WIEFP 2016
OCTOBER 25-26 · FLORIANÓPOLIS - SC · BRAZIL

FPNI Ph.D. Symposium on Fluid Power
OCTOBER 26-28 · FLORIANÓPOLIS-SC · BRAZIL 2016

Application of advanced control functions for double regulated turbines at the Jirau power plant

Henrique Augusto Menarin, REIVAX S/A

3rd Workshop on Innovative Engineering for Fluid Power
9th FPNI Ph.D. Symposium on Fluid Power
October 25-28 - Florianópolis – Brazil – 2016

Summary

- Introduction
- Issues in the process control
- Advanced control solutions
  - Adaptive control
  - Operating point limiters
  - Disturbance detection
- Control functions for the hydraulic actuators
  - Reduction in runner blades movement
  - Frequency response test
- Current status at the power plant

Jirau Hydro Power Plant

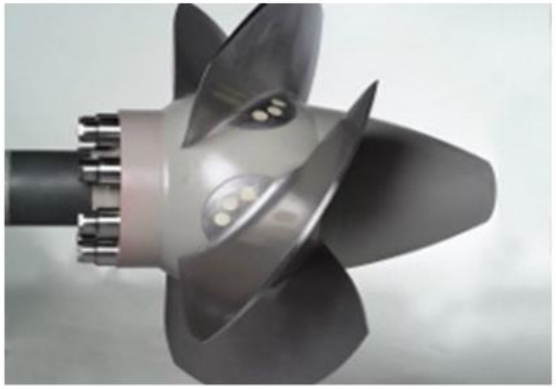
- Jirau hydro power plant in Madeira River
- Rated at 3,750 MW - fourth biggest hydro power plant in Brazil

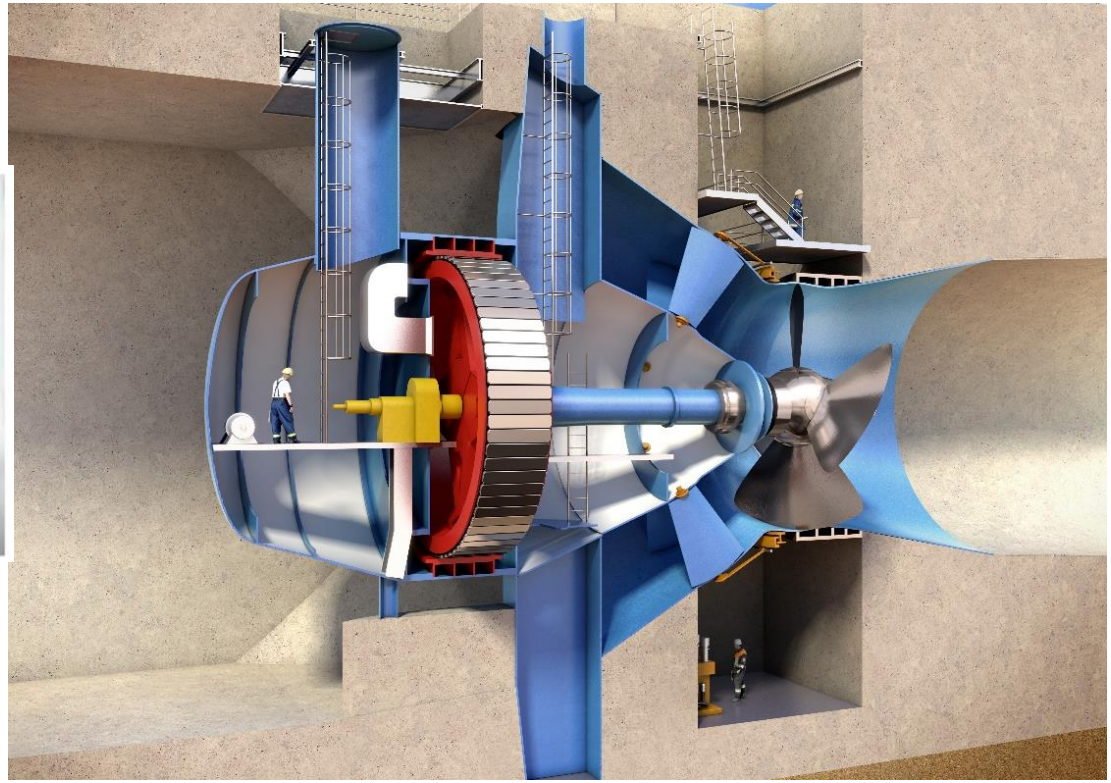
Jirau hydro power plant

- 50 turbines rated at 76.5 MW each
- Biggest Bulb turbines in the world
- Runner diameter of 7.5 m

