Anomaly Detection in Multiphase Flow Facility

Problem Overview:

This project addresses anomaly detection in a multiphase flow facility using machine learning. Anomaly detection refers to identifying deviations from normal operating conditions within a system. In this case, the system is a facility that mixes and separates water and air.

The PRONTO project provides a benchmark case study for this problem. The data is collected from a facility at Cranfield University's Process System Engineering lab. The experiment involves controlling water and air flow rates to create various operating conditions. Sensors monitor pressure, flow rate, temperature, and density throughout the facility, generating a rich dataset.

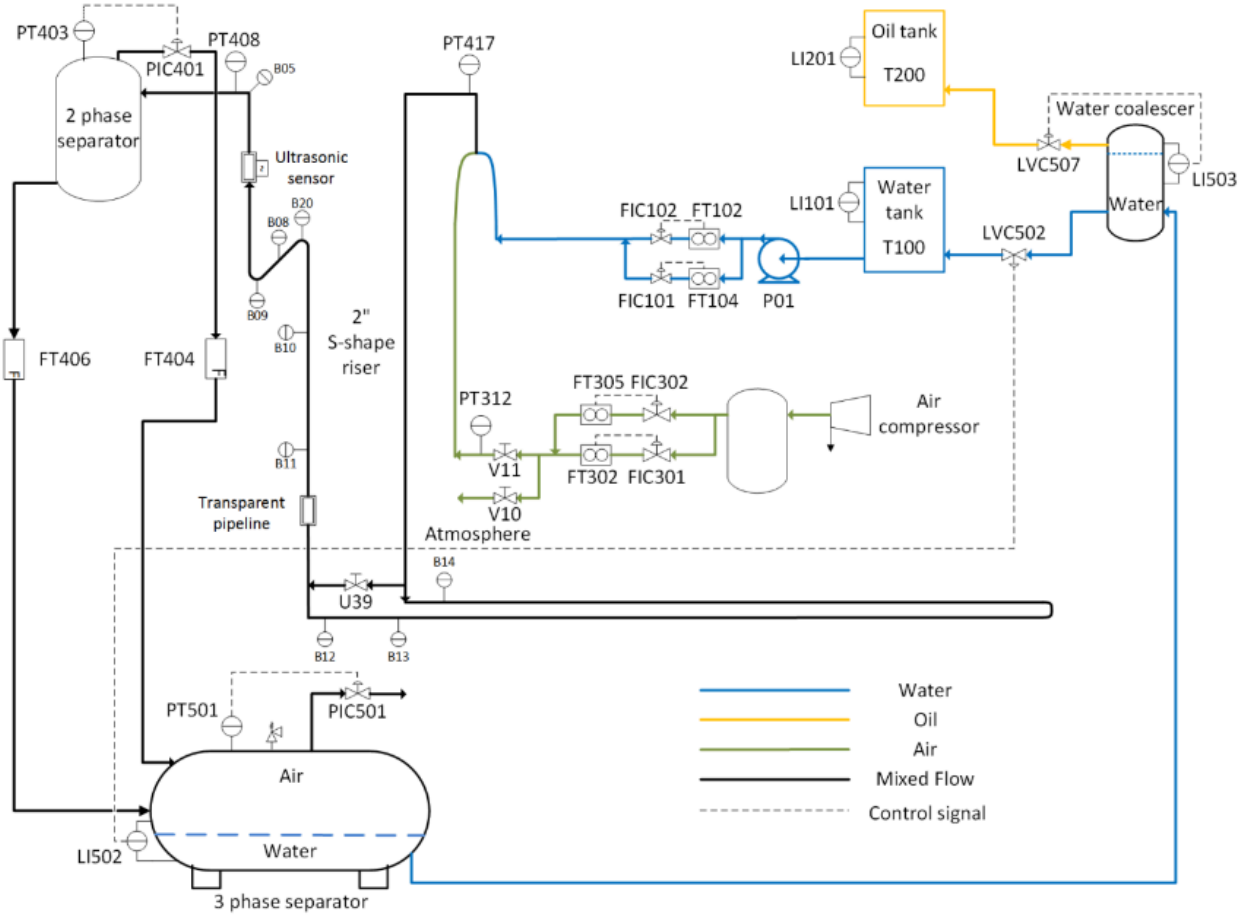

Figure: Process Schematic

Objectives:

Develop a robust machine learning model to:

- **Identify** the normal and Anomaly operational conditions.
- **Label** the anomaly points/clusters taking into consideration that there are 2 types of anomalies (air leakage and air blockage)

Data Sections:

The data consists of 29 features with 17 process variables, as shown in Table 1, collected during the experiment. These variables can be categorised into:

- **Control Variables:** These directly influence the operating conditions, such as input air and water flow rates (FT305/302, FT102/104).
- **External Variables:** These influence the operating conditions but are not directly controlled, such as input air and water temperatures (FT305-T, FT102-T).

Additional Information:

- The experiment includes two main flow regimes: stable (normal) and unstable (slugging).
- The training data will likely only include data from normal operating conditions.
- The model's performance will be evaluated on data from the slugging regime to assess its ability to handle unseen conditions.

Table : Selected process variables with their corresponding tag and unit.

Sensor tag	Measured process	Variable Unit
FT305/302	Input air flow rate	Sm^3/h
FT305	Input air temperature	°C
PT312	Air delivery pressure	barg
FT102/104	Input water flow rate	kg/s
FT102	Input water temperature	°C
FT102	Input water density	kg/m^3
PT417	Pressure in the mixing zone	barg
PT408	Pressure at the riser top	barg
PT403	Pressure in the top separator	barg
FT404	Top separator output air flow rate	m^3/h
FT406	Top separator output water flow rate	kg/s
PT501	Pressure in the 3-phase separator	barg
PIC501	Air outlet valve 3-phase separator	%
LI502	Water-oil 3- level phase separator	%
LI503	Water coalescer level	%
LVC502-SR	Water coalescer outlet valve	%
LI101	Water tank Level	m
FIC302/PID1/OUT.CV	Inlet air flow rate controller 1 valve opening	%
FIC302/PID1/SP.CV	Inlet air flow rate controller 1 set point	Sm^3/h
FIC302/PID1/PV.CV	Inlet air flow rate controller 1 process value	Sm^3/h
FIC301/PID1/OUT.CV	Inlet air flow rate controller 2 valve opening	%
FIC301/PID1/SP.CV	Inlet air flow rate controller 2 set point	Sm^3/h
FIC301/PID1/PV.CV	Inlet air flow rate controller 2 process value	Sm^3/h
FIC102/PID1/OUT.CV	Inlet water flow rate controller 1 valve opening	%
FIC102/PID1/SP.CV	Inlet water flow rate controller 1 set point	kg/s
FIC102/PID1/PV.CV	Inlet water flow rate controller 1 process value	kg/s
FIC101/PID1/OUT.CV	Inlet water flow rate controller 2 valve opening	%
FIC101/PID1/SP.CV	Inlet water flow rate controller 2 set point	kg/s
FIC101/PID1/PV.CV	Inlet water flow rate controller 2 process value	kg/s