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THEORETICAL RESEARCH ABOUT SOLAR ENERGY

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Abstract: This paper presents parts of the author's theoretical research concerning the solar energy and the energetic potential of the renewable energy sources in Romania.

1. INTRODUCTION

Major transformations have occurred in the energy sectors of many European countries, determined by the necessity of safety increase in energy supplying to the consumers; the renewable energy sources provide a viable solution, including the environmental protection.

The safe energy supply to the consumers of the EU is compulsory ensured by taking into account the energy import in the conditions of free energy market and according with the acute need for attenuation of the impact over the planetary climatic environment.

The necessity of ensuring a durable development in the energy field, along with a efficient environment protection, led to the intensification of the preoccupations concerning the promotion of the renewable energy sources and of the support industrial technologies in the late 10 – 15 years. The EU policy, expressed in the European Directive 2001/77/CE concerning the energy production from renewable sources, envisages that EU will have to ensure 12% of its energy supply from renewable sources. In this context, these preoccupations have concretized in the use of these renewable sources by means of several technologies in many developed European countries (France, Italy, Germany, Austria). In Germany, a special program with benefic effects is stimulated, that supports the construction of thermal solar installations by public means.

On global level, fuel constitutes the main energy source (70%): coal, petrol, gas, wood, combustible residues. Another part is played by the energy produced in hydroelectric and nuclear power plants. Of all consumed energy, approximately one third is used for household heating and hot water. According to the actual population growth rate and the technological development, the need for inexpensive and renewable energy resources increases rapidly. Also, it becomes clearer to see that the use of classic energy resources features negative aspects, as noxious gases emissions, accident risks, greenhouse effect, dependence on the common resources and networks, bigger and bigger costs etc. Furthermore, it becomes even mandatory for us to find and promote new technologies about the use of non-conventional energy resources as solar energy, eolian energy, geothermal energy etc. The energy from these sources features a whole series of advantages in comparison with the traditional resources:

- it is totally ecological, without any noxious gases emissions or residues;
- it is practically exhaustless;
- it does not imply any preparation or transport installations before use.

Various solar collectors and accessories for water heating have appeared on the market. Their working principle is based on the conversion of the solar radiation into heat in order to increase water temperature. The resulted hot water can be used as is, as household hot water or as heating agent.

2. THEORETICAL ASPECTS

The worldwide energy shortage has determined the search for new types of resources: solar, geothermal, eolian, tide power, hydraulic etc. In this context, the solar energy constitutes a valuable energetic potential that is taken into account by the researchers. The use of solar energy as thermal or electric energy is made by means of direct or indirect conversion; in the case of indirect conversion, the intermediary phases (chemical or mechanical energy) are to be covered.

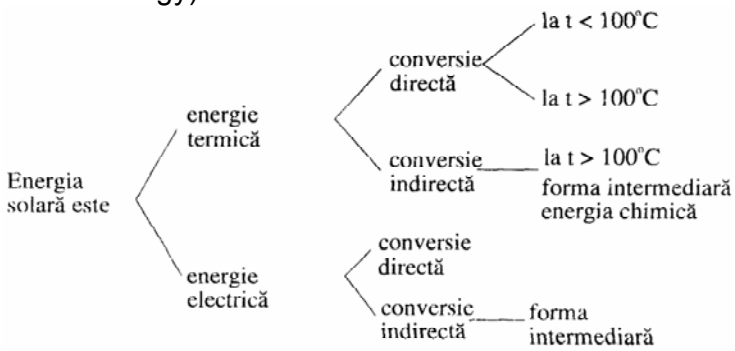

Fig.1. Classification of solar energy.

The Sun, the main energy source of Earth, is one of the approximately 10^{10} stars of our galaxy. It is a G2 spectral type star and has the following characteristics:

- ✓ average surface temperature T = 5762 ± 50 K;
- ✓ radius r = (6,96 ± 0,001) · 10^8 m;
- ✓ mass M = (1,991 ± 0,002) · 10^{30} kg.

