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Study for a photovoltaic system to supply electricity to an isolated apiary

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Abstract *The paper presents, based on the study and the experience of the authors in the field, some considerations, especially from an application aspect, useful in building a photovoltaic system for supplying electricity to an isolated apiary, as well as simulations for such a system, made with the PVGIS program . The main high-performing electric machines of today with relatively high energy consumption from an isolated beehive are identified, as well as their specific mode of use, during a calendar year, an essential factor for establishing the installed power of such a photovoltaic system and a its effective technical-economic design.*

Keywords**:** *apiary, isolated, system, photovoltaic*

1. Introduction

Apiary is the generic name for an agricultural formation that includes several hives with bees and a set of specific tools and equipment used by the beekeeper (the person who works in the apiary) to extract honey [1], [2] produced by bees and other adjacent products, such as: pollen, royal jelly, propolis, bee venom. [3]. Beekeeping, like other fields, has developed and continues to develop in order to obtain higher quality products and better economic efficiency. This development involves the use in the apiary of more complex and more efficient tools that are powered by electricity. At the same time, strategies for optimal use of work in an apiary must be devised

2. Structures of photovoltaic systems for an apiary

An apiary can be located both in areas inhabited by humans - in this situation there are certain legal restrictions [4] in quiet areas, far from human settlements, but also from areas where there is intense human activity such as factories, heavily trafficked roads and railways, i.e. generally where pollution is high.

To obtain honey and other bee products, the beekeeper uses a series of specific tools and machines [1], [5] some of which are simple, others more complex, more efficient, more productive. The latter are in most cases fed from a source of electricity, the voltages required for their supply being 230Vac (most) or 12Vdc/24Vdc. As a rule, where there are settlements and human activity, electricity from the national power grid is available, but in isolated areas, where the largest and most productive beehives are located, no power source is available, so electricity it must be produced in the place where the hive exists.

In the context of the production of increasingly cheaper and more efficient photovoltaic panels, the development of electricity production systems using photovoltaic panels has gained momentum. Currently, it is generally appreciated that such a system can be used for a period of 15-25 years with low / reasonable maintenance costs, and energy efficiency does not fall below 80%.

For an apiary located in an area where there is available electricity from the national energy system, electric machines have the overwhelming majority of cases, as the primary source of energy, electricity produced in the national energy system. However, in cases where the owner has a photovoltaic system and where it is also a prosumer, the machinery and other electrical equipment in the apiary can be supplied with alternative electricity from the system's inverter terminals (figure 1).

If there are machines in the apiary that require a 12Vdc/24Vdc power supply, they are powered by an electric rectifier connected to the output of the inverter (not shown in figure 1).

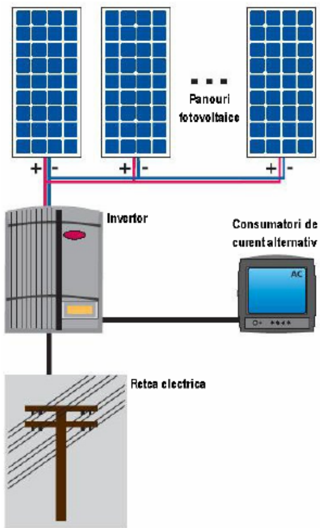

Figure 1. Photovoltaic on-grid system

For an isolated apiary, two structures of photovoltaic systems can be considered of interest, shown figure 2, figure 3 [6], [7].

The system shown in figure 2 can generate electric current, simultaneously alternating and continuous, both from the photovoltaic panels and from the diesel generator. The alternating current, of the desired voltage and frequency, is available at the output of the inverter and the direct current, at the output of the regulator. Photovoltaic panels generate electricity, of course, only during the day, when sunlight is available, direct or diffused, with a sufficient intensity to supply the power needed by consumers [8]. The primary source of energy, sunlight, is free. The Diesel generator generates electricity based on the diesel it is fueled with.

It has the advantage that it can work at any time, day or night, and also that it takes over the load peaks of the consumers connected to the inverter or regulator. In addition, the system can be dimensioned in such a way that the total capacity of the batteries in the system is lower, compared to the situation in which the generator would be missing, without significant restrictions on the use of the system. As disadvantages, we note that diesel fuel must be purchased against the cost, the noise produced by the diesel generator in operation is quite high, which can disturb the bees. We also note that environmental pollution occurs through the noxious substances it emits, a fact that could also affect the quality of the honey obtained. Last but not least, it should be mentioned that by using a diesel / gasoline generator, the complexity of the installation increases, so its reliability decreases and, as a rule, the efficiency of the initial investment in the electricity production system.

