Hydrostatic Transmissions Used to Drive a Collapsible Solar Thermal Collector

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Abstract: *This paper presents some considerations regarding the use of renewable energy, and also some results obtained by the institute INOE 2000-IHP Bucharest in promoting advanced technologies and equipment for solar thermal panel technologies, in order to use the renewable energy resources for individual users. There are presented some results obtained in ROMANIA regarding the development of actuation/guidance devices, named hydraulic solar tracking systems, used in construction of equipment for conversion of solar energy directly into thermal energy. Finally, there is presented an experimental model of an collapsible solar thermal collector, developed in the institute INOE 2000-IHP, with hydraulic tracking systems, which allows optimizing the working regimes, in order to increase the efficiency of collecting the solar energy and its adaptation to the variations of thermal loads during the day. The obtained results can be transferred to industry.*

Keywords*: renewable energy, solar energy, solar thermal panel, solar tracking systems, hydraulic orientation/guidance system*

1. Introduction

The Romanian government has developed the **Romanian Energy Strategy** for the period 2007 - 2020 updated for the period 2011 - 2020, in which, for the country's **sustainable development**, there have been set a number of objectives including: increasing the energy efficiency; promoting energy production based on renewable resources; promoting the production of electric and **thermal energy** in cogeneration plants; supporting research, development and dissemination of applicable research results; reducing the negative impact of the energy sector on the environment; rational and efficient use of primary energy resources [1]. For ***sustainable development of the country, it is necessary to promote*** energy production from renewable sources, so that the share of electricity produced from these sources of the total gross electricity consumption to be 35% in 2015 and respectively 38-40 % in 2020. **24%** of the gross domestic **energy** consumption will be supplied from renewable sources in 2020.

In the Strategy there is stated that because conventional energy resources are exhaustible, the only possible way to ensure coverage of increasing energy demand in Romania will be by increasing the use of renewable energy.

Also, in this Strategy there are presented the Renewable energy sources in Romania, mentioned in the National Action Plan for Renewable Energy *(PNAER) – 2010* [2].

Solar energy is the energy emitted by the Sun, being a renewable energy source (Wikipedia). At European level, respectively, in Romania, the distribution of solar radiation is shown in Figures 1 and 2. The sun is a source of free and environmentally friendly energy. The average annual solar radiation in Romania varies from 1100 to 1300 kWh /m^2 for more than half of the country territory.

The use of solar energy potential is done by solar thermal and photovoltaic systems (photovoltaic conversion). Solar thermal systems are used for the production of heat and domestic hot water for individual households and centralized small power units. For use with high efficiency of solar energy, it is recommended that these systems operate in hybrid mode along with other conventional or non-conventional heating systems. The potential usable in solar thermal systems is estimated at about 1.434 million Toe (tones of oil equivalent).

Considering the European strategy on increasing the contribution of **renewable energy sources** to achieve **the goal of 20%** renewable energy contribution of the total energy used by each EU Member State, by 2020, through the **European Solar Thermal Industry Federation** (ESTIF) it was established that, **by 2020, 50% of energy** used for heating /cooling should be obtained from solar thermal systems.

