

B04 — PV array with power curtailment (EMS)

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 photovoltaic (PV) array with an energy-management system (EMS). 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 PV array provides **available power** (`y_available_power`) depending on irradiance and temperature. The plant has a grid-export limit and its own site load.

Available / in the process:

- **EMS task:** the PLC sets the delivered-power fraction (`u_curtailment_cmd`) to respect the export limit.
- **HMI setpoints:** the site load (`SiteLoad`) and export limit (`ExportLimit`) are set on the HMI.

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
<code>u_curtailment_cmd</code>	Real	–	0.0 – 1.0	Delivered-power fraction (EMS)
<code>u_enable</code>	Real (0/1)	–	0 or 1	Enable

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

Variable (FMU)	Type	Unit	Range	Description
<code>u_plane_irradiance</code>	Real	W/m ²	0 – ~1000	Plane-of-array irradiance
<code>u_module_temperature</code>	Real	K	~270 – 330	Module temperature

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
<code>y_available_power</code>	Real	kW	0 – ~200	Available power

Variable (FMU)	Type	Unit	Range	Description
y_delivered_power	Real	kW	0 – ~200	Delivered power
y_energy	Real	kWh	≥ 0	Cumulative energy
y_dc_current	Real	A	0 – ...	DC current

4. What the PLC must achieve (control objectives)

Your PLC program must:

1. Deliver as much power as possible without exceeding the export limit (limit + site load).
2. Set u_curtailment_cmd = desired / available, with 0..1 limiting.
3. React smoothly to clouds (sudden drop/rise in irradiance).
4. Connect/disconnect safely.

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

5. Suggested control structure (guideline)

EMS calculation (0.5 – 5 s):

- $\text{PowerCommand} = \min(y_{\text{available_power}}, \text{SiteLoad} + \text{ExportLimit})$;
 $\text{u_curtailment_cmd} = \text{PowerCommand} / y_{\text{available_power}}$ (limit 0..1).
- Protection against division by zero at low available power.

Energy management (10 – 60 s):

- Export profile through the day; coordination with a battery (if present).

6. Recommended sample times

Layer	Recommended cycle
EMS calculation / limit	0.5 – 5 s
Energy management	10 – 60 s
FMU co-simulation communication step	~1 s

SiteLoad and ExportLimit are HMI parameters, not FMU variables.

7. Test scenarios and acceptance criteria

Scenario	How to trigger	Expected PLC behaviour	Pass criterion
Cloud passing	u_plane_irradiance sudden drop	fast delivery adjustment	no limit exceedance
Export limit	reduce ExportLimit (HMI)	reduce delivery	$y_{\text{delivered_power}} \leq \text{limit}$
Shutdown	u_enable = 0	delivery to 0	safe interruption
Limit ramp	slowly change ExportLimit	smooth tracking	no jumps
Stale sensor	freeze y_available_power	robustness	no runaway

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_plane_irradiance, u_module_temperature) 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.
- SiteLoad and ExportLimit are HMI parameters used by the EMS; they are not exposed as FMU variables.