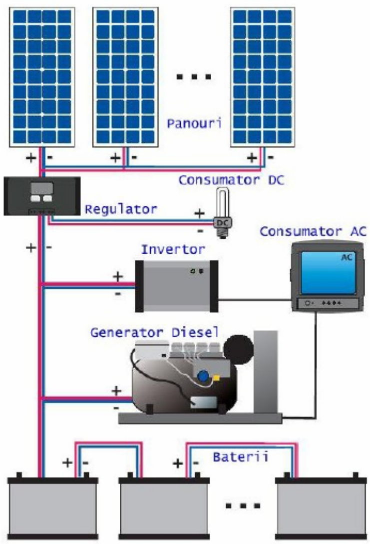

Figure 2. Isolated hybrid system with photovoltaic off-grid system

The system shown in figure 3 can also generate, simultaneously, alternating and direct current due to the presence of photovoltaic panels. It eliminates the disadvantages of using a diesel / gasoline generator, but the number of batteries used, compared to the previous system, is slightly higher, depending on the work schedule that the user sets. This is the type of photovoltaic system recommended for powering machinery and auxiliary consumers from an isolated apiary [7].

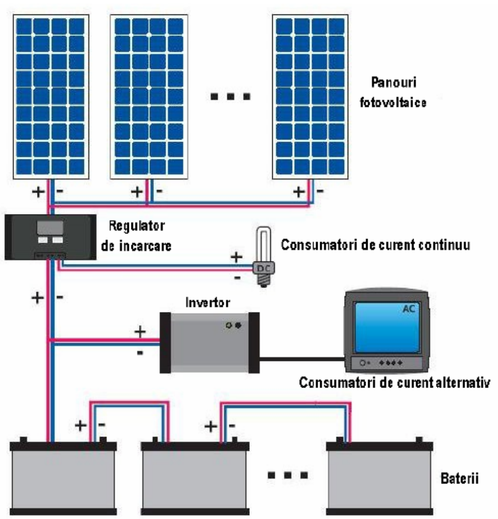

Figure 3. Isolated system with photovoltaic off-grid system

3. Considerations for the sizing of a photovoltaic system for supplying electricity to an apiary

The sizing of a photovoltaic system for supplying electricity to the devices/ equipment used and auxiliary consumers in an apiary involves several stages [5], which can be summarized as follows:

a – establishing the variant of photovoltaic system used and the main component elements;

b. – establishing in the field the place where the photovoltaic system will be located;

c.- establishing the machinery and auxiliary consumers that will be powered from the photovoltaic system and the powers required by them for each major work cycle;

d- dimensioning of the photovoltaic system.

3.1. Establishing the used photovoltaic system variant and the main component elements

The variant of photovoltaic system used is essentially determined by the area where the apiary is located, with or without access to the national electrical energy system [6]. In the first case, a system like the one in fig.1 will be used, in the second a system like the one in figure 2 or figure 3.

3.2. Establishing the location of the photovoltaic system

The photovoltaic system is usually located in a compact space, without large differences in level, preferably as flat as possible, protected from possible natural calamities such as floods, landslides. In this phase, the size of the chosen land is, of course, approximate. However, it can be approximated quite well, under the logical assumptions that the installed electrical power of the photovoltaic system is known from the beginning and considering that photovoltaic panels occupy the largest area of the land, where the dimensions of a photovoltaic panel in the photovoltaic system are known.

The land must be chosen so that the photovoltaic panels can be oriented to the South or with small deviations to the West from this azimuth. They must not be obstructed by any kind of obstacles (buildings, trees, other forms of relief, etc.) when the sun moves across the sky from East to West. It is preferable that the distance from the apiary, respectively the bee house, does not exceed 50 meters, but also not less than 7-8 meters from the apiary. The exact space and location of the system components will be done after all the components are concretely known.

3.3. Establishing the machinery and auxiliary consumers that will be powered from the photovoltaic system and the powers required by them for each major work cycle

An inventory is made of the apiary machines that must be supplied with electricity, but also of the auxiliary consumers. The most frequently used ones are those for lighting, necessary in the beehive, knowing that a series of operations can also take place when the light is weaker, (in the evening or sometimes even at night, when the hives are additionally fed, with syrup, for example, to eliminate stealth). Other consumers, of the auxiliary type, can be an electric water pump, an electric heating resistance or even a small refrigerator in the beekeeping hut, for temporary storage, for example, of products for the treatment of bees.

