Possibilities of Using an Energy Surplus of Photovoltaic Power Plants

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***Abstract*— Nowadays, the installation of photovoltaic power plants on the roof of houses is becoming more and more common. Compared to earlier times, the surplus electricity to the grid is not well-financed. It leads to increasing pressure to maximize the use of the electricity generated on the premises. Energy storage in batteries is becoming standard but is still insufficient. In most cases, the distribution of the building's consumption does not correspond to the PV generation, and the size of the battery storage would be economically prohibitive to utilize the surplus fully. A solution to this problem can be to control selected appliances depending on the PV production. This paper describes controlling the output of heat pumps, EV chargers, and resistive load. Our goal is to develop a control system for smaller buildings that allows communication between the devices and control their operation depending on the current and future PV production.**

Keywords—PV powerplant, heat pump, EV charger, control system, energy management

I. Introduction

In the Czech Republic, the measurement of the PV surplus electricity is carried out in individual phases. For this reason, it is advantageous to use an asymmetrical inverter, which allows an adequate distribution of power to individual phases according to the actual consumption of the building. The asymmetrical inverter is equipped with a measurement module, which monitors the magnitude and direction of the currents in the individual phases. The whole system can be supplemented with battery storage to increase the share of self-consumption from the PV system.

In order to increase the self-consumption of the PV plant, it is necessary to optimize the operation of individual appliances according to the production of the PV plant. In an air-to-water heat pump operation, the PV production corresponds to the interval of high daily temperatures, making the overall operation even more economical. A requirement for its use is the large storage capacity of the building or storage tanks. For a more precise use of small powers, extending the system with smooth control of the surplus of the generated electricity to the resistance loads is advisable. It includes, for example, the heating of water in tanks or the control of electric heating. Thanks to Solid State Relay (SSR) control, their output can be precisely controlled depending on the flow to the grid.

With the current boom in electromobility, adding an electric car charger to the electrical installation is advisable, especially for new buildings. Using the electric car to accumulate electricity from PV power plants is possible, mainly in summer. In our case, these are mainly AC chargers, which are relatively affordable and can be controlled efficiently.

The possible control of individual appliances during the day depending on the PV production is shown in Fig. 1. The most significant consumption is represented by the heat pump and the electric car charger. These appliances cannot be controlled precisely according to the actual PV production. To minimize the energy surplus to the grid, resistive load control with SSR can be used.

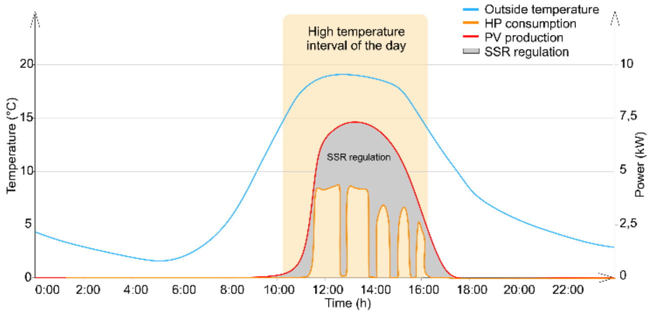

Fig. 1. Control of individual appliances during the day depending on the PV production

II. Heat Pump Control

The possibility of controlling an air-to-water heat pump was tested in a building in Domažlice (Czech Republic). The building is equipped with underfloor heating and storage tanks. Due to the large storage capacity of the building, it was possible to shift the operation of the HP to the PV production area.

A comparison of hourly PV generation and HP consumption is shown in Fig. 2. From the course of the HP consumption, it can be seen that most of the electricity consumption was covered by PV production. An undesired start-up of the HP in the morning hours at low outdoor temperature was caused by a drop in room temperature below a set limit. By eliminating this start-up, higher utilization of the electricity produced by the PV plant could be achieved.

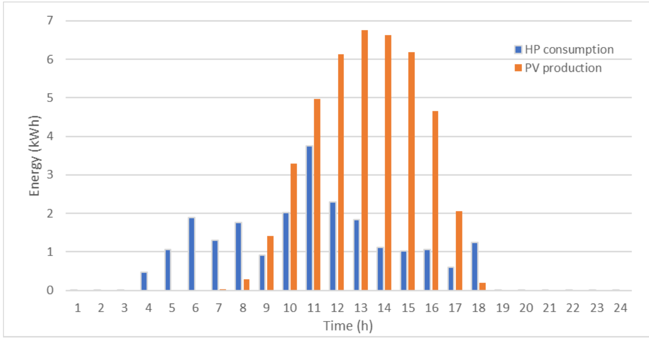

Fig. 2. Coverage of HP consumption from PV in hourly intervals

III. Controlled Charging of Electric Vehicles

The proposed system was tested with AC charging station Schneider electric (EVB1A22P4ERI), and TESLA Model S electric vehicle (85 kWh) was charged with an on-board charger of 3x16 A. Based on the observation that EVs have different minimum charging currents, a function for determining the control range of charging was implemented. The system sets the minimum charging current according to the charging station (in our case, 8 A) and then starts increasing the charging current until the EV starts charging. It then considers this current value as the minimum value for the PV surplus control system. If the measured current value does not increase when the maximum charging current is subsequently increased, the system considers this value as the maximum value for surplus control. The measured values for determining the EV charging control range are shown in Table1.

