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Amal Mtibaa

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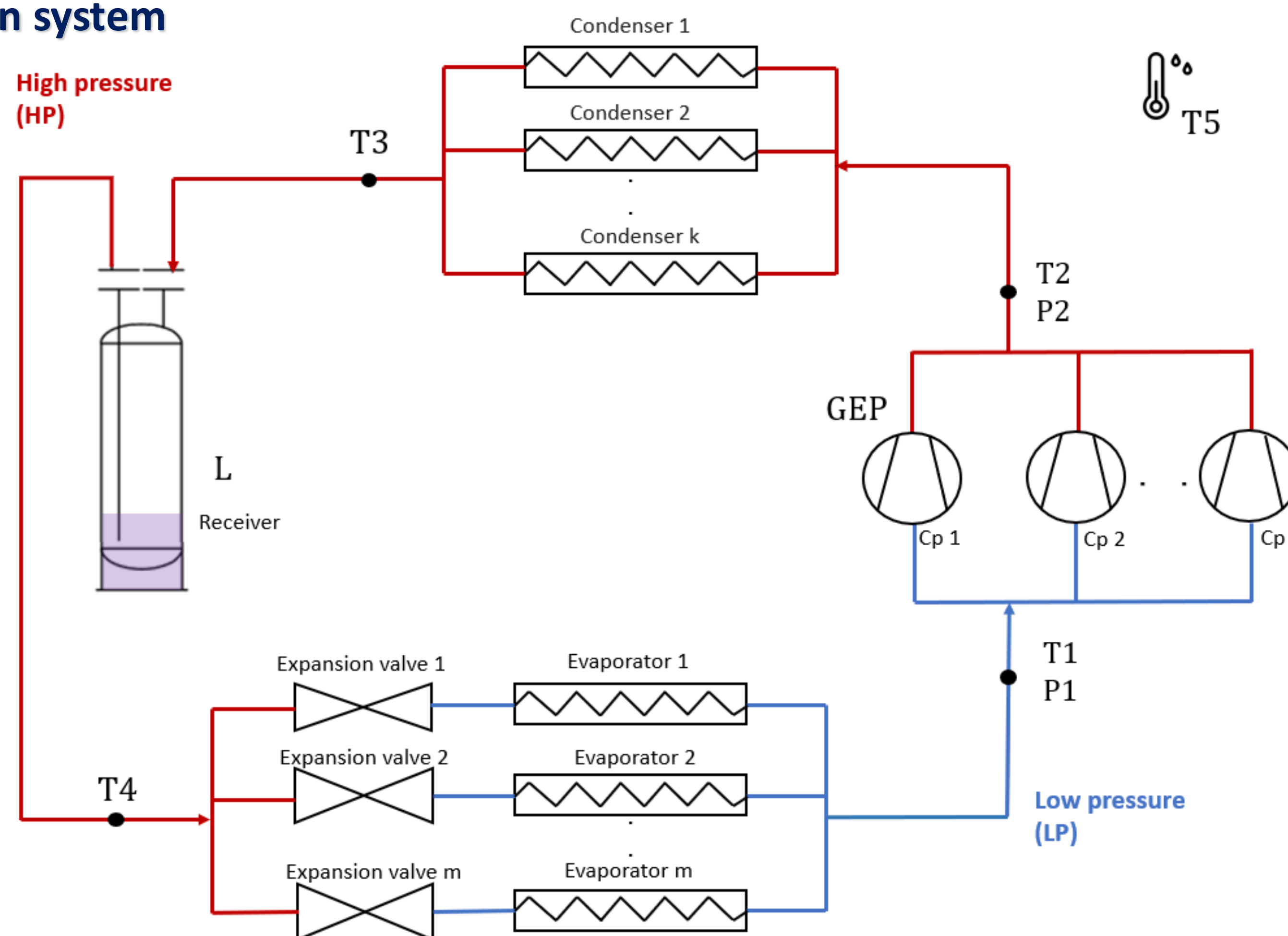
Refrigerant leak detection in industrial vapor compression refrigeration systems using machine learning

Amal Mtibaa, PhD student at CMA, Research engineer at Clauger 3E

- Efficient detection of refrigerant leakage is utmost importance for Heating, Ventilation, Air conditioning and Refrigeration (HVAC& R) systems, particularly in industrial refrigeration systems due to its potential to cause substantial impacts on system performance and the environment.
- Research has given considerable attention to maintaining HVAC& R systems using Fault detection and diagnosis (FDD) techniques, often conducted in laboratory data or specific settings.
- A data-driven refrigerant leak detection method for industrial vapor compression refrigeration systems is proposed to predict the fault-free liquid level in the receiver. Real-world data obtained from operational installations are used for feature and model selection, as well as validate the effectiveness of the method.
- The proposed approach can detect gradual leaks regardless of the physical installation characteristics and regardless of the operation condition (steady-state and transient).

