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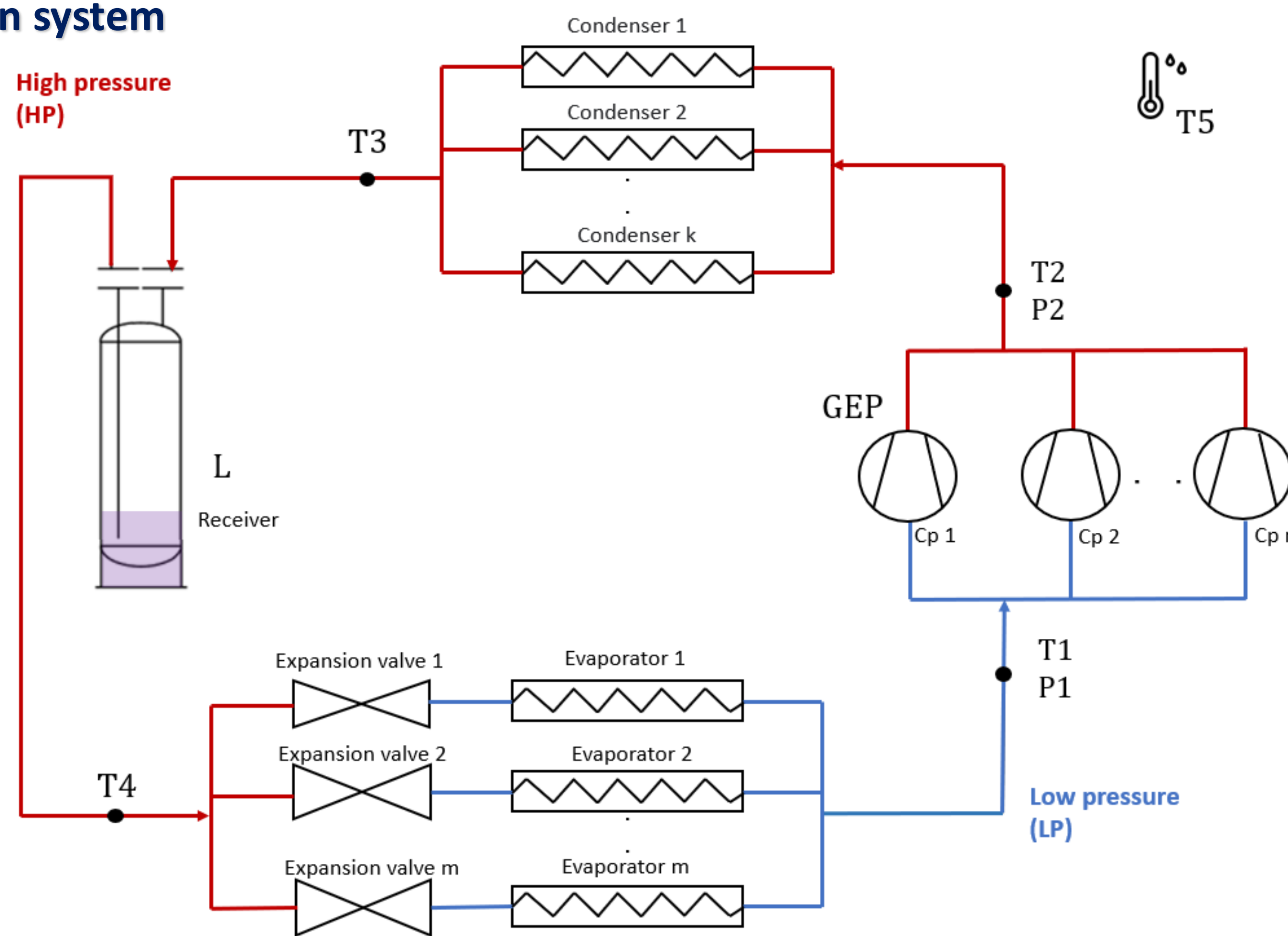
# Refrigerant leak detection in industrial vapor compression refrigeration systems using machine learning