The average Sun-Earth distance is 1,5 · 10^8 km. The temperature in the center of the Sun is T = 1,5 · 10^7 K. The solar radiation intensity is I_0 = 1353 W/m^2, measured by NASA. The amount of energy received from the Sun is of approximately 1,5 · 10^{15} MWh, which represents 23000 times the actual consumed energy or 5 ÷ 10 times all fossil known fuel reserves, including the uranium ore.

The use of solar energy features many advantages, resulted from the following characteristics of the Sun as energy source:

- ○ it is a practically inexhaustible energy source, although its mass decreases in time;
- ○ it has an enormous energy potential; a 6 · 10^{10} MWh amount of energy can be obtained by covering 10^{-3} of the Earth surface with solar collectors of only 5% efficiency;
- ○ it is a dispersed energy source, which ensures the conversion on the collecting spot, without the need of distance transportation;
- ○ it is non-pollutant and does not affect the Earth's biological balance.

In spite of these exceptional characteristics, the use of solar energy features also some disadvantages because of:

- low density flux;
- variations of the solar radiation because of the day/night alternance and the interchange of sunny and less sunny seasons.

In order to efficiently use the solar radiation, several problems must be solved:

- ❑ collecting and concentrating of solar radiation;
- ❑ conversion of the solar energy in a directly usable energy form;
- ❑ accumulation of the energy in some sort and in sufficient amount to be used when solar radiation becomes weak.

The solar energy is collected by means of:

- ❖ greenhouse effect, using simple collectors or collector fitted with radiation concentrators;
- ❖ photovoltaic effect, using photovoltaic cells;
- ❖ photosynthesis.

3. USE OF THE SOLAR ENERGY

The solar energy can be used:

At low temperatures – by means of simple collectors without special concentrators, with up to 60% efficiency; they are used for household climate maintenance, in both active and passive heating versions;

At high temperatures – referring to classic cycle thermodynamic conversion, which apply to the thermal machines and solar power plants; fig.2 shows the main block diagram of a power plant based on helio-thermodynamic cycle.

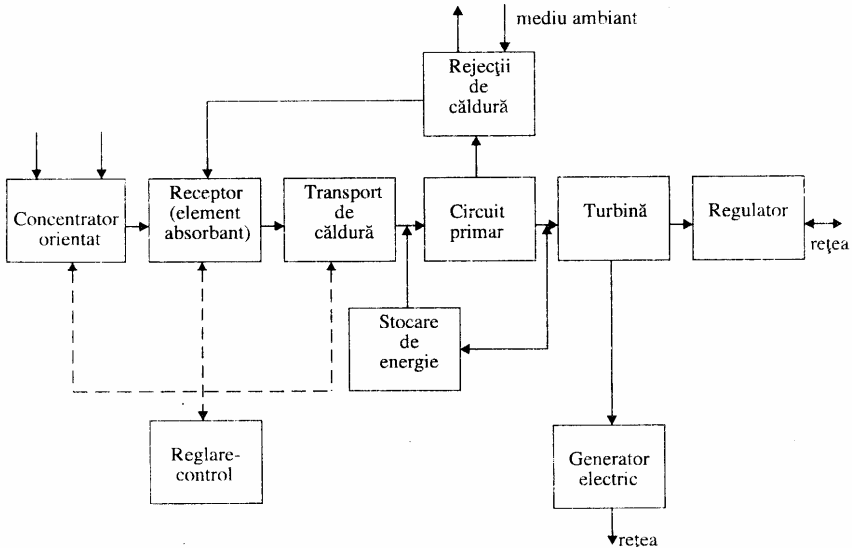

Fig.2. Main block diagram of a power plant based on helio-thermodynamic cycle.