Bulb turbine

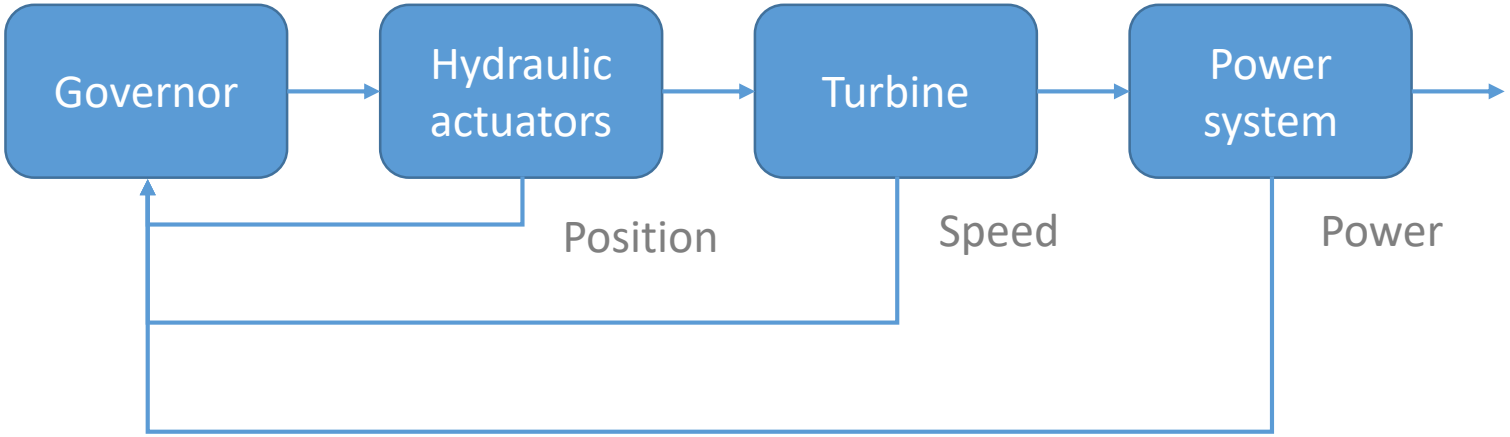
- Two hydraulic actuators
  - Wicket gates
  - Adjustable runner blades





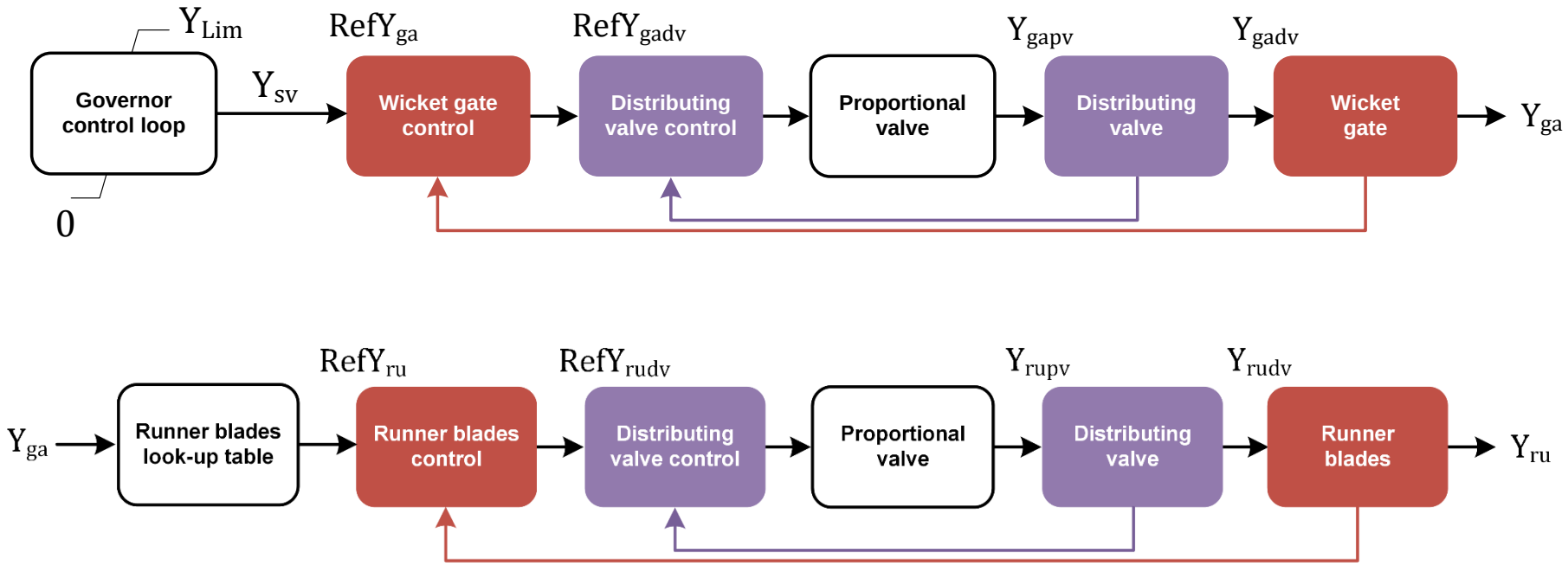
Governors

- Control generating unit speed and output power to follow their desired values
- Manipulate the two hydraulic actuators: wicket gate opening and runner blades angle
- Wicket gate opening changes flowrate accross the turbine
- Runner blades angle is corrected to maximize efficiency



Hydraulic actuators control

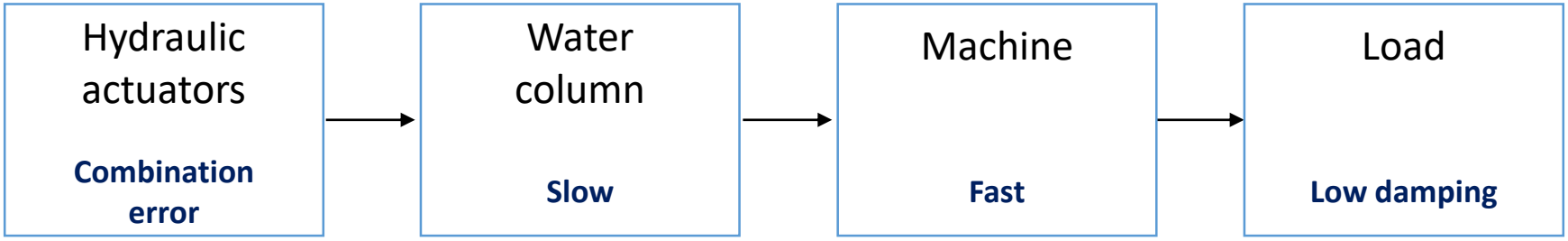
- Proportional valve → Distributing valve → Main actuator
- Combination curve for determining runner blades reference according to wicket gates



