DEVELOPMENT OF PNEUMATIC TECHNOLOGY FOR AUTOMATION AND CONTROL OF SMALL HYDROPOWER PLANTS

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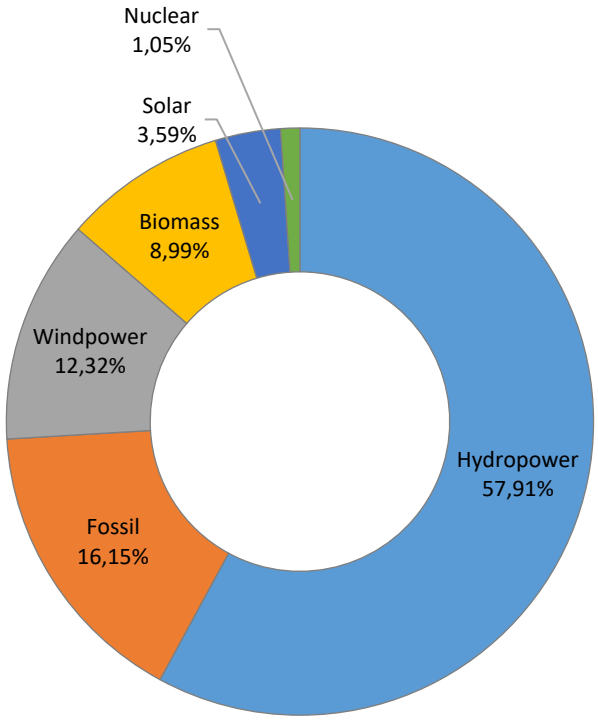
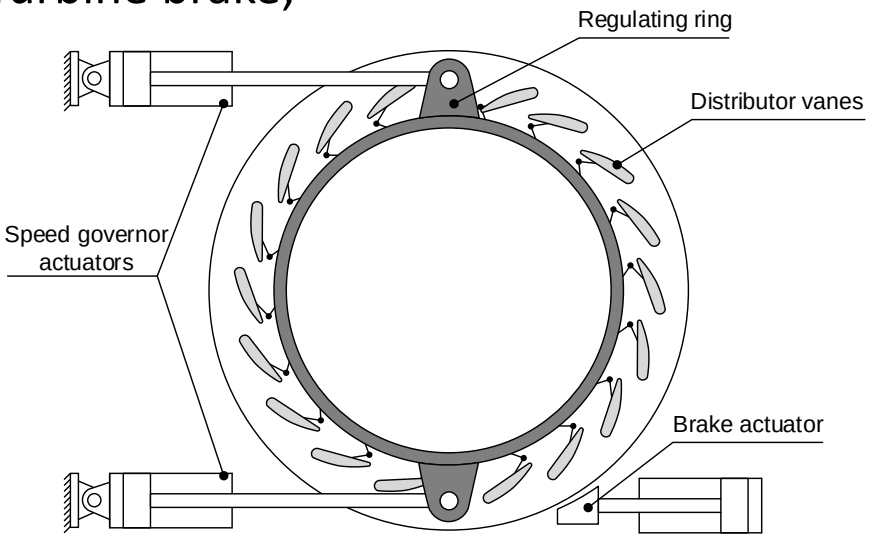
INTRODUCTION

