Optimization of self-consumption for PV systems with heat pumps and batteries

info@csem.ch www.csem.ch

Y. Stauffer, N. Koch, T. Gorecki, A. Hutter

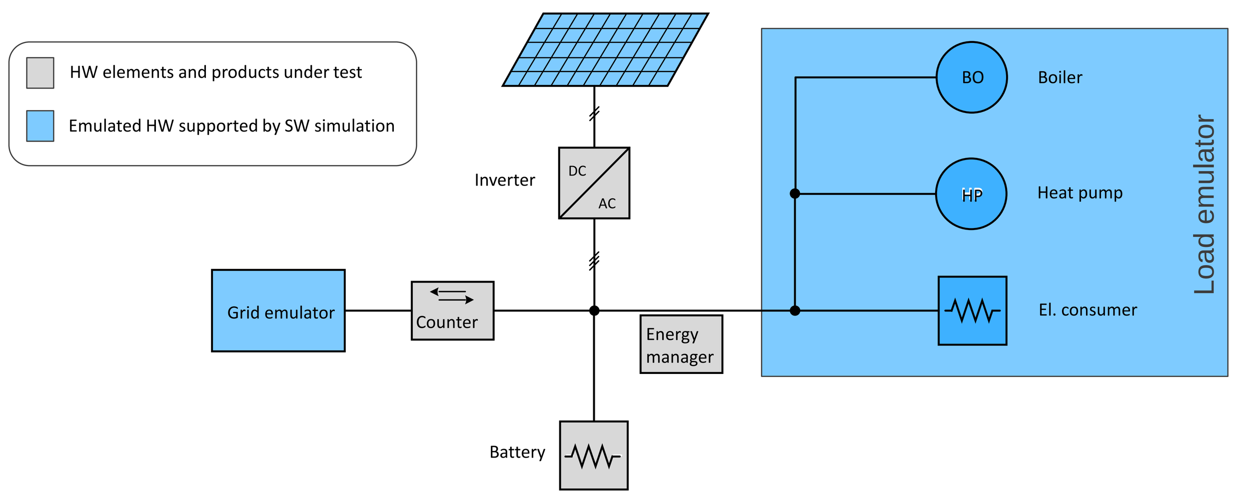
CSEM SA, Switzerland

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Federal Office of Energy SFOE

In the SFOE funded ProsumerLab project, CSEM investigated energy management systems (EMS) in a controlled environment to assess their self-consumption (SCR) and operational expenses performances. The test bench is composed of PV/grid/load emulators and physical batteries. The building, in particular the heat-pump (HP), tanks and heat demand are emulated using Polysun. The EMSs' SmartGrid ready like output was used to perform overheating of the domestic hot water and/or space heating tanks to maximize SCR. Given the real time execution of the physical tests, yearly results were achieved via simulations by coupling Polysun to Matlab. The three tested EMSs increase the SCR by 3-4% (w.r.t. no EMS). Tests using modulated HPs (i.e. the EMS controls the amount of power to be drawn by the HP), increased the SCR to 5% (w.r.t. no EMS).

The setup



The HIL ProsumerLab test bench is composed of the following elements:

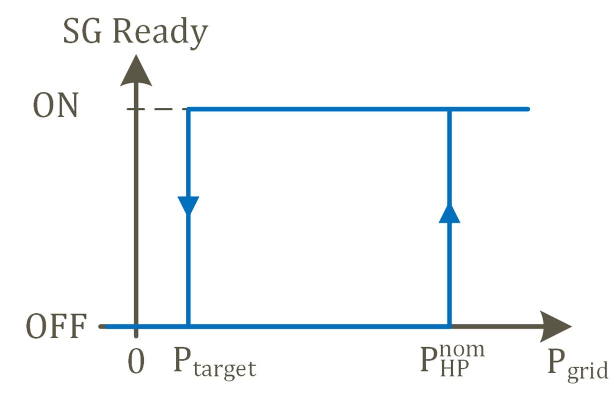
- Batteries: VARTA (elements 6, 6.4kWh) & Tesla (powerwall 1, 6.4kWh). The batteries can easily be changed, other models can be incorporated
- Energy manager: different EMS can be connected
- PV emulator & inverter: 8x 62050H-600S Chroma 5kW DC, SMA Sunny Tripower 7000TI 7kW
- Grid emulator: TC.ACS Regatron 50kW
- Load emulator: TC. ACS Regatron. In order to emulate the behavior of a building, the load emulator is driven by a Polysun simulation running in real time.