Introduction

- Left bank: 22 units
- Original governors were subcontracted by the turbine manufacturer, not by the plant owner
- Customer dissatisfied with governors
  - Long setup time for putting the units into service
  - A conventional governor is not proper for this application
  - Behaviour not adequate for customer needs
- Governors replacement
  - Detailed analysis of the process
  - Customized solutions for the issues
  - New governors commissioning and testing

Singular characteristics in Jirau



- Wicket gates: 15 s
- Runner blades: 30 s

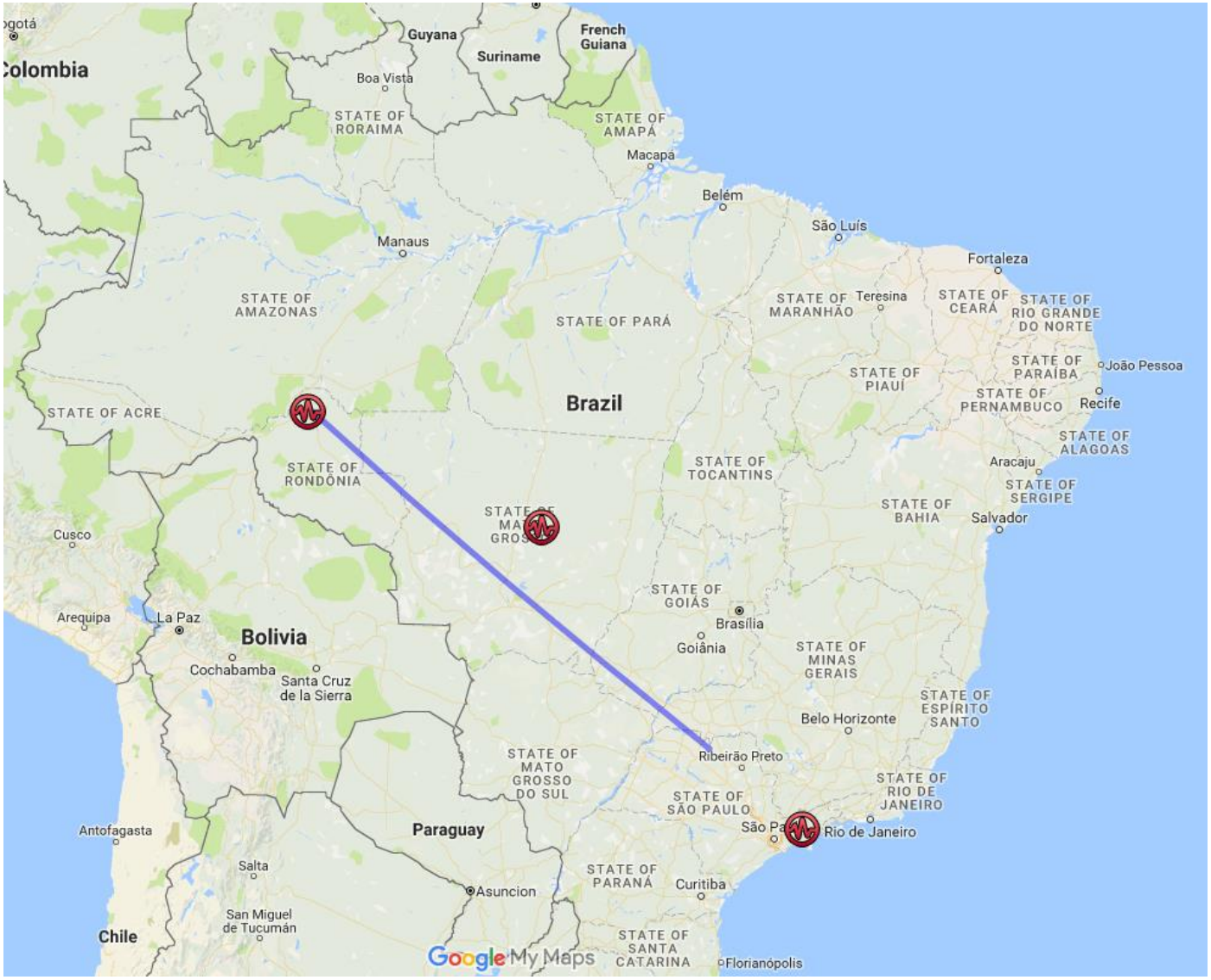
- High flowrate
  - High time constant Tw
- Head variation
  - 9 to 20 m
  - Tw wide operating range
- Operating limits

- Low inertia time constant (2H)