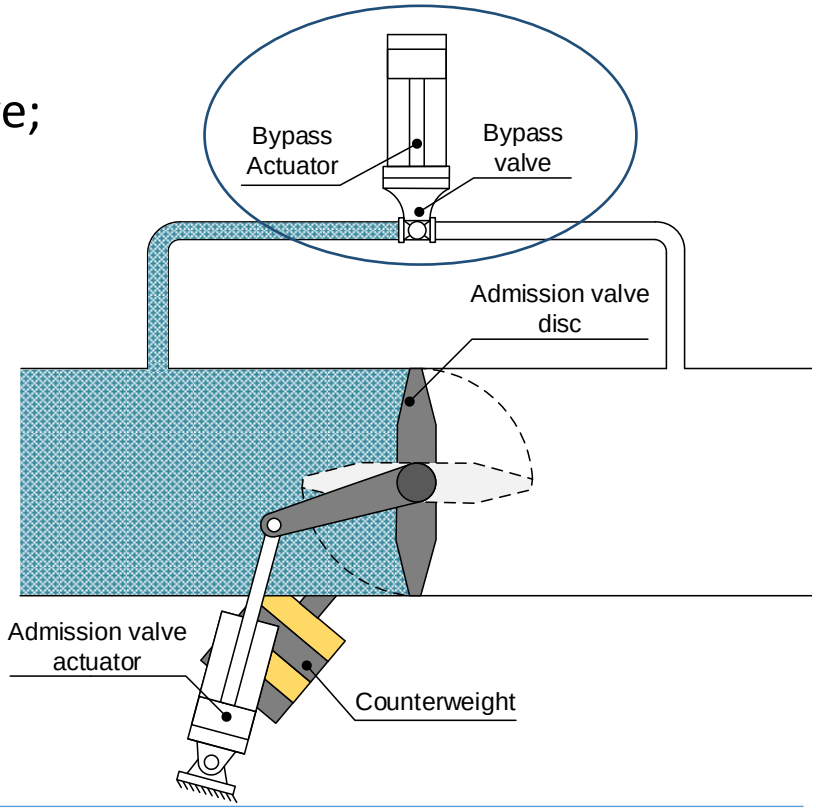
- Hydropower plants are known as a major contributor to renewable sources;
- Every source of energy has an environmental impact;
- Small capacity hydropower plants is an alternative to reduce the environmental impacts of hydro generation;
- Joint effort between **LASHIP** and **Reivax** to develop a solution to automate and control Small Hydropower Plants (SHPs) with **pneumatic technology**;
  - Reduction of fossil based products;
  - Lower acquisition costs;



Understanding the requirements

- Speed regulation of the generator unit:
  - Turbine start-up;
  - Synchronism;
  - Load taking;
  - Load rejection;
- Opening and closing of the admission valve;
- Actuation of a bypass valve;
- Turbine brake;





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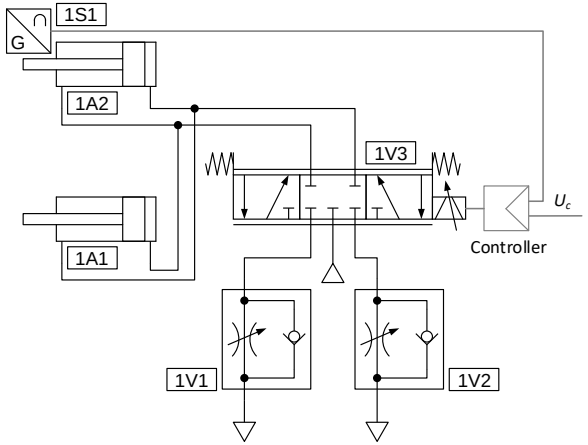
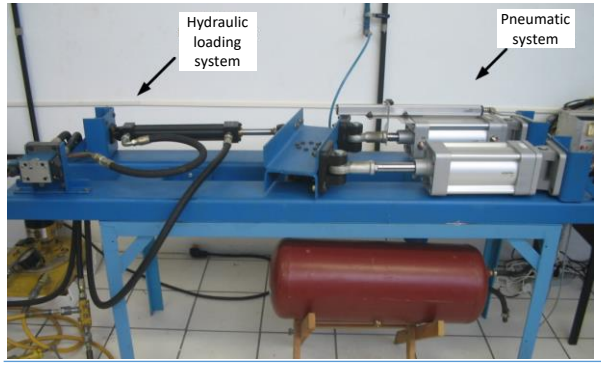
LASHiP HYDRAULICS & PNEUMATICS

