CURRENT HYBRID SYSTEMS OF PRODUCING ELECTRIC AND THERMAL ENERGY

SISTEME HIBRIDE ACTUALE DE PRODUCERE A ENERGIEI ELECTRICE ȘI TERMICE

Teodor POP[1], Radu-Dumitru PENTIUC[1], Laurențiu-Dan MILICI[1], Cezar-Dumitru POPA[1], Constantin UNGUREANU[1], Dumitru CERNUȘCĂ[1], Visarion-Cătălin IFRIM[1]

Abstract: *This paper presents the current stage of some types of hybrid electric and thermal power plants which are being developed worldwide. The first part contains an analysis of hybrid power plants PV-CSP which produce electric and thermal energy by means of the solar concentrated method, as well as an analysis of the main types of power plants, while the second part comprises a description of the power plants that produce thermal energy using the combination of solar energy and biomass. There is also an analysis of the highest yields which are obtained in optimum climatic conditions of CSP, based on the type of solar concentrators, their worldwide evolution, examples of hybrid systems that use both solar and biomass energy, the functioning principle, trade applications, their advantages and disadvantages, followed by conclusion regarding the types of studied hybrid power plants.*

Keywords: PV-CSP, photovoltaic, power plants, biomass, energy, yields.

Rezumat: *Această lucrare prezintă stadiul actual al unor tipuri de centrale hibride de producere a energiei electrice și termice implementate pe plan mondial. În prima parte sunt analizate centralele hibride PV-CSP ce produc energie electrică și termică prin metoda solară concentrată și analiza principalelor modele de centrale, iar în cea de-a doua parte a lucrării sunt descrise centralele pentru producerea energiei termice prin combinația dintre energia solară cu energia biomasei. De asemenea, sunt analizate randamentele maxime obținute în condiții climatice optime ale CSP, funcție de tipul concentratoarelor solare, evoluția lor pe plan mondial, modele de sisteme hibride ce folosesc atât energia solară, cât și cea a biomasei, principiul de funcționare, aplicații comerciale, avantajele și dezavantajele lor, urmate de concluzii cu referire la tipurile de centrale hibride studiate.*

Cuvinte cheie: PV-CSP, fotovoltaic, centrale, biomasă, energie, randament.

[1] Faculty of Electrical Engineering and Computer Science, University "Ștefan cel Mare" of Suceava, Suceava, Romania, e-mail: teodor.pop@usm.ro, radu.pentiuc@usm.ro, dam@usm.ro, cezarp@eed.usv.ro, costel@usm.ro, cernusca_dumitru@yahoo.com, ifrimpv@gmail.com.

1. Introduction

Nowadays, the main issue is global warming, which most world leaders of developed countries consider a priority on their agenda. This problem can be solved by reducing greenhouse effect gases (GEG), by using environmentally friendly sources, by reducing the use of conventional fuels. An example is given by the photovoltaic, wind sources and the hybrid systems, hybrid power plants that produce electric and thermal energy and use regenerating energy. Monitoring these systems also means improving the efficiency and yield of the used system [1]. The set of photovoltaic processes has become important, even major in the area of producing electric energy all over the world [2]. Clean, green energy is the energy source of the future, as it is an authentic, inexhaustible non-polluting source. The techniques of developing new green energy sources have been increasing for the past few years, therefore purchasing such sources has become easier thanks to the continually decreasing costs. Installing power plants using regenerating energy sources represents the optimum solution both for the areas with temporary power cuts or isolated and for the consumers who want to cut the electric energy expenses [1], [3].

The most important regenerating source, with a major market impact, is solar energy, collected and transformed into electric and thermal energy by using sets of photovoltaic and hybrid elements. Alongside the upgrade and improvement of photovoltaic panels, current analysis systems of remote control and monitoring of energy quality and efficiency by means of some plans aiming at increasing the efficiency of an installed system have appeared [4]. Photovoltaic units are a regenerating energy source with a durability span of 25 to 40 years, with minimum maintenance costs, rapid recovery. Thus, they are the cleanest systems by means of which we can get electric and thermal energy [4].

