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MAXIMIZING SELF-CONSUMPTION FROM PHOTOVOLTAICS

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Abstract **:** The present study refers to the maximization of self-consumption through the automation of a residential consumer that is or not fed from the low-voltage electrical network and from its own photovoltaic system. The level of self-consumption from photovoltaic sources in the residential sector is strictly dependent on the power installed in the own sources, as well as the load profile of the respective consumer.
Two major directions are relevant regarding the possibility of increasing and optimizing self-consumption: the management of electrical energy storage systems (especially through the use of battery systems), respectively the implementation of load management systems, through the partial or total redistribution of their operation over time, but also through prioritization of critical consumers
Key words : consumption, electric, energy, hybrid, load, network, production, photovoltaics.

1. INTRODUCTION

The A conventional photovoltaic system, called on-grid, provides electricity for a household mainly during the day. Most of the energy produced by this way is fed into the network because it cannot be consumed without automation, i.e. more than 30% of the electricity. The off-grid hybrid system represents an energy storage system in batteries. This is profitable because self-consumption is doubled to about 60%. Its disadvantage is the price, which is still very high.

The cheap alternative for using photovoltaic electricity, instead of supplying energy to the public grid at a very low price for the prosumer in relation to the price of energy consumed from the grid, is to convert this energy for water heating, home heating, thermal storage in inertial thermal mass (daily or seasonal) or the charging option of an electric car.

For the energy produced in the middle of the day, when it is assumed that the share of energy from photovoltaic sources would be maximum, there should be consumers who absorb all this amount of electricity produced instantly. Situations are reached that have become common through the repetitiveness observed on weekends when, due to the lack of electricity consumption, its sale price has reached 0 or negative values. The minimum instantaneous consumption reached 3250 MW at the national level on 05.06.2024, which is reflected in negative prices for the sale of energy. But for the household consumer, these negative prices are not noticeable.

Thus, under current conditions, the cheapest form of energy that you can store or convert into another energy source is the one that is produced closest to the place of consumption, namely your own photovoltaic system for electricity production, especially because you are not obliged to pay the transport tax on the network, other cogeneration, environmental taxes.

One of the residential consumer load management methods is oriented towards the use and conversion systems of electrical energy into thermal energy, stored in water from the beneficiary's boilers or buffers. In periods characterized by a surplus of energy, it is used for the preparation of domestic hot water, heating or cooling thresholds. The water level in boilers is monitored with the help of temperature and level sensors, which transmit the information to a central control unit. The disadvantage of such use consists in the need to acquire and transmit additional information regarding the temperature, water level, pressure, water flow consumed, as well as the addressability of the method only to a particular category of receivers. The advantage of a such solution is that it can ensure a certain degree of energy independence, but also a new alignment with the new standards imposed for environmental protection related to climate change, generating a heating without greenhouse gas emissions.

There are two main ways of using this excess electricity, depending on the nature of the generation mode of the photovoltaic system. These can be classified into on grid and off grid systems. In the on-grid systems we can also include systems with hybrid inverters that can ensure energy storage in a direct current storage battery to ensure a backup or to be able to provide energy independence for a certain period of time depending on the capacity of the battery and the chosen

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discharge method or that depends on the used consumers. In the off-grid systems, the inverters used for energy conversion and storage are without the constructive possibility of injecting this electricity into the national electricity distribution network. In this category we can also add inverters called hybrid by some companies, but they can only extract energy from the net, being connected to the low-voltage electricity distribution system. They generally operate by needing a connection to a battery, but there are also inverters that can work without batteries.

It is common to have an overproduction of energy that we don't know what to do with and that is sent to the public grid on a regular basis. One solution to avoid wasting this excess is to send it to an electric water heater, heater, pool pump, etc. For example, if we have a photovoltaic production of 2500 W and 1300 W consumed in the house, we still have 1200 W available for a water heater. The diverter provides 1200 W to the water heater and no more than normal, absorbs 2400 W. The diverter acts as a flow control valve. It ensures that zero watts are withdrawn or injected into the public grid.

2. EXPERIMENTAL SETUP

The system is divided into three functions:
- Shelly Em power meter
- processing using an ESP32 microcontroller (Figure 5);
- actuators with a triac and relays to power different loads with optional control, a temperature sensor.

A current and voltage measurement is performed simultaneously at the entrance to the house. A current sensor is used through which the phase wire from the network passes. At the output it gives the same current, but 2000 times less. The ESP32 microcontroller, through its analog / digital converters, provides and calculates the multiplication of the instantaneous digital quantities of voltage and current, UxI, for power measurement. [1]

2.1 Types of variable regulation of excess load:

A single-phase Shelly Em module installed at the main switch makes it possible to obtain information about the energy consumption network in real time. The actuation of the discharge of the load on a resistive consumer will be done with the help of a triac. To regulate the current to be injected into the water heater or a heater, a drive from RobotDyn or Krida Electronics consisting of a Triac and a voltage zero crossing detection system can be use.