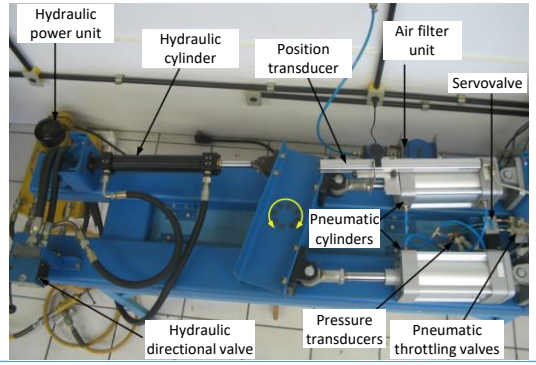
First approach

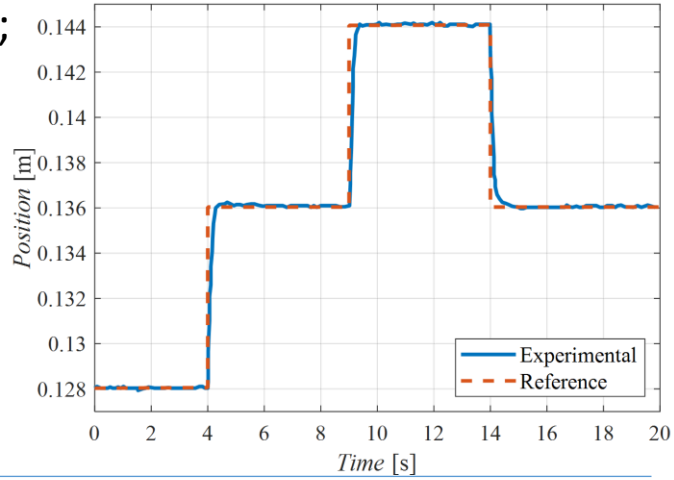
- Classical concept of a servopneumatic system:
  - Proportional servovalve, linear actuators, flow control valve;
  - Controller: PID with dead-zone compensator
- Development of dynamic simulation model:
  - Initial assessment of dynamic performance and system behavior;
- Development of a test rig:
  - Load generated by a hydraulic actuator;
  - Settling time: 0.56 s; Steady state error: 0.24 mm;



MATLAB® & SIMULINK®







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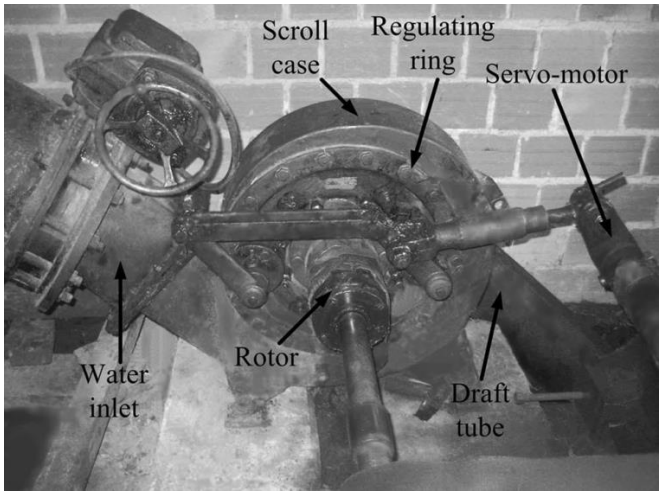
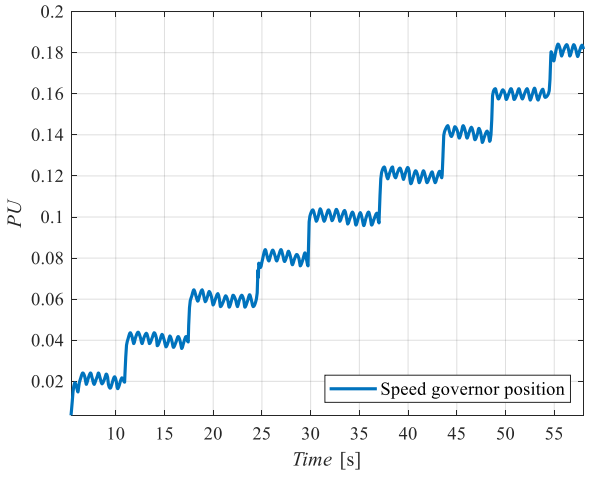
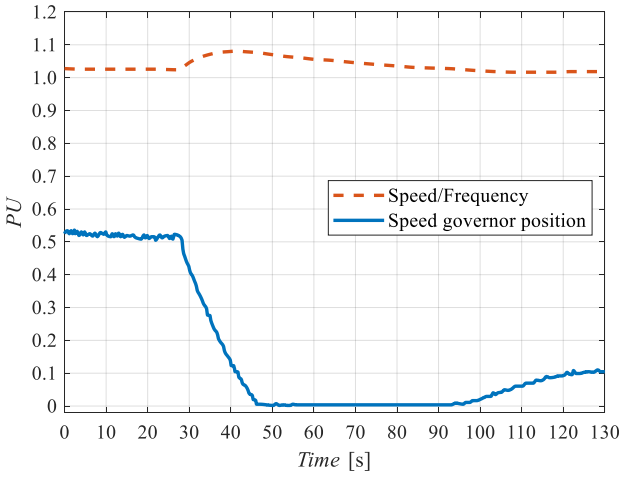
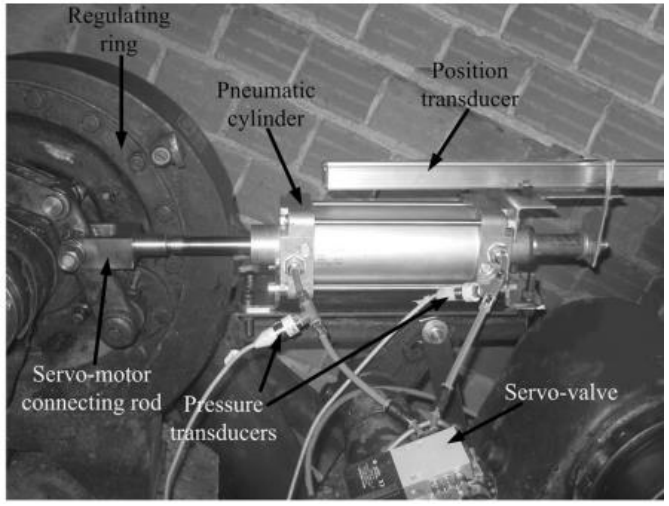
Small-scale prototype

