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# DESIGNING AND OPTIMIZING A PHOTOVOLTAIC – BIOMASS HYBRID SYSTEM

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**Abstract – In this paper is presented the harness of two renewable sources, the source of the sun and of biomass. It was designed an electrical energy generation system, based on the simulation program named HOMER. In the article is described the optimization result after simulations, theoretical result which can be implemented in practice to generate electrical energy.**

**Keywords:** photovoltaic system, biomass system, electrical energy generation, optimization.

## 1. INTRODUCTION

The fossil energy sources, such as coal, oil and gas are on path of exhaustion, when the energy consumption in the world is above 390.000.000 MWh /day. Otherwise, these energy sources are too pollutant, this is the second factor that the fossil resources must be changed with the renewable ones.

Due to the fact of the increasing number of the population of the world, the energy demand also is in a continuously growth; to may satisfy the requirements, the renewable energy sources gain ground in the producing of electrical and thermal energy.

The sources offered by the nature, the sun, wind, biomass, sea, tidal, geothermal energies are inexhaustible, because they have an infinite reloading cycle, they are renewable.

In the European Union (EU), and in Romania the primary energy production, the gross inland consumption is given in Table 1, respectively in Table 2. [1]

**Table 1 – Primary energy production in 2011 [%]**

| | Hard Coal | Lignit | Oil | Gas | Nuclear | RES* |
|---|---|---|---|---|---|---|
| EU 28 | 9 | 12 | 11 | 18 | 29 | 20 |
| Romania | 0 | 24 | 16 | 31 | 11 | 18 |

*Renewable Energy Sources

**Table 2 – Gros inland consumption in 2011 [%]**

| | Hard Coal | Lignit | Oil | Gas | Nuclear | RES |
|---|---|---|---|---|---|---|
| EU 28 | 11 | 6 | 35 | 23 | 14 | 10 |
| Romania | 3 | 19 | 25 | 31 | 8 | 14 |

In table 3 are given the energy consumptions for EU 28 and Romania by sectors.

**Table 3 – Energy consumption by sector [Mtoe]**

| | Industry | Transport | Rezidential | Services |
|---|---|---|---|---|
| EU-28 | 288 | 366 | 275 | 141 |
| Romania | 7.11 | 5.16 | 7.86 | 1.77 |

## 2. BIOMASS ENERGY RESOURCES

The biomass may be utilized either as material or as energy [2, 5]. In category of biomass resources are included all biomaterials that are bio derived resources. This kind of energy source is not only from woods, pellets, but also from crops and municipal solid waste, etc. obtained. The typical components of the biomass are celluloses, hemicelluloses, lignin; starch; proteins, and other organic and inorganic components [2,5.6].

The biomass, the organic materials are degradable, in anaerobic or aerobic environment [5, 6]. In case of anaerobic environment, are satisfied the following conditions:

- Environment without oxygen
- Certain percent of moisture
- The presence of certain bacteria;
- Temperature.

In these conditions, due to some biochemical reactions there will be biogas product. The big quantity of municipal solid waste may be transformed in landfill gas, which high $CH_4$ contain may be harnessed to produce electrical or thermal energy.

The landfill gas is composed of [3]

- $CH_4$ – 40 – 55% vol.
- $CO_2$ – 35 – 45% vol.
- $N_2$ – 0 – 20% vol.
- $O_2$ – 0 – 5% vol.

By using the landfill gas to product energy is also reduced the green house gases – GHG - emission, which emission conduct to climate changes.

## 3. THE ENERGY OF THE SUN

The energy of the sun may be harnessing by converting it into electrical and thermal energy. The conversion into electrical energy is made by using photovoltaic (PV) panels based systems, as with solar system with thermal panels may be obtained warm water, used for residential or industrial heating.[4,7]

A good operation of a PV system depends on:

- the daily insolations of the PV panel
- daily temperature

- geographical localization of the site
- season.

## 4. DESIGN AND OPTIMIZATION OF A BIOMASS – PV SYSTEM

The system designed for electrical energy generation, is a hybrid power system, composed from a PV and a biomass system. Because Oradea is a municipality, it has the possibility to use the solid waste biomass and to convert it into landfill gas; the daily average solar radiation is 3.423 kWh/m$^2$/day, it is useful to implement a hybrid system, based on biomass and PV integrated system. In the studied case is supposing that the designed and optimized system does not model the grid.

