control software.

Differences between legacy governors in terms of available cabinet space and available floor space drove the USACE to specify two styles of control cabinets. Where existing governor cabinet space is ample an appended cabinet design will be used. The appended cabinet (typical example seen in Figure 7) will insert into the existing governor cabinet and occupy the space made available by the removal of the legacy governor controls. This provides for a clean installation with no additional floor space required. If existing cabinet space is limited, or floor space is abundant, a free standing cabinet (typical example seen in Figure 8) will be used.



Figure 7: Example of an appended cabinet installation.



Figure 8: Example of a free standing cabinet installation.

Although two cabinet types will be provided, a standard back panel arrangement can still be utilized. All 146 control cabinets will be built to the same layout, using the same components⁴. Figure 9 and Figure 10 show the panel arrangements for the appended cabinet and the free standing cabinet, respectively. It can be seen that regardless of which cabinet is required, the panel layout remains the same. A standard panel arrangement provides significant benefits in panel building and component cost savings, as well as in future support and maintenance cost savings.

⁴ There will be differences in the exact number of high capacity and medium capacity relays between sites.

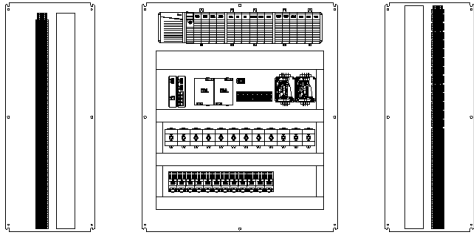


Figure 9: Appended cabinet back panel arrangement.

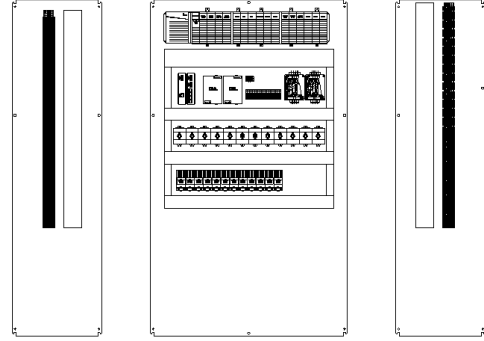


Figure 10: Free standing cabinet back panel arrangement.

Most of the field devices provided for the conversions will remain the same between plants; all units will require the same type of electronic speed, wicket gate position, blade angle (if applicable), and watt transducer devices. However, with four governor types (Woodward, Pelton, Voest-Alpine, and Allis-Chalmers) and two unit types (Francis and Kaplan), specialized Electro-Hydraulic Interface (EHI) assemblies and adapter devices are typically required. To progress the standardization initiative, American Governor developed a single EHI manifold assembly which can be used on all 146 units, regardless of governor or unit type. The manifold, which contains duplex filter assemblies, can accommodate two NG6 proportional valves. Figure 11 shows the Kaplan manifold with two sets of valves for both wicket gate and adjustable blade control. Figure 12 shows the Francis manifold with just the wicket gate valve installed – the ports for the blade control valve are blocked off. Again, savings in design, production, training, and service costs will be realized with this design.

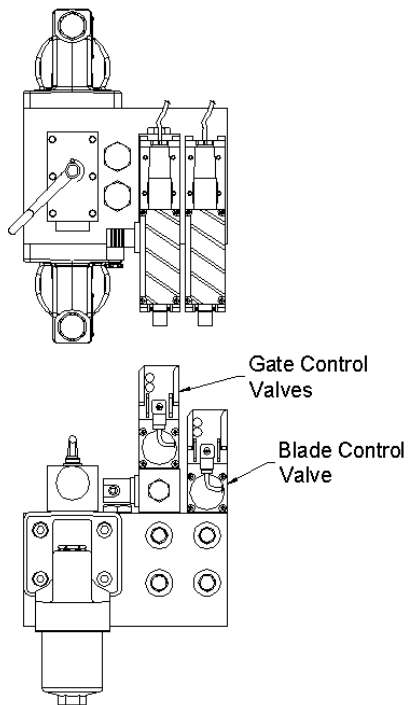


Figure 11: EHI manifold assembly for Kaplan Turbines.

