EFFICIENT USE OF ENERGY PRODUCED WITH PHOTOVOLTAIC SYSTEMS

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ABSTRACT: *The decrease in the price of photovoltaic systems for electricity production but also the facilities granted by some states for the installation of such systems has led to an increase in the number of household consumers who use this option. The additional energy produced is injected into the electricity grid but at a reduced price. This paper proposes a system to control the consumption of this additional energy in the house in order to increase economic efficiency.*

KEYWORDS: Electricity, photovoltaic system, monitoring, control, economic efficiency.

1. INTRODUCTION

The process of converting light to electricity to voltage is called the solar photovoltaic (PV) effect. Photovoltaic solar cells convert sunlight directly into electricity [1]. They use thin layers of semi-conducting material that is charged differently between the top and bottom layers. The semi-conducting material can be encased between a sheet of glass or a polymer resin.

When exposed to daylight, electrons in the semi-conducting material absorb the photons, causing them to become highly energised. These move between the top and bottom surfaces of the semi-conducting material. This movement of electrons generates a current known as a direct current. This is then fed through an inverter, which converts the power to alternating current (AC) for use in home.

An on-grid photovoltaic system is a system connected in parallel to the public electricity grid, and when the energy produced by the photovoltaic panels is insufficient, the necessary is provided by the electricity distribution network. On-grid photovoltaic systems do not have batteries, and the electricity produced during the day is used for their own consumption or injected into the grid for use by other consumers. As the on-grid inverter is connected in parallel to the grid, consumers use the energy produced from the panels and the rest from the national grid.

Expensive on-grid inverters have the option of limiting energy production to the value of consumption, so a special contract with the energy supplier is not necessarily necessary.

The structure of such a system is shown in Figure 1.

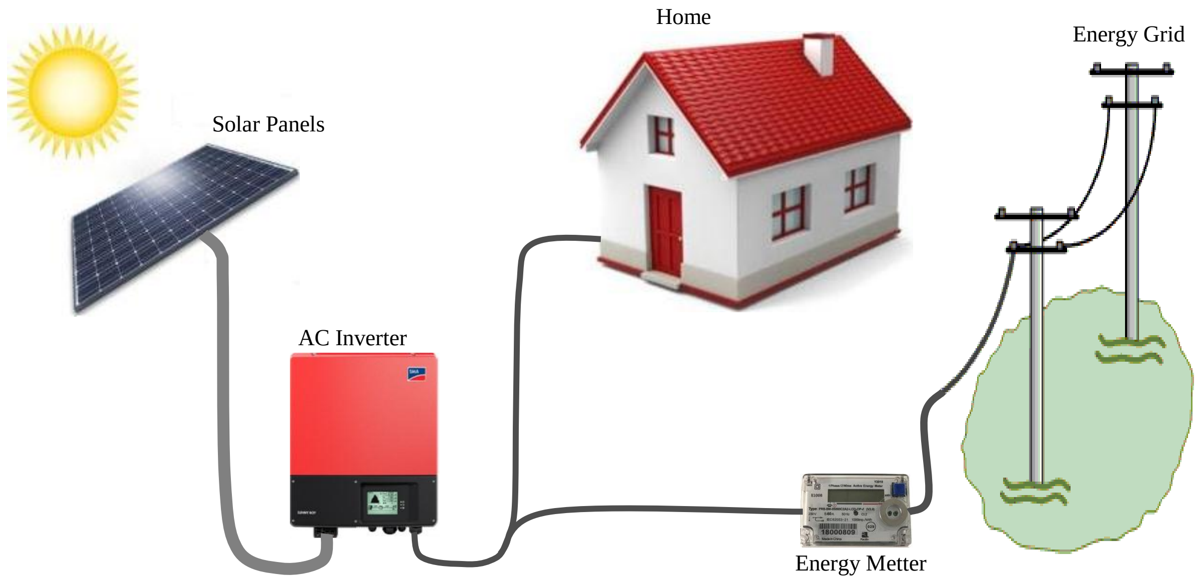


Fig.1 The structure of an on-grid photovoltaic

Due to the policy of encouraging the installation of photovoltaic systems, more and more home consumers have installed systems with an installed power of at least 3kw. This produces electricity that is used in the household and the surplus is injected into the grid. Unfortunately, the price of electricity injected into the network is much lower than that for electricity consumed. For household consumers, no compensation is made for the electricity consumed with that produced. One way to increase economic efficiency is to install additional energy storage systems produced (batteries), economically unreliable solution.

