Adaptation and optimization of a photovoltaic system for a country house

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Abstract. This chapter provides the rationale for monitoring photovoltaic (photovoltaic) systems, its purpose, the need for proper measurement, and the frequency required to obtain meaningful results. The need for system monitoring falls into three groups: user feedback, performance review, and system evaluation. Each group is briefly summarized; other related topics include calibration, data storage, and data transfer. The text covers various monitoring modes such as performance testing, system evaluation, data collection and storage, as well as data analysis and reporting. The evaluation standards given by the International Electrotechnical Commission (IEC) are noted in the Data Analysis and Reporting section. The figures are provided to illustrate several types of displays that are an integral part of monitoring. Optimized modes of operation of the power part of a household photovoltaic system consisting of photovoltaic panels, an MRRT controller, an inverter and an electric energy storage unit, with Autonomous and network connection of the load. To build an optimal and cost-effective energy management strategy, it is necessary to take into account the energy profile of the resident, the characteristics of electricity production based on photovoltaic cells, and the electricity tariff for utilities. A photovoltaic system can be connected to the grid in order to receive energy from the grid or enter it into the network to eliminate the discrepancy between the generated, consumed and stored energy.

1 Introduction

Photovoltaic systems can be used to meet the electricity needs of a residential block or neighborhood. Photovoltaic systems are usually installed on the roofs of residential buildings. This reduces the space required for photovoltaic panels and components, which eliminates direct construction costs [1-4]. One of the economic advantages of this system is that, according to the household's energy profile and the local electricity distribution tariff, network capacity can be realized or the excess part sold to the utility network. [5-7].

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to the household's energy profile and the local electricity distribution tariff, network capacity can be realized or the excess part sold to the utility network.

Energy buffers or power storage devices, such as batteries, are required. When the available power from photovoltaic panels is greater than that consumed by consumers, the excess power can be used to charge batteries and Vice versa, batteries can be used when the users' power consumption is greater than the available power from solar panels. The system can also be connected to the network in order to get energy from the network or enter it into the network to eliminate the discrepancy between the generated, consumed and stored energy.

To build an optimal and cost-effective energy management strategy, it is necessary to take into account the energy profile of the resident, the characteristics of electricity production based on photovoltaic cells, and the electricity tariff for utilities. Fig. 1-4 show the block diagrams of the four main suggested operating modes for a household system [8-25].

2 Methods

A photovoltaic system consisting of photovoltaic panels, an inverter, and an energy storage battery is shown in Figure 1 with household load and network connection. A DC Converter is required to track the MPG point. A bidirectional electronic power interface that can work as a DC inverter or AC rectifier is required to charge the battery pack from the mains or a utility to discharge the battery into the load or network.

The configuration of the studied system is shown in Fig. 1. It consists of a PV array, input capacitor, an MPPT power stage and a sliding controller.

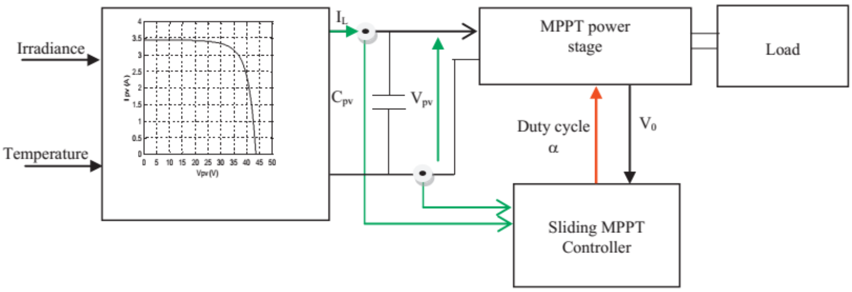

Fig. 1. Proposed system [10]

The simulation is based on the datasheet of Siemens SM110-24 photovoltaic module. The parameters of this solar module are given in Table 1. The module is made of 72 solar cells connected in series to give a maximum power output of 110 Wc.

Table 1. Parameter of the PV panel SIEMENS SM 110-24.

PPV	110 W
I_{mpp}	3.15 A
V_{mpp}	35 V
I_{sc}	3.45A
V_{oc}	43.5V
αsc	1.4 mA/°C
βoc	-152 mV/°C
P_{mpp}	110 W