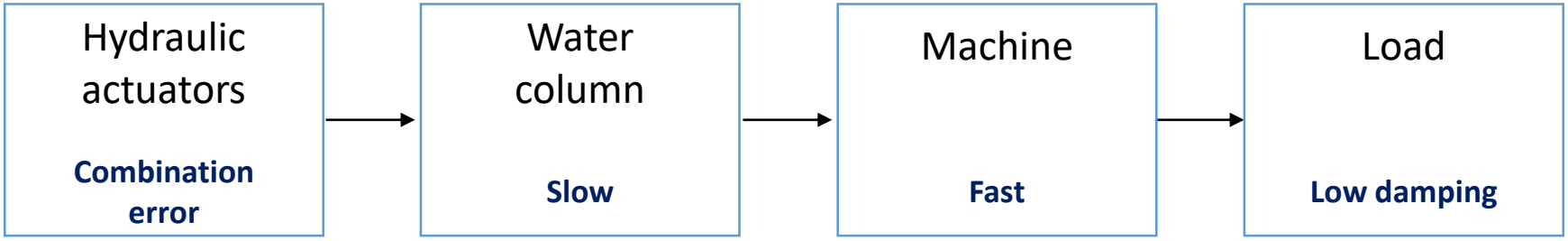
- HVDC converters (2 x 3750 MW)
- Jirau and Santo Antônio (100 x 70 MW)