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- 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<sub>sat</sub>, bar]

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

### LIQUID LEVEL [mm]

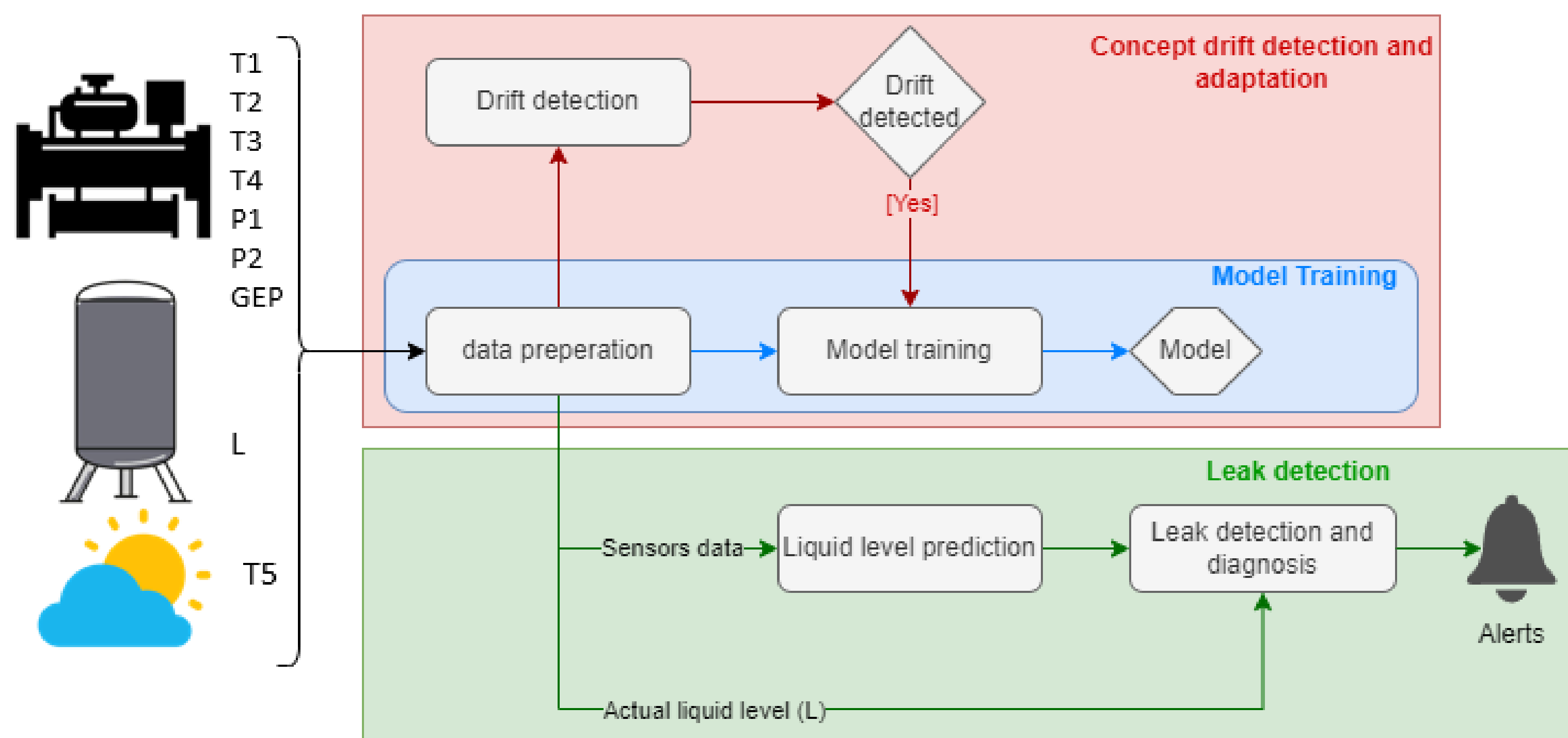
- L – Refrigerant liquid level in receiver

### POWER [Kw]

G<sub>elec\_power</sub> – 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.

