TEAM

F003

Smart Emissions Control System: Air-to-Fuel Ratio Optimization for NOx Reduction in Industrial Reactors

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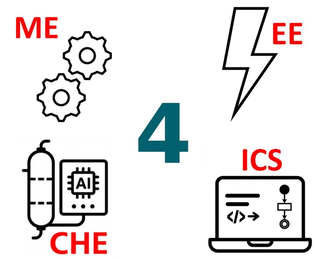


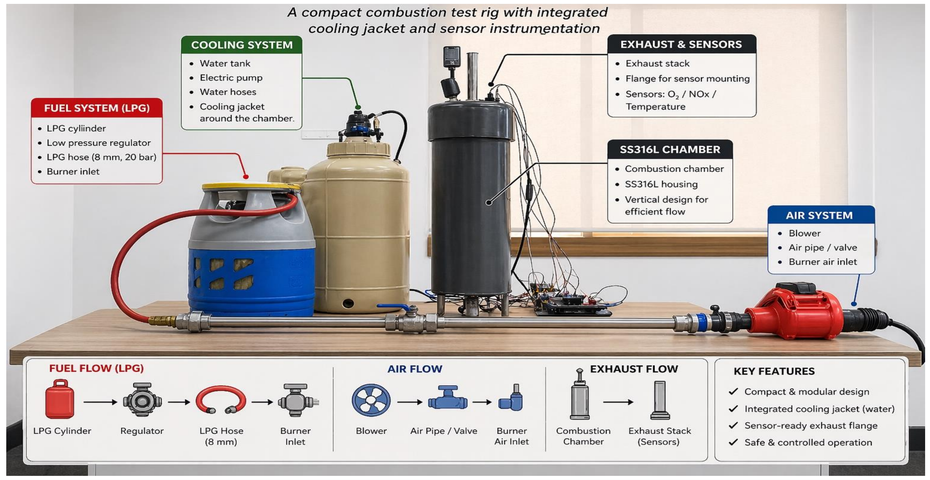
Problem Statement

Industrial combustion systems in refineries and petrochemical plants are major sources of harmful emissions, particularly **nitrogen oxides (NOx)** and **carbon monoxide (CO).** These emissions are highly sensitive to variations in the air-to-fuel ratio (AFR), which directly affects pollutant formation. Conventional control methods cannot handle real-time disturbances, causing combustion systems to operate away from optimal conditions, resulting in higher NOx and CO emissions, reduced efficiency, and instability.

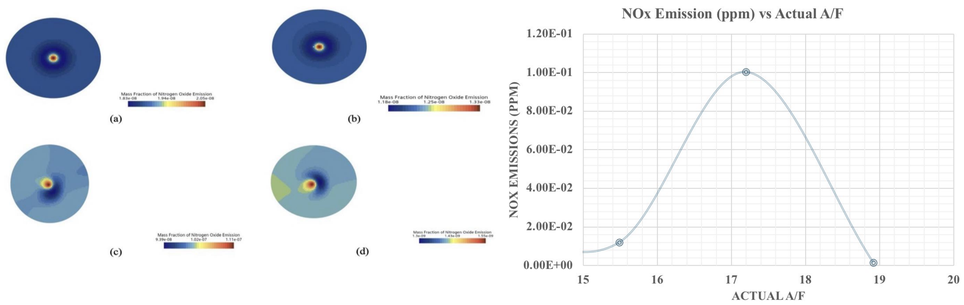
Proposed Solution

The system integrates gas sensors, a microcontroller-based PI controller, and an air/fuel actuator to regulate combustion. By continuously comparing measured NOx levels with a target value, the controller adjusts AFR to compensate for disturbances and maintain optimal operation. This approach **reduces NOx emissions, maintains safe CO levels**, and improves efficiency and system stability.

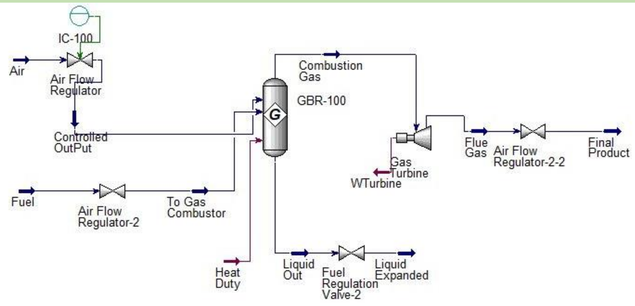
Prototype



Testing and Validation



Aspen HYSYS Simulation



Constraints

- Operates within a safe voltage range of **3.3–15 V DC**
- CO emissions must **remain ≤ 300 ppm**
- **Pipes rated ≥ 1.5×** operating pressure
- Safe operation under thermal conditions

Specifications

- Response time **≤ 5 s**
- Sensor accuracy **± 5 ppm**
- Dashboard update **≤ 2 s**
- Data logging **≥ 95%**
- Outlet temperature maintained ≤ 1700

Integrated Specifications

- NOx reduction **≥ 20%**
- System uptime **≥ 80%**
- Air-Fuel Ratio: **0.8 ≤ λ ≤ 1.2**

Conclusion

This project **demonstrates** a Smart Emissions Control System that improves combustion through real-time AFR control. The system effectively reduces NOx emissions, maintains safe CO levels, and **ensures stable and efficient operation under disturbances**. The proposed approach offers a practical and scalable solution for cleaner and more efficient industrial combustion.