SYSTEM CONTRIBUTIONS OF RESIDENTIAL BATTERY SYSTEMS: NEW PERSPECTIVES ON PV SELF-CONSUMPTION

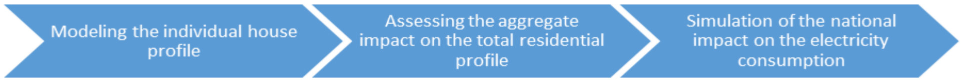
Hyun Jin Julie YU, CEA (French Alternative Energies and Atomic Energy Commission)
Phone +33169086710, E-mail:julie.yu@cea.fr

Overview

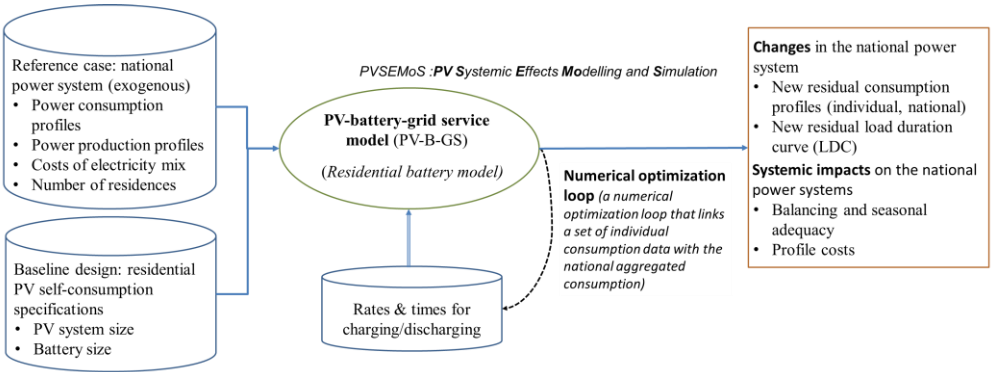
The market dynamics of the PV sector and coupled Li-ion batteries are likely to enhance the economics of residential PV self-consumption in the near future. When PV self-consumption systems become economically competitive, end-users will be willing to switch to PV self-consumption instead of using power from the grid. However, the large penetration of PV systems in the electricity mix provokes systemic effects (e.g. additional costs related to the integration of PV into the existing electricity system). The majority of the systemic costs concern the back-up power system associated with variable PV integration. These costs vary from one country to another because of the different energy profiles. France has higher back-up power costs since France's annual electricity consumption peaks occur in the winter evenings. This means that the massive and rapid integration of PV without systemic strategies can affect the energy system and stakeholders. In this context, this study proposes an innovative grid service model based on the secondary application of residential batteries installed for PV self-consumption. Our optimization model to minimize the cost of residential PV self-consumption deployment at the system level is based on the strategic utilization of residential batteries when they are not in use in the winter months. Our study identifies potential opportunities for the strategic utilization of residential battery systems in France to reduce systemic costs in line with the large diffusion of PV self-consumption in the future. Our study also identifies optimal grid service conditions and evaluates the extent to which this model can reduce PV integration efforts (e.g. balancing and seasonal back-up capacities). We performed an economic analysis to calculate the savings made in terms of PV integration costs and the benefits resulting from the secondary use of batteries. Our study then concludes with several key messages and policy recommendations to prepare the proper institutional and political strategies.

Methods

Our study includes the following steps:



We developed an optimization model of the PV-battery-grid service (PV-B-GS) to increase the systemic value of residential PV self-consumption in France. This involved developing a numeric simulation tool that defines the mechanism behind the optimal use of residential batteries for peak shaving. The following schematic (conceptual) diagram explains the logical flow of our model.



