Part 8

RENEWABLE ENERGY SOURCES

8.3. Solar power plants and heat supply systems

8.3.1. Photoelectric converters and power installations on their basis

8.3.1.4. Solar installations on the basis of photoconverters

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Photo-electric installations (PEIs) became widespread in the world practice. They function in a system of autonomous and local power supply. In many countries well-known programs "solar roofs" are introduced. Under this name PEIs, mainly, in a form of flat PEMs, are meant, which are placed on roofs of buildings, including individual living houses. There were also many constructive solutions developed, the so-called "building integrated photovoltaic', that is, PEMs in-built in construction, which are simultaneously its architecture-constructive units: parts of walls, roofs, screens [21, 22]. A number of such installations world-wide makes tens thousands at the total capacity of 1800 MW. At overcapacity, the power from such PEI is delivered to the network by inverter. At a lack of PEI capacity, the power is delivered to the customer from the network. At a great amount of connected PEIs, a local network is formed, ensuring power supply of village, a small region, etc. A block-diagram of such installation is shown in fig. 8.11.

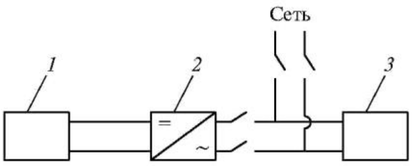

Fig. 8.11. Block-diagram of power supply system using photoelectric installation at available connection with the network: *1* — photoelectric installation; *2* — inverter; *3* — power consumer; сеть - network

Such technology of PEI application is the most rational because of the following:

- withdraws the question on divergence of power consumption in time and its generation by PEIs;
- supplies complete use of total power, generated by photo-electric installation, that is rather important for increase in its technical-economic parameters;
- leads to absence of any accumulative devices in the system, for example, electrical-chemical accumulators, which are expensive, require professional service and environmentally unsound.

Systems with autonomous production and power consumption, which are based on PEI appliance, should have, if required, an electrical accumulator and in most cases, a doubling power installation, with any traditional power carrier. Block-diagram of such a completely autonomous system is shown in fig. 8.12.

The characteristic feature of solar photo-electric station (SPES) is its module implementation. The required capacity of SPES is reached by appliance of this or that number of modules. In the world practice two types of such modules are applied: flat PEMs, which use solar radiation of natural density, as a rule, installed motionless, and modules with concentration of solar radiation, which require application of tracking for sun position. Direction of PEM cost reduction is rather perspective by decrease in the required SE surface by concentration of solar energy (at equal power capacity) [23].

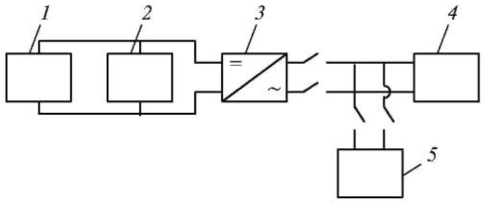

Fig. 8.12. Block-diagram of fully autonomous power supply using photoelectric installation: *1* — photoelectric installation; *2* — accumulator; *3* — inverter; *4* — power consumer; *5* — doubling power installation

The simplest concentrators have, as a rule, a small level of concentration, but they allow partially or fully to exclude the problem of tracking for sun and have the simplest air system of SE cooling.

In the All-Russian Research Institute of Agricultural Electrification (ARSIIAE) [24] there were developed PEIs with the level of geometrical concentration of 3,5, which includes photo-electric generator in a form of SE commuted stripes with double-sided sensitivity and motionless paracylinder facet reflector with capacity of 100 and 50 W. It is supposed that its cost will be in 1,5…2 times less than the cost of flat PEMs.

There were also developed stationary motionless PEMs with concentrators of a special form [25], which are suggested to be also used as elements of constructions (facades, walls, etc.) (fig. 8.13). However, similar systems have certain disadvantages. Average annual power generation of the module with motionless concentrator is less than of flat PEM of the same square, because of non-optimal pitched angles of beams.

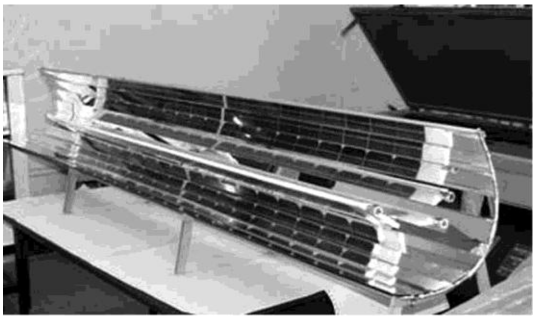

Fig. 8.13. Motionless photoelectric module with SEs of double sided sensitivity of ARRIAE production

At creation of photoelectric power plants with capacity from few MW and more, the best technology is the combination of solar power concentrators, sun-oriented with module implementation, and cogeneration of electrical and heat power, that significantly increases technical and economic characteristics of similar installations.

