THE SYSTEM FRIENDLINESS OF SOLAR SELF-CONSUMPTION UNDER DIFFERENT REGULATORY REGIMES

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Overview

The cost of photovoltaics (PV) has drastically declined over the last decade, a development that is transforming energy markets worldwide [1]. Residential PV systems have a strong economic appeal to consumers in many parts of the world as they allow for local, clean electricity generation which can be efficiently self-consumed at the spot. The time variability of solar generation can be partially offset with the additional use of batteries, thereby increasing self-consumption rates substantially in such combined PV battery systems [2]. Since batteries likewise seem to be on a similar cost decline trajectory as previously PV [3], these systems are becoming economically viable for end-consumers under certain regulatory regimes and local solar generation potentials [4], [5].

Residential PV battery systems are not free of concerns, however, both technically and economically. Their economic attractiveness depends largely on the avoided costs for retail electricity. In Germany, for example, consumers are subject to average retail electricity prices of around 0.29 €/kWh, while solar electricity can be produced for 0.12 €/kWh or less under ideal conditions. So-called “prosumers” have thus an incentive to self-consume as much of their locally generated electricity as possible. Since the retail electricity price consists only partly of the cost of generation, but also incorporates grid fees, taxes, levies etc., local self-consumption is attractive because one avoids to pay for those extras. Self-consumption to minimize consumer payments for electricity differs substantially from the traditional way of offering electricity at the competitive wholesale market. PV battery systems are hitherto *not* “system optimal” or “*system-friendly*”, as their incentives to being built and operated are not in line with overall optimal system operation (assuming a frictionless, centrally optimized power system). This situations incurs additional costs and introduces economic inefficiencies [6]. Furthermore, as prosumers circumvent network fees, retailers have to recuperate their costs by increasing fees for existing consumers thus again increasing the appeal of self-consumption (reinforcing the risk of a so-called “utility death spiral”).

So far, there is only very limited quantitative research on the system effects of PV battery systems, the possible parasitic effect on the overall energy system and what can be done about it. The following paper thus want to delve into the two following questions: What constitutes a “system-friendly” charging and discharging behavior of PV battery systems? And: How can regulators influence the operational variables of these systems?

Methods

Three regulatory interventions are investigated, making up for 2^3=8 different cases:

- **Capacity based tariffs (C)** vs. volumetric network charges (BAU)
- **Real time pricing (RTP)** vs. constant /kWh tariffs (BAU)
- **Time variable feed-in tariffs (vFIT)** vs. constant FIT (BAU)

To evaluate these 8 regulatory scenarios, we propose a so-called *system-friendliness indicator* that measures how the household battery dispatch matches with that of the ‘ideal’ case (i.e. an arbitrage battery of the same size solely reacting to wholesale market price signals). It measures the difference between the charging state (CS) of the arbitrage case and the evaluated case as follows:

$$SFI(t) = 1 - \frac{\sum_{t=1}^{T}\left(cs_{arbitrage}(t) - cs_{actual}(t)\right)^2}{2T}$$

The charging state (CS) is either 1 (charging), -1 (discharging) or 0 (else). The SFI is normalized so that it can take values from -1 (completely system-unfriendly (charges when an arbitrage battery would discharge and vice versa) and +1 (same charging and discharging behavior than an arbitrage battery of the same size). Both the arbitrage and the policy scenario are optimized to maximize revenue. To obtain the optimum interaction between the system components, a mixed integer linear programming (MILP) problem has been developed investigating the household solar self-consumption in Germany with regards of different tariff structures (details in the extended version).

Results

Figure 1(a) and (b) shows the main results of the study. All alternative policies show a higher system-friendliness than the current BAU case. The combination (RTP + vFIT) has the highest SFI, as time-varying price signals for both generation and consumption get transmitted to the prosumer. Capacity based tariffs do not have a considerable effect on SFI, but can alleviate the cross-subsidies between consumers to prosumers. Alternative policies all have comparable profitability for consumers (measured in terms of IRR, details in the extended version).

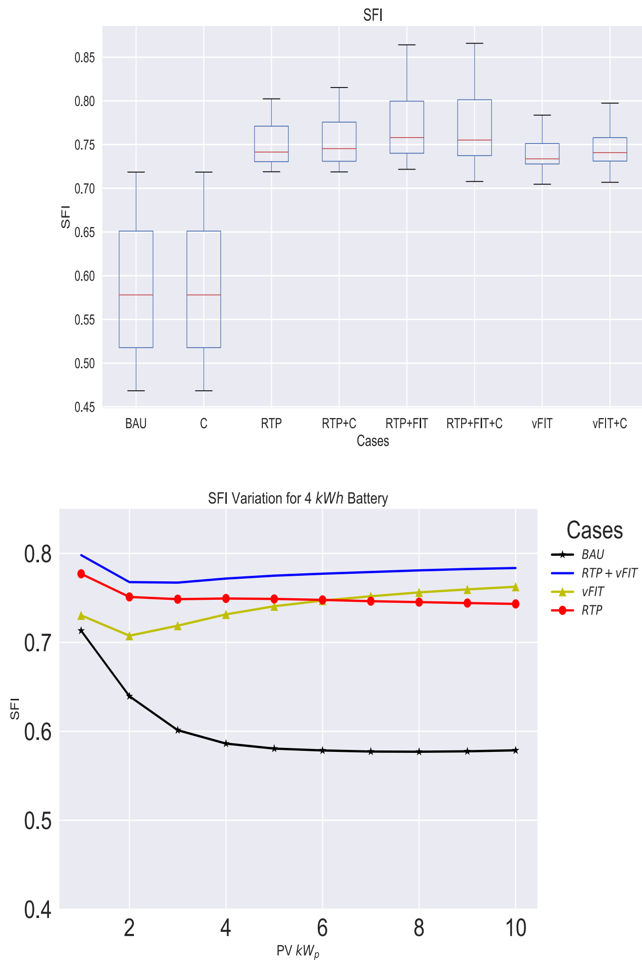

Figure 1: System-friendliness (SFI) of PV battery systems for different regulatory regimes

Conclusions

Policy makers can achieve most of the benefits with 'simple' changes like implementing a variable FIT. Variable schemes offer a reduction in avoided fees which could also help in the issue of avoided network charges. Next, the cases will be evalutad for future scenarios with higher shares of RES and storage in the system. The future market prices are simulated with the help of an agent-based market model [7]. Additionally, alternative SFI formulations will be tested, e.g. time-weighting of the SFI with the spot-market price.

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