The price of photovoltaic modules has diminished with over 50% between 2010 and 2020 [5]. These changes bring an important energy technology of regenerating energy closer to competitive alternatives to fossil fuels (such as coal and natural gas). The photo-voltaic solar cells represent one of the energy technologies with the fastest development worldwide, with an annual increase rate of about 40% in the last ten years [3], [4].

The use of regenerating energies leads to the increase of building autonomy as far as the electric energy consumption is concerned and it thus makes it possible for these buildings to have, in the near future, their own solar panels, biomass boilers or electric car charging stations in the community garage or community spaces [6]. According to the statistics provided annually by the International Energy Agency (IEA) the global weight of regenerating sources will grow from 26% in 2018 to 44% in 2040.

The photovoltaic and wind, PV/T hybrid technologies will provide two thirds of the required electric energy during this period [6]. Starting from these hybrid systems which produce both electric and thermal energy from regenerating sources, future research aims at improving and optimizing the increase of module yield, the performance of PV/T modules by using new technologies and components, from the point of view of the geometry and of the factors that influence the electric and thermal efficiency of hybrid PV/T modules [6].

This paper is a short review about the current hybrid systems which are producing electric and thermal energy. We combined in this paper two analysis, one of the hybrid plants PV-CSP and one of the main types of the power plants, in the end a description of the power plants that produce thermal energy using the combination of solar energy and biomass was made.

2. Hybrid electric and thermal energy hybrid power plants

The technologies of transforming solar energy into electric and thermal power are varied. The easiest method consists of using photovoltaic panels and elements which make the direct conversion in direct current through the photoelectric effect [7]. Another type of converting solar radiation is the indirect conversion, made by means of solar conversion devices or lenses.

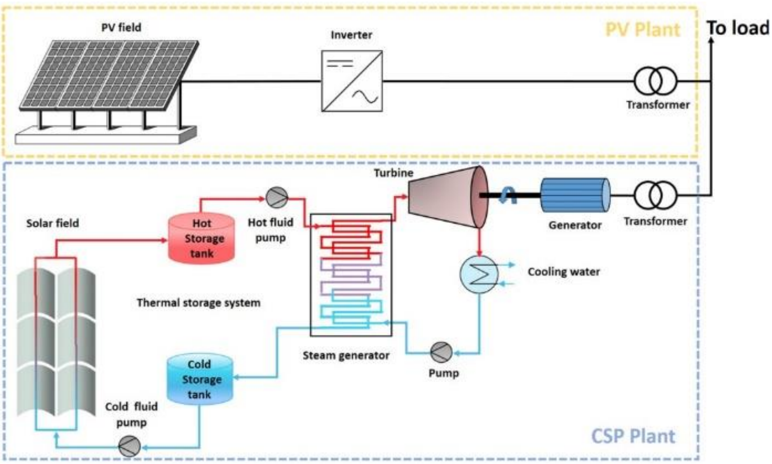

Figure 1. Schematic diagram of concentrated solar method (PV-CSP) [8].

The concentrated solar method (PV-CSP), exposed in figure 1, makes the luminous radiation be concentrated on a heat conversion system and then the energy is transmitted to a fluid. Afterwards, the process goes through a series of conventional operations of producing electric energy (for instance: steam-turbine (power machine)-current generator) [7], [8].

The third type of conversion consists of a combination of a solar conversion device and a Stirling power machine, an engine which activates an electric generator. These systems need automatic mirror orientation and a continuous maintenance activity in the situation of centralized energy production [7].

3. Hybrid Concentrating Solar Power Plants (PV-CSP) for producing electric and thermal energy

In thermal-electric solar power plants, the concentration of luminous radiation on a technical system called heat switch is transmitted to a fluid (the Clausius Rankine cycle). The fluid in the heat switch is known as HTF (Heat-Transfer Fluid). Thus, a model of producing electric energy with concentrating solar power and solar capacity (CSP-Concentrating Solar Power) is obtained. The CSP power plant can function independently or simultaneously with a conventional power plant, which leads to saving fossil fuels [7], [8]. The CSP systems can be ranked into two groups: according to the production technology and according to the arrangement setting of the solar collectors [7].