3.4. Principles in sizing the photovoltaic system

The sizing of the photovoltaic system is the most complex part of the realization and is specific to the system variant chosen [7].

Considering that the most used system is the one in figure 3, some elements related to it will be briefly presented.

As said, the electricity provided by the photovoltaic system must mainly power the electrical machinery/devices used in the apiary. There are several machines/apparatus that should exist in any medium/large size apiary (containing from a few dozen hives to several hundred hives) for the productive activity to be normal and efficient. These would be: the centrifugal machine, used to extract the honey deposited by the bees on the frames in the hive; the stripping bench, used for stripping existing honey cells on the hive frames; the dehumidifier, used by the beekeeper to reduce the amount of water (if any) in the honey up to a percentage of 18%, (standardized for the commercialization process); bottling machine, used for bottling honey for commercial purposes, ; the heater, used at the same time as the bottling machine because the honey bottling process requires the honey to have a lower viscosity suitable for bottling.

Each of these devices have an electrical power of several hundred watts to several kW [9], [10].

If all of these would work simultaneously, the required useful electrical power would be:

$$P_{TOT} = P_{cen\ mac} + P_{hon\ dec} + P_{deh} + P_{bot\ mac} + P_{hea} \qquad (1)$$

The photovoltaic system must, theoretically, produce this energy plus that to compensate for losses in the system and that required for auxiliary sources, the latter reaching, as the case may be, around 1 kW.

In practice, however, the 5 machines do not work simultaneously, but:

the centrifugal machine and the stripping bench are used intensively together in the months of May-June, when the bees collect pollen and nectar from which they obtain honey, i.e.:

$$P_1 = P_{cen\ mac} + P_{hon\ dec} \qquad (2)$$

the heating and bottling machines are used as appropriate in autumn – winter, i.e.:

$$P_2 = P_{bot\ mac} + P_{hea} \qquad (3)$$

and the dehumidifier is used in the period before bottling, i.e.:

$$P_3 = P_{deh} \qquad (4)$$

It therefore follows that the photovoltaic system must be dimensioned for P_{SV} power:

$$P_{SV} = \max (P_1 , P_2 , P_3) \qquad (5)$$

From the compared technical data of these 5 machines it can be concluded that, as a rule, for an established situation, it is possible to opt for P_1 to be at least double compared to P_2 and P_3 respectively, an important and useful fact in dimensioning taking into account the energy that it can be captured by the panels in the months of May - June compared to December - January, when it is minimal. So P_{SV} will choose the value of P_1.

As is known, the energy provided by a photovoltaic system is uneven throughout the year, being high in summer and low in winter. In addition, the energy given by the system depends on the geographic coordinates of the system's location. [8] but also the state of the weather, which is partly unpredictable, the forecasts being estimates.

We also add that the stupar's activity is asymmetrical over the course of a year. there are intense moments of activity, such as those during the picking, honey extraction, honey bottling, with some moderate in intensity, such as the preparation and maintenance of the beehives, but also temporary inactivity, such as late autumn and early winter. It also follows that the need/consumption of electrical power in the apiary has large variations at different times of the year.

The main elements of the system. [11], [12], [13] the photovoltaic panels, the solar accumulators, the inverter in particular, must be chosen correlated, in terms of number and technical performance, in order to obtain a functional and reliable system for a long time and to ensure the recovery of the investment in the shortest possible time.

4. Simulations for sizing the photovoltaic system

Currently, an optimal sizing of photovoltaic systems requires the use of appropriate software [14], [15], [11], [16] Several simulations were carried out with the PV GIS program [17, 33] for the dimensioning of a photovoltaic system, for the south-west area of Romania, for several power variants required from the system. For one of the cases it was considered that:

$$P_{SV} = P_1 == 22800 \text{ W} \tag{6}$$

Simulations were made for various elevation angles (20^0, 30^0, 35^0, 45^0) , the panels being oriented to the south (azimuth 0^0), for several powers of the photovoltaic panels (by default a different number of panels of the same type), different energy as the value stored in the solar accumulators (by default a different number of accumulators of the same type present in the system).