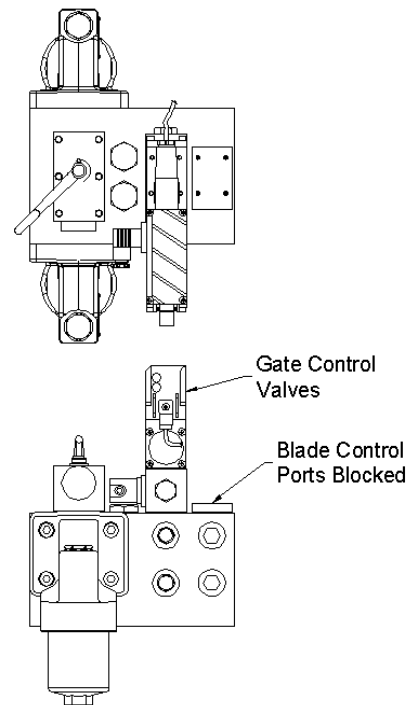


Figure 12: EHI manifold assembly for Francis Turbines.

All of the governors in the USACE project will share the Allen-Bradley ControlLogix platform, which uses RSLogix5000 development software. Since all 146 units will use the same PLC platform and software, only two basic versions of software will be required - one each for the Kaplan and Francis turbines⁵. Excluding the blade controls which are only present in the Kaplan software, every unit will now have the same software structure, with the same function blocks and the same calibration parameters. While there is no material cost savings in standardized software, the engineering and training savings gained are considerable.

This same approach has been taken with the Human Machine Interface (HMI) design. Standard screens are developed which will be used on each unit. This allows operators, technicians and engineers to enter any of the 21 upgraded plants and immediately be familiar with the controls.

Cost Control through Process Innovation

American Governor always performs system level testing of digital governors prior to installation and commissioning. Specifically, every governor is subject to two sets of tests: wiring integrity and Hardware-In-Loop (HIL). In the wiring integrity tests, point-to-point circuit continuity and power isolation are tested for verification against the design. In the HIL testing, the PLC and associated cabinet devices are tested in real time with another PLC that simulates the behavior of the plant targeted for installation, as depicted in Figure 13.

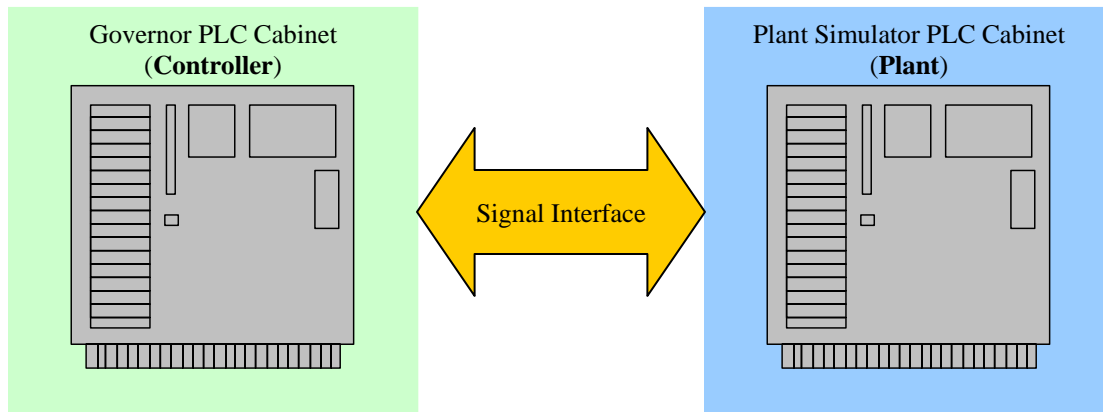


Figure 13: Diagram depicting Hardware-In-Loop (HIL) testing

In conventional digital conversion projects, the systems level testing is conducted during the latter portion of the project process, as generalized in Figure 14. The work streams are categorized as engineering, production, and procurement & back-office operations. The engineering path involves mechanical and electrical engineering activities including panel design, hydraulics design, and software development, just to name a few. The production path involves

⁵ Although there is a basic software platform associated with each of the two turbine types, Francis & Kaplan, site-specific modifications to the software may be required to adapt to specific plant control needs.

building & wiring panels as well as assembling cabinets. The procurement and back-office operations path involves billing and all supply chain activities such as purchasing and inventory management. All of these work streams are managed under the guidance of a single project manager, who is ultimately responsible for the success of the project. The actual work flow and project management process is more elaborate and proprietary to American Governor.

