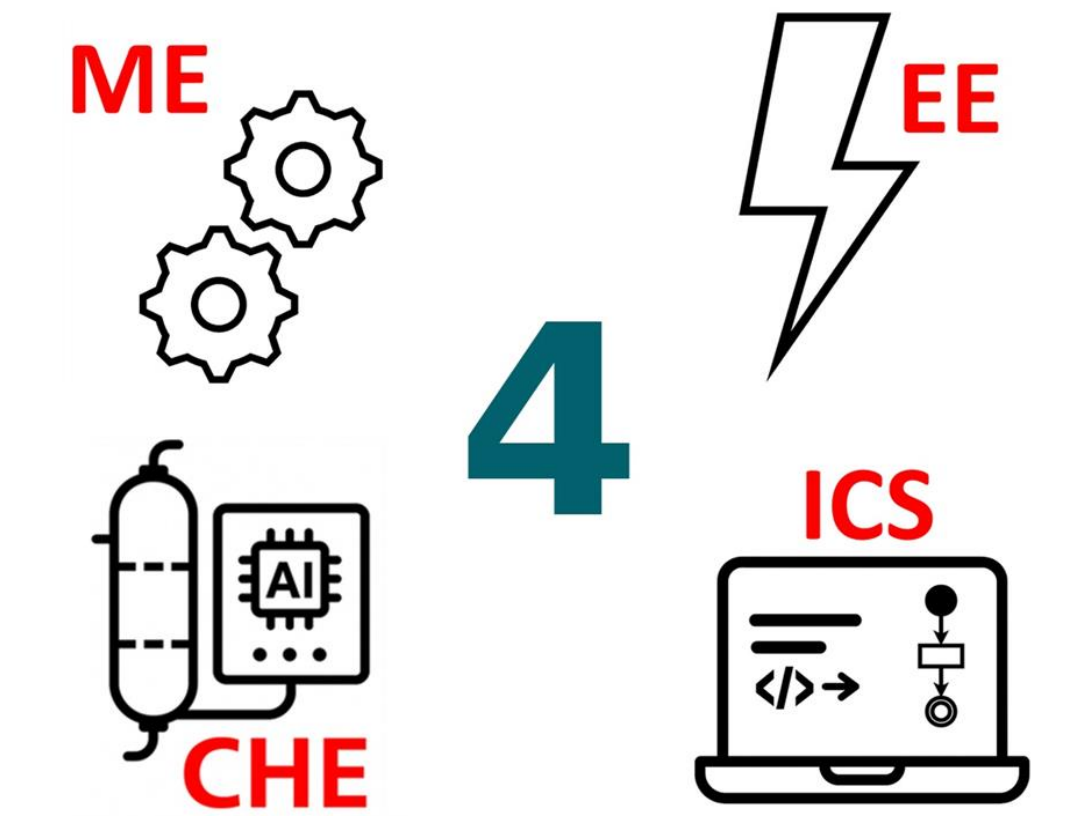


Intelligent Filtration System for Reliable and Clean Feed

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Problem Statement

Conventional hydrocarbon filtration systems rely on reactive monitoring, filter clogging is only detected after pressure drop or flow rate exceed thresholds, meaning blockage is already severe. This leads to unplanned shutdowns, downstream equipment damage, and costly manual interventions. No existing commercial solution combines early degradation detection with automated response in a unified system.

Solution

An intelligent multi-layer filtration system integrating a 3-stage filter (coarse, medium, fine) with continuous sensor monitoring (pressure, flow rate, optical turbidity sensor). An AI-based predictive model detects early clogging signs and automatically switches flow to a parallel standby filter, eliminating manual intervention and ensuring uninterrupted hydrocarbon feed.