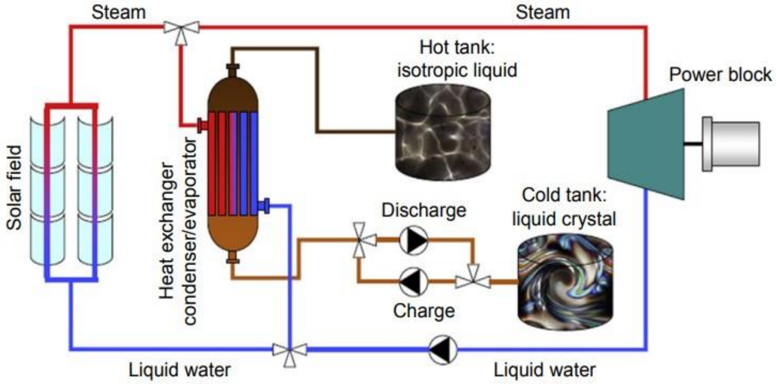

Figure 2. Schematic diagram of a direct steam generation solar plant with liquid crystal based thermal storage [9].

With the direct steam generating CSP systems, presented in figure 2, water is the main liquid which takes the solar energy which goes into the stage of overheated steams (temperatures of up to 500 degrees Celsius) [9], [10]. The steam feed the turbine, which is connected to a generator. The direct steam generating technology has a high yield, diminished energy consumption used to pump an intermediate thermal agent (HTF) and no heat switch is necessary [10]. With the two thermal circuits and two operations-successions of heat release, the solar energy from the first circuit is taken by a substance, melted salt or synthetic oil and then transferred to a second liquid, which is usually water, through a secondary heat switch, activating the turbine-generator set [11].

The CSP systems which have linear focalization collectors can use parabolic troughs or Fresnel reflectors (linear mirrors which are inclined and reflect the radiation towards the collector). These systems require a set of elements which are oriented after a single axis. [7].

The installations of power plants that use Fresnel reflectors use methods with direct steam generating in the collector and work with pressures of approximately 55 bar [7], [12].

With CSP systems with punctual focalization, a series of discoid parabolic mirrors or solar towers (heliostat-a field of mirrors) with focalization on a point located in a tower can be used. Here, a two-axis orientation system is necessary. The device which must receive the energy is a heat switch which uses as thermal agent air or melted salts, or even water if the direct steam generating technology is implemented [7].

Solar power plants with energy storage systems, exposed in figure 3, are used to produce electric energy from thermal energy during cloudy periods or at night time. They are formed of two tanks where the storage place (a liquid) is formed of a eutectic mixture (a mixture of substances for which the temperature of state change-melting or crystallizing-is lower than the temperatures of state change corresponding to any of the constituent substances) of potassium nitrate (40% percentage) and sodium (60%) [7]. The heat waste has a low value, of about 1-3% for a storage system of 15 hours, with a 20 times smaller investment than the battery energy storage alternative [13], [14].

The power plants with parabolic troughs are widely sold. They catch the solar radiation and are set on parallel rows usually directed in the north-south. The rows can be 20-150 m long. For the heat transfer salts, mineral oils gases (CO_2, N_2) or steam can be used. In the case of mineral oils and melted salts, a heat switch is necessary so that thermal energy can be transferred towards a second thermal circuit and steam can be produced [7].

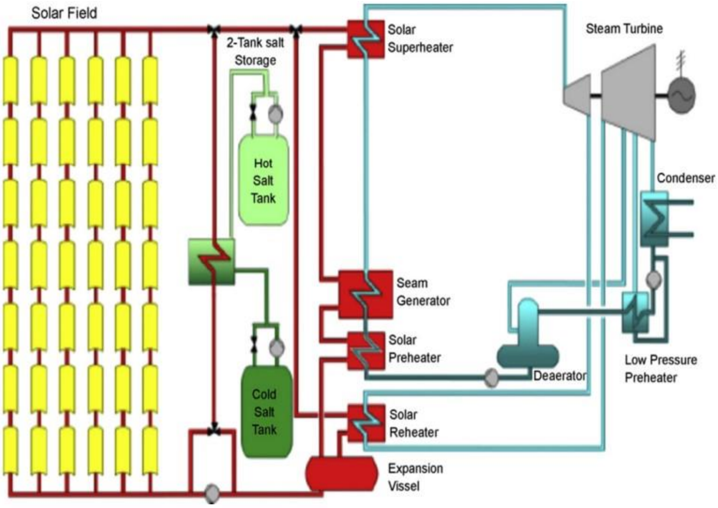

Figure 3. Schema of a parabolic trough solar power plant with a two-tank molten salt storage [14].