	Typical	Jirau
2H/Tw	> 2.5	1

Transmission line



Control solutions

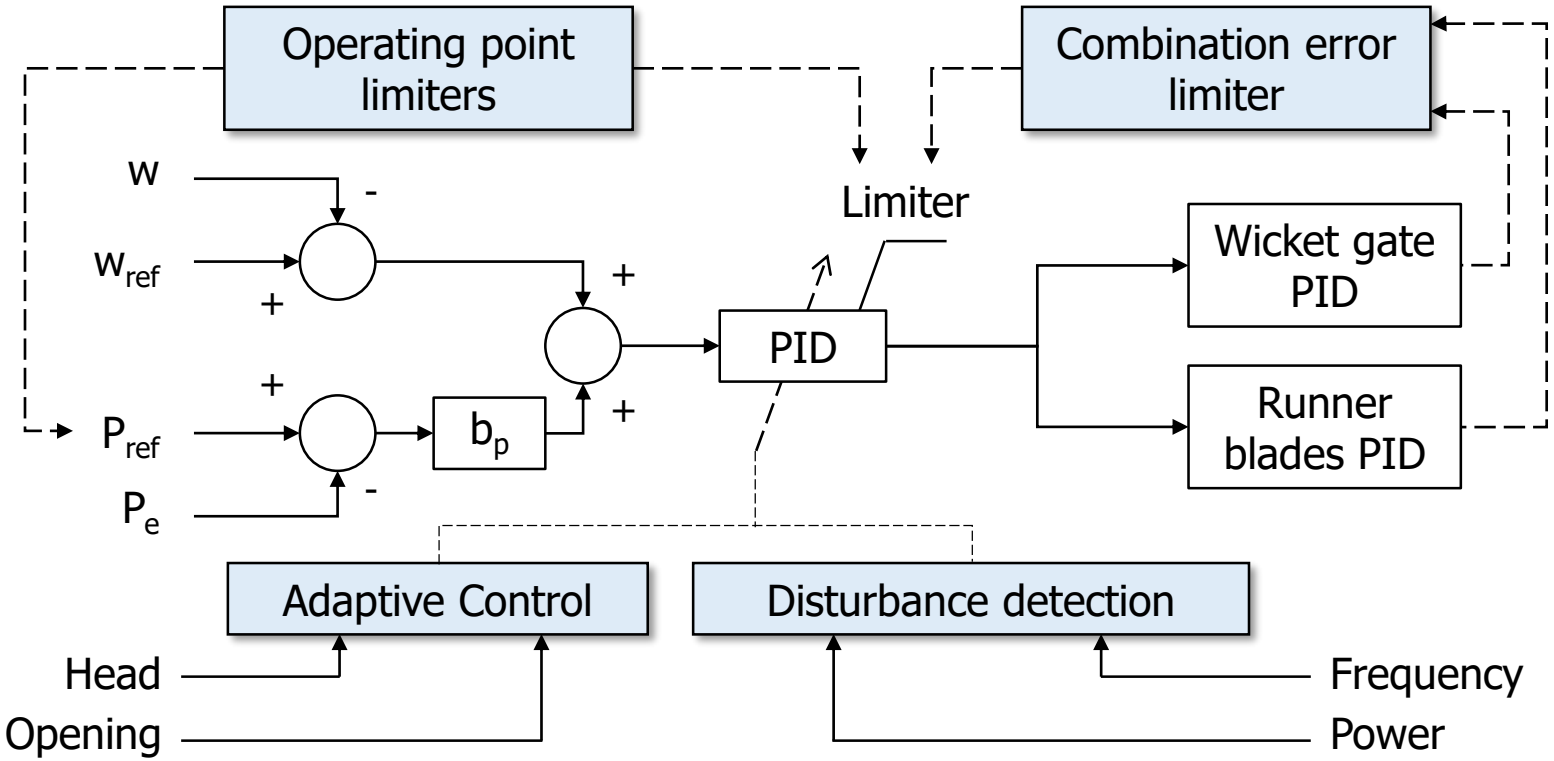


- Combination error limiter

- Adaptive control
- Operating limiters
- Monitoring screen with hill chart

- Disturbance detection

Control solutions

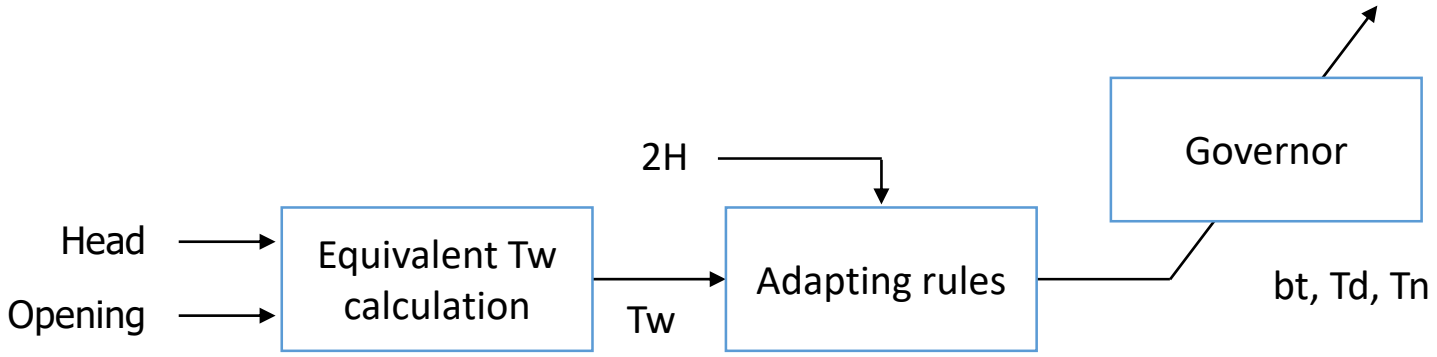


Adaptive Control

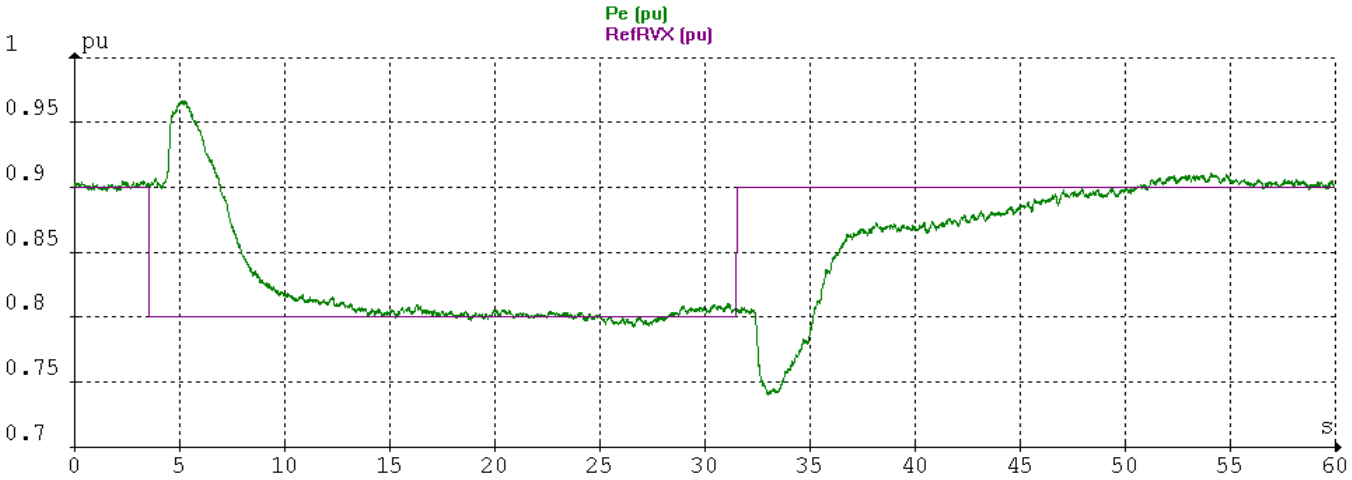
- Turbine head dynamics (Tw) depends on head and flowrate

$$Tw = Tw_{rated} \frac{\text{Flowrate (pu)}}{\text{Head (pu)}}$$

- Tuning for the worst condition (max Tw) is not adequate for other operating points
- Behaviour is improved when parameters are updated according to operating point
- This leads to more regular values for performance indicators such as overshoot, stabilizing and rising times
- Adapting rules may be tuned to make responses more aggressive or more conservative

