TOPIC 6: PV SYSTEM PERFORMANCE AND INTEGRATION
6.4 GRID AND ENERGY SYSTEM INTEGRATION

FROM PV SYSTEMS TO ENERGY SOLUTIONS PART II [1]

FROM THE CONCEPT TO REALITY

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ABSTRACT: Residential buildings are turning from energy consumers to prosumers using PV. The building as a system combines two or more of the following branches: energy efficiency, clever PV production, thermal energy management and electric mobility. Using a smart energy- and load management as a conductor or mastermind within the building allows controlling and optimizing PV production and power consumption. Managing existing loads can help reduce the need for additional storage in form of batteries while optimizing self-consumption and grid-services and multiplying possible fields of PV deployment.

2016 an existing building with PV and electric mobility was equipped with new heating technology (heat-pump), additional PV and the conductor/mastermind system and is since in operation. Production and consumption is monitored and evaluated. With the upcoming conference in September 2017 measured and analysed data for a full heating-season as well as the intermediate seasons will be available. First findings include: maximized PV self-consumption, higher economic efficiency of the PV plant for post-FiT, individual mobility with PV (solar gas station), reduction of energy consumption for heat and general electricity, lower energy costs, impact on CO_2 balance of buildings, monitoring of power production and energy consumption.

Keywords: Photovoltaic deployment, load management, self-consumption, storage, Grid-Services

AIM AND APPROACH USED

In Switzerland about 1/3 of the overall final energy of 232.9 TWh (2015) is consumed in the transport sector, the largest part for individual mobility in the form of fuels. Another third of the Swiss energy is consumed by residential homes, whereof only a small part is direct electricity and the largest part is used for heating. The last third is used in industry and the service-industry.

PV production in residential buildings with heat-pump and electric mobility not only targets general electricity consumption but also heating and mobility, increasing demand and multiplying possible fields for PV deployment. Todays energy-efficient residential buildings with PV can cover the energy demand, at least in the annual balance. Residential homes are becoming "prosumers", producers and consumers. Mostly production and demand do not occur at the same time and are not coordinated. Further deployment of electric cars and PV systems can lead to annoying production and demand peaks in power grids. In addition to these power grid aspects, it is also advantageous to coordinate production and consumption from an economic point of view.

To coordinate the different components in a residential building, an electronic building automation "conductor" was developed, acting as the mastermind. It dynamically and continuously adapts the power demanding loads such as charging stations for EV's and heat pumps to the available PV production while ensuring user needs. 2016 two pilot projects were realised to verify the capabilities of a conductor/ mastermind controller for Smart-Energy-Home.

The first pilot project is a low energy "Minergie" single-family house near Zurich, Switzerland. The house, built in 1999, was renovated with newest building technology including a 6 kWp PV system, a modulating brine-to-water heat pump (2.5 kWmax el.) and a controllable charging station for EV (11 kWmax) (Fig. 1). The charging station is primarily used for charging a car with 85 kWh battery capacity (Tesla S). Individual room temperature control and thermal management are also part of the system. "TNCALL Conductor" as mastermind for

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coordinating all these components is implemented in this project with a focus on optimizing PV self-consumption over all available loads. The project is equipped with a large number of sensors and a monitoring system, which continuously records the operating data.

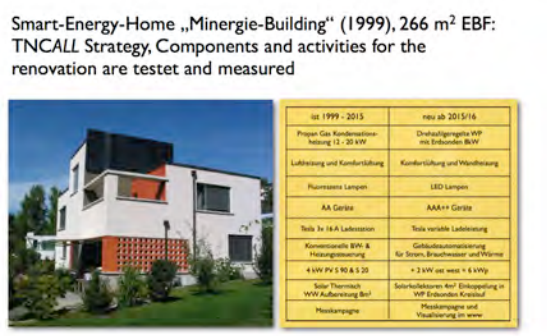

Fig. 1: Pilot project single-family house before and after renovation

The second pilot project is an office building equipped with a 12 kWp PV system and a controllable charging station for EV (11 kWmax). In this project, the focus is on charging the company's own electric car with 22 kWh battery capacity (Renault ZOE) with PV.