At the OJSC "ENIN of G.M. Krzhyzhanovskiy" and the OJSC "Institute Rostovteploelektroproject" a project of the test Kislovodsk photo-electric power station was developed with power capacity of 1 MW of the module type with combined power and heat generation [26]. Each module with one-axis sun-orientation includes a mirror concentrator of solar radiation of paracylinder type, but consists of flat facets. In the focus of concentrator, where photoelectric bus is placed, denary concentration of solar radiation is accumulated. Therefore, the working temperature of silicon photobus should not exceed 60^0C, it is cooled by water. This water is fed for heat supply of communal objects.

A structure scheme of SPES, intended for combined power and heat generation, is shown in fig. 8.14. Modules form a number of fields, from outlet bus bars of which DC voltage is induced to inverter substation. At this substation constant voltage is transformed by thyristor inverters into three-phase alternative voltage, which is output by bus bars of generators GBB. By the force transformer TF capacity is delivered into the power system.

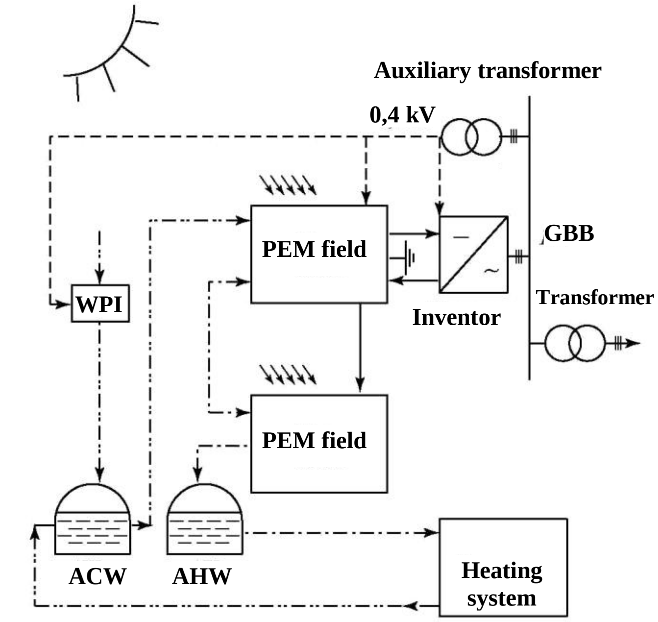

Fig. 8.14. Structure scheme of solar photoelectric plant, which is intended to combined power and heat generation:
Electrical circuits — ---------- ; hot water — — • — ; cool water — — • • —

Cooling of solar batteries is realized by chemically cleaned and air-free water, which is obtained at water-preparation installation WPI and is accumulated by accumulator of cool water ACW. From ACW the water is transported by cool water pump to cooling chambers of PEM. From PEM outlet the heated water is transported into additional water-heating modules, where it is heated up to standard temperature of heating system, and after it into accumulator of hot water AHW, where it is accumulated during the light period of the day. From AHW it is twenty-four-hour transported by hot water pump into the heating system. By the backward main of heating system the cooled water is returns ACW.

Power supply of pump apparatuses, WPI equipment, inverter substation, automated control systems of technological processes, auxiliary devices of the station is realized from GBB by transformer of auxiliaries TA. Calculations show that at power capacity of 5…10 MW pay off of similar stations makes 5-6 years.

Much higher concentrations of radiation flux can be reached in concentrators on the basis of paraboloid of revolution and pointed Frenel lenses. This is the high-concentrating devices, focusing the parallel stream of beams in the point. For normal operation of such concentrator, creation of more complicated two-axis sun tracking system is required, as of special technologies of production, assembly and adjustment of installation.

Frenel lenses advantage with the pointed focus is their small thickness, but modules, which combine round Frenel lenses and SEs, could not be large in size, that is their constructive feature [27-29].

As a result of researches and developments, conducted in the Physical and Technical Institute of Ioffe, PEMs were created with 16, 24 and 48 element lens blocks and heterostructure AlGaAs/GaAs solar elements, which have successfully passed all lab and nature tests at ground conditions and which have confirmed the operability of PEMs and their design characteristics (fig. 8.15).

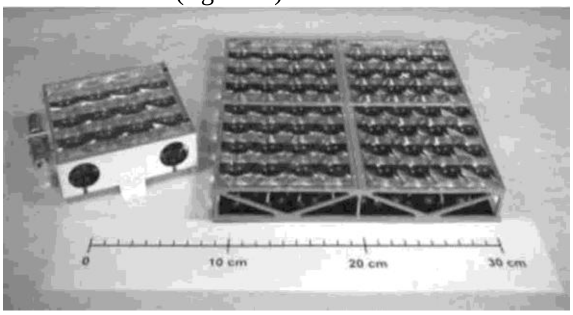

Fig. 8.15. Samples of compact modules with the concentrating panel made of composite Frenel lenses, designed in Ioffe Institute

At present there are all conditions for setting out the industrial mastering of PEI of module type with capacity of 1…5 kW with concentrators on the basis of Frenel lenses and with hetero-transformed AlGaAs/GaAs solar elements [13].

In Russia basic regions of PEI appliance can be south regions of the European and Asian parts of countries.

In a number of organizations output of SEs and PEMs with annual volume of production of about 5 MW at their cost from 4 to 7 US $ per W, is arranged. However, home market of this product is practically absent.