This technique can also be combined with thermal energy storage, but, unlike solar towers, it equally has some drawbacks, due to the fact that high temperatures that lead to a low yield of the thermo-dynamic cycle cannot be reached and it is necessary to have bigger storage capacities [7], [13].

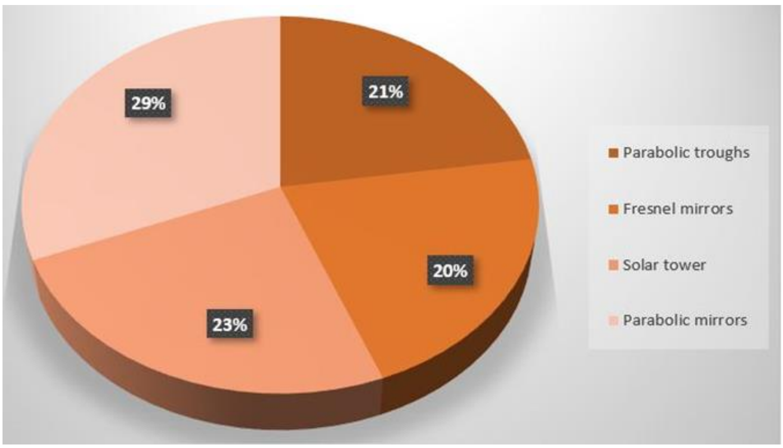

Figure 4. Maximum yields of CSP in optimum climatic conditions [7].

Solar power plants with discoid parabolic mirrors use a mirror as the element that comprises solar radiation. This mirror has the shape of a threedimensional paraboloid with automatic system of following the solar trajectory, with two freedom degrees which adjust the inclination angle and the angle formed by the plane of the meridian of a place with the vertical one of that direction. In the area of the mirror focal point there is a compact construction (the solar radiation conversion unit) made of three parts: thermal receiver, Stirling engine and an electric generator [7], [15].

The thermal receiver is formed of a set of pipes where a cooling fluid goes, which also has the role of working fluid that converts concentrated solar radiation into heat and transfers the heat flow towards the Stirling engine. The volume of the gas is diminished in the cold part of the engine and dilated in the warm one cyclically, from which machine work results [7], [15]. The yields reached by CSP power plants (Concentrated Solar Power) according to the category of solar concentrators are completely presented in figure 1 [7].

From the graph of maximum yields reached in optimum climatic conditions one can see that the highest weight belongs to the discoid parabolic power plants, which have a percentage of 29% [7].

The graph below, figure 5, presents the evolution of CPS capacities installed all over the world until 2020. As one can see, these capacities considerably grew between 2010 and 2020 [16].

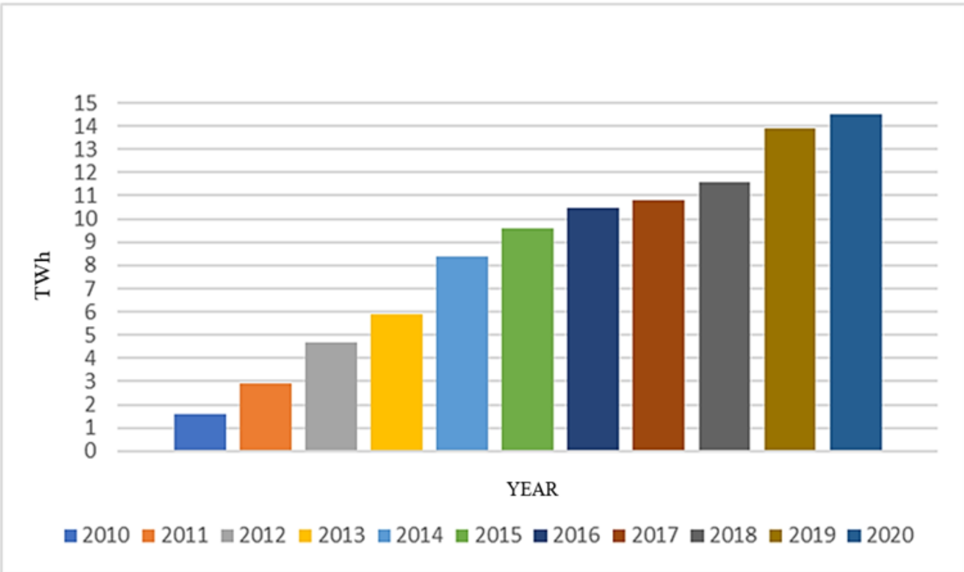

Figure 5 The capacities of solar energy concentration power plants [16].

