ELABORATION OF SOLAR PLANTS WITH STIRLING ENGINE

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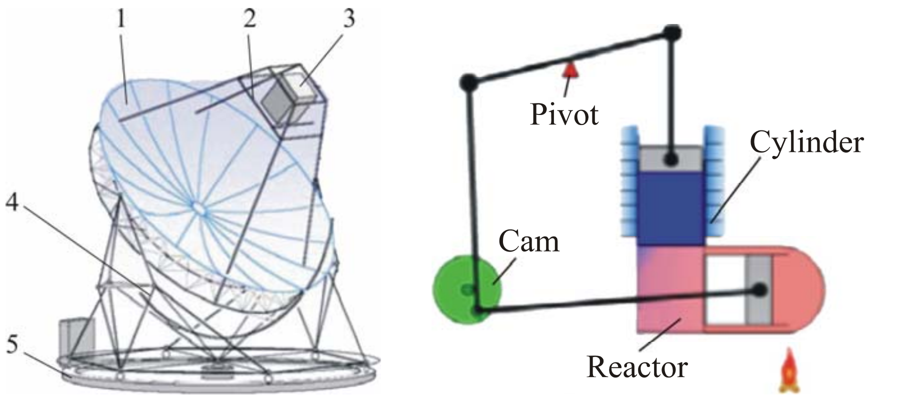
1. INTRODUCTION

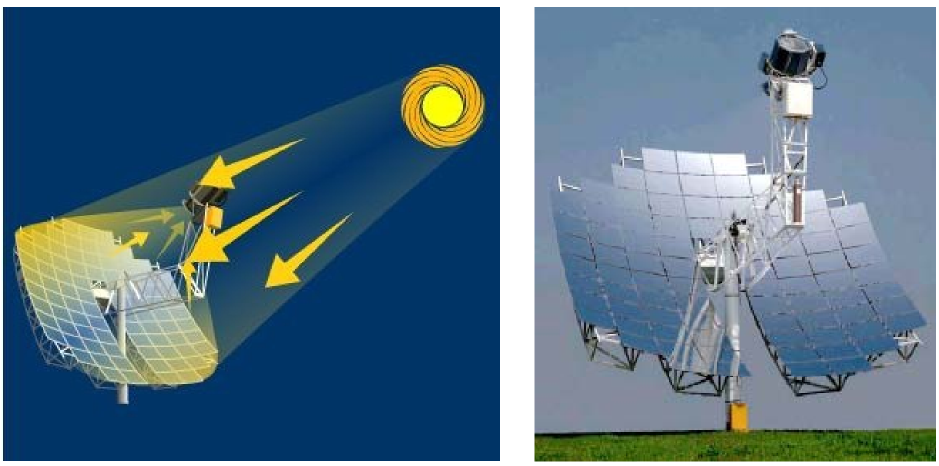
Stirling engine parabolic solar technologies have been demonstrated in a variety of complete systems over the past two decades and can move further towards commercial application over the next five years. Several U.S. and European projects are aiming at the use of solar energy this way. Stirling engine parabolic units have several common characteristics compared to the wind turbines. Like wind turbines, Stirling solar parabolic units are an intermittent energy source, include a base that can be built within a few days, are small power energy facilities and are modular units. Regarding Stirling parabolic units marketing, some wind turbines market penetration tactics may be used.

Fig. 1, *a* shows structural drawing of a paraboloidal concentrator solar thermal system (plate) and Stirling engine [1]. The system includes a parabolic concentrator (plate) 1, heat receiver 2 and a heat engine/heat generator 3, which are installed on a support 4 with a concentrator orientation mechanism towards the sun 5 (Fig. 1, *a*). Stirling engine is used as heat motor/generator. Fig. 1, *b* presents the operating principle of the Stirling engine. The operation principle of Stirling engine parabolic solar system and of Stirling engine is shown in Fig. 2,a). Parabolic concentrator reflects solar radiation received by the cavity of the receiver, located in the focus point of the concentrator. Generated temperature heats Stirling engine working agent and makes it operational. To better understand the issue, a brief history, construction and operating principle of the Stirling engine is presented. Parabolic modules with Stirling engine can produce between *5* and *40 kW*. A network of modules can be used for producing electricity in large quantities. Fig. 2,b [2] presents a Stirling paraboloidal system including an air heating system and a mechanism for rotating the parabolic mirror concentrator around two axes. This allows the collector to be continuously oriented to the sun. The system was designed and built by SES (Stirling Energy Systems), which together with the STM Company today are most aggressive in implementing Stirling parabolic systems on the market. They are engaged in developing and building new Stirling parabolic facilities. In SES opinion, engine and collecting system changes will increase peak efficiency of the coming



a. ***b.***

Figure 1. Operating principle of the solar unit with Stirling engine [1].



a. **b.**

Figure 2. Solar rays concentration principle in the Stirling engine unit (a) and Stirling solar parabolic system (SES) [2] (b).

plants by 10%. This is a new efficiency world record for any solar electricity generation technology and it will increase the annual electricity production by 6,3%.