For increased economic efficiency, more and more electricity consumers who have installed on-grid photovoltaic systems want to consume the entire amount of energy produced. If there is a surplus of energy, it will be used for household utilities such as a contribution to heating the house in winter, heating domestic hot water, cooling the house in summer, filling basins with water from wells, etc.

2. PROPOSED SYSTEM

The proposed system is one that monitors the electricity before the electricity meter and controls the supply of certain electricity consumers with a variable voltage in order to fully consume the energy produced. These consumers are stopped if there is an increase in consumption in the household over the production capacity of the photovoltaic system.

Starting from the structure of the system presented in figure 1, the proposed system can be easily and without major modifications, the principle scheme of the resulting system is presented in figure 2.

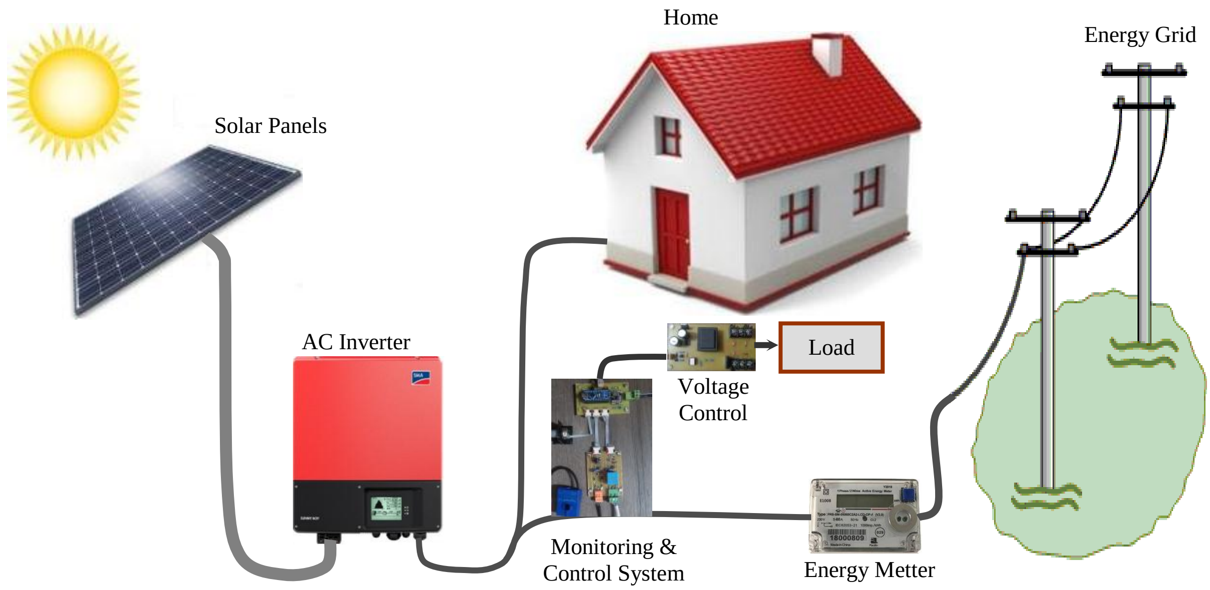


Fig.2 The structure of the system for increasing economic efficiency

The proposed system must monitor electricity by measuring current and voltage. If the current is positive (from the grid to the household) it means that electricity is consumed from the mains. Negative monitored current occurs if there is a surplus of energy that is injected into the grid. The system will control the consumption adjustment for dedicated consumers until the current drops to a preset minimum value. Thus all the electricity produced is consumed. Dedicated consumers are stopped when there is no surplus of electricity, so these consumers do not have to be of major importance in the household. The proposed system has the block diagram shown in figure 3.