An alternative, to regulate the current to be injected, is to use SSR (Solid State Relay) relays on the free GPIO pins of your choice of the ESP32 to control one or more devices depending on the state of consumption or injection of power at the level of the house. There are many models of 10, 25 or 40A SSR relays for the 230V AC side. The triac or relays can be controlled in various ways to draw the available power (Figure 1).

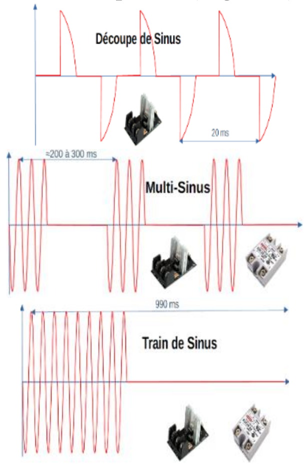
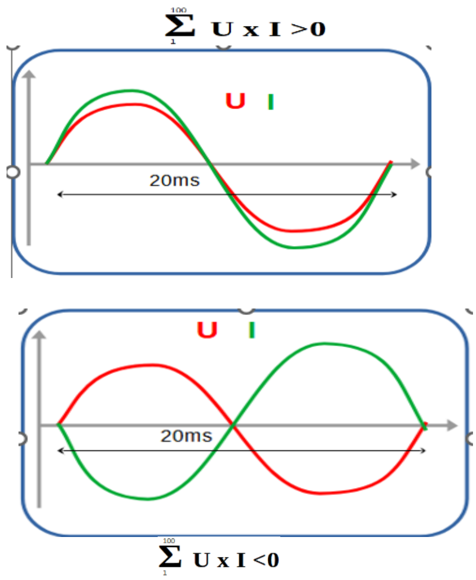


Figure 1 Representation of the 3 types of variable regulation of excess load: dimming, multi-sine, sinusoidal train

They must work in 3.3V voltage level to be able to be controlled via the ESP32 microcontroller.

2.2 The consumption and injection in the network:

At the entrance to the house when the voltage U and the current I are of the same sign, this means consumption. Power is injected into the distribution network when the voltage and current are of opposite signs (Figure 2).



a)

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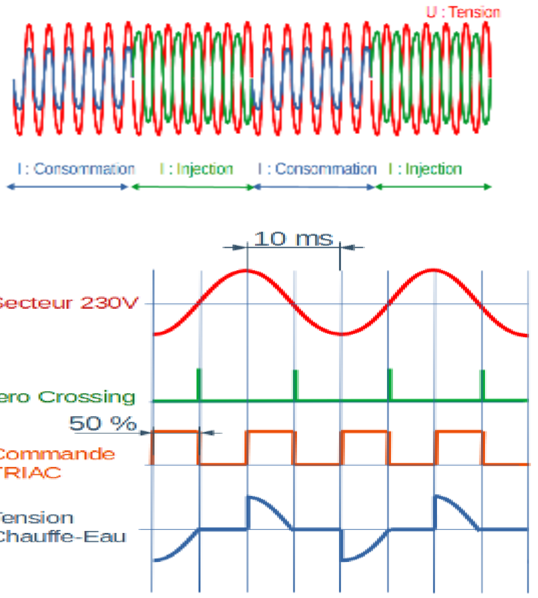
$$P_W = \frac{1}{10000}\sum_{i=1}^{i=10000} U_i \times I_i$$



b)

Figure 2 Representation of U and I in the situation of consumption (a) and injection to the network (b)graphic representation of the waveform - signal crossing through zero - triac command, triac output waveform. [3]

Dimming mode means every 10ms, the Triac is open for a certain duration to adapt to the power to be transferred. Cannot be used for SSR relays. This is useful for water heaters and heaters. It features quick adjustment.

Multi-Sinus means every 200 to 300 ms, we send a burst of several 1/2 sinusoids corresponding to the power to be transferred. This is available for Triac or SSR relays and is useful for water heaters and heaters. It shows slower regulation and less noise generated.

Sinusoidal train menas every 990 ms, the number halfperiods corresponding to the power to be transferred is sent. It is used 990 ms and not 1000 ms to never restart on the same voltage sign and have a continuous component for odd series. This is available for Triac or SSR relays.

At the entrance to the house, the power measurement is done over a time longer than 20 msec to take into account any variation. Measuring equipment used by the distribution operator measures the power over 1s interval. It must have an average of about 10000 UxI products to comprehensively sample the waveform of the voltage U and especially the current I. This average of more than 10000 samples includes consumption periods (currents in phase with voltage) and injection periods (current in phase opposition to voltage). The alternation of consumption and injection takes place in less than one second. They do the arithmetic average and do not count it separately into Wh consumed and Wh injected. It can be observed on the meter, during the periods of regulation by the diverter, the energy we pay or inject correspond to a slower rotation. [1]

In order to know if energy is entering or leaving the house, the electrical voltage must also be measured. It is done by comparing the phase of the current I and the voltage U and by this way we will know the direction of the energy transfer.