Logic flow diagram of the PV-B-GS (PV-battery-grid service) model (proposed by author)

This PV-B-GS model has been developed based on PV self-consumption systems coupled with Li-ion batteries in the French residential sector. We first defined the input data of the PV-battery system specifications to design the French residential PV self-consumption model. The French transmission system operator (RTE, Réseau de transport d'électricité) provides an open platform for its energy system database (RTE, 2018). Our simulation thus uses exogenous data based on the national hour-by-hour power consumption by segment and the national PV hour-by-hour production from RTE. The model aims at minimizing the national demand peaks, and the optimal parameters are defined via a numerical optimization loop that links a set of individual consumption data with the national aggregated consumption. The scope of analysis includes the systemic effects resulting from the secondary-use application of residential batteries in the winter months. The systemic effects are measured with the numerical tool known as PVSEMoS (PV Systemic Effects Modelling and Simulation). Our analysis is based on three scenarios:

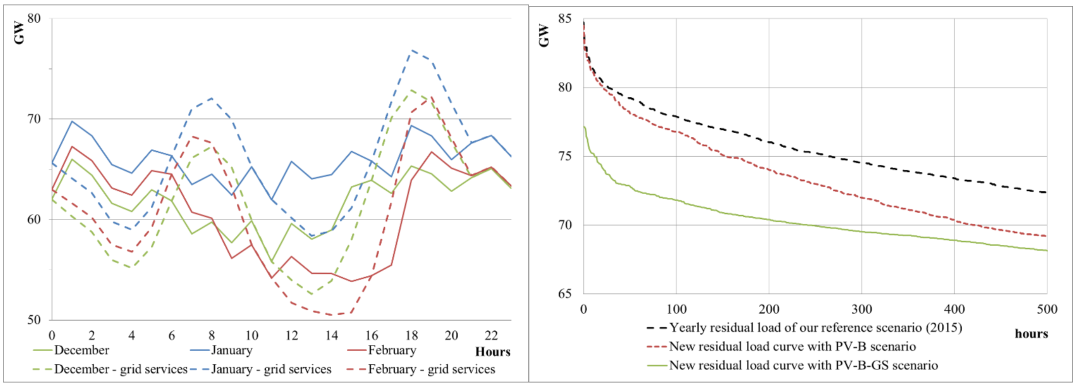
- Reference case: 2015 situation of PV integration (PV Ref.)

- Scenario 1: PV self-consumption with batteries (no grid injection) (PV-B model)
- Scenario 2: PV self-consumption with batteries + new grid services (no grid injection) (PV-B-GS model)

Results

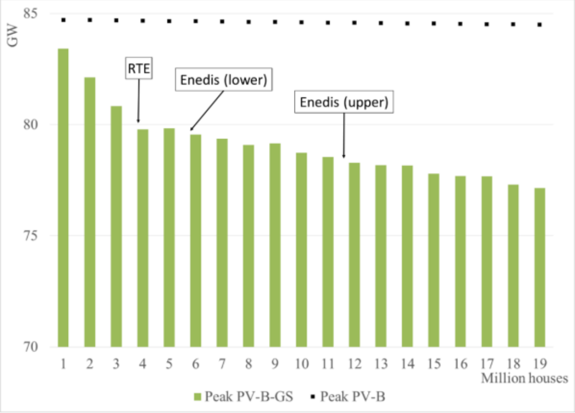
Systemic effects

1) Smoothing daily variations (peak shaving) 2) Annual peak shaving



Left: Grid services to smooth the daily load variation (December-January-February), Right: Focus on the annual peak period of the load duration curves

3) Sensitivity analysis of annual peak saving impact on a national level



Conclusions

Our grid model uses residential batteries for PV self-consumption when they are not in use to store electricity from the grid with the objective of flattening the consumption profile. The expected effects concern the winter period because batteries are not usually used due to low PV power production and higher power consumption from households. It should be highlighted that the grid service model moves a share of the consumption during daily peaks and annual peak demand to other times zones when the national load demand is low, which reduces the additional efforts for PV integration to balance the system. We have concluded that our optimized residential PV self-consumption model with grid service increases the rate of battery use during winter and significantly helps address balancing and back-up issues (possible to reduce the required back-up capacity by 7.4 GW). For this to be feasible, the model needs a relatively simple yet standardized control system that includes automatic operation based on optimal conditions (rates, times). In addition, policy can support the development of the model (e.g. regulation, standardizations). Regulations can be designed to allow grid operators to access the battery capacity to address seasonal peak demand.

References

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