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SYSTEM FOR SUPPLYING ELECTRIC ENERGY WITH ZERO CO_2 EMISSIONS

Abstract: *In this paper we are presenting an innovative system for supplying cities and villages with electricity in a system with zero carbon dioxide emissions with solar panels with Fresnel lens and Stirling engines, into an automatized setup.*

Key words: electrical energy, thermal energy, Fresnel lens, renewable energy, Stirling engine.

INTRODUCTION

Climate change in recent years, as well as fears that fossil fuel reserves will soon be exhausted, have led scientists to focus their attention on alternative energy sources. A renewable and almost free energy source is the one obtained from the Sun using different conversion systems.

The need to find alternative solutions for production of electrical and thermal energy from renewable energy sources is all the more important and urgent as, from year to year, global demand for energy increases significantly.

Therefore, the most effective solution we have to reduce the energy bill is to act on the amount consumed by increasing energy efficiency, i.e. by using renewable energy sources [10].

The study of a thermoelectric power plant with Fresnel lens and Stirling engine as an alternative source of thermal and electric energy production may be a good alternative to help us avoid the gloomy perspectives regarding reserves of primary energy.

In order to obtain electric energy from the Sun, a small power plant that includes a 0.52 m^2 Fresnel lens and a beta type Stirling engine has been built. The technology can make significant contributions in order to reduce carbon dioxide emissions and air pollution and to be able to offer electric and also thermal energy to villages and cities where classical systems do not exist or do not cover the need for energy [1,2,8,9].

EXPERIMENTAL SETUP

A small power plant has been built. The power plant contains: a Fresnel lens, a beta type Stirling engine with a generator in order to obtain electric energy, a double frame with two-axis systems following the Sun automatically, the upper part supports the lens and at optimal length from the focal point, the Stirling engine with the generator. On the lower frame, the control module for following the Sun on the sky is placed and all the measurements equiments.

The piranometer is placed on the upper part, movind together with the upper frame and the lens. At 2m above, the anemometer registers the wind speed. The datalogger, thermometers, multimeters and rest of equipment is placed on the lower frame. In figure 1 it is shown the upper part of the frame with the lens altogether with the beta type Stirling engine and the generator.

At the same time, one can not speak of a particular type of solar collector as the best for the multitude of systems and applications in which they can be used. Factors such as system temperature, working temperature, geographic position, solar radiation of the place, type of installation, system lifetime; all of these must be well identified and defined to be able to dimension and choose the type of solar collector that is most promising for what we want to install [15-21].

The Fresnel lens used is imaging type (reproducing the Sun's image on the receiver, i.e. point-based focusing), and it has been used in the solar-thermal plant in order to benefit from it's dual use: for direct heat and electricity generation with the help of the Stirling engine and the generator. The lens is thin and light, reliable and durable, and although this type of lens can induce energy losses through reflection on interfaces, they are easy to use and correct with anti-reflective thin layers. Also, the lens does not transmit all the light intercepted to the focal spot due to those regions that although they appear to be vertical, they form angles of about 2 degrees, but this can be improved by modern,

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innovative and more accurate manufacturing technologies [12-14].

In the small power-plant, a beta type Stirling engine having a single cylinder in which a displacement piston and a working piston are mounted on the same shaft has been used, linked to a generator. The electrical generator that converts the mechanical energy into the electrical energy used in the experimental installation has an operating voltage between 0.3-12 V, rated speed 2500 RPM, starting current 10 mA and maximum torque 5.5 g/cm.

Experimental data was conducted in several stages, with clear sky conditions, cloudy sky, and high wind speeds.

In this paper, results from measurements in clear sky conditions are presented. The experimentally determined measurements were as follows: solar radiation, wind speed, the temperature in the focal spot on the Stirling engine, the temperature on the hot part of the radiator, temperature on the radiator on the cold side, the temperature inside the Stirling engine on the lower part, voltage at the terminals of the electric generator and current at different load resistances [2,3,4,15].

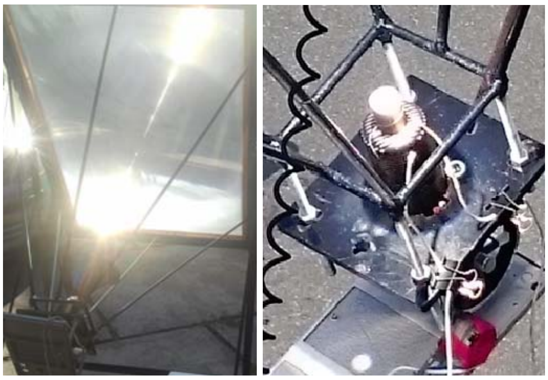

Figure 1. *System with Fresnel lens and Stirling engine*

In this setup, the Stirling engine uses as a working fluid air, where the receiver is heated from the Sun with the help of the concentrating Fresnel lens [2,3,4,6].