It is very important to know with accuracy – in point of view of solar energy – the geographical localization of the site, the site where we want to implement the system. For this reason, significance has the site's latitude and longitude, the season, the clearness index and the daily radiation.

The simulated system is localized in Oradea municipality, at latitude 47.1$^o$ and longitude 21.9$^o$, where the average clearness index is 0.482 and the daily average radiation is 3.423 kWh/m$^2$/day.

The parameters above described – daily radiation and the clearness index - are simulated with HOMER program and the results are in given fig. 1.

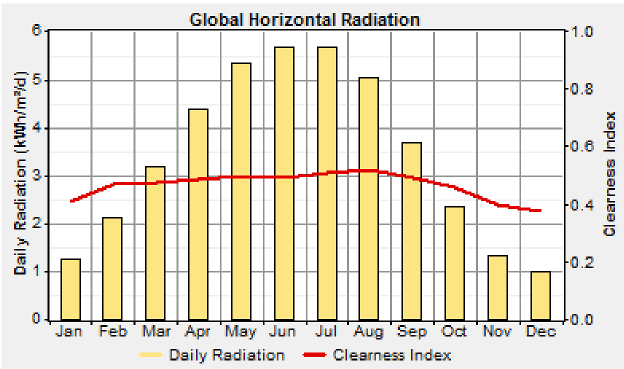


**Fig. 1. Global horizontal radiation, daily radiation and clearness index**

In fig. 2 is represented the biomass resource that is an annual average availability of 11.76 t/day.

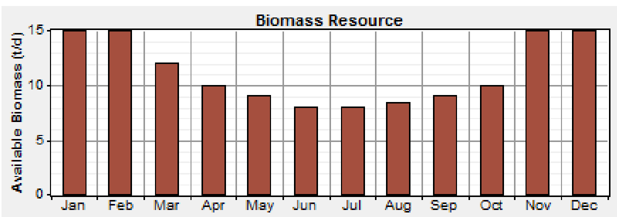


**Fig. 2 – Biomass resource availability**

Knowing these parameters, it can be considered the system that is composed from PV panels, a biogas plant, a converter, consumer and a battery. Is very important to know what is the daily demand of electrical energy, because in function with this requirement will be designed the installation. After introducing for each hours of a day the values of the electric load, the Homer program simulates the daily consume, which in this case is 20 kWh/day, fig.3.

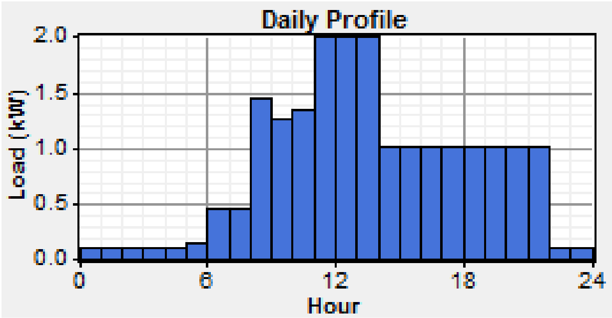


**Fig. 3 – Daily load profile**

After simulation results that the scaled annual average value is 19.6 kWh/day, as the scaled peak value is 3, 6 kW$_{peak.}$ The daily profile for each months of the year is given in fig. 4.

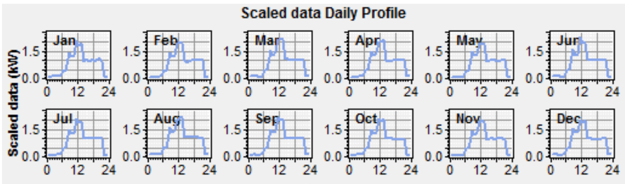


**Fig. 4 – Daily profile for a year**

The scaled annual average

The system considered is presented in fig. 5.

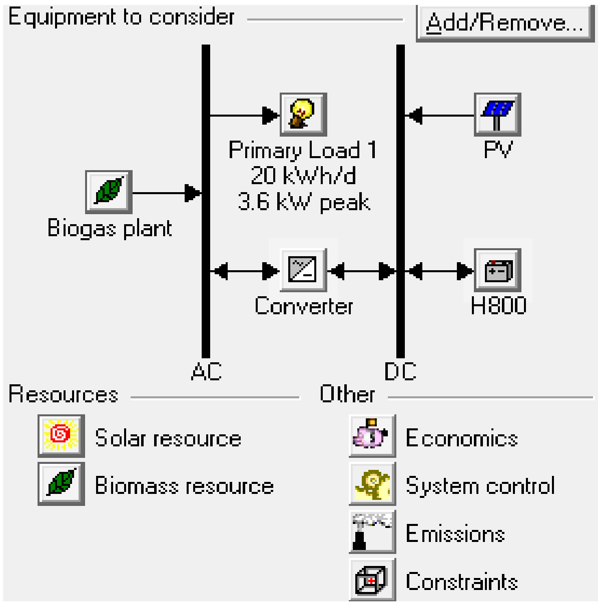


**Fig. 5 - Hybrid system composed of biomass and PV unit**

The converter is necessary to serve an AC system a DC load, or contrary; the battery has role of storage the energy.