The three tested EMSs

Three commercial EMSs that aim at maximizing self consumption by driving controllable loads were tested. In this context the objective was to control the heat pump (HP) in order to minimize grid exchanges. The logic of the EMSs is very similar:

Turn HP ON condition: $P_{grid} > P_{HP}^{nom} + P_{target}$ **and** $time_{min}^{ON}$ **over**

Turn HP OFF: $P_{grid} < P_{target}$ **and** $time_{min}^{OFF}$ **over**



Where:

- P_{target} : minimal power level
- P_{HP}^{nom}: nominal HP power level
- P_{grid}: power exchange with the grid
- $time_{min}^{ON}$, $time_{min}^{OFF}$: minimal ON / OFF time of the EMS output

Test results and analysis

To ensure meaningful results:

- different types of buildings were tested (well, average and poor insulation)
- different usage were included (working couple and family with kinds)
- PV and battery sized according to the 1:1 rule

In addition, to assess the pertinence of the findings:

- PV, storage tank and battery sensitivity analysis were conducted
- Standard HP control (ON/OFF) and modulated HP control were done

Impact of EMS type, HP control mode and batteries on SCR

The results of the 3 EMSs are summarized in Table 1. It can be highlighted that:

1. The average SCR increase is 4%.
2. Adding HP modulation increases the SCR to 5%. The HP electrical power is modulated to cancel out grid injections.
3. Adding batteries increases the SCR to 49%. Batteries are controlled to minimize grid exchanges (bi-directional).

Given the similar control logic that drives the 3 EMSs the similarity in result was expected.

Table 1: EMS test results (standard HP and modulated HP control)

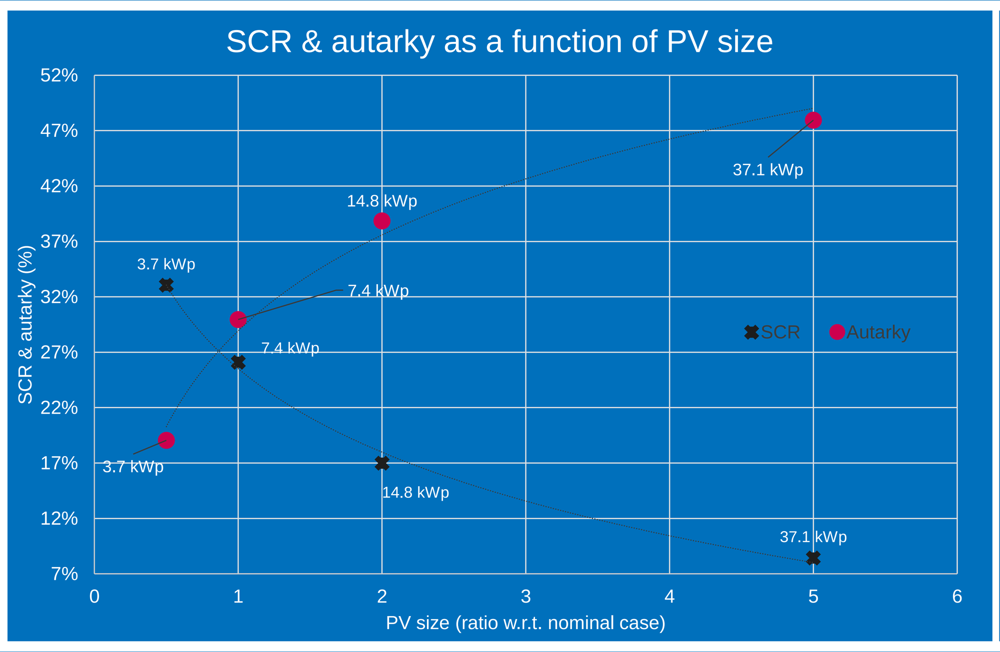
HP control type	ON/OFF	ON/OFF			Modulated	ON/OFF
Controller	ref.	EMS1	EMS2	EMS3	EMS1	ref. with battery
SCR	21%	24%	24%	25%	26%	49%
SCR increase w.r.t ref.	-	3%	4%	4%	5%	28%