2. PARABOLIC SOLAR THERMAL POWER PLANTS WITH STIRLING ENGINE AND PRECESSIONAL TRANSMISIIION

To simplify the construction, increase the efficiency and develop functional capabilities, in Fig. 3 *a*, *b* and Fig. 4 *a*, *b* are presents a Stirling parabolic system and Stirling engine with piston rods linked kinematically to presessional transmission satellite, developed and patented by the authors [1,3,4].

The examined solutions propose to simplify the transformation mechanism of the alternative movement of Stirling engine pistons into rotary motion. Crank mechanism and the cams (see the original construction of the Stirling engine above) of a Stirling engine is replaced with a precessional planetary transmission 2, which reduces the speed of output shaft 3 of Stirling engine. Precessional transmission satellite block 4 is connected kinematically with piston rods 5 of the Stirling engine, which allows direct conversion (without using additional elements) of alternative translational motion of the pistons into reduced rotation of electric generator.

In order to spin parabolic concentrator together with Stirling engine in an azimuth and zenith plane precessional drive mechanisms 6 and 7 (Fig. 3 *a*, *b*) are used. To simplify construction and reduce costs of these orientation mechanisms, the research team of the Department of Theory of Mechanisms and Machine Parts, at the

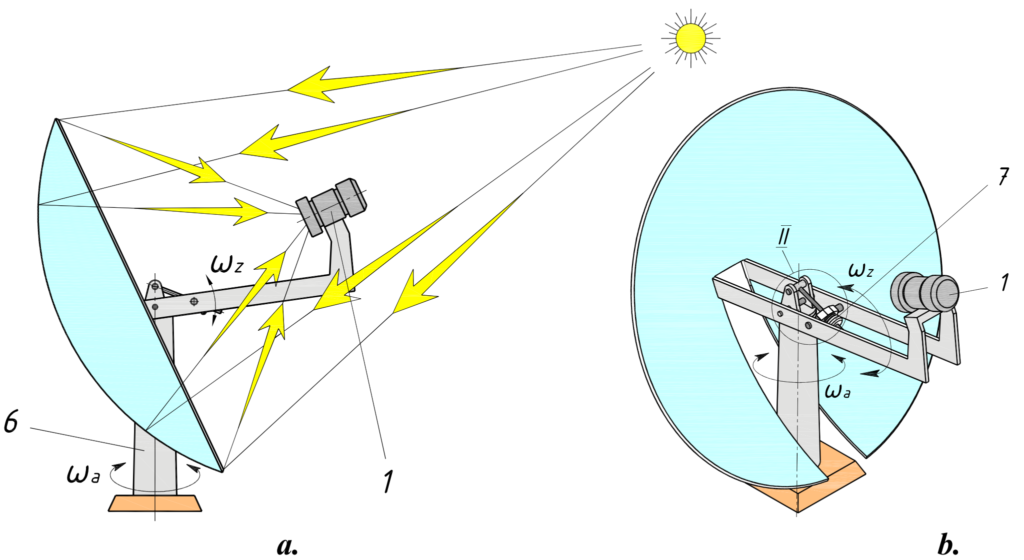


Figure 3. Stirling parabolic solar system, author's elaboration [3].