SCIENTIFIC INNOVATIONS & RELEVANCE

Targeting not only the general electrical consumption of buildings, but also the thermal energy (heat-pumps) and individual mobility (EV's) multiplies the potential areas of PV deployment, while contributing to the transition to a renewable energy system and reducing CO_2 emissions. At the same time, this approach requires to consider buildings as energy systems related and influencing to each other. With the use of an additional conductor or master-controller for coordinating and optimizing operation of existing controllers and optimizers for specific applications within buildings such as heat-pumps, charging stations for EVs, storage devices, etc. it is possible to operate a building with PV as an energy system and not only as the sum of energy components.

Possible operation modes can vary from PV self-consumption, self-sufficiency, economical optimization to power grid services and can be adapted based on software code without necessity of new hardware installations. This provides higher flexibility to adapt to changing requirements, political or economical frameworks.

The functionalities of the conductor are: the management of the different loads within a building such as charging electric cars, battery storage management, efficient heat pump operation for heating and hot water, operation of comfort ventilation systems, operation of domestic appliances. The direct PV yield is optimized in operation incl. the weather forecasts. The system provides monitoring of PV plant production and consumption of the different loads integrated.

With the implementation of this system in pilot projects, first experiences in implementing and operating such a system are gained. This includes for example the integration of components with different interfaces for communication (bus-systems), shown in Fig. 2.

Fig. 2: TNCALL "Conductor" and the interfaces-hell

Monitoring of the components included in the system provides much needed and essential operational data. This data can not only be used for verifying operation as expected, but also to verify simulations or assumptions from existing models and models under evaluation for buidlings.

Evaluation of operational data shows the potential and impact of using demand-side management and existing loads to reduce the need of additional storage for different purposes such as maximizing self-consumption or providing grid-services.

Measurements in the pilot projects before implementing the conductor show that the PV plant produces power at noon without enough loads to use the produced solar energy. At the same time, the electric vehicle is charging during the night, leading to high load peaks. (Fig. 3)

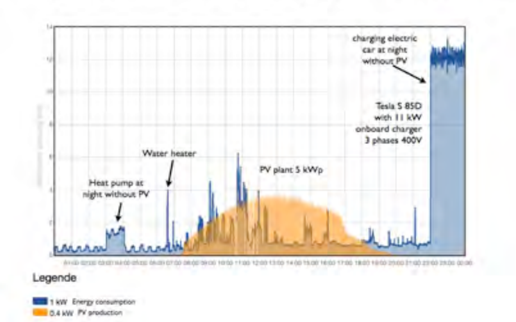

Fig. 3: Measured data of PV production and consumption in residential home without TNCALL

Fig. 4 shows that on the economical side the excess energy from the PV plant is redeemed at a low price by the grid operator. The electric vehicle is charged during the night and electricity must be bought at the higher end customer tariff. The obvious solution is to charge the car with the energy of the PV plant when available. The same can be done with other loads.

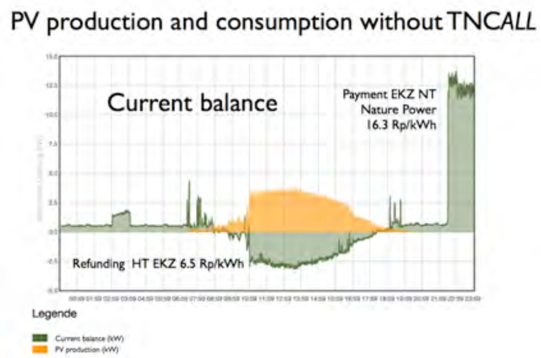

Fig 4: Current balance at grid connection point without TNCALL for residential home

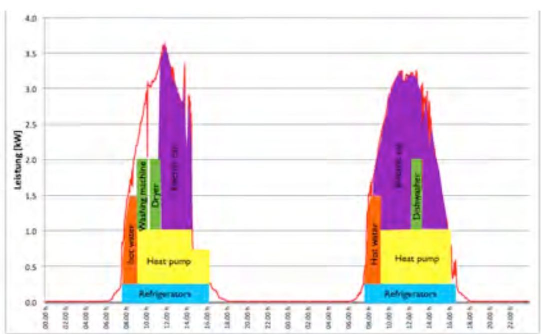

Fig. 5: Applied energy balance for a weekend with TNCALL

The aim is shown in Fig. 5. All loads should be moved to production times of the PV plant as far as possible. When the possibilities of the existing loads are exploited, a well-dimensioned stationary battery storage system can provide the final optimization.

