TABLE-TOP DEMO OF A SYSTEM-LEVEL CONTROL ON A PIPELINE NETWORK

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Abstract

This capstone project was a collaboration with Pembina Pipeline, who tasked us with designing and building a table-top apparatus to demonstrate key concepts in pipeline system operations and control.

The goal of the project was to create an educational tool that could be used to demonstrate to students and engineers' key concepts about pipeline systems.

Our apparatus features:

1. Pipes with an equivalent length-to-diameter ratio no less than 10,000
2. Actuated valves
3. Pumps that are monitored and controlled with proportional-integral-derivative (PID) control
4. Centralized control panel with an interactive display
5. Shows real-time data and allows the user to adjust control parameters
6. 5-gallon Co-op water jugs as tanks,
7. Aluminum pipes for the apparatus.

We used:

1. Arduino UNOs for ADCs and DACs,
2. Raspberry Pi for the computer,
3. Flowmeters with analog voltage output,
4. level switches and pressure gauges with i2c output

Overall, our design is a useful educational tool for anyone interested in understanding pipeline systems and their operation.

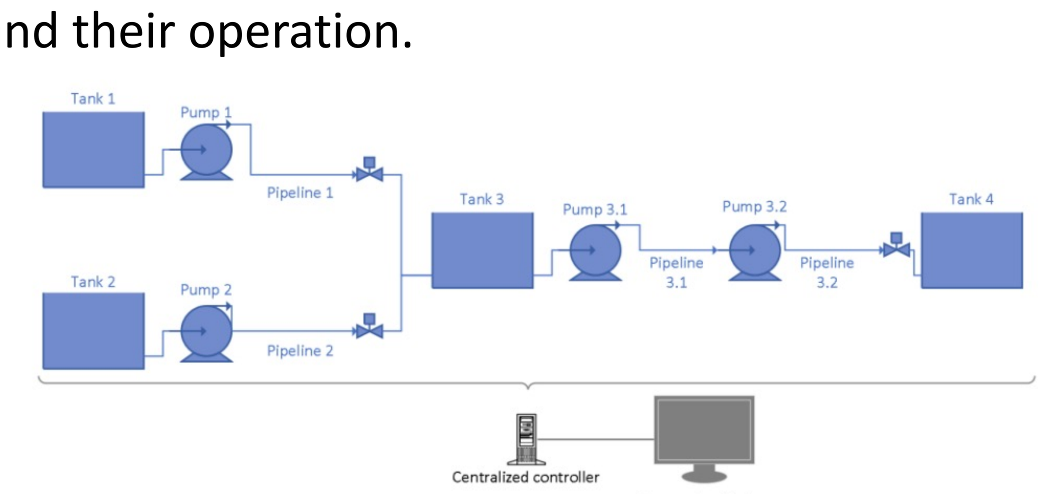

Figure 1. Minimum requirement of the key components and layout of the demo

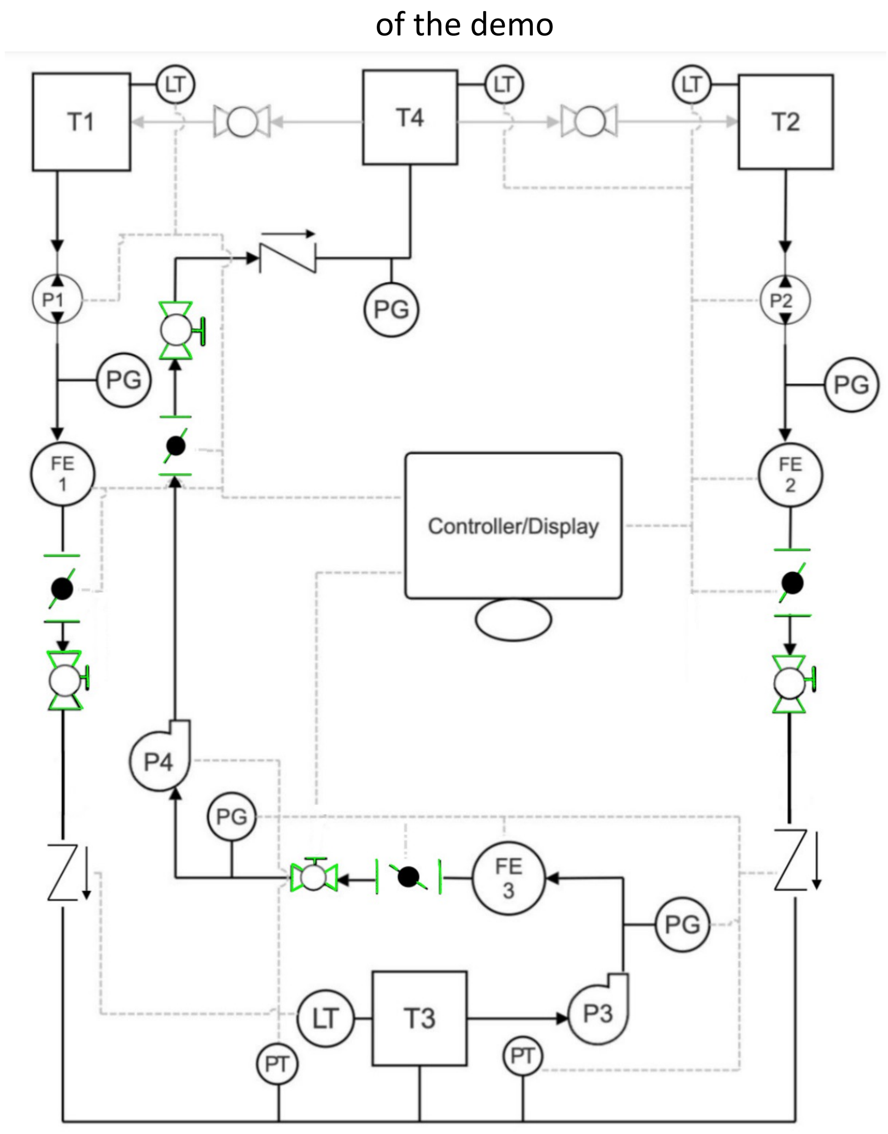

Figure 2. P&ID of current design

Background

Transmission gas and liquid pipeline networks play a crucial role in society's energy infrastructure. To optimize these transportation systems for energy efficiency and adaptability to rapid changes in supply and demand, engineers must understand the technical fundamentals of pipeline design and operations. However, these concepts can be complex and unintuitive.