Fig. 1. Solar map of Europe

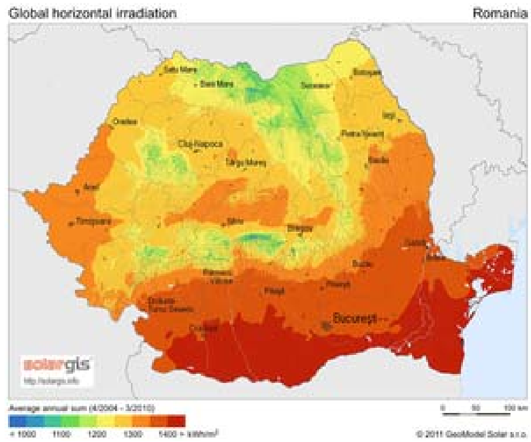


Fig. 2. Solar map of Romania

The use of renewable energy sources required continuous development of manufacturing and implementation technologies of renewable energy conversion systems in order to identify solutions characterized by high efficiency, low cost, reliability and adaptability to implementation conditions.
The solar thermal energy is the cleanest source of energy and is practically inexhaustible. It can be captured using **solar thermal panels** that directly absorb the heat of the sun and deliver it to some hot water tanks, to provide domestic hot water or for contribution to heating a house or a pool.
Therefore, in our institute there have been also conducted a number of projects at national level for the development of solar thermal energy collecting technologies, which bring great economic benefits to the users.

2. Conversion of solar energy into thermal energy

The sun is the source of life on Earth. Earth captures about 2.8·1021 kJ of total solar radiation emitted [3]. Direct radiation, received on the earth's surface, is influenced by the coverage of the sky with clouds. Another important factor influencing the **intensity of solar radiation** is the relative position. Majority of the energy from the sun, about 95%, has **wavelengths between 0.3 and 2.6 mm**, and only 1% has wavelengths greater than 4.0 mm. In **solar thermal applications** the spectrum of interest is the **infrared** one for direct heating and the **visible spectrum** for solar-thermal conversion.
Among the types of solar energy conversion, **photothermal conversion** presents a particular interest in all branches of activity, as the heat generated can be used directly (stored in various fluid, gas or solid environments) or indirectly (electricity, thermo-chemical transformations etc.). Solar energy is converted by means of solar-thermal collectors (CST) into clean thermal energy used for heating space and domestic water. Harnessing solar energy is achieved by **passive or active systems** [4].
Any black surface exposed to beams, called ***absorbing surface***, converts solar energy into heat. This absorbent surface presents the simplest example of **direct converter of solar radiation into thermal energy**, called ***flat plate solar collector***. Thermal conversion of solar energy includes several technologies: water heating with flat plate or evacuated tube collectors.
Usually, a solar heat collector looks as in Figure 3.
The main components of a flat plate solar collector, presented in Figure 4, are: black case-5, with thermo-insulation of three walls-4, covered on the front with transparent surface-3. The heat exchanger is of type metal plate-pipe, namely absorbent surface-1 and pipes 2.
The functioning of the solar **collector** is based on the two physical phenomena: the **absorption** by a black body of solar radiation incident on the absorbent surface **and** the **greenhouse effect** achieved on the transparent surface. In the case of a solar collector there is achieved an artificial greenhouse effect. A surface is transparent to sunlight and opaque for the infrared radiation. Temperature of the absorbent surface increases and heat is conveyed to the water flowing through the pipes 2.

Fig. 3. Flat plate solar heat collector

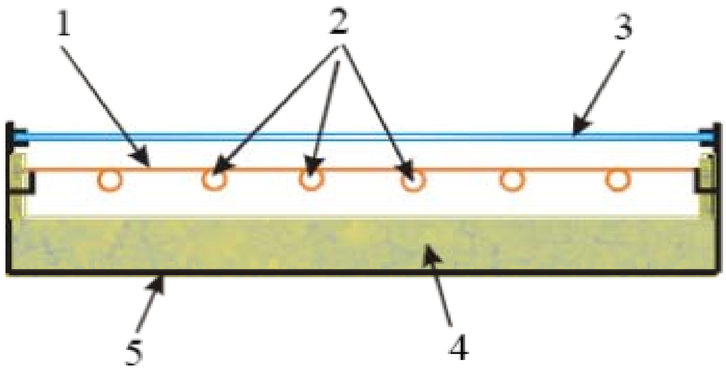


Fig. 4. The components of the solar heat collector

3. The hydrostatic transmissions used in actuating solar thermal collectors

In order to increase the efficiency of collecting solar radiation, through guidance around the Sun, in our country there have been developed various guidance means of uniaxial and biaxial mechanisms, based on hydraulic systems, similar to those used for orientation of photovoltaic systems. Moreover, optimization of diurnal orientation of thermal collectors has also the goal of achieving adequate correlation between variations of heat load and solar energy collected.
Sun position is given with reference to the azimuth angle (a) and elevation angle (alpha). In determining the position of the solar radiation collector against the sun, so the yield be maximum, the following angles are important: θz -zenith angle and solar azimuth angle -γs, Figure 5, where the γs is solar azimuth angle, α -elevation angle of the sun, zenith angle -θz and hour angle -ω, [5], [6].