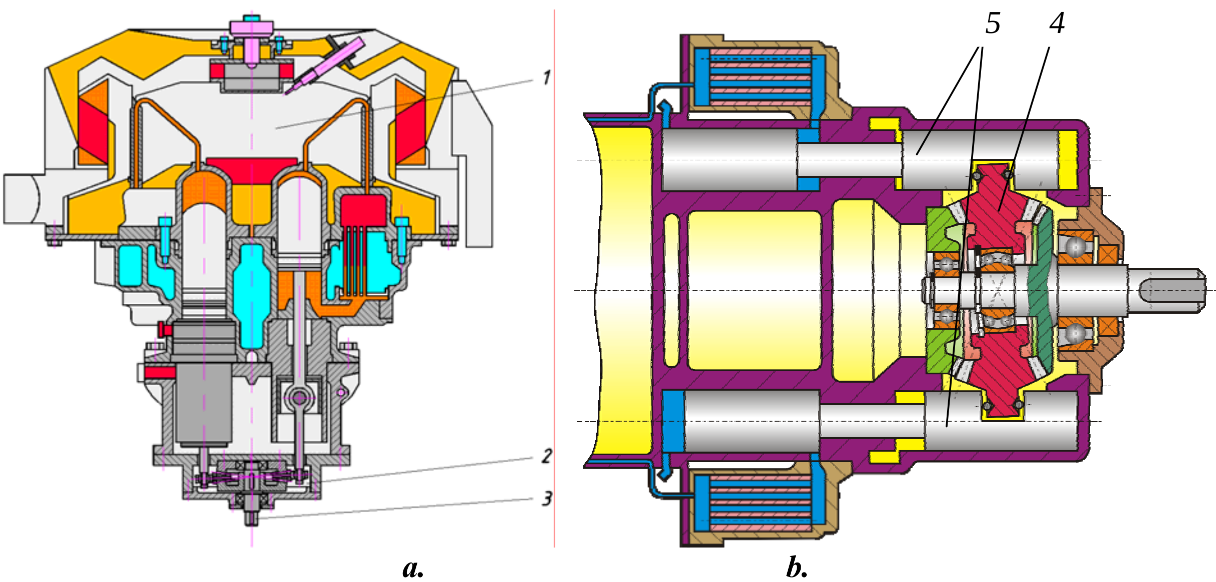


Fig. 4. Stirling engine with piston rods linked kinematically to presessional transmission satellite, author's elaboration [5].

Technical University of Moldova, designed and patented the self-orientation solar unit conceptual diagram [5]. The parabolic concentrator is oriented to the sunlight, being rotated in azimuthal and zenithal planes by driving mechanisms with precessional transmission (Fig. 3). Very broad cinematic options of precessional transmissions ensure very slow rotation around the two axes (one revolution in 24 hours). In the developed system, slow motions of rotation, necessary for the revolution of the solar panel in azimuthal and zenithal planes, are performed by precessional planetary transmissions in two steps: for the rotation of the solar system in the zenithal plane - 6 (Fig. 3, a) and in the azimuthal one - 7 (Fig. 3, b), subject to the motion of the sun in the sky (actually the earth rotating around the sun). Precessional transmission gear ratio in one step is to 3600. A simple calculation shows that, to ensure rotation of the solar system in azimuthal plane within 24 hours with a $1500\ min^{-1}$ servomotor, reducer gear ratio must be equal to $i=2160000$. To achieve this transmission ratio, it is recommended to choose two steps precessional gear reducer. To achieve this transmission ratio, a 5-speed planetary gear would be required, which includes at least 25 gear wheels; while the precessional gear reducer in two steps includes only 4 gear wheels and two satellite wheels with two toothed crowns. Relatively simple construction of the driving mechanism (to obtain a high transmission ratio, dictated by the necessity of very slow rotation, using a small number of elements), and high reliability ensures relatively low cost of the solar photovoltaic installation and long period of operation.

These, due to very high transmission ratio (up to 3600 at single stage) ensure very slow rotational motions (basically, a rotation around the axis of the tower for 24 hours) required for permanent orientation of Stirling parabolic system after sun position.

CONCLUSIONS

The essence of the proposed consists in the following:

– kinematic connecting of precessional transmision's satellite block with piston rods of the Stirling engine, allows direct conversion of alternative translational motion of the pistons into reduced rotation of electric generator;

– precessional drive mechanisms developed are compact and reliable, containing a small number of elements compared to other transmission systems, and this provides low cost;

– the Sun's trajectory tracking movements in meridional and latitudinal directions are made by a relatively simple system that operates in automatic mode without operator's intervention, which considerably increases the plant efficiency.

References:

1. ***Bostan I., Dulgheru V., Sobor Ion, Bostan V., Sochirean A.*** *Systems for Renewable Energies Conversion: eolian, solar and hydraulic (in Romanian), Ed.: BonsOffices SRL, 2007, 592pp.*

2. *http://www.brighthub.com/environment/renewable-energy/articles/65860.aspx*

3. ***Bostan I., Dulgheru V., Dicusară I.*** *Solar unit with Stirling motor. MD Patent, No. 3348. 2007,*

4. ***Bostan I., Dulgheru V., Bostan V., Ciupercă R.*** *Anthology of Inventions, vol. III. Systems for Renewable Energies Conversion (in Romanian), Ed.: BonsOffices SRL, 2009, 458pp.*

5. ***Bostan I., Dulgheru V., Nicu T., Ciuperca R.,*** *External Combustion Engine. MD Patent, No. 2679. 2005.*

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