For water de-salinization – the conversion equipment can be classified as follows: silicon solar batteries, flat collectors and concentrators, the latter being the most useful for this particular use. The concentrators offer the widest range of possibilities concerning their use due to their features: favorable profiles, high reflecting abilities, Sun tracking, high working temperature and good efficiency. Low-temperature flat collectors can be used for household use of the solar energy, because they can collect the diffuse solar radiation. In order to increase the installation efficiency, the salted water in the evaporator is pre-cooled by means of condensers. The entire amount of electric energy is supplied by the solar power plant. An irrigation system can be added to the de-salinization installation, and the required energy for water pumping can be obtained by using a more powerful power plant.

The use of renewable energy sources is rational for only a few number of applications, of which we mention:

- ➢ heat production by means of passive and active systems;
- ➢ photovoltaic conversion of solar energy into electric energy;
- ➢ use of eolian energy for obtaining electric energy;
- ➢ hydroelectric power plants;
- ➢ use of ambient air and Earth surface heat (use of low thermal heat by means of heat pumps);

- use of deep underground geometric energetic potential variations for production of heat or electric energy (use of hydrothermal resources, use of deep underground heat by means of deep wells, use of underground hot rock for electric energy production);
- use of photosynthetic energy for the production of heat, electric power and fuel (energy production based on biomass);
- use of marine energy (waves, tide and currents).

The possibilities of using the renewable energy potential are shown next. The production of final and useful energy from renewable sources is possible due to the energy flux caused by gravity and planet movement, by heat accumulated in earth and then released, and mainly by the radiant solar energy.

Tab.1. Reference values for electric energy obtained from renewable sources. [4]

Country	1997 RES (TWh)	1997 RES (%)	2010 RES (%)
Belgium	0,86	1,1	6,0
Denmark	3,21	8,7	29,0
Germany	24,91	4,5	12,5
Greece	3,94	8,6	20,1
Spain	37,15	19,9	29,4
France	66,0	15,0	21,0
Ireland	0,84	3,6	13,2
Italy	46,46	16	25.0
Luxemburg	0,14	2,1	5,7
Netherlands	3,45	3,5	9,0
Austria	39,05	70,0	78,1
Portugal	14,3	38,5	39,0
Finland	19,03	24,7	31,5
Sweden	72,03	49,1	60,0
United Kingdom	7,04	1,7	10,0
EU	338,41	13,9	22,0
Romania	17,51	29,0	30,0

Note: RES – Renewable Energy Source
Source: Appendix to the Directive 2001/77/EC (except Romania)

4. CALCULATION OF THE THERMAL ENERGY REQUIREMENT

For example, a small 23 kW power plant can produce household hot water instantaneously, at the following parameters [8]:

- ✓ hot water flow: 11 liters/minute (660 liters/hour);
- ✓ $\Delta T = 30^{o}C$ (ΔT is the temperature variation between the output hot water and the input cold water).

Considering that the average input water temperature is 10ºC, a $\Delta T = 30^{o}C$ heating gives an output water temperature of 40ºC, perfectly usable. So, for each consumed kW we can obtain 28 liters of hot water. Thus, by using the energy given by only one solar panel we can obtain:

- heat quantity: Q = 2700 KWh;
- household hot water quantity: 2700 kWh × 28 liters/kWh = 75600 liters (approximately $75m^3$) per year, at 40^0C temperature.

In order to evaluate the household hot water requirement, we will use the standard requirements according with to the European normative:

Tab.2. Standard household hot water consumption [8]

Building	Liters/day x person	Liters/year x person
Homes:		
Low comfort	15 ÷ 30	5475 ÷ 10950
Average comfort	30 ÷ 60	10950 ÷ 21900
High comfort	60 ÷ 120	21900 ÷ 43800
Hotels:		
Rooms with bath and kitchen	170 ÷ 260	62050 ÷ 94900
Rooms with bath	135 ÷ 195	49275 ÷ 71540
Rooms with kitchen	75 ÷ 135	27010 ÷ 49275
Pensions	40 ÷ 70	13505 ÷ 27010