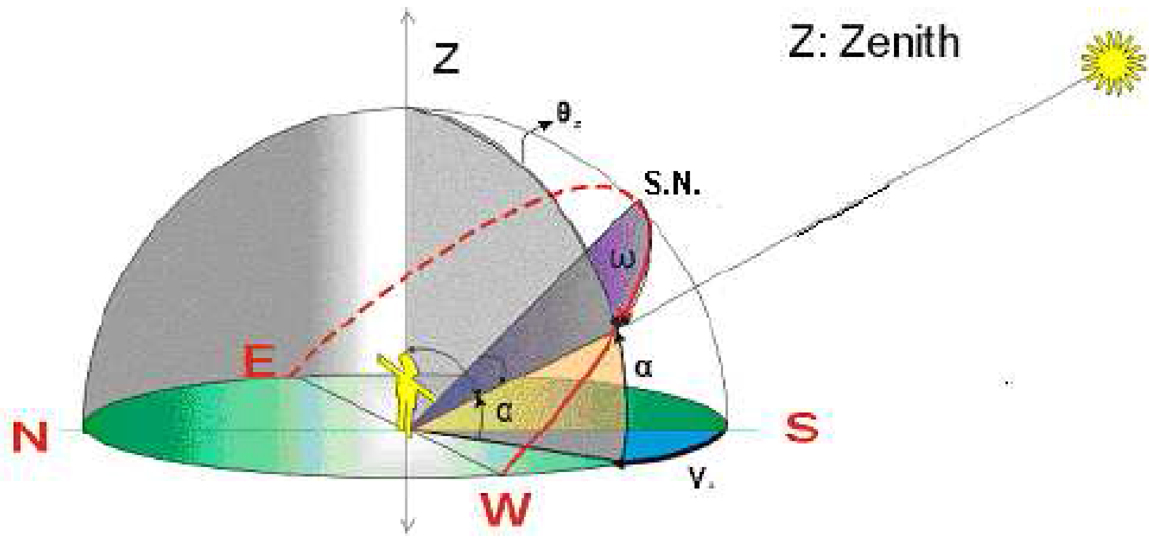
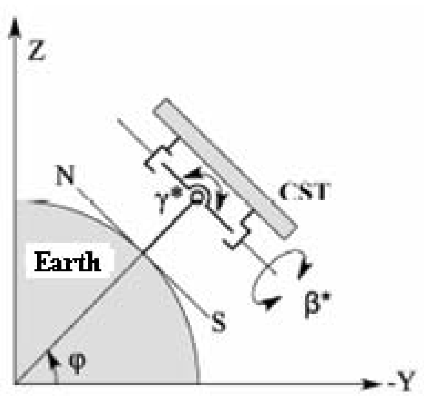
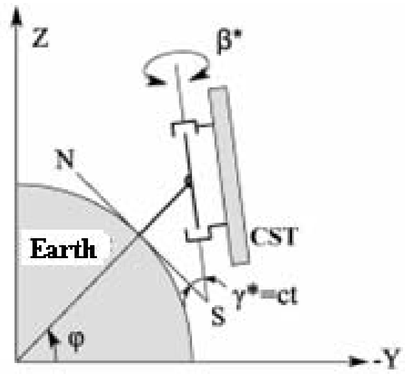


Fig. 5. Trajectory of the sun in the sky- important angles

For orientation around the Sun, in our country there have been analyzed various constructive variants, both uniaxial and biaxial mechanisms, but sometimes in the end the research was focused on the hydraulic uniaxial mechanism, Figure 6.