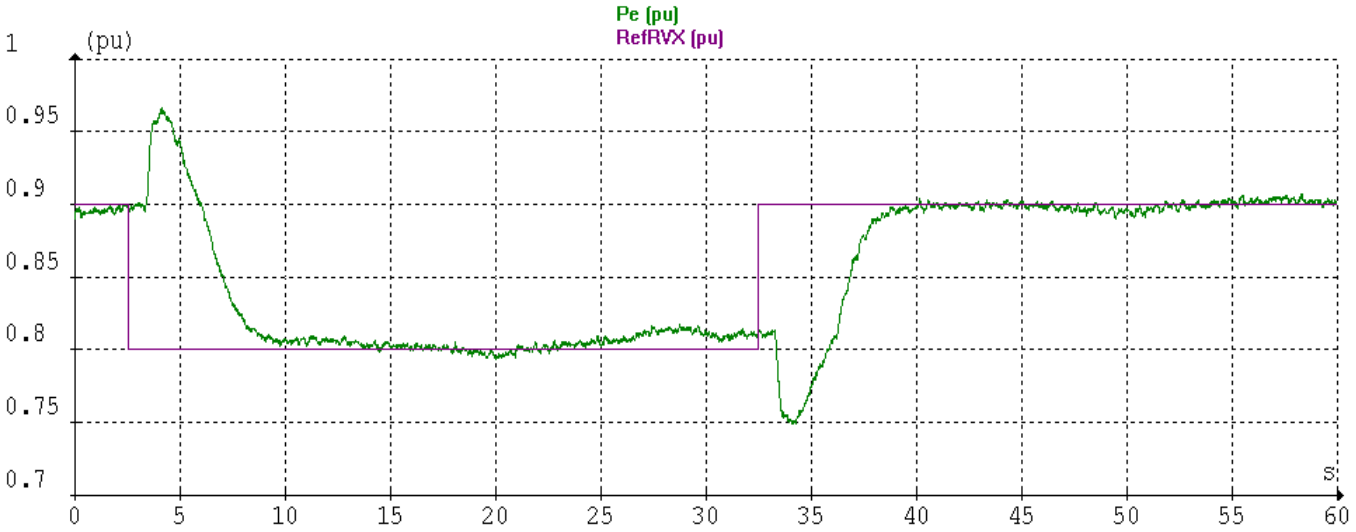


Adaptive control



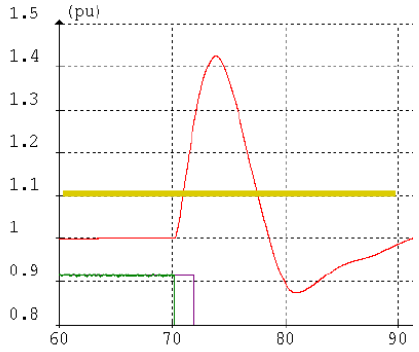
Fixed control parameters

Adaptive Control



Disturbance detection

- Changes in operating scenario
  - HVDC converters frequency stabilization is disabled
  - Frequency disturbance
  - Load rejection in the transmission line
- This changes control stability margins
- Such conditions require adapting the gains