The supposed system was designed and optimized with the HOMER program, the obtained results of simulation are given in fig. 6.

Sensitivity Results | Optimization Results

Double click on a system below for simulation results.

| | PV (kW) | Bio (kW) | H800 | Conv. (kW) | Disp. Strgy | Initial Capital | Operating Cost ($/yr) | Total NPC | COE ($/kWh) | Ren. Frac. | Biomass (t) | Bio (hrs) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 20 | 20 | 8 | 25 | CC | $ 21,808 | 3,312 | $ 64,144 | 0.701 | 1.00 | 45 | 3,540 |
| | 20 | 20 | 8 | 25 | LF | $ 21,808 | 3,312 | $ 64,144 | 0.701 | 1.00 | 45 | 3,540 |

**Fig. 6 – Optimization results of the system**

The monthly average electrical energy production is given in fig. 7.

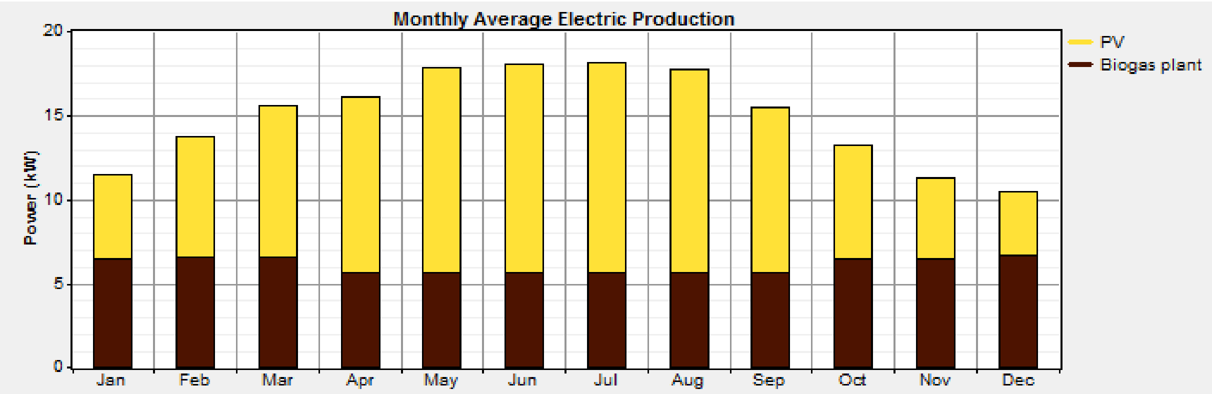


**Fig 7 – The monthly average electrical energy production**

In the simulated case, the system contains a PV installation of 20 kW, a biomass plant of 20 kW, eight battery Hoppecke.

The PV system's output is presented in fig. 8, as in the fig. 9.the biomass plant's output.

The PV system power production in a year is 31,107 kWh/year, as of the biogas system is 21,240 kWh/year.