Besides being complex and intuitive, pipeline networks are:

- not accessible to everyone (off-site)
- Require authority as there are safety and legal concerns that are involved.

To bridge this gap, our capstone project aimed to design and build a table-top apparatus of a pipeline network. In doing so, we can showcase to engineers, students, or anyone interested in pipeline, how a network would work

Our main deliverables by our sponsor:

1. 10,000 L/D ratio,
2. Pipes do not burst
3. Have actuated valves
4. Centralized control panel with an interactive display
5. Making sure our model can fit through any door.

Methods and materials

1. Design and Conceptualization:
- Comprehensive research of pipeline system operations and control

2. Components:
- Utilized 1" aluminum pipes with threaded holes
- 5-gallon Co-op water jugs as tanks
- Pumps with PID control,
- Flowmeters, level sensors, pressure gauges
- Ball and butterfly valves that simulates the 10,000 L/D pressure drop.

3. Assembly:
- Cut and threaded pipes to fit required length
- Fitted tanks with holes to accommodate inlet/outlet nozzles and sensors.
- Various components (valves, gauges, pipes, flowmeters) are linked together with their NPT threads.

5. Control and Data Analysis:
- Designed and programmed a centralized control panel with an interactive display using Python
- real-time data monitoring and adjustment of control parameters.