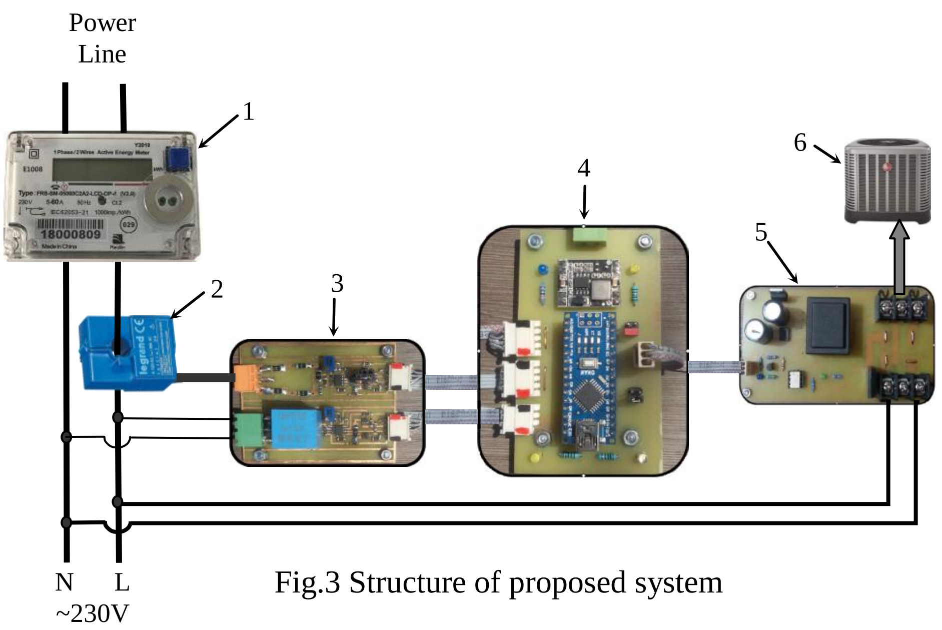


Fig.3 Structure of proposed system

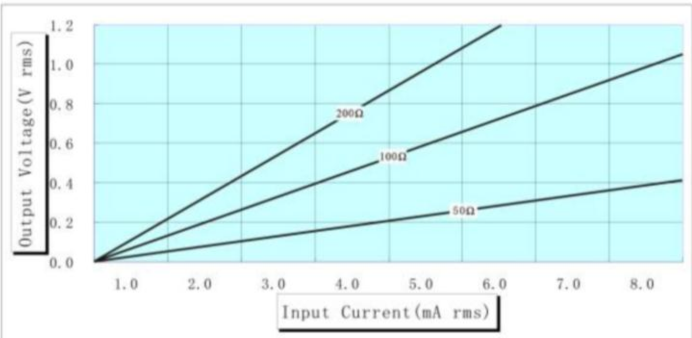
Where:

1. Electricity meter
2. Current sensor
3. Current and voltage measurement mode
4. Command mode
5. Voltage converter
6. Drinking

The current and voltage measurement module has two signals at the output, one sinusoidal for determining the value and one rectangular for synchronizing by determining the zero crossing of voltage and current. Both modules have almost identical electronic schematic, but using a specific sensors for the measurement.