EXPERIMENTAL RESULTS

For the experimental determination of the voltage at the terminals of the electric generator and the load current, a Texas Instruments acquisition system has been used. The data acquisition system uses the LabVIEW programming environment [5]. The block-diagram is shown in figure 2.

The program contains two virtual instruments, namely *Acquisition 3 signals.vi* used to record the signals from the acquisition board, and to configure it, respectively *Processing 3 signals.vi* used for processing the voltages and currents.

The *Virtual Acquisition 3 Signal.vi* tool with the block diagram presented in figure 2 allows the user to view the signals acquired in the main panel (on the computer screen), the voltage of the generator and load current voltages. The purchased signals can be saved on the computer's hard drive in a file that can be accessed and used later.

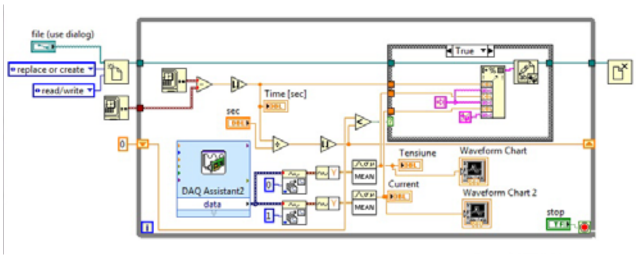

Figure 2. *The block diagram of the virtual instrument for the acquisition of voltages and currents*

Figure 3 shows the front panel of the virtual instrument, indicating the value of the measured data as well as the time variation of these measurements.

On the front panel of the virtual instrument the cases of parameters are shown. These can be visualized, modified and saved; as well as the location where the file with data recorded in *.txt* can be exported. On the panel the box labeled "sec", is the one that can permit to set the step of the time for the program to write in to the output file the registered measured values in *.txt* format.

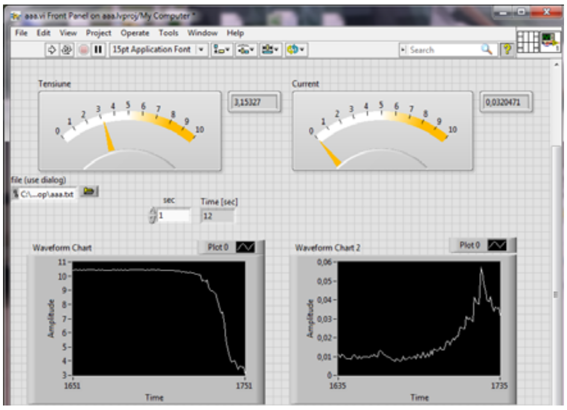

Figure 3. *The front panel of the virtual instrument for the acquisition of voltages and currents*

In Table 1 the values of the voltage (*U*), the current (*I*) and the power of the generator (P), the output temperature of the Fresnel lens: (T_1) temperature of focal point of the Fresnel lens, on the top of the Stirling engine, (T_2) temperature of the hot zone, temperature of the cold zone (T_3) of the Stirling engine at certain time values and load resistance are shown. Ambient temperature was T_{amb} = 36°C, variable wind speed between 14.4 and 18.9 km/h.

Table 1. *Results of experimental setup*

No.	Solar Rad. [W/m²]	R [Ω]	n [rpm]	T_{1avg} [C]	T_{2avg} [C]	T_{3avg} [C]	U_{avg} [V]	I_{avg} [A]	P_{avg} [W]	P_{max} [W]
1	848	1100	344	293	87,88	30,31	7,82	0,0068	0,05	0,12
2	848	1000	318	267	93,14	30,86	6,43	0,0068	0,04	0,09
3	850	900	318	267	95,71	31,29	6,98	0,0039	0,02	0,09
4	854	700	591	540	106,33	31,00	8,24	0,0114	0,09	0,17
5	853	500	327	276	122,35	31,41	9,09	0,0173	0,15	0,24
6	851	300	541	490	135,17	30,75	8,62	0,0268	0,23	0,31
7	851	100	404	353	132,55	30,73	4,52	0,03	0,14	0,33

Figure 4 shows temperature dependence on the top part of the Stirling engine (in the focal point) (*T*1), the temperature of the hot zone (*T*2) and the temperature of the cold zone (*T*3) of the Stirling engine depending on time. From this diagram it is found that the temperature in the focal point (on the Stirling engine) has an important variation over time (35-57) s and range (70-85) s.

The temperature of the focal point on the top of the Stirling engine has a minimum value of 197°C and a maximum value of 624°C.

Figure 5 shows the voltage dependence of the electric generator over time at various load resistors, changing the load resistance value in steps of 100 Ω from 100 Ω to 1100 Ω. The internal resistance of the electric generator was determined from the idling and short-circuit tests, changing the generator's speed in the (878-1268) RPM range in the beta type Stirling engine

The thermo-electric-solar power plant with Fresnel lens and Stirling engine was placed on the roof of Politehnica University of Timisoara, body C.