6. Analysis:
- Evaluated system performance and reliability using quantitative metrics and qualitative measures, including stakeholder feedback.

Discussion

During our capstone project, we encountered various challenges that tested our problem-solving abilities.

1. Sealing the nozzle holes within the tanks: resolved this by employing multiple methods, including acrylic cement, and silicon sealant before finally settling on using tank fittings with an O-ring
2. Power supply issues: due to the high-power demands of our pumps, which required us to acquire specific power supplies.
3. Budget constraints: influenced our design choices, such as using butterfly and ball valves in place of expensive globe valves to simulate pressure loss.

Despite these obstacles, our team was able to successfully complete the project through continuous meetings and a problem-solving approach. Our experience provided us with technical skills related to pipelines and taught us the importance of collaboration and perseverance in achieving project goals.

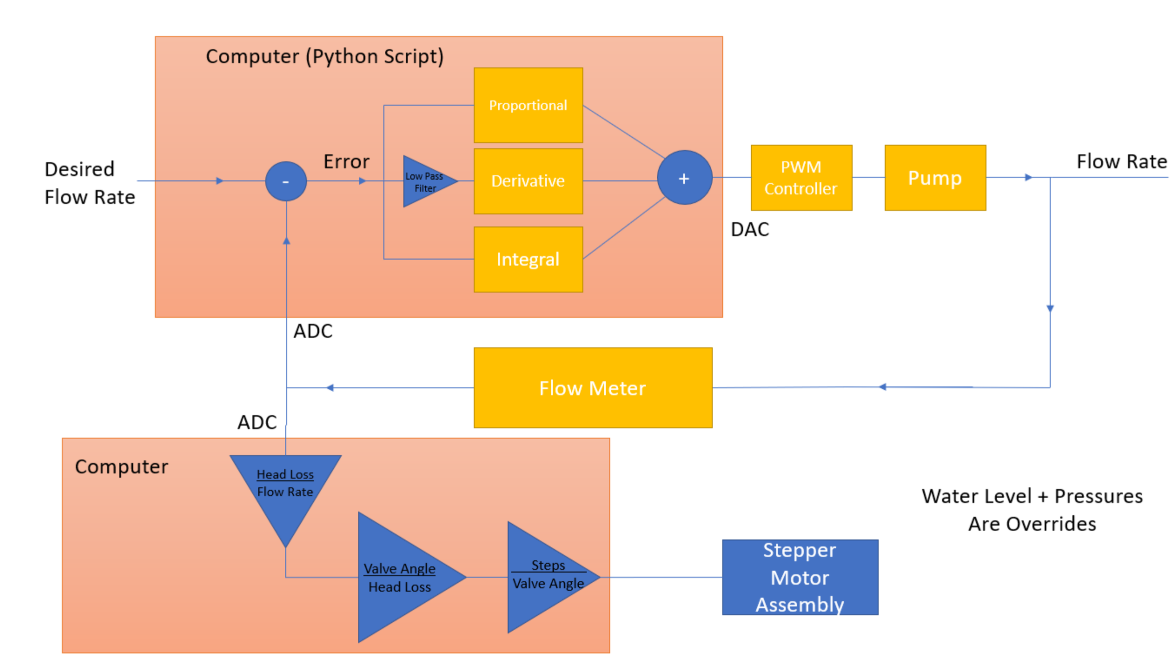

Figure 3. Block diagram of pump PID control loop

Conclusion

Our capstone project with Pembina Pipeline resulted in the successful design and construction of a table-top apparatus that serves as an educational tool for understanding pipeline systems and their operations.

The apparatus features:

- pipes with a minimum length-to-diameter ratio of 10,000,
- actuated valves and pumps
- a centralized control panel with an interactive display.

It is a hands-on learning experience that demonstrates key concepts in pipeline system operations and control.

We were able to showcase the complexity of pipeline systems:

- In a more accessible and intuitive way
- Resulting in it being easier for students and engineers to learn and apply these concepts.