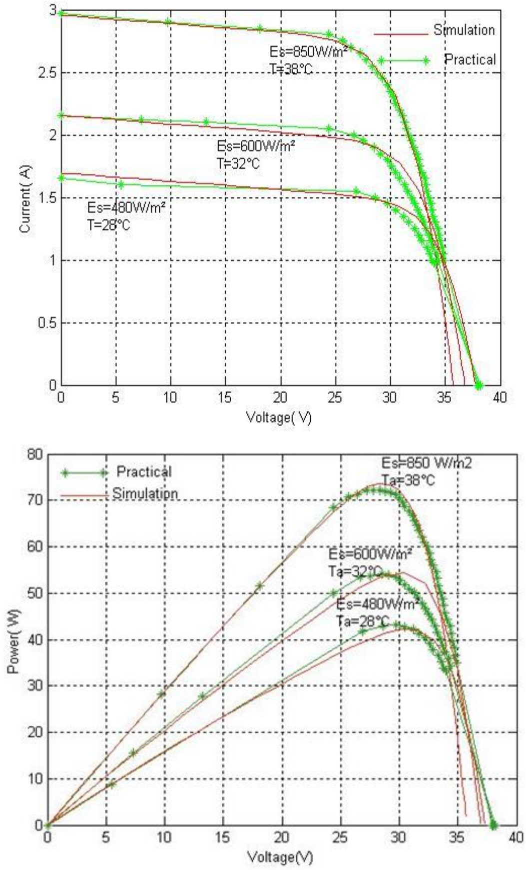

Fig. 2. Comparison of experimental results with simulation ones (I V and P V) [26].

A cost-effective solution is to operate the proposed system in accordance with the daily operating schedule shown in Figure 6. The battery is charged during the off-peak period of the network and the cost of kWh from the network is saved, since the battery provides the peak load capacity of the residential block. Through bidirectional power meters, excess power can be sold to the network if the power mode allows it [27, 28].

The configuration of the proposed PV energy storage system is shown in Figure 3, in which the DC Converter is responsible for tracking the maximum power, and the bi-directional battery Converter is a single-phase bridge Converter that is capable of working with both a DC inverter and AC Converter modules.

The proposed system consists of the following main parts: a step-up Converter, a controller with an algorithm for tracking the maximum power of the MRRT, and a bidirectional DC/AC-AC/DC Converter.

The boost Converter is installed between the photovoltaic panels and the battery pack and is responsible for controlling and adjusting the working point of the photovoltaic panels. The configuration of the photovoltaic panel amplifier Converter and batteries is shown in Fig. 3.

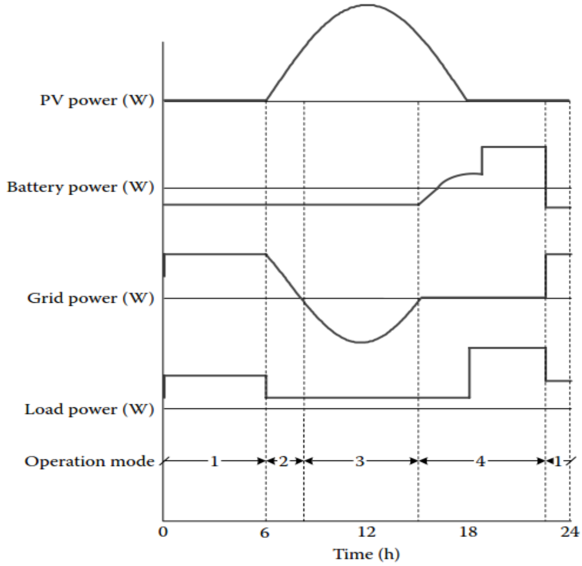

Fig. 3. Scheme of daily operation of the proposed photovoltaic household system.

The output current of the PV panel (I_{PV}) can be controlled by controlling the current of the Converter (I_C). This is achieved using the current boost Converter control mode.

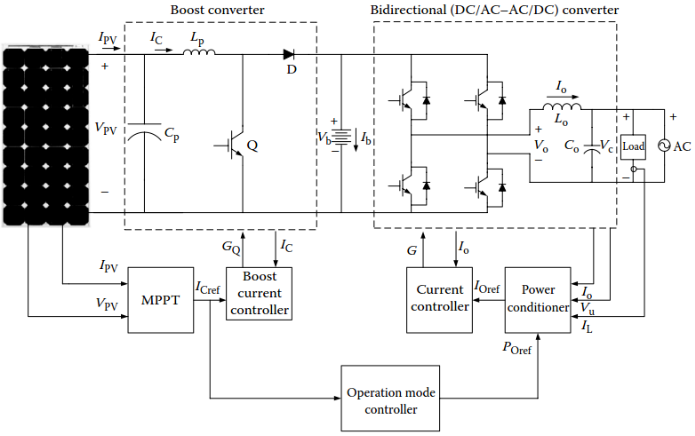

Fig. 4. Configuration diagram for connecting a photovoltaic system to the network.

3 Results and discussion

Under steady conditions, the voltage of the Cp capacitor reaches the output voltage of the photovoltaic panel.

$$I_{PV} = I_C \tag{1}$$

Using the averaging method, you can get and average two different circuits for turning the switch on and off. When the switch is in the "on" position, the circuit is a parallel CL circuit, and

$$L_P \frac{dI_C}{dt} = V_{PV} \tag{2}$$

When the switch is turned off, it is an open circuit; the current of the inductor charges the battery.

$$L_p \frac{dI_C}{dt} = V_{PV} - V_b \tag{3}$$

Equations 2 and 3 can be averaged on the basis of duty cycle, d, as

$$L_p \frac{dI_C}{dt} = V_{PV} - (1-d)V_b = V_{PV} - V_b + dV_b \tag{4}$$

The block diagram shown in Fig. 5, is an implementation of equation 4.