The program provided results that show the solar energy received by the photovoltaic system, the energy stored in the accumulators, but indirectly, and if the realized system provides at any time the necessary energy requested by the consumers of the apiary. Thus, for example in figure 7, the 100% presence of the indication of the lack of energy in the accumulators shows that the system is undersized (here the observation is made that the one who interprets the results must extract from the diagram only the time interval associated with P_{SV}).

Next, figure 4, figure 5, figure 6, figure 7 show some of the results of the simulations made.

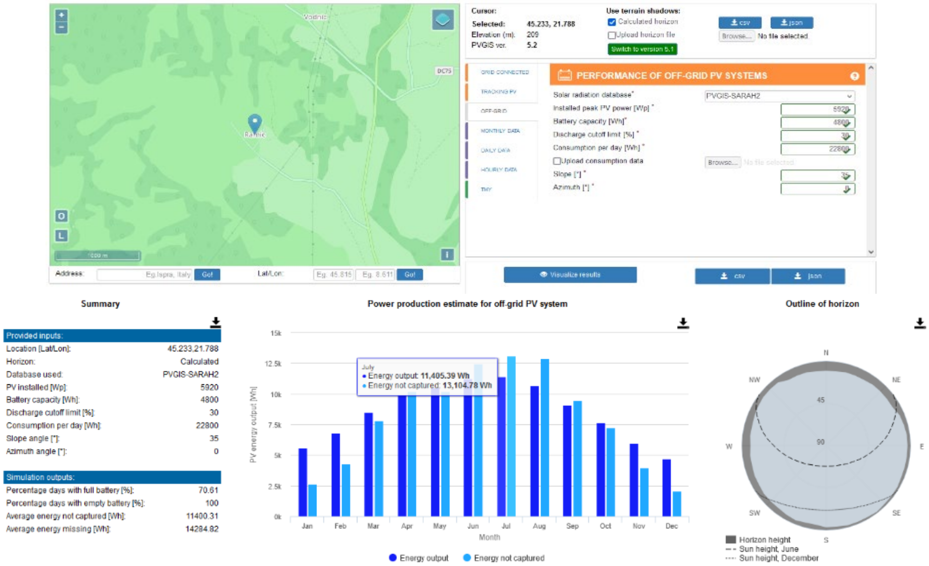

Figure 4. Simulation number 1

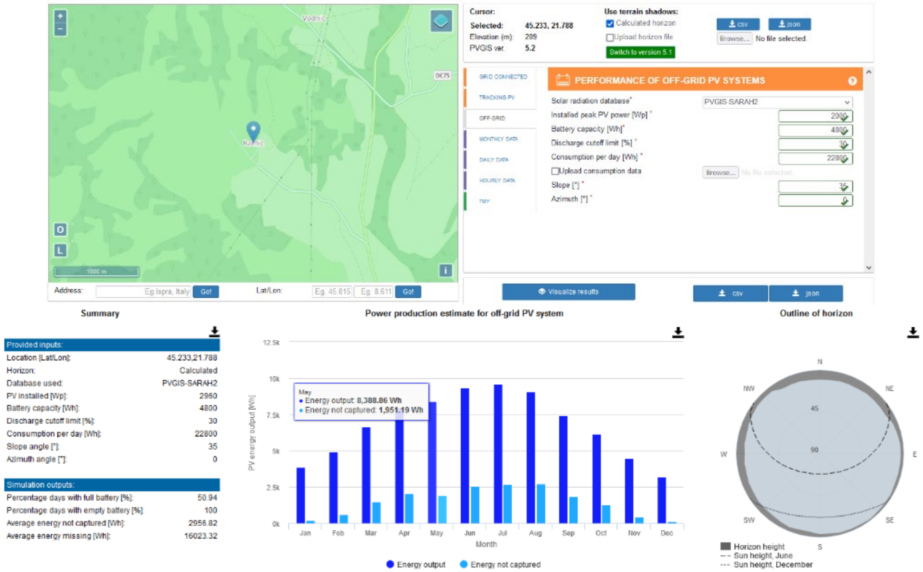

Figure 5. Simulation number 2

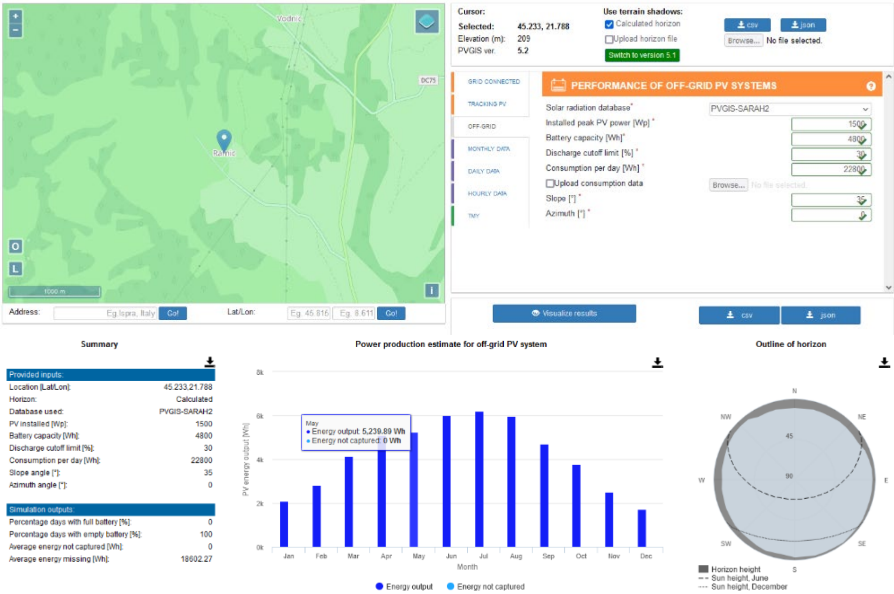

Figure 6. Simulation number 3

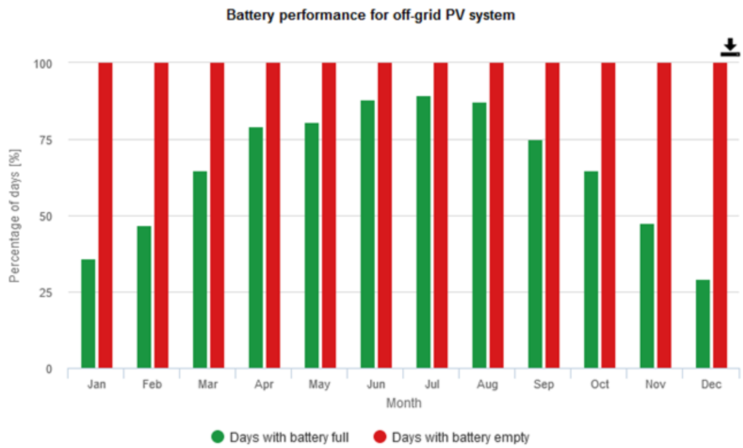

Figure 7 Battery performance for off grid PV system

The term of probability, from figure 7 reveals precisely the uncertainty of the results caused especially by the impossibility of knowing the meteorological situation in advance. The existence of 100% probability in the prediction of the battery state of charge clearly indicates that there will be at least one day in the month when the energy demand is insufficient.

5. Conclusion

The need for the presence and use of electricity in an apiary is determined by the fact that, on the one hand, there has been an increase in the complexity of the activity in such an agricultural household, which has led to the appearance and use of more complex machines powered by energy electrical, and on the other hand, the automation of some operations in the apiary was imposed in order to increase labor productivity and economic efficiency.