Constraints

- Max operating pressure: 20 bar
- Max inlet temperature: 60°C
- Dashboard compatible with standard desktop web browsers
- Filter material cost (SS): ≤ 4,000 SAR
- All ESP32 signal interfaces: ≤ 3.3 V

Specifications

- Inlet velocity: 3.0–4.5 m/s
- Target cleanliness: ISO 4406 = 14/12/9
- Filter efficiency: $\beta_{10}(c) \geq 200$
- AI accuracy: ≥ 75%
- Dashboard updates every 30 min
- Two stainless steel filters in three layers
- Pressure sensor update rate: ≥ 5 Hz
- Control & instrumentation: ≤ 48W at 24V DC
- Pump: 750W at 220V AC

Prototype

The prototype consists of a physical system and a digital dashboard. The physical system includes a Feed Tank, Pump, 3-Way Solenoid Valve 1, Main Filter Unit (with Large, Medium, and Small filter stages), Spare Filter Unit, 3-Way Solenoid Valve 2, and Product Tank. It is equipped with Pressure, Concentration, and Flowrate sensors. The system is controlled by a Controller connected to an AI Model and a Data-Processing Interface. The Intelligent Filtration Dashboard provides real-time monitoring for pressure, flow rate, and turbidity, displaying key metrics like Pressure Drop (0.01 bar), Inlet Flow Rate (0.15 L/min), Outlet Flow Rate (0.02 L/min), Inlet Turbidity (10.00 NTU), and Outlet Turbidity (10.00 NTU). It also features trend graphs for Pressure Drop, Flow Rate, and Turbidity.

Testing and Validation

=== Evaluation Results ===
Accuracy: 0.9972364784840111
Error Rate: 0.0027635215159889093

Confusion Matrix:

```
[[ 4244  97  0]
 [ 1 10917  0]
 [ 0  0 20203]]
```

VARY 1	SILICAS	MIXED	TOTAL	W4	SSFLOW	KD/HR	VARY 2	DP	P1	P2	PSD3	PSD6	PSD9	PSD12	PSD15	PSD18	PSD21	PSD24	PSD27	PSD30	
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
60	1.00E-06	2.45E-07	10.1325	10.1325	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60	2.00E-06	2.45E-07	10.1325	10.1325	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60	3.00E-06	2.45E-07	10.1325	10.1325	1	4.35E-07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60	4.00E-06	2.45E-07	10.1325	10.1325	0.991068	0.008932	2.99E-27	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60	5.00E-06	2.45E-07	10.1325	10.1325	0.929599	0.070401	3.39E-20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60	6.00E-06	2.45E-07	10.1325	10.1325	0.91782	0.08218	4.88E-17	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60	7.00E-06	2.45E-07	10.1325	10.1325	0.915969	0.084031	1.84E-15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60	8.00E-06	2.45E-07	10.1325	10.1325	0.915443	0.084558	5.17E-15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60	9.00E-06	2.45E-07	10.1325	10.1325	0.915229	0.084771	6.52E-15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60	1.00E-05	2.45E-07	10.1325	10.1325	0.915122	0.084878	6.89E-15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60	1.10E-05	2.45E-07	10.1325	10.1325	0.915059	0.084941	7.02E-15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60	1.20E-05	2.45E-07	10.1325	10.1325	0.914992	0.084998	7.08E-15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60	1.30E-05	2.45E-07	10.1325	10.1325	0.914933	0.085056	7.11E-15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60	1.40E-05	2.45E-07	10.1325	10.1325	0.914873	0.085077	7.12E-15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
120	1.00E-06	9.81E-07	10.1325	10.1325	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
120	2.00E-06	9.81E-07	10.1325	10.1325	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
120	3.00E-06	9.81E-07	10.1325	10.1325	1	4.35E-07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
120	4.00E-06	9.81E-07	10.1325	10.1325	0.991068	0.008932	2.99E-27	0	0	0	0	0	0	0	0	0	0	0	0	0	0
120	5.00E-06	9.81E-07	10.1325	10.1325	0.929599	0.070401	3.39E-20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
120	6.00E-06	9.81E-07	10.1325	10.1325	0.91782	0.08218	4.88E-17	0	0	0	0	0	0	0	0	0	0	0	0	0	0



Conclusion

The intelligent filtration system successfully transitions hydrocarbon filtration from reactive to predictive operation. Multi-layer filtration, real-time sensor monitoring, and AI-driven condition assessment minimize unplanned shutdowns and maintain clean feed with minimal manual intervention. Future work includes:

- Scaling the system for full industrial deployment
- Exploring self-cleaning filter mechanisms