- Francis-type turbine (35 kVA)
- Step response:
  - Settling time: Less than 0.25s; Limit: 1.25s
  - Oscillations of less than 1mm caused due vibration of the machine;
- Load rejection:
  - Speed overshoot of 8%; Limit: 30%









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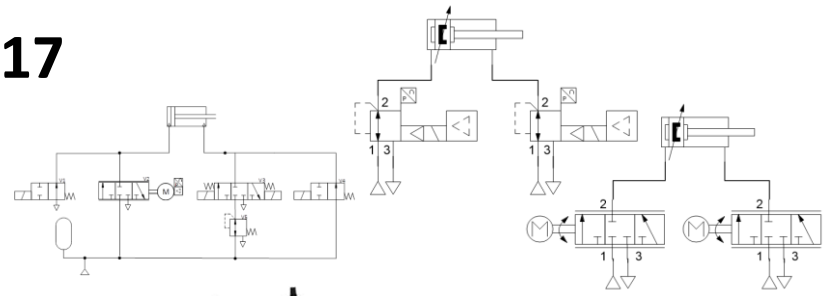
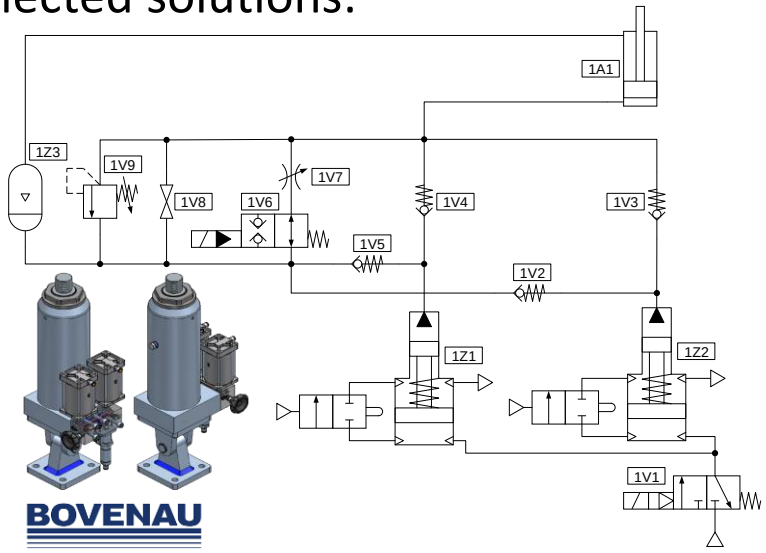
ANEEL R&D project PD-00387-0117/2017

