Abstract :

Thermal solar power plants using Rankine cycles are, at least in the large power range, the technologies which have so far come the closest to the present economical electricity prices. One of the advantages currently explored is the integration with other fuel based technologies in order to ascertain a given power disponibility and to increase the use of the investment in the power unit. The previous projects have confirmed the potential of all the hermetic components selected to construct a small thermal solar power plant. Calculations have been reported on the reference [CSIP3][1].

This paper presents the analysis of a original design of small hybrid solar plant. All of its components are realized in terms of the Solar Power System project (SPS)[2] including:

a) A power unit of Superposed Organic Rankine Cycles equipped each with hermetic scroll expander-generators (scroll orbital type) with an installed total capacity of 12 kWe. Each turbine works with a new lubrication system whose feasibility, simplicity and robustness are experimentally confirmed. The system includes full instrumentation of both cycles (including mass flow meters, etc.) and a computer acquisition and control running with LabView.

b) A Solar Plate Concentrating Reflector (CEP) unit equipped with mirror bands fixed on a plane surface which focalize solar energy on the vacuumed collector tubes. In this first phase of the project, only one array of 50 m2 (against 100 m2) of the solar field is assembled and tested. The realization of the second line of collectors is planned.

c) A 15 kWel cogeneration Diesel engine unit to ensure power availability independently from the variations of solar radiation with a self regulation system. A total thermal power of 34.5 kW can be recovered (43% on the combustion gases used at the high temperature cycle and 57% on the motor cooling system for the low temperature cycle).

The integration of those different units is in phase of realization. The following performances are expected: 12% of efficiency for the solar operation mode (Electricity power / Solar thermal incident) and 22% for the solar hybrid operation mode (Total Electricity Power / Solar thermal incident + Fuel Power).

Measurements on the power unit of 12 to 13 kWe were carried out with thermal oil heating at 170°C and water cooling at 7°C. Refrigerants HCFC123, resp. HFC134a are used in the high, respectively low temperature cycles. Results show an excellent behavior over a broad range of parameters with an efficiency of the order of 18% (50% exergetic efficiency), which is very promising particularly when considering that the concept of superposed cycles will allow operations at higher supply temperatures with further technological developments. However efforts will be targeted on the improvement of the concept and of its components, in particular the evapo-condenser, to improve efficiency by increasing the exchange specific capacity. Complementary tests can be envisaged to analyze the influence of lubrication oil on the performances of the concept but also to determine the operating parameters and regulation system for the coupling with the cogeneration system. In addition, the use of working pump directly coupled to the motor shaft of the expander is planned.

The concept presented can be used for several applications such as Industrial waste heat recovery, Domestic cogeneration etc... The extension of the detailed modeling program to facilitate the thermodynamic and economical optimization of those solar power plants (Solar Power System Program) will be continued. These are parts of the new engineering tools opening the way to the realization of small hybrid solar plants which represent nowadays the most efficient approach, both energetically and economically, to convert solar energy into power.

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[1] Allani, Y., Favrat D., Kane M., Zanelli R. et al. : CSIP3, Projet détaillé d'une mini-centrale pilote électrothermosolaire de 10 kWe. Rappot final pour OFEN, (1997)

[2] SPS (Solar Power System) : LENI's project in collaboration with COGENER and financed by OFEN (Swiss Federal Office of Energy).