



## Run of River Hydro Control Solutions

A Petrotech, Inc. White Paper

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## Abstract

In Run-of-River hydropower operations, the natural flow of the river is used to produce electricity via the hydro-electric turbine. The ability to effectively and reliably control the hydro-electric turbine depends largely on the performance of the turbine governing system. The primary function of the hydro-turbine governor or regulator system (Hydro\_TR) in run-of-river hydro operation is to smoothly pass the water flowing through the turbine(s) back to the river while keeping the reservoir level within regulatory compliance limits and optimizing generation. The Hydro\_TR system ultimately provides a demand signal to control the position of the hydro-turbine wicket gates which in turns modulate the water flow.

Other major functions of the Hydro\_TR include Start-up and shutdown control, Isochronous/Droop speed control, Power control, Flow control (re-regulation), Pump control; and Units coordination control. Protection functions such as overspeed, step change, and condition monitoring are also part of the Hydro\_TR scope.

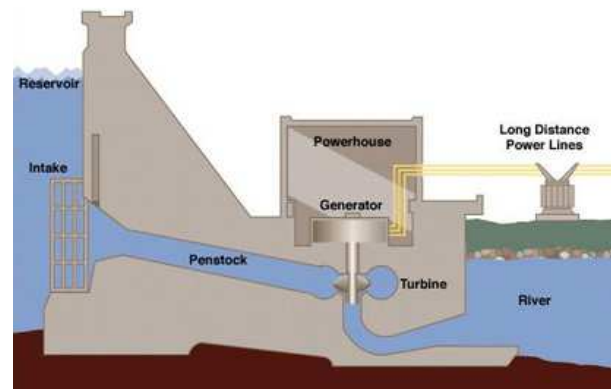
This paper describes the Petrotech core Hydro\_TR solution for Run-of-River Systems, highlighting its flexible and scalable features. The Hydro\_TR is intended to be a solution platform that is highly adaptable to meet the needs of any Run-of-River governing system.

## Run of River Hydro Control

In Run-of-River hydroelectric plant, the generated electricity depends on the amount of water flowing in the river. Run-of-River systems are characterized by relatively small "impoundment" or storage of the water, thus minimizing impact to the natural river flow. In Run-of-River systems, a portion of water from the river is diverted to a channel or reservoir. The water is then "dropped" into a pipeline known as the penstock that delivers the water to the power plant which houses the hydro turbine(s). The moving water rotates the turbine that spins a shaft driving a generator to produce electricity. The water that passes through the turbine(s) is returned to the river.

Petrotech Hydro\_TR is built upon proven subsystems that reflect our 40+ years expertise in turbine applications and process know-how. The subsystems are

designed to cover virtually all hydro turbine governing requirements for run-of-river systems. The Hydro\_TR is designed to provide the highest degree of flexibility and scalability. The use of our proven subsystems ensure reliable control and monitoring of hydro governing operations.



*Hydro-Turbine Power Generation*

Our Hydro\_TR solutions provide adaptability from a single turbine generator system, to multi-units power house, to cascaded hydro plants or to the entire generating fleet.

## Petrotech Run-of-River Control Algorithm

The Run-of-River Hydro\_TR is responsible for monitoring key hydro-operation process parameters (i.e. head/tail water level, flow, power), along with turbine specific signals (i.e. speed, gate position) and apply a selected control algorithm to determine the position demand for the turbine wicket gates to regulate water flow through the turbine.

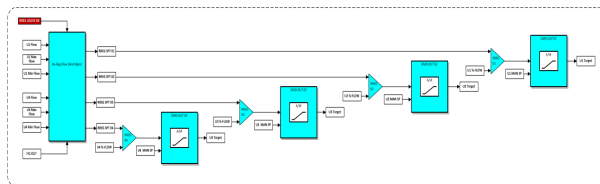
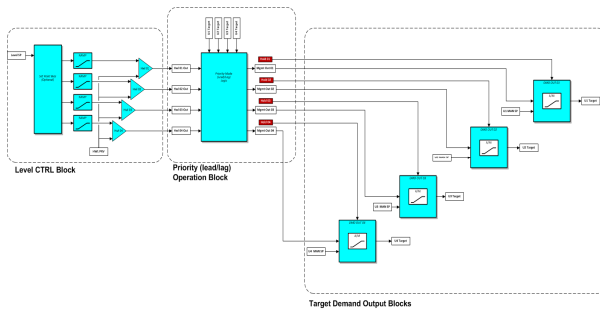
Required process and turbine signals are conditioned (i.e. validation, averaging, step detection and selection) using functions implemented in the Hydro\_TR prior to application of the control algorithm.

The Hydro\_TR includes a large set of control algorithms that could be configured in various combinations to achieve the Run-of-River control objective of maintaining reservoir level within licensing limits while optimizing generation and smoothly regulating the flow back to the river system.