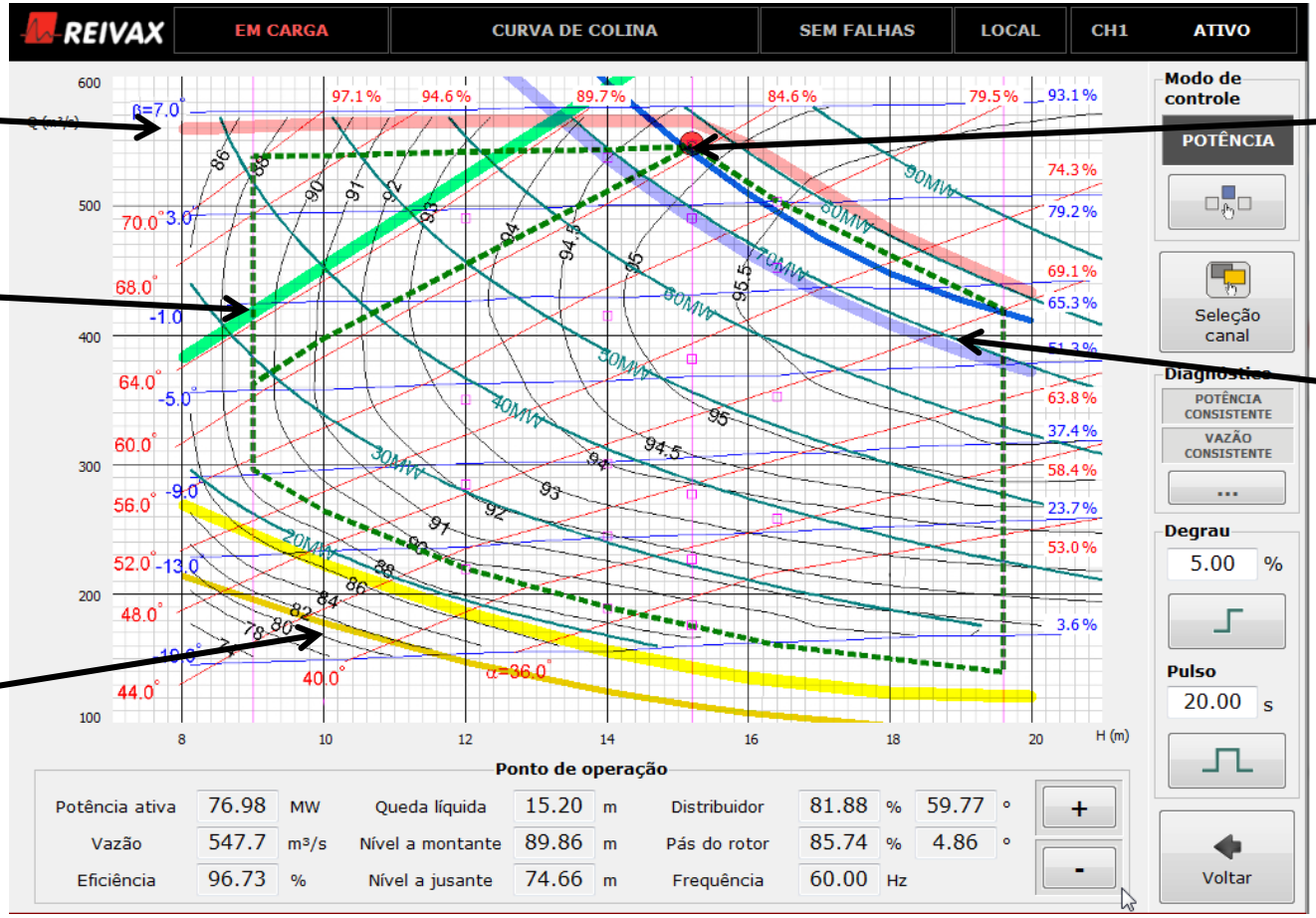


Hill chart

Maximum opening limit

Cavitation limit

Minimum power limit



Operating point

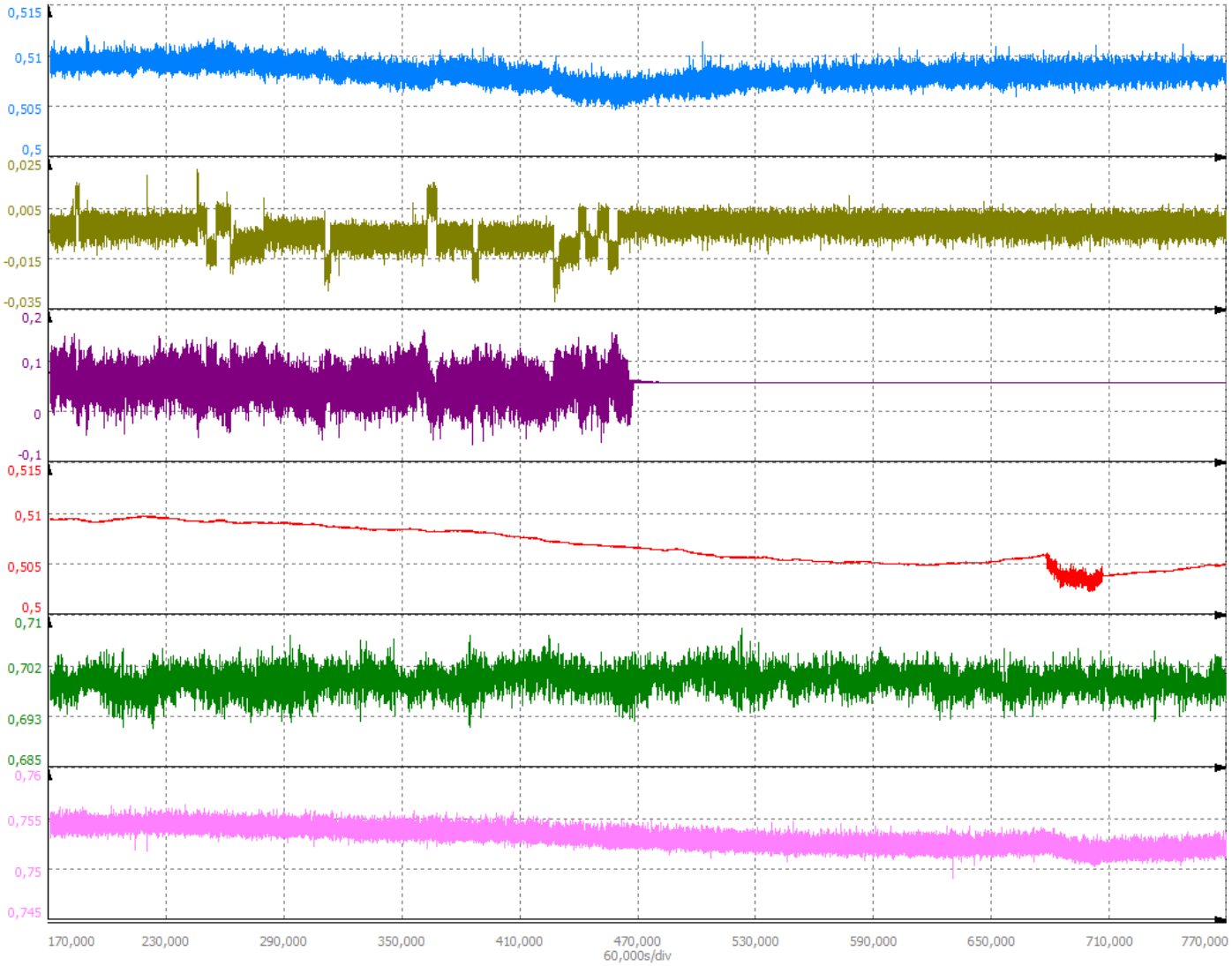
Maximum power limit

Runner blades motion reduction

- Runner blades positioned according to wicket gates to optimize efficiency
- A small combination error does not cause cavitation and the efficiency loss is negligible
- Under steady-state time, the blades might remain fixed

- Advantages
  - Prevent excessive oil consumption
  - Avoid mechanical wear in the actuators
  - Reduce oil pumps operating hours
  - Increase equipment lifespan
  - Reduce maintenance shutdowns