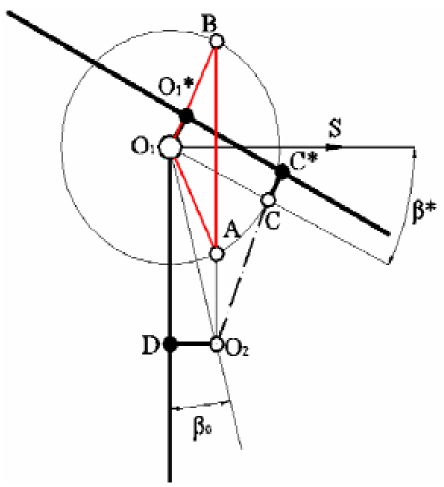
a)



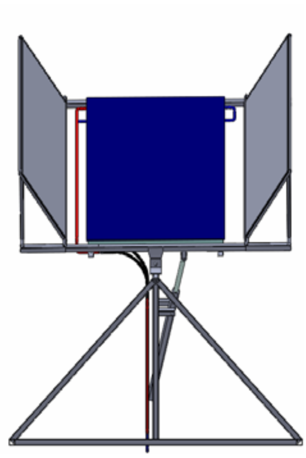
b)

Fig. 6. Pseudo-equatorial guidance systems a) biaxial, b) uniaxial

For example, in a doctoral thesis developed at Transilvania University of Brasov [7], there has been developed a research for understanding and analyzing the hydraulic systems in the structure of equipment for direct conversion of solar energy into thermal energy. They used a common solution to increase the efficiency of collecting solar radiation, through **guidance around the Sun**, by means of mechanisms/**uniaxial hydraulic systems**, similar to those used for orientation of photovoltaic systems.
In **Figure 7,** there is presented the structural diagram of the mechanism **with uniaxial inclined guidance** (a), triangle type with one side adjusted by a linear actuator (hydraulic cylinder)**,** and also **the physical model** (b) of a demonstrator solar thermal system.



a)



b)

Fig. 7. Uniaxial mechanism for solar thermal panel guidance

In another doctoral thesis, also developed at Transilvania University of Brasov [8], there is proposed a pseudoazimuthal guidance mechanism to perform (diurnal) movement of the solar thermal collector, mechanism shown in Figure 8.
Diurnal movement is performed around an horizontal axis which contains the hinge of the base A, the thermal solar collector being mounted inclined along annual optimal angle of elevation, $\rho^*=21°$.