A proportional (P) or proportional-integral (PI) controller can be used to control the current of the boost Converter. The control scheme of the Converter with proportional control is shown in Fig. 5.

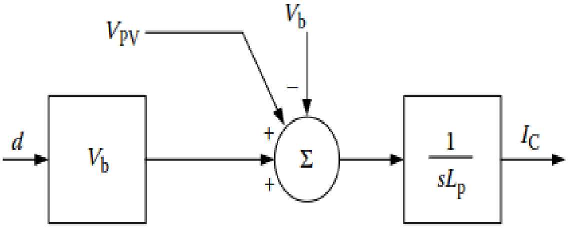

Fig. 5. Block diagram of the implementation of equation 4.

The equivalent transfer function of the system Fig. 6 can be written as

$$\frac{I_C}{I_{Cref}} = \frac{KV_b/L_p}{s+KV_b/L_p} \tag{5}$$

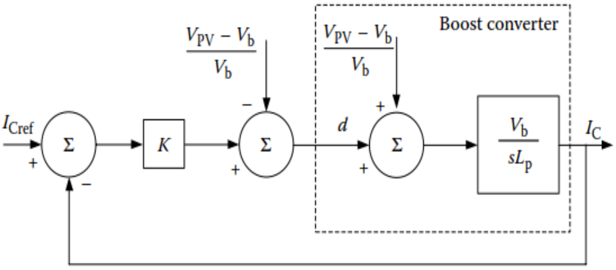

Fig. 6. Current control scheme of the step-up Converter.

The transfer function can be written as a function of the bandwidth as:

$$\frac{I_C}{I_{Cref}} = \frac{\mu}{s+\mu} \tag{6}$$

where μ-is the bandwidth of the control loop. In order to reduce the system's build-up time, the throughput must be increased. Therefore, at higher values of proportional gain (K), the system will have a faster response. However, the system bandwidth must be limited to be less than the controller switching frequency. The rise time and throughput ratio can be approximated as follows:

$$t_{r}\cong\frac{0.35}{\mu} \qquad (7)$$

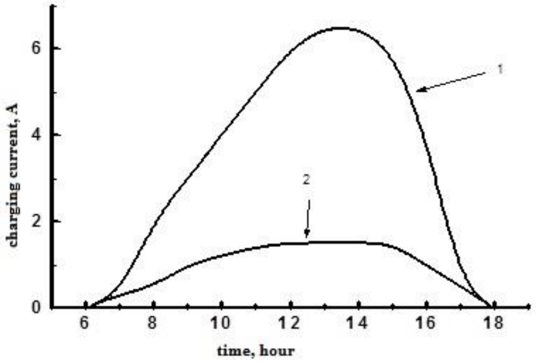

Fig. 7. The dependence of the charging current on the weather condition. 1 - in clear weather. 2 - with continuous clouds.

The short-circuit current, no-load voltage and power of the PV batteries consisting of 40 SE with an efficiency of 18.5% were measured. Measurements were carried out in the Republic of Uzbekistan in winter in clear and cloudy (solid cloud cover) weather.

4 Conclusion

For Fig. 7. the results of short-circuit current measurements depending on the time of day are presented. It can be seen that the charging current in clear weather (42.7 A·h, at 790 W/m^2) is 4 times greater than the charging current in cloudy weather (11.6 A·h, at 280 W/m2). It is obvious that in cloudy weather, photovoltaic batteries can not work effectively due to a decrease in the charging current, and their charging time depends on the daytime. To reduce battery charging time and ensure the profitability of photovoltaic batteries, you can use, for example, a traditional power grid on winter or cloudy days.

Shows a possible switching diagram of the PV device to the mains, in this case, a PV system must be equipped with a device, switching of the consumer in the absence of solar energy or discharge of the batteries on the supply from the mains.

In the method the sliding mode, regardless of the ranges of variation of meteorological parameters, the responses are more stable, more accurate and robust. Tests conducted by the variation of insolation and temperature, clearly show that the system is insensitive to the first test and are very insensitive with the simultaneous action of the two parameters. The sliding mode control (CMG) has good static and dynamic performance (stability and accuracy), that is to say a tolerable response time without overshoot. In addition, it also gives better tracking and a near total rejection of the disturbance. In this paper, we can concluded that the correct choice of the surface of the slide, allows the sliding mode control, to make improvements over linear MPPT controls (such as P & O). An experimental device was made, which is a square foil plate with vertical and horizontal measuring lines fixed on it at right angles to determine the optimal orientation angles of photovoltaic batteries. Thus, thanks to the created control system, the operation of the autonomous photovoltaic installation was optimized, as a result of which its efficiency increased. At the time of writing, this article is under development.

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