Runner blades motion reduction



Runner blades position

Runner blades distributing valve

Runner blades control signal

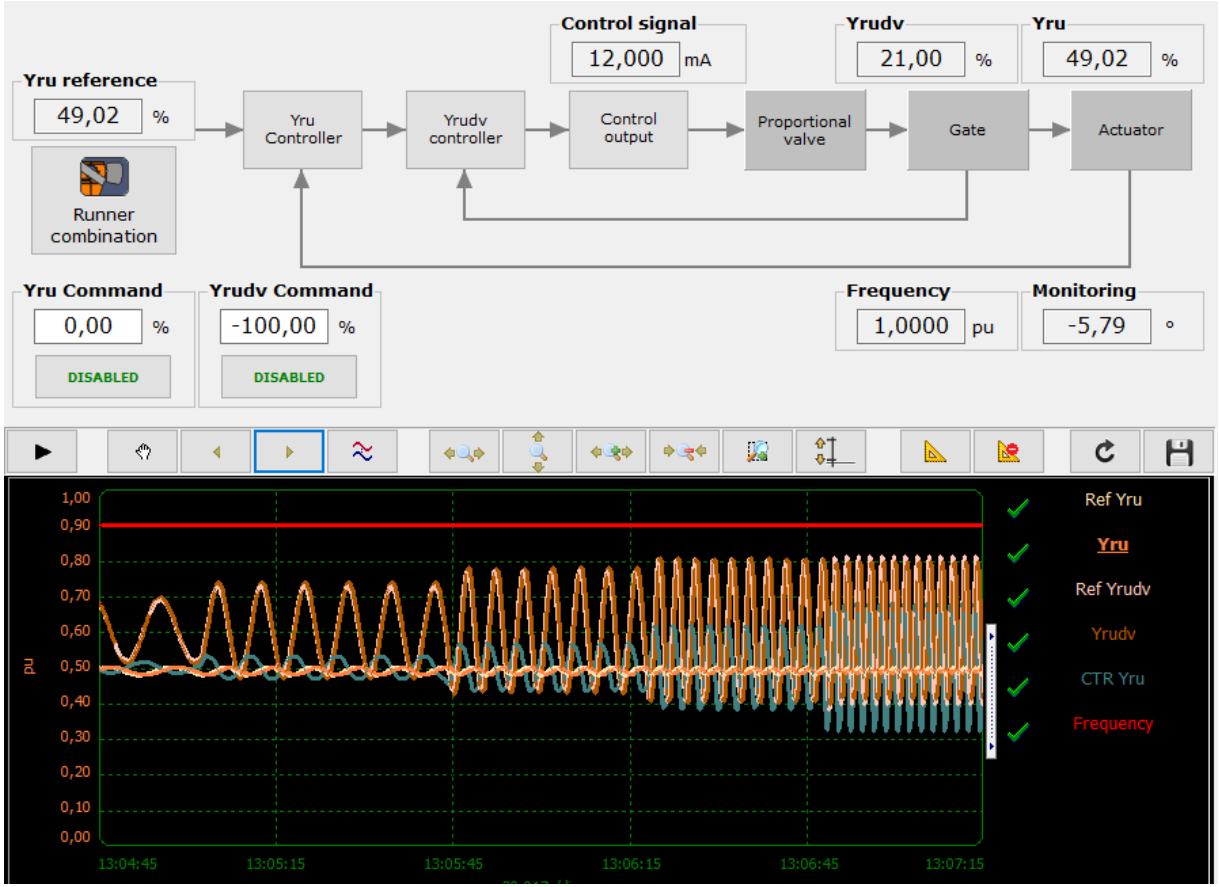
Runner blades reference

Active power

Wicket gates position

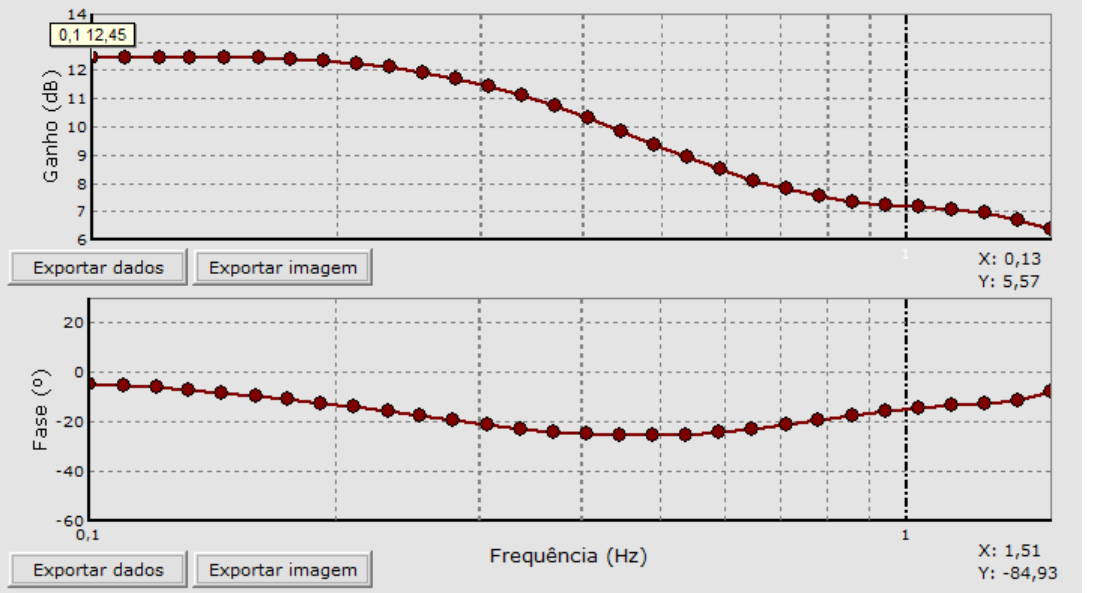
Frequency response tool

- Automatic application of sinusoidal signals with varied frequencies
  - Excitation signal may be sumed at various points of the control loop



Frequency response tool

- Real time calculation of gain and phase
  - Analysis may be performed for many input/output signals of the control system
  - No need for external equipment
- Applications
  - System identification: deadband, dynamics, non-linear
  - Control system performance indicators: gain margin, phase margin, cutoff frequency
  - Identify valve sticking



Current operating status

- The governors have been operating since February 2015
- System event in 2015
  - During the validation time of the first governor
  - Outage of all units in Jirau and Santo Antônio (50 x 70 MW) power plants, except for this unit
  - The unit was able to sustain the auxiliary power supply of the whole power plant, which feeds emergency and supervision systems
  - Analysis confirmed this was due to the advanced functions installed
- 16 units in the left bank of the power plant are already using the new governor with advanced functions
- Other 6 units are to be commissioned this year
- Jirau is the plant with the highest power availability in the Brazilian system, with an average of 99.1% in 2016

Thank you for your attention.

Henrique Augusto Menarin

ham@reivax.com.br