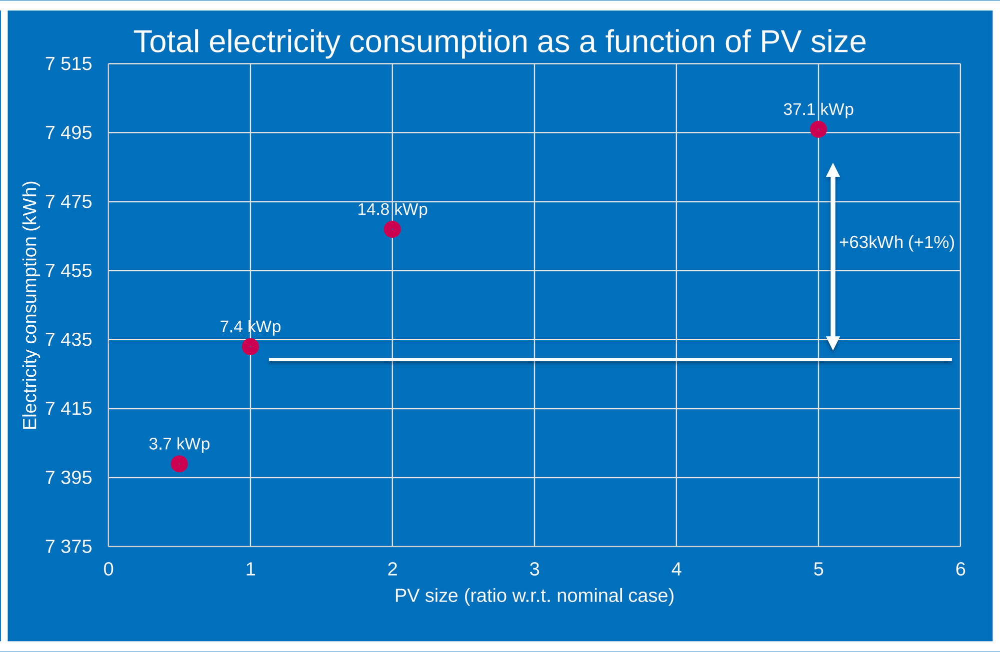
Impact of PV sizes

As expected, for bigger PV installations the SCR decreases whereas the autarky increases.

Interestingly, the total electric consumption also increases with larger PV plants. This effect is linked to:

- increased tank heating that induces more losses
- more HP activations, that lead to higher energy usage





Cost analysis

Table 2: yearly electricity costs for different configurations under various tariffs (negative values indicate earnings), the cost increase w.r.t ref. is given in parenthesis.

Condition	ref	EMS3	EMS1	EMS2	Modulated	Battery
Grid parity	-237	-226 (+11)	-229 (+9)	-226 (+12)	-231 (+7)	-136 (**+101**)
Interesting feed in tariff	394	377 (-16)	379 (-14)	379 (-15)	364 (-30)	288 (-106)
Low feed in tariff	1084	1038 (-46)	1045 (-39)	1040 (-44)	1015 (-69)	752 (**-332**)

Yearly costs are highly dependent on the electricity tariffs.

In case of grid parity, increasing SCR is not desirable

For low feed in tariffs, operational costs can be reduced by promoting self consumption

Conclusions

The performed work showed that:

1) Tested EMSs provide marginal SCR increase, the full potential is not used. Improvements, based on model predictive control for instance, would improve economic impact.
2) Batteries significantly increase the SCR. Their installation costs are very high which currently limit their financial attractivity
3) HW and commissioning costs of EMSs (~1000CHF) are high with respect to yearly savings (~40chf with favorable electricity tariffs).
4) Economic benefits are on large installations (multi family houses) are achieved faster.