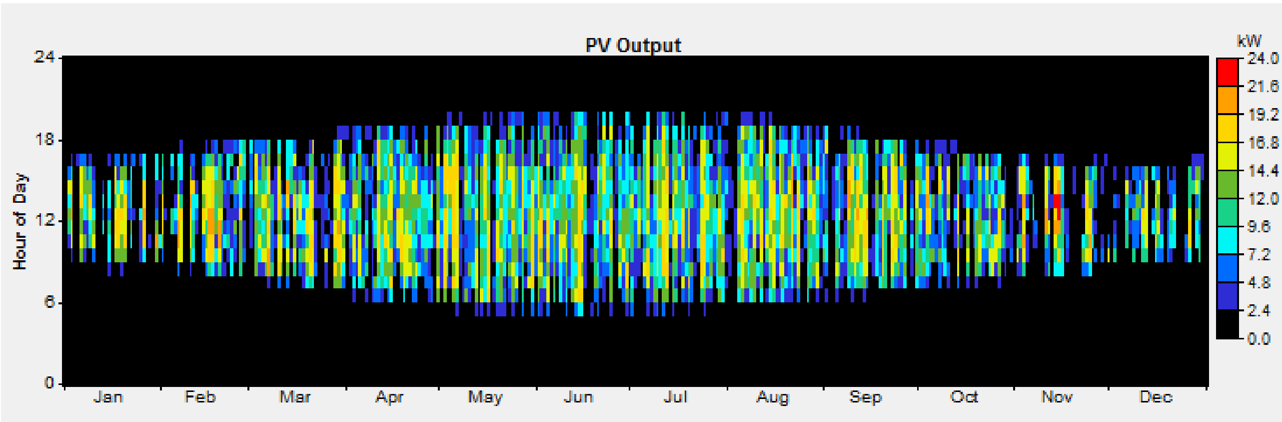


**Fig. 8 – The PV system's output**

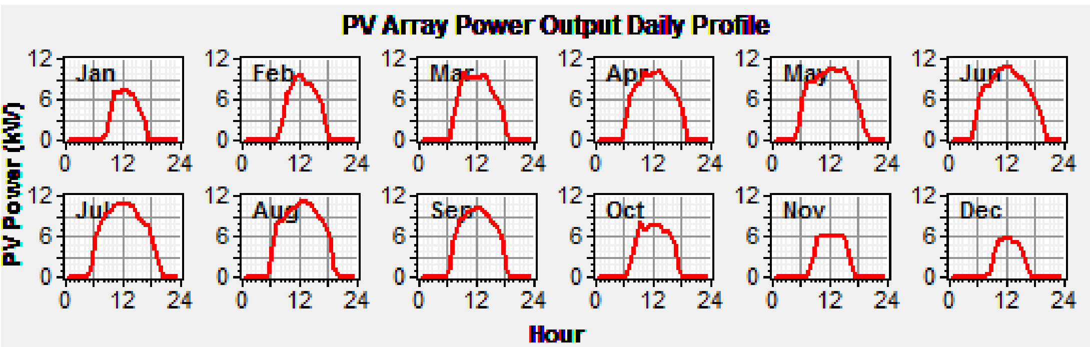


**Fig. 9 - PV daily output**

As it can be seen in figure 9, the daily outputs of the PV panels are important in May, June July and August.

The biomass feedstock resource for a year is given in figure 10, as the yearly biogas electrical output in figure 11, for biogas system for 24 h