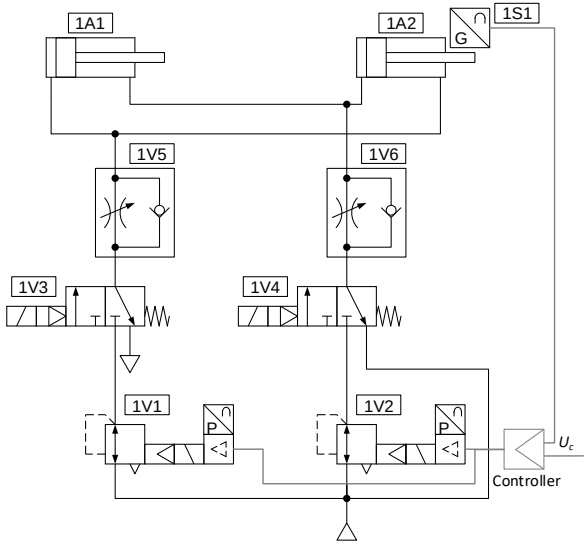
- Main goals:
  - Control the distributor (Reduce costs);
  - Actuation of the admission valve;
  - Pilot project;
- Analysis of possible solutions:
  - Meet design requirements;
  - Technically and economic viable;
- Selected solutions:



Hydropneumatic jack



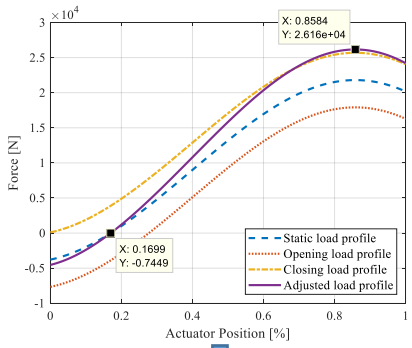
Proportional pressure regulators



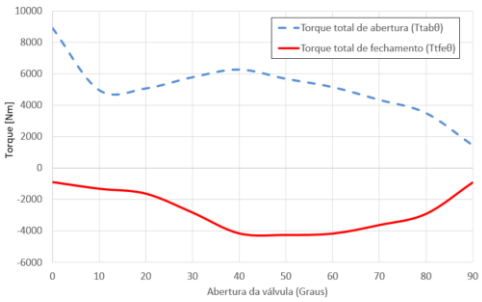
Solution assessment

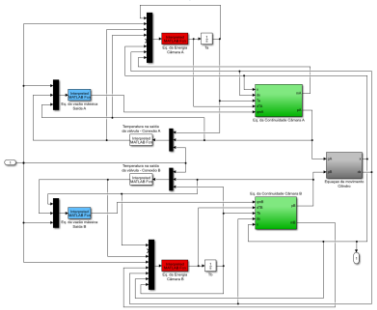
- Simulation models:
  - Expected theoretical loads;
  - Modeling and parametrization;
  - Expected performance (Distributor):
    - Settling time: 1.3 seconds
  - Expected performance (Admission valve):
    - Opening time: 138 seconds