5. SOLAR ENERGY POTENTIAL IN ROMANIA

The solar energy potential is given by the average energy amount brought by the incident solar radiation on horizontal plane, which is approximately 1100 kWh/m^2/an in Romania. The preoccupations concerning the solar energy reached a peak in 1979, when the solar energy systems were widely used for producing household hot water; Timişoara was the first city ever where a whole district, named ”Zona Soarelui” (”Sun Zone”), was fitted with such installations, followed by the hotels from the Black Sea coast, agricultural and industrial hot water systems etc.

After 1990, photovoltaic systems of various power levels and operating conditions were built in Romania, as parts of research-development-demonstration programs:

- self-supported power supply systems for remote consumers (individual homes, social and cultural centers in the Apuseni Mountains, Black Sea coast, Danube Delta), radio-telecommunications installations, water pumping installations, public lighting or traffic signaling contained in rural electrifying programs etc;
- power supply systems connected to the network (pilot photovoltaic power stations with mobile panels, immobile integrated systems etc).

In the Romanian solar and meteorological conditions, a solar collector works safely in March-October period at 40÷90% efficiency. The solar systems are very useful to produce household hot water.

The solar collectors can operate at high efficiency in conjunction with other conventional or non-conventional thermal systems. The solar radiation may have a rather low level, because the passive solar systems can operate efficiently in zones with lower solar radiation intensity, such as the northern regions – Transylvania or Moldavia.

Because the solar resources are inexhaustible, a durable system will be developed in the course of time. Because the Sun itself cannot be privatized, nobody will be able to endanger this model, which will result in a larger individual, social and economical independency that does not develop to the detriment of others. The orientation towards the worldwide solar economy would necessitate a second industrial revolution of energy technological nature.

The amount of renewable energy sources in Romania is planned to reach 11% of the total consumption in 2010 and 11,2% in 2015 (tab.3)

Tab.3. Amount of renewable energy sources from the total energy consumption in Romania [2]

Renewable energy sources	2000 (th. tep)	2010 (th. tep)	2015 (th. tep)
Solar energy, of which:	-	7,50	17,00
solar – thermal solar – electric	- -	7,34 0,16	16,00 1,00
Eolian energy	-	27,00	86,10
Hydro energy	1272	1565,20	1608,20
Biomass energy	2772	3347,30	3802,00
Geothermal energy	-	17,50	23,90
TOTAL	4044	4946,00	5537,20
Amount of renewable energy sources [%]	10,0	11,00	11,20

The resource types and the energetic potential of the renewable energy sources in Romania are shown in tab.4.

Tab.4. Energetic potential of renewable energy sources in Romania [2]

Renewable energy source	Annual energetic potential	Energy economic equivalent (th. tep)	Application
Solar energy - thermal	$60 \cdot 10^6$ GJ	1433	Thermal energy
Solar energy - photovoltaic	1200 GWh	103,2	Electric energy
Eolian energy	23000 GWH	1978	Electric energy
Hydro energy	40000 GWh	516	Electric energy
Biomass energy	318 · 106 GJ	7597	Thermal energy
Geothermal energy	$7 \cdot 10^6$ GJ	167	Thermal energy

The renewable energy sources may contribute to the current electric energy and heating requirements in the rural regions. The use of renewable energy sources in the energy competitive market becomes advisable by adopting and putting into practice policies and specific instruments or ”green certificates” (ecological certificates).

6. CONCLUSIONS

The renewable energy sources can be assimilated to a ”natural energetic flux”, whether we speak about solar, eolian, hydro, biomass or geothermal sources. The development of renewable sources as significant non-pollutant energy supply is one of the main objectives of the worldwide energetic policies which, in the context of durable development, aim at safety increase in energy supplying, protection of the environment, commercial development and using viable energetic technologies.

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