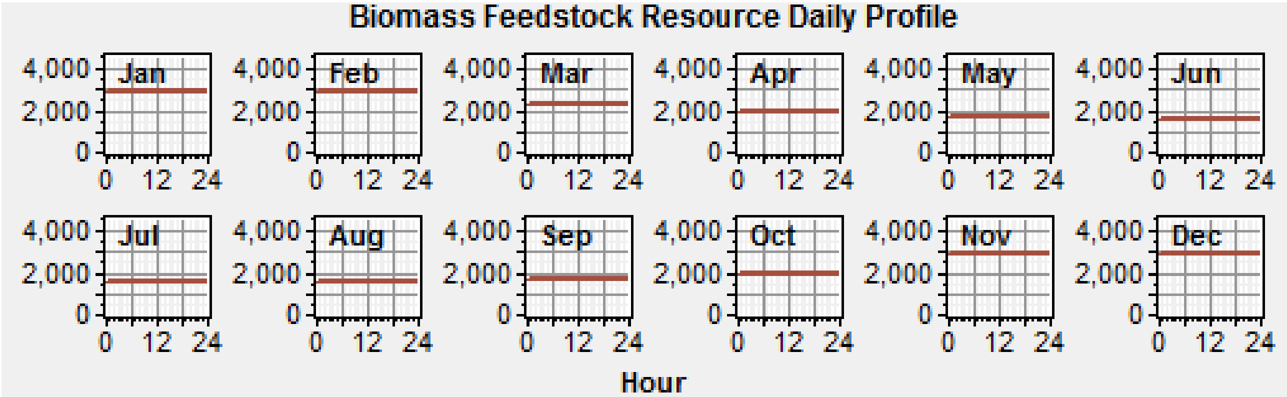


**Fig.10 – Yearly biomass feedstock resources**

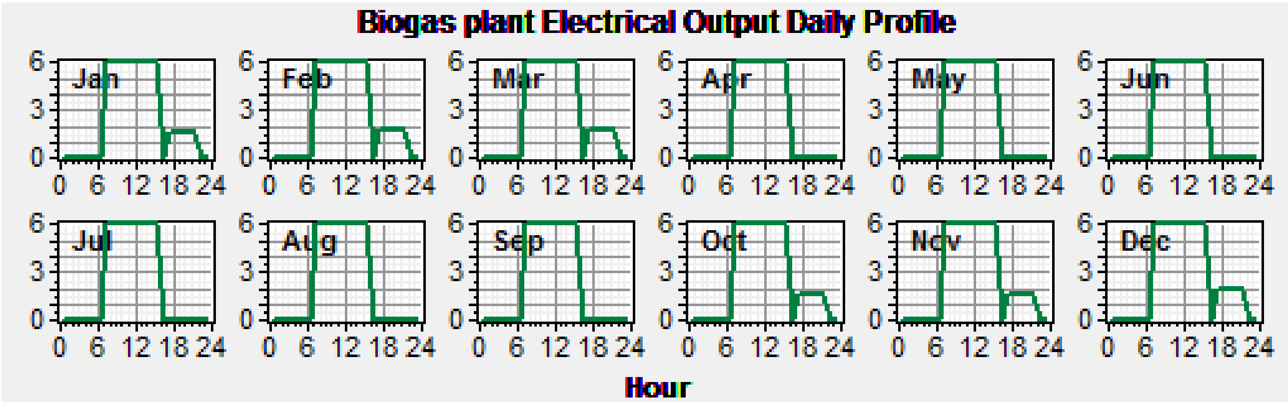


**Fig. 11 – Hourly biogas electrical output**

In the following figure, fig. 12, are the results for the chosen battery given

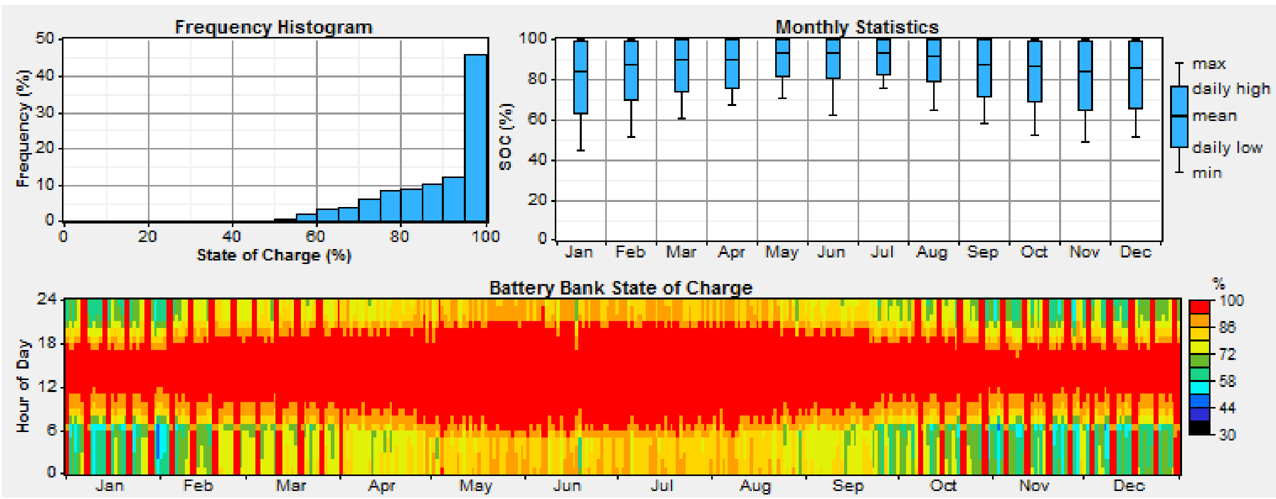


**Fig. 12 – The operation of the batteries for the simulated case**

The results of the converter in figure 13 are given.

| Quantity | Inverter | Rectifier | Units |
|---|---|---|---|
| Capacity | 15.0 | 15.0 | kW |
| Mean output | 0.3 | 0.1 | kW |
| Minimum output | 0.0 | 0.0 | kW |
| Maximum output | 1.8 | 3.2 | kW |
| Capacity factor | 1.8 | 0.4 | % |

| Quantity | Inverter | Rectifier | Units |
|---|---|---|---|
| Hours of operation | 5,219 | 588 | hrs/yr |
| Energy in | 2,657 | 637 | kWh/yr |
| Energy out | 2,391 | 541 | kWh/yr |
| Losses | 266 | 96 | kWh/yr |