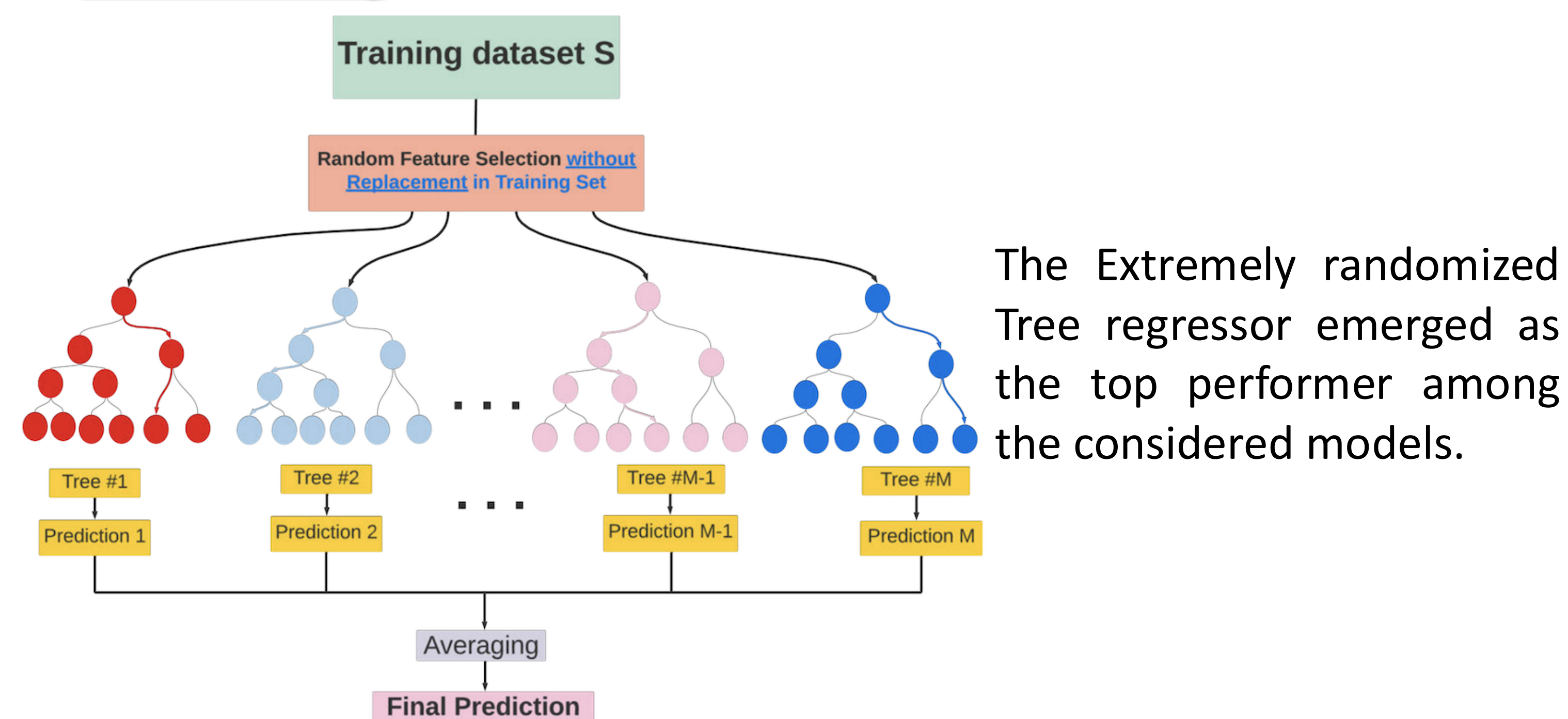
A dynamically calculated threshold based on the standard deviation around the mean of a moving window of the predicted values is used for anomalous points detection. A leak alert is activated when a certain percentage of consecutive points are identified as anomalous.



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