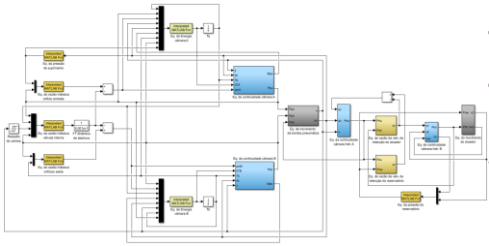
Turbine distributor



Admission valve

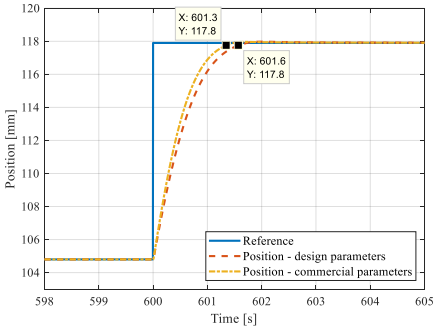


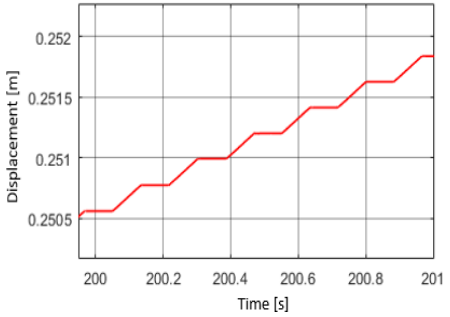




Hydropneumatic pump characterization

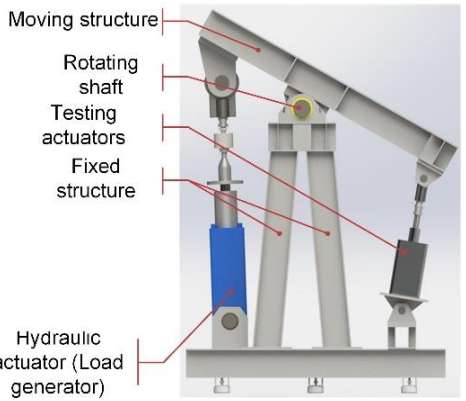
Friction force determination

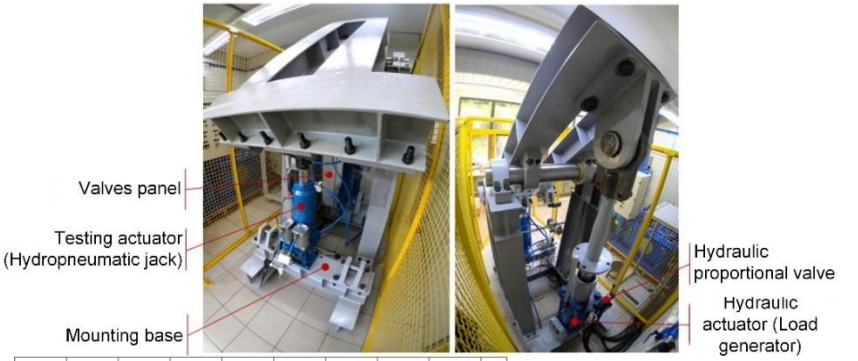


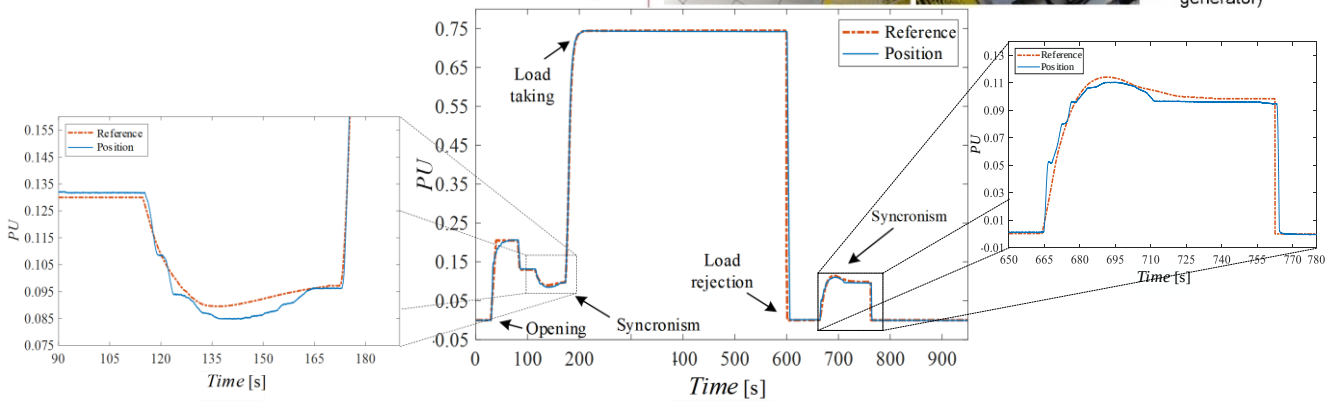


Solution assessment

- Experimental evaluation:
  - Test rig for full-scale testing (160 kN);
  - Distributor testing:
    - 26 kN of applied force;
    - Steady-state error: 0.64 mm;
  - Admission valve testing:
    - 153 kN of applied force;
    - Opening time: 150 seconds;
    - Stability: 0.35 mm over 8 hours.