Larger hives are usually located in isolated areas without access to the national energy system, and therefore, the production of electricity is a local activity. At present, the production of electricity in beehives is mostly carried out with generator sets with diesel or gasoline, which are polluting solutions with toxic gases for the environment, but also noisy, and the current and maintenance expenses are high. The use of photovoltaic systems eliminates these disadvantages.

Some considerations and recommendations of an applicative nature, taking into account the experience of some of the authors in the field of beekeeping, useful in the design and realization of a photovoltaic system for supplying electricity to an apiary located in an isolated place. are :

- the structures that can be used for photovoltaic systems to supply electricity to an isolated beehive are the ones often used in many applications [6], [7]. Their installed electrical powers are currently of the order of kilowatts or more, differing significantly depending on the number of hives in the apiary that we estimate would be suitable to be equipped with such a system, and which, indicatively, can be 50 - 300 beehives;

- the main types of high-performing electric machines from today with high relative energy consumption from a hive were established, and their specific way of use was indicated, according to the needs, during a calendar year, so as not to affect the technical-economic performances in an isolated apiary;

- the simulations carried out with the PVGIS program show that in cases where the positioning of the photovoltaic panels at elevation angles in the 20^0-45^0 range or the azimuth with +/- 10^0 relative to the South position, leads to variations in the estimated amount of electricity supplied by the photovoltaic system with a maximum of 2-3%.

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