1. A vapor compression refrigeration system

The presence of a receiver enables the system to compensate for the lost fluid during the occurrence of a refrigerant leak, resulting in less immediate variation in system performance indicators.



TEMPERATURES [°C]

- T1 – Compressor suction temperature
- T2 – Discharge outlet temperature
- T3 – Refrigerant temperature at condenser outlet
- T4 – Liquid temperature in high pressure
- T5 – Ambient temperature

PRESSURES [°C_{sat}, bar]

- P1 – Compressor suction pressure
- P2 – Compressor discharge pressure

LIQUID LEVEL [mm]

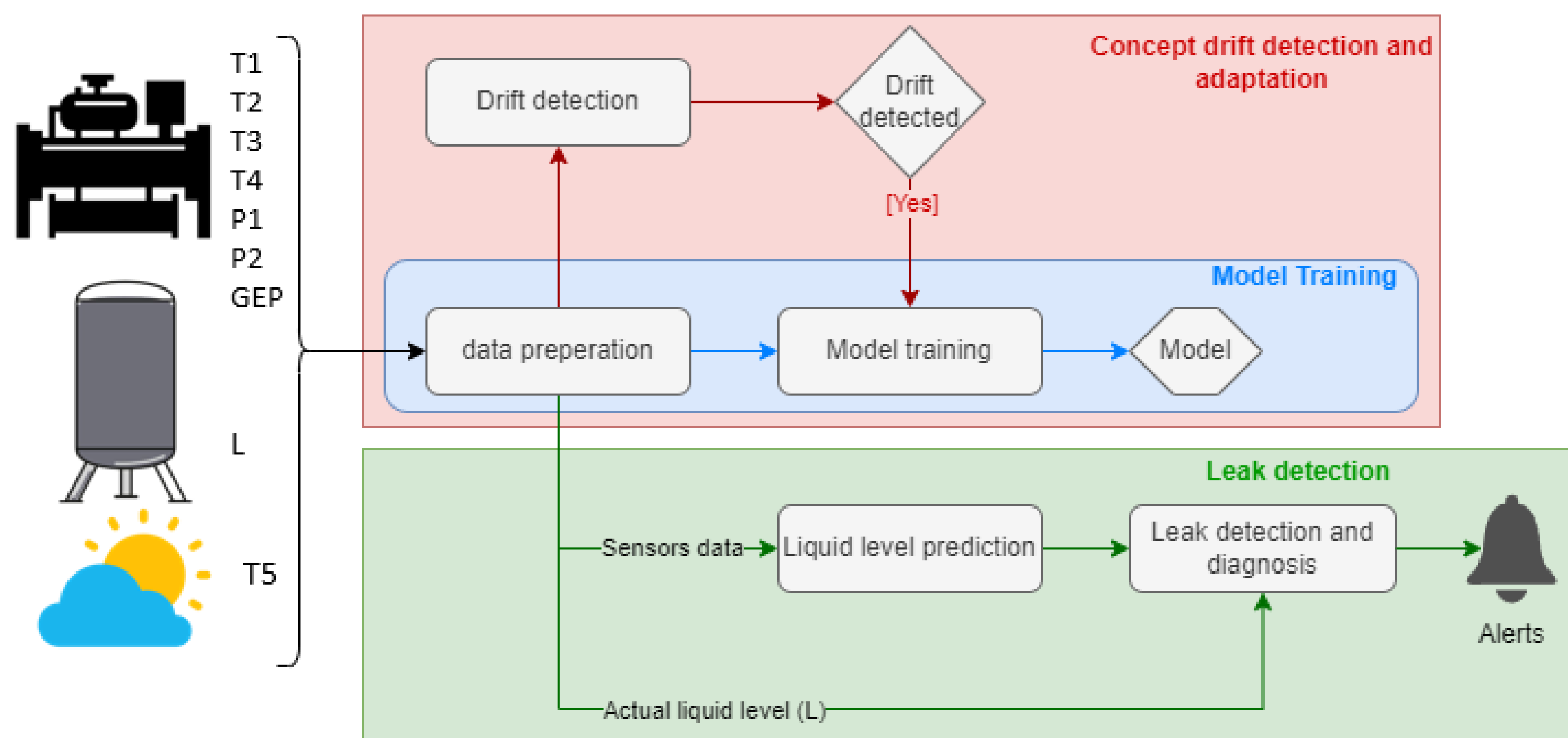
- L – Refrigerant liquid level in receiver

POWER [Kw]

G_{elec_power} – General electric power

$$= \sum_{k=1}^n \text{elec_power}(\text{Compressor}_k)$$

2. Data-driven approach



4. Leak detection and diagnosis

The predicted liquid level is compared to the actual liquid level in the receiver. A leak is identified when the measured liquid level drops in comparison to the predicted one.