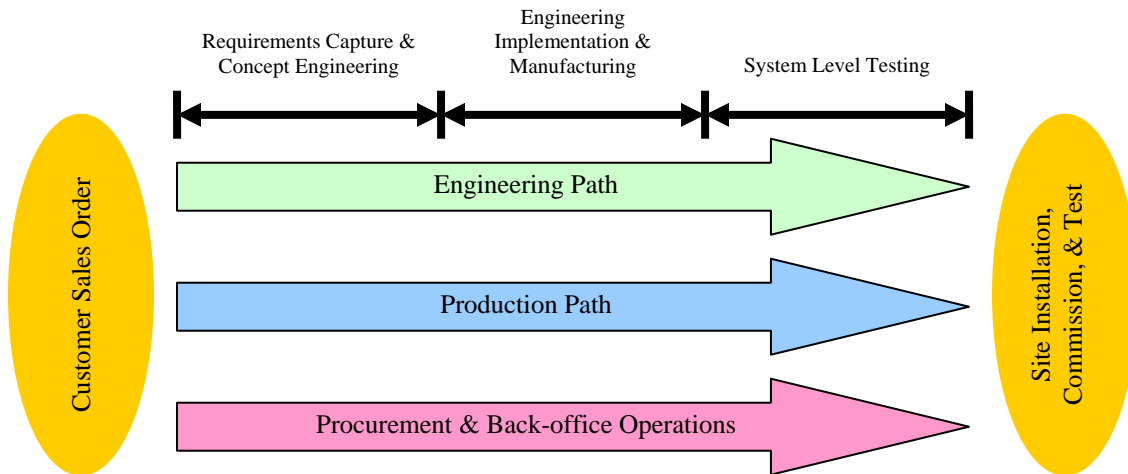


Figure 14: Generalized project process for conventional digital conversion projects, managed under the guidance of the project manager

The process of Figure 14 has been proven for small scale projects, but it is insufficient for the large scale of the U.S. Army Corps project. Although this process could be replicated for each of the 146 units in the project, given the goal to standardize engineering, there will be limited site-specific engineering aside from site-specific integration needs and change orders. The majority of engineering effort will take place prior to many of the site installations, thereby reducing the engineering cost per unit. For the large number of units involved in the U.S. Army Corps project, the total cost for problems caught during the system level or site testing could be potentially high. American Governor has therefore taken several measures to reduce the likelihood of problems during the system level or site testing.

Design-related corrections have been uncovered and resolved during the early engineering effort. There have been intensive design reviews and coordination with USACE, including the development and finalization of a System Design Specification for each turbine type that covers everything from component selection to software block diagrams.

Hardware related issues at the time of site testing could be costly because of the additional effort required for removal from the panel/cabinet and reinstallation at site. A portion of this cost may be avoided by more extensive component quality checks and testing during the procurement and manufacturing phase. More extensive component level quality checks are possible given the high level of component standardization for this project, compared to the variety of parts and manufacturers that would occur if the same 146 units had been bid separately, by each plant.

Depending on the type of part, a log is maintained for the successful quality check and testing of components by serial or batch number. A record of part serial or batch number is maintained with the bill of materials for each governor unit built, for traceability to avoid issues appearing during the system level or site testing. This is an example where additional cost invested upstream in the process can lower the total project cost by avoiding downstream costs.

To verify each unit before shipment, American Governor utilizes extensive factory operational test procedures, including tests of:

- a) Governor control functions
- b) Speed switches
- c) Local and remote flat panel displays (HMI)
- d) Automatic-manual governor control transfer
- e) Ramp rates on all ramped functions
- f) Solenoid operated devices
- g) Limiting provisions
- h) Auxiliary switches or relays
- i) Gate position switches
- j) Transducers
- k) Power supplies
- l) Meters

The additional engineering investment for cost and quality improvements as well as the additional processes for component level testing introduces another dimension of complexity to the engineering and production process. The amount of engineering work for this project also requires more engineering resources than conventional smaller scale projects. In order to address this dimension of complexity and facilitate work decomposition, system engineering fundamentals were used to elaborate the project engineering process prior to defining a standardized governor system as shown in Figure 15 [2]. The process of Figure 15 is intended to deliver a high-quality standardized design, by decomposing the design, test case definition, and testing by system level detail and delegating responsibilities to three groups of engineers – lead engineers, project engineers, and system engineers. This whole process is under the guidance of the project manager, who is ultimately responsible for the success of the project. The process of Figure 14 still applies to every site, and includes the testing branch of the detailed process in Figure 15 as well as any site-specific change orders.