In the presence of a dimmer / triac providing a Zc (Zero Crossing Voltage) signal on GPIO23, the operation of the ESP32 is perfectly synchronized with the network. In this way, the moments of opening and closing can be timed with respect to the sinusoid of the mains voltage.[1]

In the absence of a dimmer/triac, it is the internal clock of the ESP32 which provides the synchronization pulse every 10ms. This pulse is asynchronous with respect to the sector. This results in opening and closing of the relays in Multi-Sine or Sinus Train mode not necessarily at zero crossing of the mains voltage. This can cause the relay to heat up more.[2], [3], [4], [5]

3. EXPERIMENTAL RESULTS

In the "Sine Train" mode, when the power cycle is almost one second, the power measurement can be performed according to the measurement time of the second cycle [6]. The control software then needs to average over a long period of time to have a good estimation of the energy consumed / injected exchange and a result similar to the meter of the energy distributor used for billing (Figure 3).

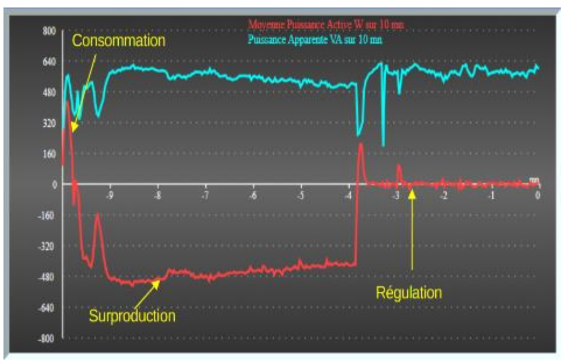


Figure 3 Example of self-consumption regulation, the red curve remains around 0

It can be seen that during the control phases, the apparent power is very high and disturbed. This is normal behavior.

During a 10 ms half sine wave, energy is consumed and injected to have zero active power balance. This results in high apparent power.

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There is, however, a paradox. An apparent power has no sign according to its mathematical definition and is always positive (Figure 4 a,b).

Figure 4 a) Active triac dimming with input-output load 2400W

Figure 4 b) Active triac dimming, sun with clouds

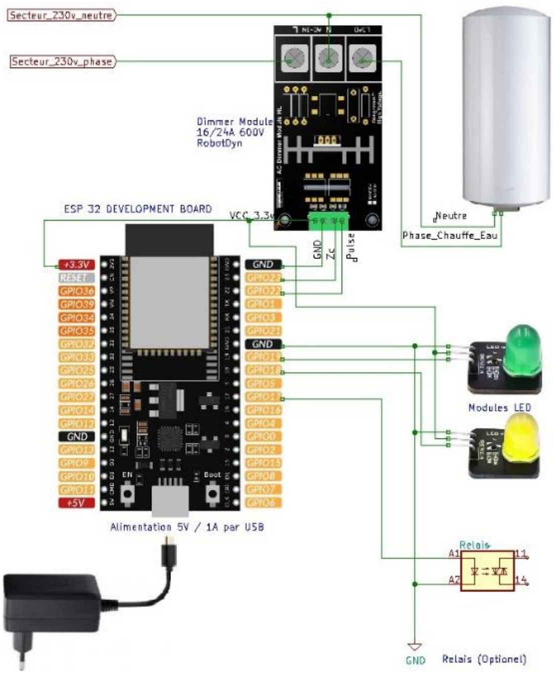

Figure 5 ESP32 control scheme for heating a boiler with water and a consumer connected via SSR relay

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The system for maximizing the electricity produced with an off-grid or hybrid inverter (Figure 6), monitors the battery voltage and the battery discharge current. When the battery is full, then the microcontroller commands the gradual opening of the triac [11], [12].

If the value of the load introduced through the triac exceeds the power available at that moment, the difference between the load discharged through the triac and the additional load will be provided from the energy storage battery.

This fact is monitored by means of a Hall current transducer. When a discharge current over 0.5 A occurs, the microcontroller commands the reduction of the load distributed on the triac until the battery discharge current signal disappears [13].

Figure 6 Off grid system to maximize photovoltaic self-consumption [7]

The software prioritizes critical household consumers and only the available surplus will convert it into another form of energy [8], [9], [10].

4. CONCLUSIONS

The solution to maximize self-consumption, as a form of conversion and storage of electrical energy into another form of energy, from sources considered renewable, is an important step for obtaining a level of energy independence and not only that.

Storing the photovoltaic energy available at times when it is not used directly, in a reservoir with inertial thermal mass, may represent a cheap solution, within reach of those who own a renewable energy source.

Generating space heating with the photovoltaic system is more economical in the long term than operating a gas or oil heating system in the conditions of the continuous increase of their prices.

Basically, every kilowatt-hour that is powered by solar electricity instead of grid electricity counts. This protects the environment and the climate and reduces heating costs.

In this way, important savings can be achieved at household level, but also improve the carbon footprint through self-generated solar energy

6. ACKNOWLEDGMENTS

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