Chapter 10

Cogeneration Solar Systems With Concentrators of Solar Radiation

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ABSTRACT

This chapter is focused on solar cogeneration systems. These systems are silicon unijunctioned photocells with an optimal combination of the value of solar radiation concentration ratio and solar cell cooling intensity within the laminar flow of the coolant. This is based on the balance of the power which is released by the photocells, into the electrical and thermal network and dispersed into the environment. There is an engineering method for calculating the annual productivity of linear photovoltaic panels presented. The principles of designing solar radiation concentrators and photovoltaic panels is also considered. A fundamental new technique for testing linear photovoltaic panels with a sun concentration is proposed. This is when the absolute temperature of the radiating surface is logically introduced and a difficultly determined parameter is excluded, taking into account the temperature distribution along the surface of the absorber, from the location of the coolant.

INTRODUCTION

In hybrid photovoltaic-thermal (PVT) installations, large-area silicon photocells are uniformly placed on the surface of absorbers along which the coolant passes (Huang, Lin, Hung, & Sun, 2001). Thanks to the cooling, the photocells give off a lot of electrical energy, and the absorbers accumulate the heat energy released by them. Therefore, PVT plants have a total efficiency of $\eta \approx 0.6$, i.e. higher than

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photovoltaic panels (PV panels) or high-quality collectors with Viessmann type glazing with η ≈ 0.5 (Viessmann Vitosol, 2017). In a detailed review work (Chow, 2010), the advantages and disadvantages of PVT installations of different manufacturers are analyzed. The Developers's desire to increase the efficiency of the technology led to the use of the concentration of the sun, which reduces the absorber dimensions and the thermal losses to the environment.

The idea of the sun concentration is realized in parabolic SolarBeam 7M installations, which from the aperture of 38.5 m2 and 1000-fold concentration ratio have a thermal peak power 25 kW and the efficiency η ≈ 0.69, and the power consumption of the double-axis sun tracking system does not exceed 100 W (SolarBeam 9M). The temperature of the coolant with a mass of about 0.5 liters reaches 270 °C. In the next development, SolarBeam 9M in PV modules has been used expensive solar cells, with an efficiency of ≈ 44%, allowing to obtain electricity and heat simultaneously. As a result of the high cost of photocells for their payback, a very high concentration of solar radiation and precise systems for tracking the sun are required. Local generation of electrical energy is accompanied by the release of a large amount of heat, which must be removed with the use of complex thermal engineering devices.

In 2017, the joint project of IBM and Airtight Energy companies is finalizing with the development of the SunFlower installation of 36 reflectors with an aperture area of 40 m^2 and sun concentration ratio up to 2000, and peak electric power ≈ 12 kW and thermal power ≈ 20 kW (Airlight&IBM, 2017). It is expected to obtain a total efficiency of solar energy conversion ≈ 80%. The heat carrier under pressure passes through a complex capillary system of channels and carries away excess heat from the photovoltaic modules, maintaining their temperature at 85-90 °C.

The Forbes Solar Cogeneration System of the Indian company "Forbes Marshall", with a parabolic concentrator of 32 m^2 and gallium arsenide photocells, has a peak electric power of 7.5 kW,a thermal power of 17.4 kW (Forbes Solar, 2017) and a cost of about 45 thousand dollars. The complexity of manufacturing and servicing parabolic concentrators, solar tracking systems, and cooling leads to very high overall costs, which reduces the competitiveness of the solar equipment market.

It is less complicated to manufacture Matarenki Light 5.3 systems with flat mirrors, aperture area of 3.4 m^2, and 6-fold concentration ratio with peak electrical power ≈ 1,05 kW and thermal ≈ 4,2 kW (Chea, Håkansson, & Karlsson, 2013). Comparative tests at different geographical latitudes show their lower performance compared to individual PV arrays and collectors, due to large optical losses of concentrators. The transfer of heat energy from a mobile framework to a stationary boiler is carried out by using bulky and unreliable technological flexible hoses.

Cogenra Solar systems with 8-fold concentration ratio and cooled photocells have more effectively conversion of the sun energy into electrical and thermal energy (BusinesWire, 2013) . Twelve flat mirrors of each module form a parabola surface with a 4.36 m^2 aperture and an optical efficiency of 0.69. Demonstration testing of installations from several modules in Port Hueneme (USA) during the year showed an electric power output of 168 kWh/year/m^2 and a heat output of 657 kWh/year/m^2 with a ratio of thermal energy to electric ≈ 3.9. In the commercials, twelve modules, six in a row, have a peak electrical power of 5 kW, which, in terms of one square meter, is about 95 W/m^2. Cogenra Solar plants extract a four times larger amount of solar energy from a unit of aperture area than conventional PV arrays or high-quality flat thermal collectors, so the payback period is ≈ 5.1 years, in comparison with ≈ 9.1 years for PV and ≈ 7,8 years for flat collectors. The specific cost of Cogenra Solar modules is ≈ \$1460/m^2, and the cost of installed electrical and thermal power is the amount of respectively \$1460/m^2/(95 + 516) W/m^2 = \$2.4/W.

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