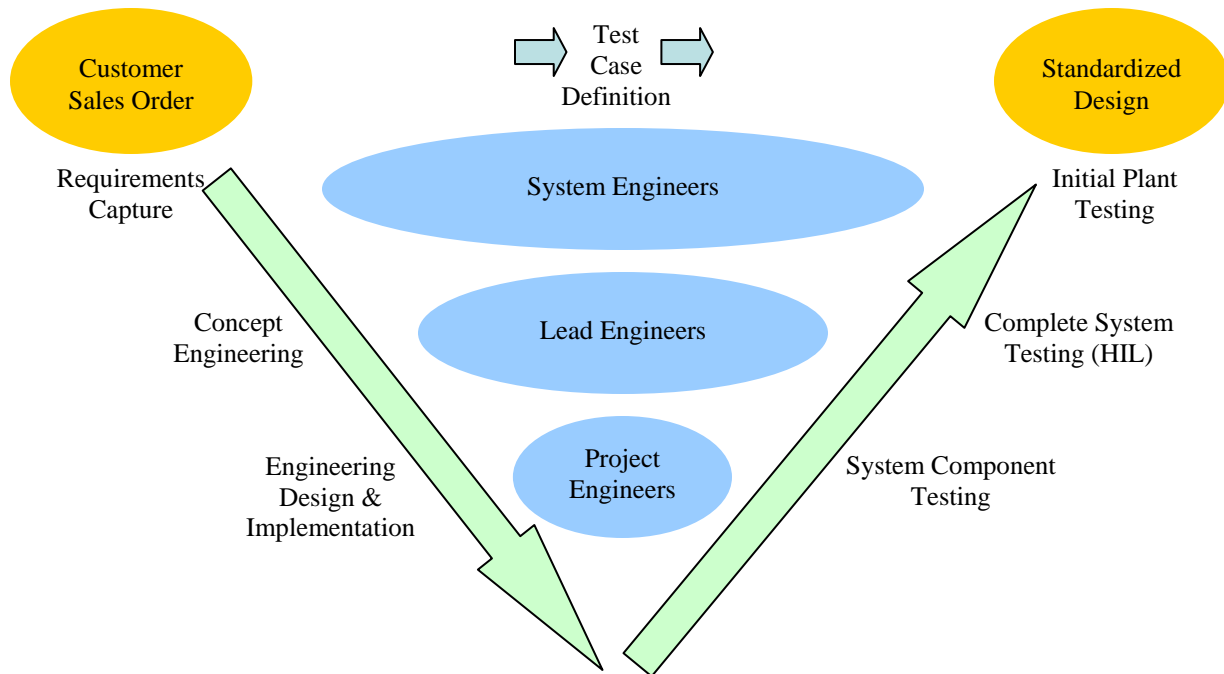


Figure 15: Systems Vee-style project engineering process for the U.S. Army Corps project process, guided by the project manager

Conclusion

The U.S. Army Corps North Pacific Region’s governor modernization project offers significant process and engineering challenges to achieve a standardized design while allowing flexibility to meet individual plant needs. In response to this project, American Governor has enhanced its project management process using system engineering principles to better control quality, thereby avoiding downstream costs. American Governor has also achieved unit cost reductions by investing additional engineering time for standardization and innovation in the design of the governor system.

Acknowledgements

The authors sincerely thank Roger Clarke-Johnson, Scott Ginesin, Greg Yohe, Dan Berrien, and other reviewers for their engineering contributions, insight, and numerous suggestions for improving the presentation of this paper.

References

1. “Governor System Retrofits – Request for Proposals: W9127N-07-R-0031,” U.S. Army Corps of Engineers, September 2008.
2. “System Engineering Fundamentals,” U.S. Department of Defense, Defense Acquisition University Press, January 2001.