Voltage sensor

ZMPT101 miniature voltage transformer [2] is designed for applications where AC voltage signals must be transformed accurately into a lower voltage signal appropriate for micro-processor based circuits. ZMPT101 current-type voltage transformer is a kind of mA current transformer, which turn ratio between primary and secondary is similar to 1:1. a limiting resistor is nessary to be in it with primary winding. ZMPT101 is popular to a limited internal space of devices. The sensor has a very good linearity of 0.1%. The output characteristic according to three values of the load resistance as well as the picture of the sensor are shown in figure 4



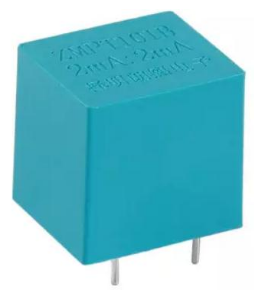


Fig.4 ZMPT101 sensor voltage characteristic

Current sensor

The “clamp-on” current sensors are particularly useful for easy and safe installation. They are installed straightforwardly onto a wire going into the electrical load without the need to do any high voltage electrical work. The current sensor consists of a Legrand LEG412002 sensor and a structure packaged in a robust plastic housing.

Clamp-type alternating current sensor [3] is a current transformer which can detect alternating current at non-contact. This divided type sensor allows mounting in existing circuits without interrupting the power supply. The rated current range is 5A to 600A, and voltage output types are also part of the lineup in addition to general current output types.

The core placed around the current bus is provided with a secondary winding (N turn), in which electromagnetic induction caused by AC electricity to be detected (I) induces secondary current (I/N). Connecting a load resistor (RL) provides output inproportion to the current to be detected.

The structure of such a sensor as well as its picture are presented in figure 5.

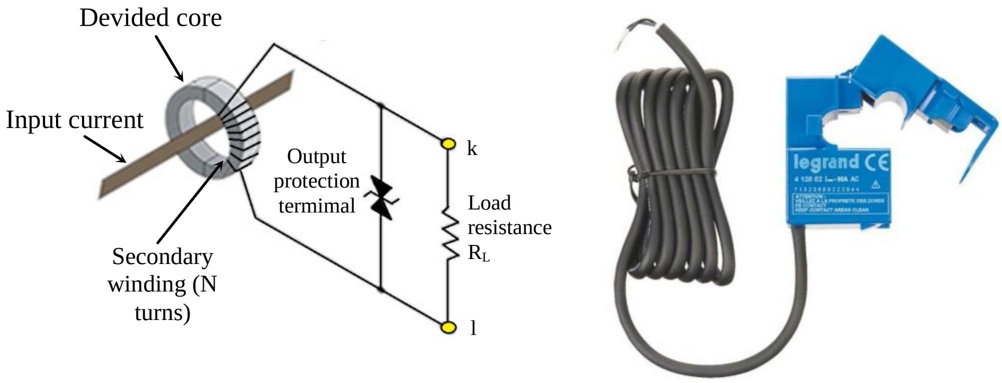


Fig.5 Clamp-type current sensor

This non-invasive current sensor (also known as a "split core current transformer") can be clamped around the supply line of an electrical load to tell how much current is passing through it. It does this by acting as an inductor and responding to the magnetic field around a current-carrying conductor. By reading the amount of current being produced by the coil, can calculate how much current is passing through the conductor.
This particular current sensor will measure a load up to 90 Amps which makes it great for building own energy monitor to keep your power usage down, or even building an over-current protection device for an AC load. This sensor does not have a load resistor built in, so in most cases it will be necessary to place a resistor across the output to convert the coil's induced current to a very small measurable voltage.

The electronic scheme of the measuring circuit and the associated waveforms are shown in Figure 6.