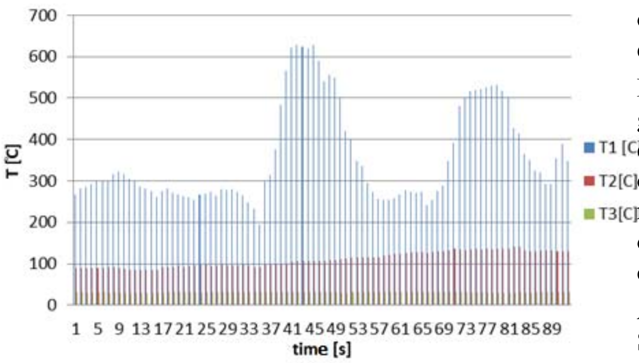

Figure 4. *Temperature in the focal point on the top of the Stirling engine - T_1, on the hot side - T_2, and at the cold side - T_3.*

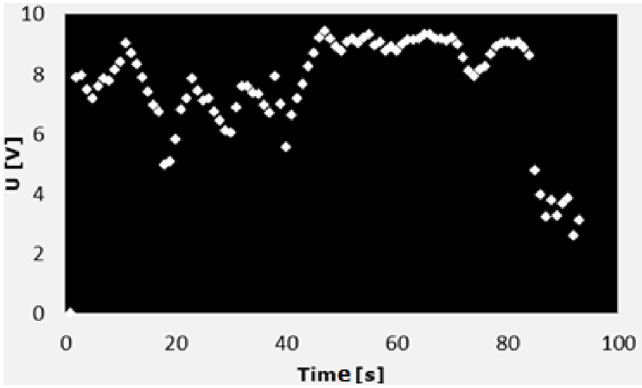

Figure 5. *The evolution of the voltage in time*

Unlike photovoltaic cells, where solar energy is directly transformed into electricity, concentrated solar energy can be used both to produce heat and electricity [11].

The results obtained and shown in this paper are justified by the fact that the transfer of heat from the source to the Stirling engine is influenced by the atmospheric conditions. During the measurements the environmental conditions were not the same, although the sky was not covered by clouds, the wind speed was quite large and variable in time, which is also observed in figure 5, where the wind speed indirectly influences the power of the system.

Also, the top of the Stirling engine is not isolated or shielded from the environmental conditions, and therefore, wind speed influences a lot the power of the system.

CONCLUSIONS

Concerns about the use of renewable energy sources in order to obtain electricity and heat is fully justified if one considers the limited reserves of conventional energy resources.

For this reason both at the European Union level and at global level, a number of measures have been taken to encourage resolving these concerns, including financial ones. It is noteworthy that the extension of the use of renewable energy sources contributes to the reduction of pollution, thus implicitly to ensuring better living conditions for the population.

Also, the use of solar concentrators allows the use of Stirling motors to power the electric generators. Stirling engines are reliable and have low running costs. Among the various categories of concentrators, Fresnel lenses have a good performance, which is why they are most used.

The main advantages of the Stirling engines are: they can use any heat source including solar energy; long service life; the residual heat is easy to use; and the can operate at low temperatures.

The use of solar thermoelectric power plants with Fresnel lenses and Stirling engines requires optimal design and several factors need to be taken into consideration, such as: the location where the power plant needs to be built; the solar energy source [7] -

climate zone, the demand of energy, consumers choice, types of materials used in the construction of the plant; type of Stirling engine used; the type of lenses used (with a linear or punctual focus). Achieving an efficient thermo-electric-solar power plant is only possible in areas where the solar radiation exceeds 800 W/m^2.

The use of solar concentrators allows the use of Stirling engines to power the electric generators. Stirling engines are very reliable and have low running costs. Among the various categories of concentrators, Fresnel lenses have a good efficiency, over 80 %.

The thermo-electric-solar power-plant equipped with automatic two-axis systems is more expensive but also the most efficient because the Fresnel lens is automatically positioned so that the sun rays have the lowest incidence angle (tends to zero) throughout the course of the day.

It is noted that the temperatures of the Stirling engine on the focal point (T_1), in the hot zone (T_2) or the cold zone (T_3) of the Stirling engine show very long and irregular variations, which also justifies the time variation of the voltage at the electric generator terminals.

This solution can be implemented for any area, urban or rural, in any part of the world where good solar radiation and atmospheric conditions are present.

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SISTEM ZA SNABLjANjE ELEKTRIČNE ENERGIJE ZA NULTU EMISIJU CO_2

Simona Ilie, Ildiko Tatai, Ciprian Sorândaru, Marian Greconici, Dumitru Toader

Rezime: *U ovom radu predstavljamo inovativni sistem za snabdevanje gradova i sela sa električnom energijom u sistemu sa nultom emisijom ugljen-dioksida sa solarnim panelima sa Fresnel objektivom i Stirling-ovim motorima, u automatizovanu konfiguraciju.*

Ključne reči: električna energija, toplotna energija, Fresnel sočivo, obnovljiva energija, Stirling motor.