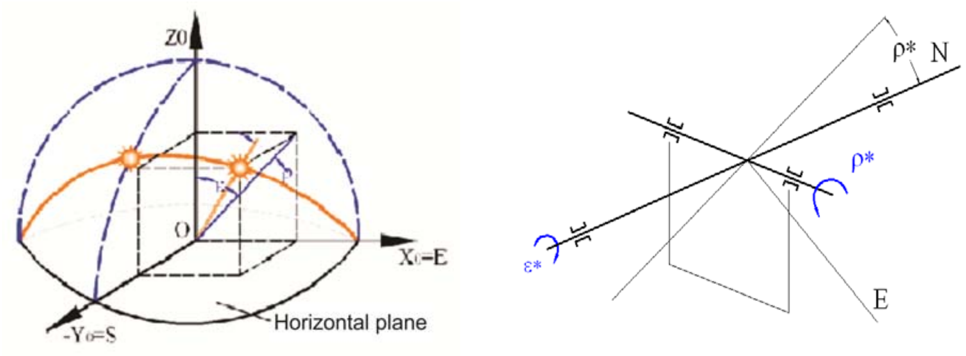
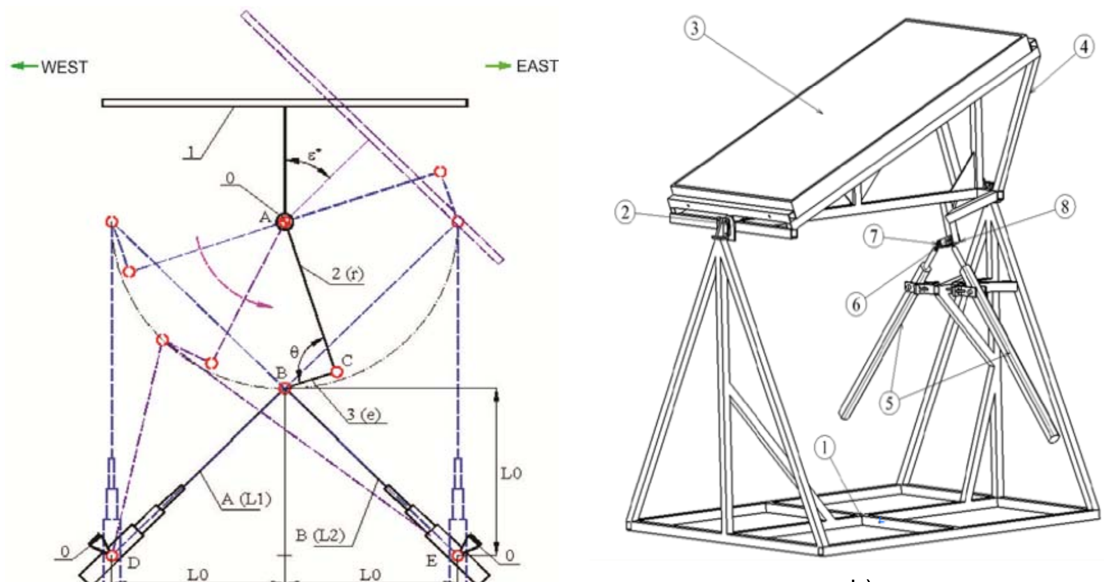


Fig. 8. Pseudoazimuthal guidance system

In Figure 9 there is presented a guidance mechanism with two linear actuators (hydraulic cylinders), arranged in triangle, having an articulated rod with one end hinged to the two actuators (hydraulic cylinders), and the other end hinged to a beam jointed with a solar panel. Structural diagram is shown in Figure 9a, and constructive solution in Figure 9b.



a) b)

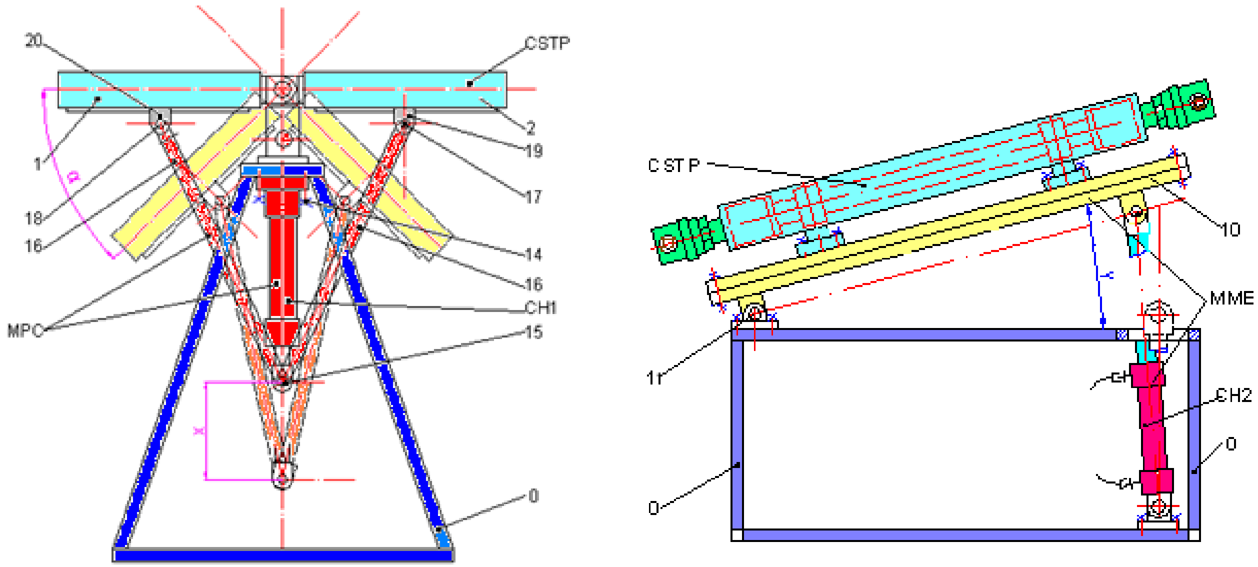
Fig. 9. The guidance mechanism with two linear actuators