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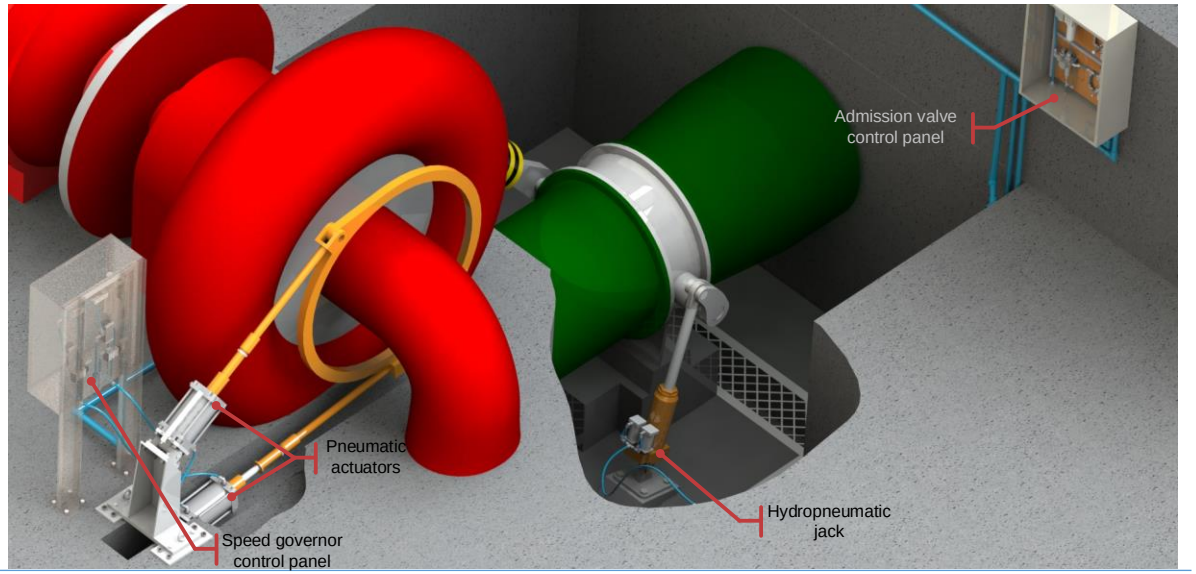
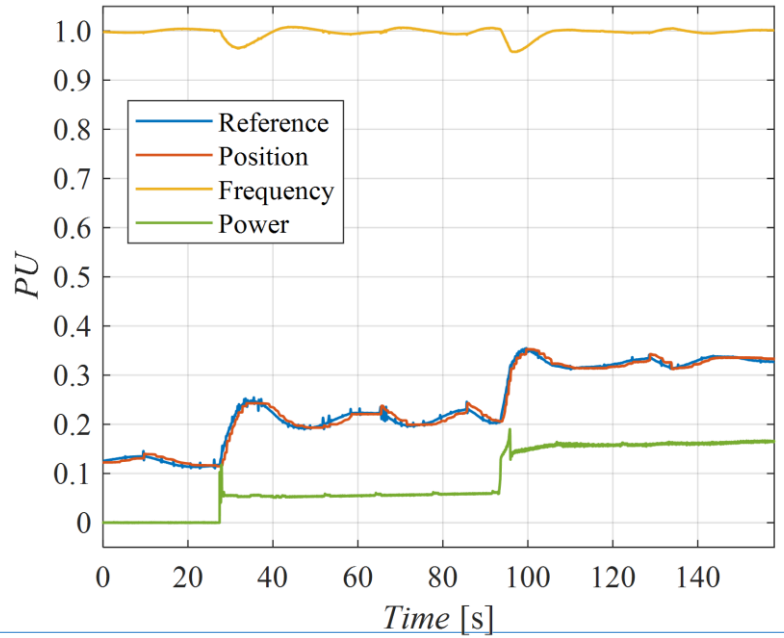
Pilot project

