

A05 — BioPower / BioGrate combustion

FMU model and guide for PLC programming

Version 1.0

Student exercise — Homa Virtual Plant (Model-in-the-Loop)

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1. Exercise objective

You are given an **FMU model** representing a biomass boiler (BioGrate) with power and O₂ control. Your task is, through **Homa Virtual Plant** to connect a PLC to this model and write a **PLC program that controls the process** according to the given objectives.

This is a **Model-in-the-Loop (MIL)** setup: the model mimics a real plant, your PLC drives it, and you develop and test your program on a virtual system. The model is “open” — it contains no controller of its own; **all control is performed by your PLC** through the model inputs.

2. Process description (what the model represents)

The boiler burns biomass on a grate. The PLC controls the combustion power (via fuel feed) and O₂ (via primary air), while monitoring the drum pressure and bed height. Fuel moisture and steam demand are disturbances.

Available / in the process:

- u_fuel_feed: fuel feed (main influence on power).
- u_primary_air: primary air (influence on O₂ and combustion).
- Fuel moisture and steam demand change the response (disturbances).

3. FMU interface — signals

This is the most important part. Pay attention to the signal direction:

Signal direction: what is an **INPUT** for the FMU is an **OUTPUT** (command) for your PLC, and vice versa. The actuators your PLC **writes**; the measurements your PLC **reads**.

3.1. FMU inputs

a) Actuators — controlled by your PLC (PLC outputs):

Variable (FMU)	Type	Unit	Range	Description
u_fuel_feed	Real	–	0.0 – 1.0	Fuel feed
u_primary_air	Real	–	0.0 – 1.0	Primary air

b) Disturbances / scenario — the environment, NOT controlled by your PLC:

Variable (FMU)	Type	Unit	Range	Description
u_moisture_estimate	Real	–	0.0 – 1.0	Fuel-moisture estimate
u_steam_demand	Real	–	0.0 – 1.0	Steam demand

You set the disturbances on the **PLC HMI** (as a parameter / simulated sensor), and the PLC forwards them to the FMU. They are not an output of your controller.

3.2. FMU outputs (measurements the PLC reads)

Variable (FMU)	Type	Unit	Range	Description
y_combustion_power	Real	MW	0 – ~25	Combustion power

Variable (FMU)	Type	Unit	Range	Description
r				
y_drum_pressure	Real	bar	~20 – 50	Drum pressure
y_oxygen	Real	vol-%	0 – 15	Oxygen
y_bed_height	Real	–	0 – 1.2	Bed height

4. What the PLC must achieve (control objectives)

Your PLC program must:

1. Control the combustion power (y_combustion_power) via the fuel feed.
2. Trim O₂ (y_oxygen) via the primary air.
3. Monitor the drum pressure and bed height (limits).
4. Compensate fuel moisture (feedforward) and disturbances.

The objectives are given; **you design the control method yourself** (a suggested structure is provided below as an aid).

5. Suggested control structure (guideline)

Cascade loops (0.5 – 2 s control):

- Power PI: y_combustion_power vs setpoint → u_fuel_feed (+ moisture feedforward).
- O₂ PI: y_oxygen vs setpoint → u_primary_air.

Supervisory (10 – 60 s):

- Limit fuel at high y_bed_height; monitor y_drum_pressure.

6. Recommended sample times

Layer	Recommended cycle
Control	0.5 – 2 s
Moisture / bed supervisory	10 – 60 s
FMU co-simulation communication step	~1 s

7. Test scenarios and acceptance criteria

Scenario	How to trigger	Expected PLC behaviour	Pass criterion
Moisture step	u_moisture_estimate rises	fuel compensation	power stays stable
Fuel step	u_fuel_feed step	power/O ₂ response	stable recovery
Demand ramp	u_steam_demand rises	adjustment	drum pressure within the limit
Frozen sensor	freeze y_oxygen	robustness	no runaway
Actuator limits	demand beyond limits	saturation	no windup

General criteria: controlled variables within limits, no instability / excessive cycling, correct response to faults.

8. Integration into Homa Virtual Plant

5. Load `Plant.fmu` (the compiled model) into Homa VP.
6. Map the FMU variables: **actuators** (`u_*`) as PLC outputs, **measurements** (`y_*`) as inputs.
7. Disturbances (`u_moisture_estimate`, `u_steam_demand`) are set on the HMI as operating conditions and tests; the PLC forwards them to the FMU.
8. Select a communication channel (e.g. OPC UA / S7) and run the closed loop.

The model is configured for **StopTime 600 s** (Interval 1 s). Real-time pacing is driven by Homa VP via a speed factor.

9. Notes on the model

Important: the model is a simplified starter plant for developing and testing PLC logic — **it is not a validated industrial model**. The parameters are illustrative; calibrate them before real use.

- The dynamics are approximate; the purpose is a control exercise, not exact process analysis.