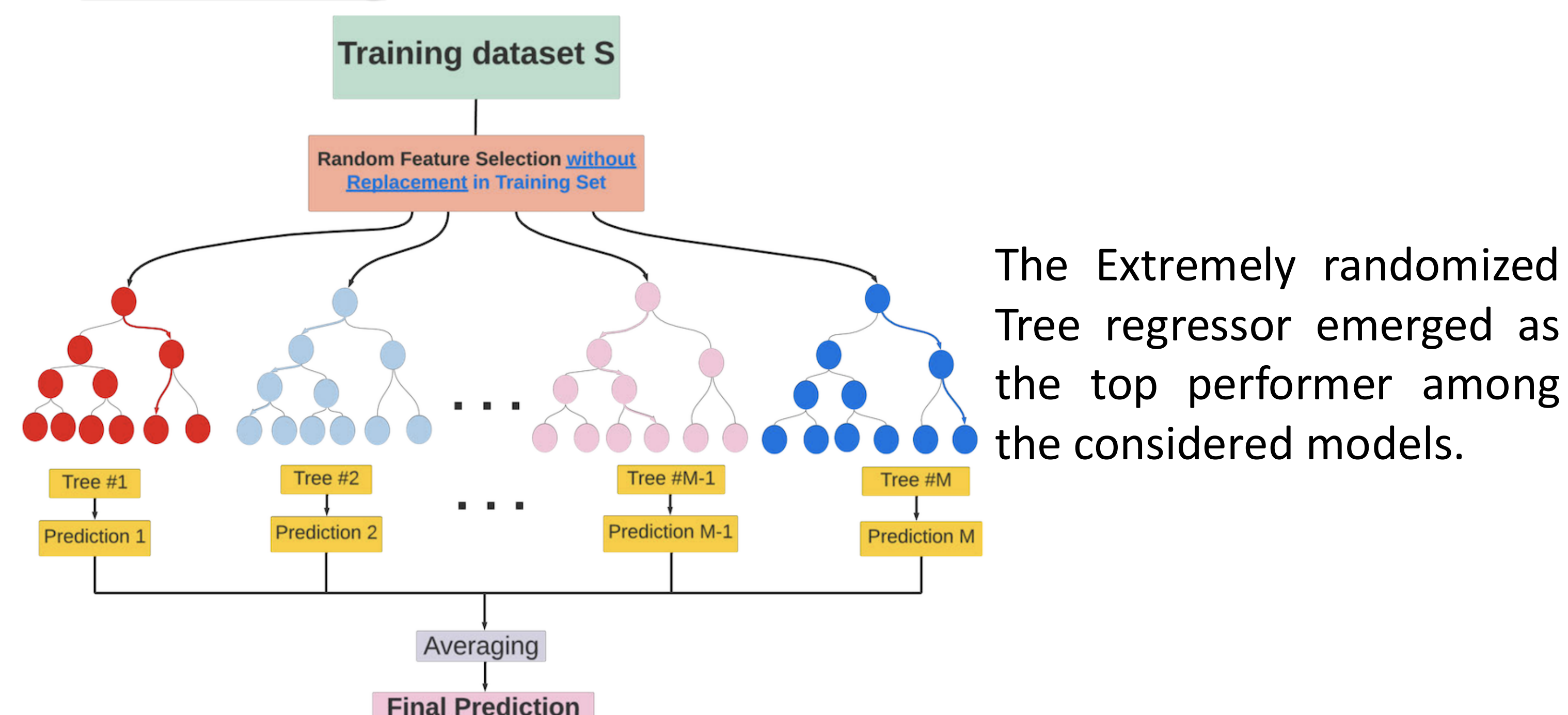
A dynamically calculated threshold based on the standard deviation around the mean of a moving window of the predicted values is used for anomalous points detection. A leak alert is activated when a certain percentage of consecutive points are identified as anomalous.



Diagnosis involves:

- Leak severity estimation
- Confidence level in detection.
- Fluid loss quantification

3. Model training



The Extremely randomized Tree regressor emerged as the top performer among the considered models.

Random Forest

Samples subsets through bootstrapping
Nodes are split looking at the best split
Medium Variance
It takes time to find the best node to split on

Extremely Randomized Trees

Samples the entire dataset
Randomized node split
Low Variance
Faster since node splits are random