Time-Series Microgrid (PV+BESS), LV Radial — Rome

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Objective — Develop and validate a reproducible 1-minute time-series model of a low-voltage radial microgrid with distributed PV and BESS, quantifying self-sufficiency, self-consumption, node voltages, and Joule losses over a full year.

System & Methods

- LV 400 V, 16-bus radial network; slack at central square (bus 1). Residential, low-density district (villas + two apartment buildings).

- Power flow: optimized Backward/Forward Sweep; all buses remain within ±5% for the entire year (525,600 minutes).

- PV: PVGIS Rome 2023 (1 kWp), hourly → 1-min PCHIP; scaled by installed $P_{\max}$.

- BESS (baseline dispatch): P-only, dead-band, SOC-safe limits (10–95%), η_c, η_d; charge on surplus, discharge on deficit.

- Annual pipeline: daily MAT → robust energy balance → monthly/annual CSV KPIs; plotting utilities (voltage maps, slack P/Q, PV vs load, self-sufficiency trends).

What I built

- End-to-end simulation workflow (day/range/year) with stateful SOC carry-over.

- Robust post-processing: import/export split at slack; Joule losses excluding slack injections; daily/monthly/annual KPIs.

- Verification suite: time-series vs robust consistency, voltage-limit assertions, "smoke tests" with figures and KPI tables.

Where I can contribute

- EMS/microgrid integration, BESS scheduling (MPC/MILP), droop control (P–f, Q–V), KPI automation, grid-forming studies, reproducibility.
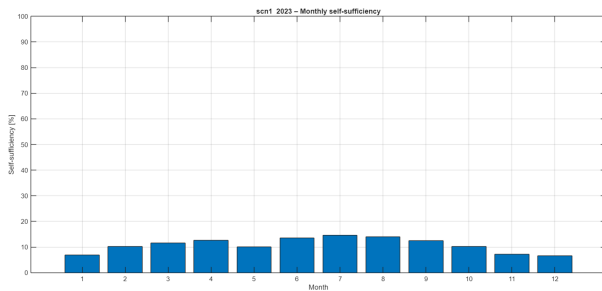
Key results (2023, multiple scenarios)

- Self-sufficiency from 0% (passive) to 60.3% with distributed PV and 4 BESS (incl. central and school units).

- Exports up to 75,426 kWh when PV is abundant; imports remain similar to the previous step because baseline dispatch is P-only and capacity-limited.

- Joule losses < 1% of circulating energy (≈ 0.7–$1.4\,\mathrm{MWh/year}$); voltages within ±5% for the entire year.

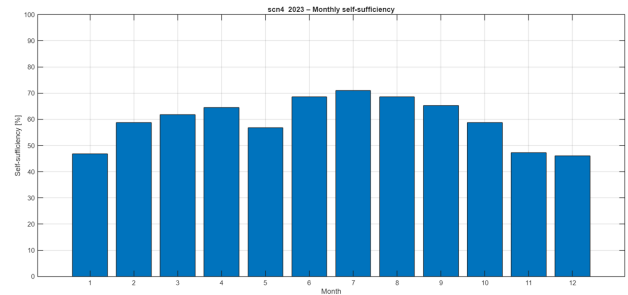**Figure 1:** Monthly self-sufficiency — `scn1` (3 PV)

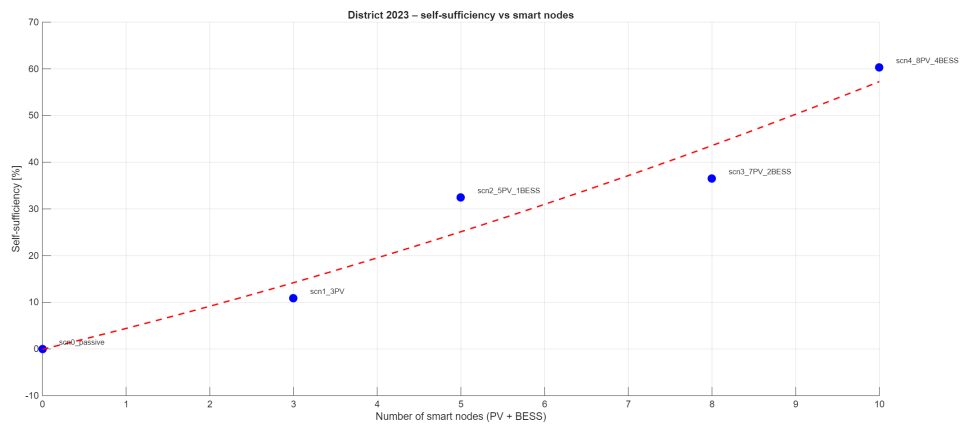**Figure 2:** Monthly self-sufficiency — `scn4` (8 PV + 4 BESS)

Figure 3: Annual self-sufficiency vs number of smart nodes (PV/BESS); non-linear gains, diminishing returns at mid-penetration.

Reproducibility — Code repository and full report link: available upon request.

Keywords: LV microgrid, BFS, PVGIS, BESS dispatch, self-sufficiency, Joule losses, time-series KPIs, MATLAB.