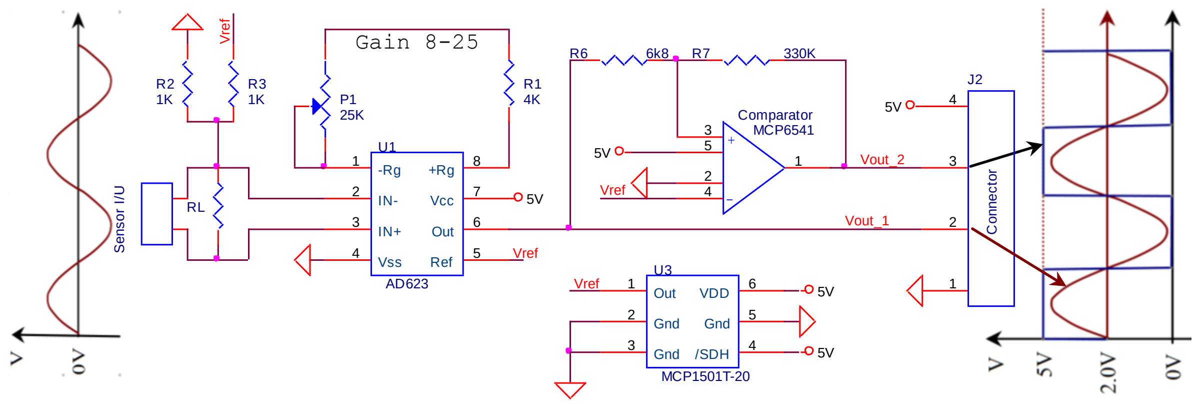


Fig.6. Circuit and signals for measure modul

Because at the output of the voltage and current sensor is an alternate bipolar signal, while the described system uses only unipolar supply voltage, a voltage translation circuit will be used. Thus for V_{Vout} = 0 at the output mode V_{Vout} = $V_{CC}/2$ will result. The circuit is a simple one and is shown in figure 6 where the signals from the output of the transformer and the one from the module output are observed.

The monitoring system is built around a numerical system like Arduino Nano [5]. This is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

The Arduino Nano can be programmed with the (Arduino Software (IDE)). The ATmega328 on the Arduino Uno comes preprogrammed with a bootloader that allows you to upload new code to it without the use of an external hardware programmer.

Current and voltage measurement procedure

For measuring voltage and current the two analog outputs that provide sinusoidal signal with an offset value of 2V are applied to analog inputs A0 and Ax. The two rectangular digital signals are applied to inputs 2 and 3 of the Arduino nano module that correspond to the external interrupts. To determine the value and direction of the current, it will be measured when the voltage has a maximum positive value. The external interrupt associated with the voltage signal is configured to operate on the rising edge of the signal which indicates the transition from negative to positive alternation of the voltage signal.

If the signal were a perfectly sinusoidal one of 50 Hz (with a half-period of 10ms), the maximum value is at 5ms of the transition from negative to positive alternation. As the electrical signal is not a perfect sinusoidal one, from the moment of activating the interruption associated with the zero crossing of the voltage, an interval of 4ms is implemented and then a number of 20 readings of the current is performed at an interval of approximately 100µs. The 20 conversions cover the 4ms-6ms range where the maximum current amplitude is found.

At the end of the 20 conversions, the absolute maximum value of the current value is determined, as well as its sign. If the current value is positive, it indicates the existence of an energy consumption in the electrical network. This situation occurs when the amount of electricity produced is less than that required for consumption. If the value of the current is negative, it indicates the existence of a surplus of electricity that is injected into the public electricity network. In this case, the monitoring system shall control the gradual increase of the intended consumers until the current injected into the network decreases to a preset minimum and is maintained at this value.

3. CONCLUSIONS

The proposed system is one that monitors electricity consumed or injected into the public energy network. In the event of an excess of electricity and in view of increased economic efficiency, the start-up of some consumers is controlled so that the entire amount of energy produced is also consumed. The consumption control system depends on the type of consumers used.

The simplest system is the one for controlling some heating elements using a rectification system and PWM control. Consumption control systems can also be used for pumps equipped with direct current motors, for cooling systems made with Peltier type elements. The system can be adapted according to the use of surplus energy by implementing only the control system for the desired consumers.

Thus, the proposed system is a simple one and to which consumption regulation systems can be attached or designed according to the needs of each household. By consuming all the electricity produced, an increase in economic efficiency is obtained by using electricity for the household needs, taking into account the large difference between the cost price between the electricity conducted and the one injected into the public network.

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