TABLE I. Determining the control range of charging of an electric vehicle

Time (s)	Charging station						PV
	Status	Max. current (A)	Power (W)	Current L1 (A)	Current L2 (A)	Current L3 (A)	Power (W)
0	EV connected	8	5	0,06	0	0	5050
30	EV connected	9	5	0,06	0	0	5050
60	EV connected	10	5	0,06	0	0	5077
120	EV connected	12	5	0,06	0	0	5077
150	EV connected	13	5	0,06	0	0	5077
180	EV charging	14	9183	12,87	12,92	12,86	5127
210	EV charging	15	9960	13,96	14,05	13,86	5127
240	EV charging	16	11282	15,83	15,93	15,78	5127
270	EV charging	17	11282	15,83	15,93	15,78	5127

IV. Resistive Load Control

The control system was tested in the same building. There ware used 6 kW direct heating elements connected in a star with a neutral conductor N installed in the PHW storage tank (volume 500 l) and the heating system storage tank (total volume 1000 l). The power control could be carried out in each phase separately.

From the temperature waveform in the PHW tank (Fig.3), it can be seen that the surplus from the PV power plant can be accumulated quite well by continuously controlling the power of the resistive loads in the PHW tank. However, there is a cooling of the water due to the inherent heat loss of the tank.

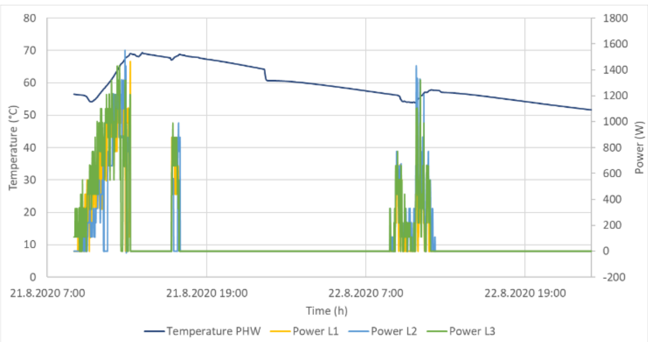

Fig. 3. Resistive load control of surplus from PV for PHW preparation

This cooling is quite significant and therefore ideally the heated water should be used as soon as possible (showering in the evening). In our case, the PHW consumption is minimal, and it can be said that a significant amount of the PV surplus is used for the tank's heat loss. This can be a problem, especially in the summer months when heating the technical room is undesirable.

Fig. 4 presents the electricity surplus to the grid in 2018-2020. The equipment installation took place in May 2020, which is also very clear from the graph, when there was a significant decrease in unconsumed electricity. However, the surplus to the grid persists due to the small volume of water storage tanks for the PWH and heating system. Other limitation are used water heaters, which are fitted with a thermostat, allowing a maximum temperature of 65 °C to be set.

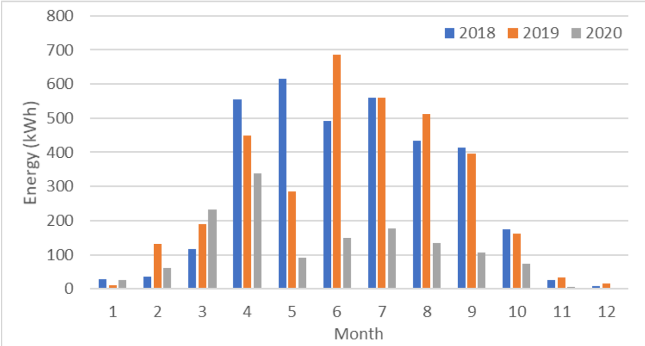

Fig. 4. The energy surplus from PV delivered to the grid.

V. Conclusion

The measurements show the suitability of using a heat pump, an electric vehicle, and a controlled resistive load to minimize the PV plant's grid surplus. At the same time, important observations have been made and should be considered for developing a control system that will include all the mentioned components. HP control is suitable in combination with a large storage capacity of a building or water tank. In the context of controlled EV charging, the recognition of the EV charging control range has been implemented in the system. The disadvantage of controlled charging is the relatively high minimum charging current (8 A). Inaccuracies in the HP and EV charging power regulation can be eliminated by continuous regulation of the resistive load using SSR.

A cloud-based application to set up and display the parameters for the user is being prepared, and a microcontroller that would enable the communication and control of the individual parts while making the proposed application cheaper for commercial use is being selected.

Acknowledgment

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