Unlike in photovoltaic systems, where controlled guidance is used exclusively in order to increase the efficiency of collecting solar radiation, in the case of thermal collectors, which in addition have large sizes and weight having also to face strong wind, hydraulic drive of guidance trackers proves to be necessary and the best one.

4. New solution for a solar thermal system with hydraulic drive developed in INOE 2000-IHP

One of the most difficult problems in the operation of solar thermal collectors is that of the water temperature control, closely related to the thermal load required.
Because the commonly used methods of orientation (for example, those in counter phase), do not manage to control strictly the difference between the heat energy delivered by the solar thermal collector and the actual heat load, it has been taken into consideration the development of one new tracking system for solar thermal collectors, which will be able to manage this issue, under more favorable conditions.

Starting from these considerations, in INOE 2000-IHP, there has been developed a novel technical solution for a hydraulic tracker, which consists in achieving a complex movement of the solar thermal collector, tracking as close as possible the position of the sun in the sky by using hydraulic drive mechanisms, both for performing the diurnal movement from east to west (the hourly angle) and for performing the raising movement of the sun in the sky (the elevation angle), in order to maximize the solar energy collected at operation under maximum thermal load, and by using a collapsible solar thermal collector, driven by a special mechanical-hydraulic mechanism, to be able to change the angle of incidence of the solar rays, depending on the thermal load (hot water consumption) [9].
The new solar thermal collector system, which is presented in Figure 10, is made up of a fixed support frame (0), on which there are mounted the 4 basic subsystems / mechanisms, namely: a collapsible solar thermal collector (CSTP), consisting of two semi-collectors / conventional semi-panels (1 and 2), hinged to one another by a tubular shaft (3) with some rotating joints (4), a collapsing mechanism (MPC), Figure 10a, consisting of a hydraulic cylinder (CH1), fixed on the upper underside of the support frame (0), the cylinder rod braket (5) being hinged with a bolt (6) to some thimble bars (7), which are hinged at the other end by bolts (8), to some eyelets (9), mounted on the back side of the two semi-panels (1 and 2) of the collapsible solar thermal collector (CSTP), a mechanism for performing the movement of elevation (MME), Figure 10b, comprising a tilting platform (10) that rotates vertically by means of a joint (11) mounted on the fixed frame (0) and driven by a hydraulic cylinder (CH2), and also a mechanism for performing the diurnal / hourly movement (MMD), similar to that shown in Figure 10a, also driven by a hydraulic cylinder (CH3).



a) b)

Fig. 10. Collapsible solar thermal collector with hydraulically actuated tracker

5. Conclusions

The article presents some specific elements of the strategy of Romania on use of renewable energy; it mentions the special solar energy potential that Romania has and briefly presents some concerns of the research work in the Institute INOE 2000-IHP on this matter.
Also, there are presented some concerns in Romania regarding the development of solar thermal collectors, and especially the development of guidance systems (trackers), based on linear actuators (hydraulic or pneumatic cylinders).
There is presented a new technical solution that helps increase the energy efficiency of solar thermal panels by using collapsible panels operated by hydraulic trackers, solution which is under a patenting process.

This new technical solution offers better control on the difference between thermal energy supplied by solar thermal collectors and the actual thermal load.

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