4. Hybrid power plants for producing thermal energy

When analyzing the existent systems of producing energy from regenerating sources all over the world, one can notice the tendency to combine solar energy and biomass energy. The biggest systems of converting wood biomass are in Austria and Finland. Denmark uses power plants with solar collectors that combine solar and biomass energy [7]. As it follows, there are hybrid system models which use both solar and biomass energy [17].

In Denmark, there are the most and best developed hybrid (solar and biomass) systems in the world. The thermal energy production by means of solar-thermal collectors and its storage in a big underground tank is the scheme the Danish model is based on. Later on, this thermal energy is used to produce electric energy or for providing warmth to houses. Beside the solar-thermal set, there is another system of producing thermal energy in biomass conversion tanks. The energy that results from biomass can be used straight for heating or it is introduced in a secondary, auxiliary installation which is based on the Rankine cycle (ORC), which is a co-generating system of producing electric and thermal energy [17].

The Swedish model is based on hybrid solar-biomass systems of block of flats/building which are combined with distinctive solar power plants. The working plan starts from the implementation of a thermal solar power plant, formed of a set of solar-thermal collectors and big tank somewhere near a community, with easy access to the regional heating system. The thermal energy which is produced by the solar-thermal collectors is distributed to families and, where necessary, it is completed with thermal energy from the biomass converting tanks [17].

With the Austrian model, solar and biomass energy is used by means of combined power plants, according to a current scheme of local producing thermal energy. This model has the possibility of exporting thermal energy by using the district heating system towards other communities or nearby buildings. It has some disadvantages, as well, such as the limitation of the available space in order to set up the solar-thermal collector system and the energy loss in the transport pipes that go to the importing communities [17], [18].

The German model is based on central systems that use solar and thermal energy. The production of thermal energy at the central level consists in converting biomass by using solar-thermal systems which are built in the proximity of the biomass power plants, using biomass. One of their drawbacks is the limited possibility of using the solar-thermal collecting system and the significant loss caused by the pipes that carry the thermal energy from the district heating system [17].

The French and the Polish model are based in both situations on autonomous (local) systems of getting energy from biomass, combined with solar collecting systems. Together, they form a district heating network. The method is used in crowded urban areas with lots of buildings/blocks of flats where there isn't available space or where solar thermal collectors cannot be installed on or near buildings.

The advantage is that collectors can be installed without affecting necessary surfaces or the area architecture. The disadvantage is that big tanks must be used in order to collect thermal energy [17].

5. Conclusions

The hybrid solar PV-CSP system has advantages for the integration of the two systems, photovoltaic and concentrated solar energy and leads to low costs, stable production which is easy to deal with in order to obtain electric energy from regenerating sources [19]. Initially, the two systems, the photovoltaic and the CSP one, were ranked as opponent technologies. But the conclusion was that they are, in fact, complementary, and they provide stable energy. Thus, the research in this area has developed for the last few years. The combination of this hybrid PV-CSP system improves the capacity factor and the energy which is produced can be used for electric charge request during rush periods.

The photovoltaic energy will cope with the electric charge necessary at daytime, whereas the storage thermal solar system will help with the electric load at night time. Most of the research done is directed towards the economical and techno-economic analysis, as well as on the exploitation strategies of these hybrid systems. The less research is on the optimum configuration of the functioning strategy.

Solar energy and biomass are regenerating energy sources which can be found in most parts of the world, but each of them has a disadvantage. According to weather and season, solar radiation can be available only for a short period of time during the day and the energy produced from biomass needs a huge amount of stock, which cannot be found everywhere and anytime. The combination of the two sources in a hybrid system and the applications in power plants have been submitted to research for the past few years and have been considered to be a promising combination for the reduction of greenhouse effect gases and for reliable energy investments.

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