Depending on application specific requirements, the control strategy could be easily configured and adapted as follows:

- PI controller(s) (for head/tail water level, flow or power control)
- PI controller(s) with anticipation feed-forward control
- PI controller(s) with predictor model
- Head/Tail water level controller(s) with cascaded re-regulation flow controller(s)
- Any combinations of the above

Extensive tuning parameters are available for our control algorithms to achieve control objectives



### Run of River Control Algorithms

### Other Control Features

Other features offered by the Hydro\_TR include functions for optimizing generation (units operate at their most efficient gate position for existing river flow condition), and priority based or coordinated control of units for efficient water resource management (i.e. setup units for load-sharing, scheduling priority usage of units at a single station or coordinating operations with other stations along the run of river, and water storage management).

Additional control modes available in our Hydro\_TR solution include turbine automatic or manual start

control, speed control, and manual control. Start control typically involves a configurable demand ramp to perform a controlled unit breakaway and start until the unit achieves normal speed. Speed control is generally used when the unit is starting and have reached a valid start speed. It is implemented using a PID control architecture and is used in auto-start mode or when the unit is not configured to use level or flow control mode. Manual control mode enables the operator to enter a target position demand or use the increase/decrease discrete command to adjust the position demand.

Associated with each control mode are extensive sets of configuration parameters, providing the flexibility to customize each mode to meet the control needs of specific run-of-river hydro applications.

### Flexibility

Petrotech Hydro\_TR system offer high degree of flexibility due to its modular structure design, extensive parameterization, and use of open system architecture composed of well-established standard components.

The system components are designed using a modular requirement approach such that the control solutions are easily deployed using only the components needed from our library of subsystems. Our field-proven control software routines are developed in standard IEC 6-1131 which allows the applications to be easily ported across any IEC 6-1131 compliant controller platforms. Thus when an upgrade or addition to the system is required, the components are seamlessly added.

Extensive configuration parameters are available on our governor control solutions, offering a wide range of control modes to meet the various demands of Run of River Hydropower applications without the need for additional programming. Thus solution can be adapted easily to provide a high degree of flexibility.

Open system architecture offers flexibility in terms of using well established industry standard components which simplify maintenance, serviceability and training. This results in reduced cost of ownership and provide client ability to use preferred platform. Open interfaces also provide flexibility to support easy integration with existing hydro plant systems.

## Scalability

Our Hydro\_TR solutions are specifically designed for open and distributed architecture platforms using a common design environment to provide the highest degree of scalability and reliability. System components are selected based on optimized performance and capability to easily expand from a single system to the entire fleet. The hydro control solutions are also designed to support system expansion in incremental fashion. As the system requirements grow, components (i.e. controllers, I/O, HMIs, Monitoring Stations and field devices) can be added without performance degradation. Future growth demand can be easily accommodated with our scalable solutions.



Petrotech Hydro\_TR offers scalable options from stand-alone system consisting of cabinet containing standard open architecture components such as controllers, I/O, network interfaces and built-in HMI, to system integrated with plant control/monitoring center, to system providing coordinated control of multiple hydro stations along the run-of-river communicating via satellite or cellular networks.

## Conclusion

In this paper, the robust and highly adaptable features of the Petrotech hydro turbine regulator (Hydro\_TR) system for run-of-river applications are described. The Hydro\_TR is a product of Petrotech more than 40-years of experience in rotating machinery and process control systems. The paper illustrates how our large set of proven control algorithms combined with the Hydro\_TR modular design concept, provide the flexibility necessary

to customize solutions for meeting the needs of hydroelectric control requirements.

Furthermore, the Hydro\_TR scalable architecture provides easy expansion to incorporate future growth demands. Thus our flexible, reliable and scalable Hydro\_TR solution is available and ready to meet any hydroelectric control challenge.

## Company Overview

Petrotech Incorporated (Petrotech), headquartered in New Orleans, Louisiana has been providing advanced turbomachinery and process control systems for more than 40 years. With facilities in Houston, Texas and Suffolk, United Kingdom, Petrotech provides a full range of products and services for rotating machinery control and instrumentation. Our products include integrated control systems for gas, hydro and steam turbines, generators, compressors, diesel engines, pumps and the associated ancillary and safety systems. We also provide sophisticated process control solutions around the rotating machinery. Our turnkey services include engineering design (software and hardware), control panel manufacturing, site I&E services, commissioning and startup.

Within the energy sector, Petrotech has installed control system solutions in most industrial plants. We help our customers increase reliability, improve efficiency and reduce downtime. Over our 40 years, we have developed a library of mature control products and applications for centrifugal and reciprocating compressors anti-surge and process control, as well as gas, hydro and steam turbines. These applications have logged millions of hours controlling, optimizing and protecting the operation of a variety of rotating machinery.

Regardless of where in the energy chain Petrotech operates, our approach remains the same; we deliver superior customer satisfaction that builds upon our reputation as a leader in rotating machinery controls.



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