Results from operation will also allow to optimally size and layout future PV plants on buildings with the aim of providing a well-balanced energy system. Possible influencing factors besides nominal capacity of the PV plants can be the orientation and inclination of the PV modules, for example the forced implementation of PV on facades.

PRELIMINARY RESULTS AND CONCLUSIONS

For the combination from PV with electric mobility first results from summer 2016 show, that with the implemented solution using the conductor, almost no energy from the PV plant is exchanged with the electricity grid.

In the residential house the car was mainly loaded on weekends with PV excess energy. This was sufficient, due to the large storage capacity of the vehicle and the rather low mileage driven during typical workdays. The system still provides the possibility to charge from the power grid, for example for longer road trips. When plugged in, almost all PV energy could be stored in the battery of the vehicle due to the large battery capacity and the rather small PV plant. (Fig. 6)

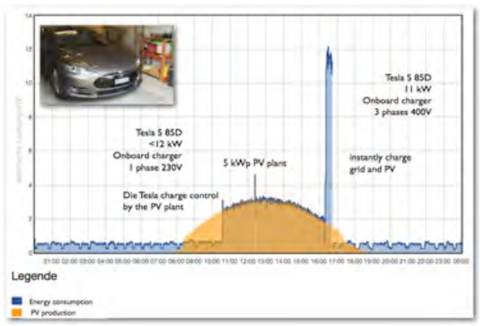

Fig. 6: Charging EV's with PV energy and optimally using the capacity of the EV's battery

In the office building the electric vehicle was almost exclusively charged with PV excess energy by the beginning of November 2016. Over a long period of time, a significantly greater mileage with PV energy for the vehicle would have been possible than the mileage of everyday use in real-life operating conditions demanded. This leads to the conclusion that additional EV's can be operated at this location or other consumers can be provided with PV energy in addition to the EV.

The heat pump of the residential home was operated with standard settings in the period

January - June 2016. Starting from July 2016 the water heating system, also provided by the heat-pump, was adapted to the PV production. With the start of the heating season at the beginning of October 2016 and a PV-optimized control of the heat pump, it is shown that a self-consumption rate of nearly 100% can be achieved during the heating season (Fig. 7).

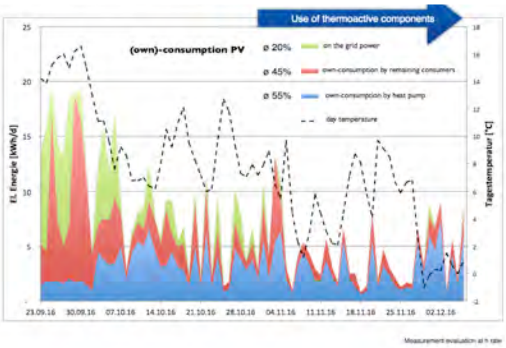

Fig. 7: Increasing self-consumption of 5.2 kWp PV plant and heat pump $P_{max\ el}$ 2.5 kW with TNCALL

From January 2017 this PV-optimized operation will be compared with the recorded operating data of the previous year under standard settings of the heat-pump using mainly grid power.

Conclusions

- We have to realize PV plants according to demand and not just from maximized production perspective.
- PV in buildings is part of the energy system of a building, together with the different loads.
- PV is used not only to cover general electricity consumption, but also heat pumps and electric mobility. This multiplies the potential of PV applications and contributes to a renewable energy system and reduction of CO_2 emissions.
- Today's energy-related components in the building are not coordinated. The Smart-Energy-Home needs an electronic "conductor", providing load management and optimization on an energy system level.
- Our experience shows that energy storage is not only possible with stationary electrical storage (batteries), but also using the thermoactive building mass, the target application "Power to Heat", the time-shift of electrical consumers and the use of mobile storage capacities from electric mobility.
- Using an additional conductor/mastermind controller allows to adapt to different requirements and frameworks (economical and political) faster and easier.
- The real-life solutions – verified by a monitoring system, measured data and analysis – are more challenging than the fast-printed high-gloss brochures.
- The conductor used by TNC provides possibilities to implement the Smart-Energy Home solution.

Outlook

- Further operational data is monitored and evaluated
- Comparison of operation before and after installation of conductor is done starting with operational data available from January 2017/2016.
- Weather forecast is taken into account for optimization of self-consumption and demand-side management, especially thermal loads
- Further energy components are fully integrated into dispatch of PV energy available
- Further projects are developed, providing even more solidly based data for different operating conditions (larger residential homes, small business, etc)