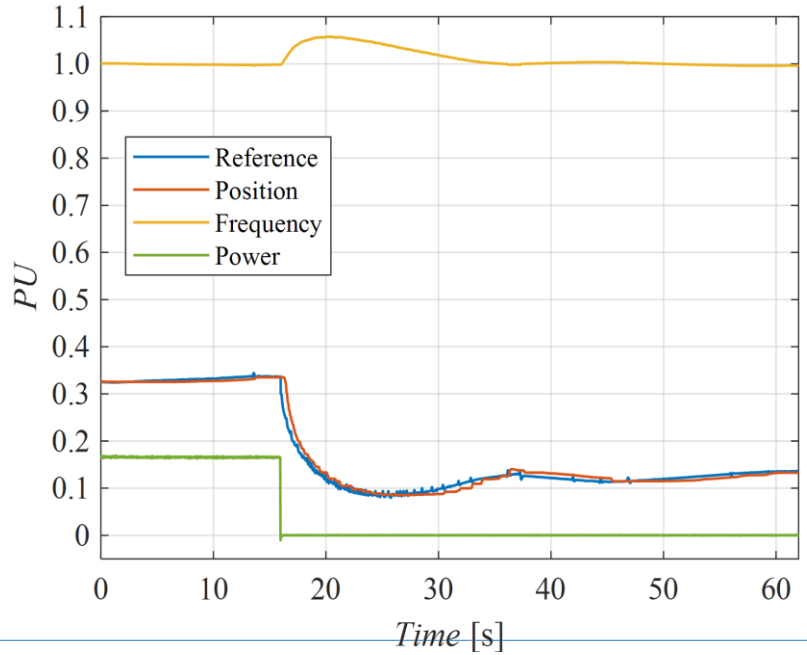
- Goal: Complete automation and control of hydraulic turbine of the hydropower plant located in Salto Grande-SP using **pneumatic technology**;
- Generating unit characteristics:
  - Generating capacity: 438 kVA
  - Average water head: 18.5 m
- Designed solution:



Pilot project

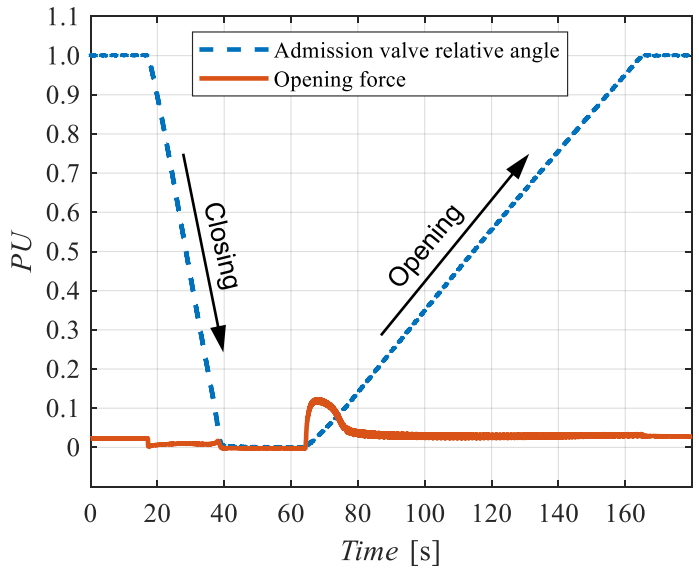
- Results - Distributor:
  - In load operation:
    - 22 and 70 kW (*Isolated from grid*);
    - Produced energy: Within +/- 0.5 Hz;
  - Load rejection:
    - 72 kW rejection;
    - Overspeed of 5.8% (*Limit is 30%*);





Pilot project

- Results – Admission valve:
  - Opening time: 101.67 seconds (*Desired between 80 and 160 seconds*);
  - Closing time: 23.35 second (*Avoid water hammer effect*)



CONCLUSIONS

- The state of the art of pneumatic technology make it possible to automate and control Small Hydropower Plants;
- The solution is capable to attend turbine with up to 30 MW of power capacity;
- It offers the possibility to reduce around 45% of the acquisition costs;
- Easier installation and maintenance;
- Reduction of fossil-based products, avoiding risks of river bed contamination;
- Contribution to cleaner energy production.

ACKNOWLEDGMENTS

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