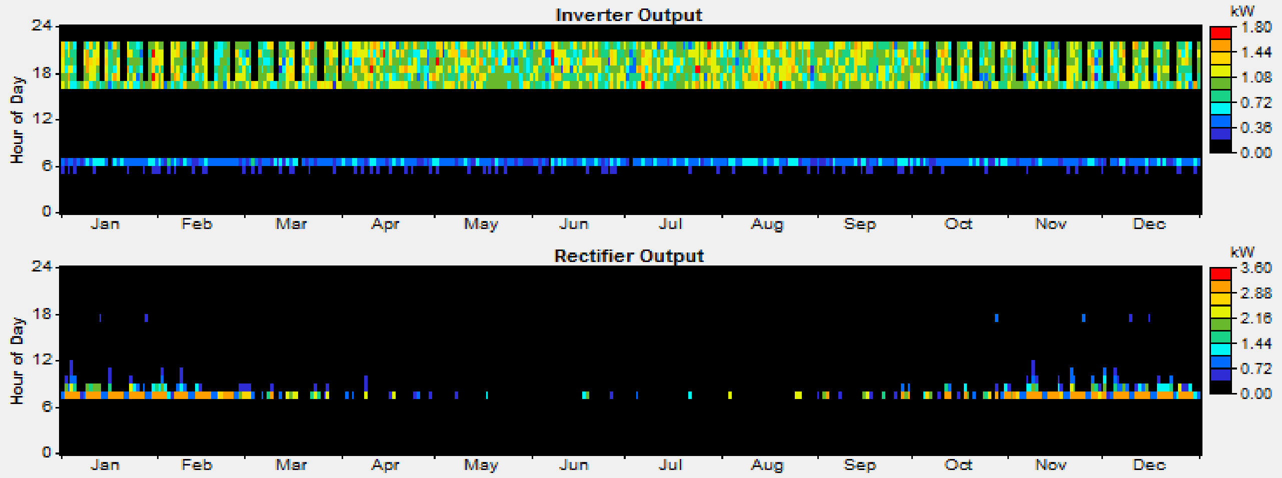


**Fig. 13 – Results for the applied converter**

The monthly inverter output is represented in figure 14. As it can be seen, the power output of the inverter is the highest between 12 – 24 hours.

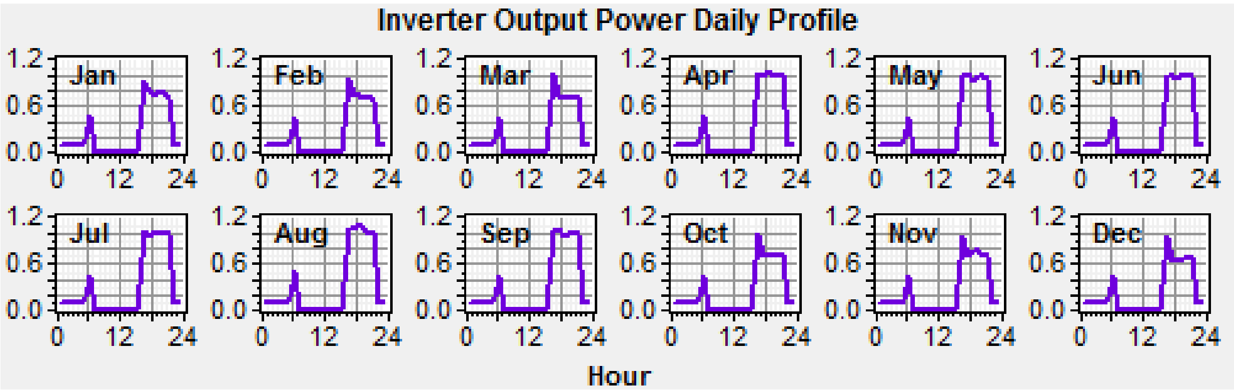


**Fig.14 – Monthly power output of the inverter**

## 5. CONCLUSION

In this article was designed a hybrid system based on solar and biomass sources, which isn't connected to the grid.. After simulations, the optimized result is presented, from which can seen that the designed system is efficiently, producing 31,107 kWh/year from the solar energy, and 21,240 kWh/year, from the biomass. The percentage values are: 58% PV as 42% biomass energy. The electrical production of the simulated hybrid system is 52.3 MWh/year.

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