THE PEGASE PROJECT

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The project PEGASE (Production of Electricity with Gas Turbine and Solar Energy) aims at setting up and testing a solar power demonstrator of 1.4 MW based on a thermodynamic gas cycle (at high temperature). As such, this project aims at carrying out R & D work needed to prepare and to develop the future of solar power plants with very high conversion efficiency (30 %) through the implementation of an innovative solar receiver technology feeding a gas turbine with a bottom combined cycle.

Keywords: solar power plants, thermodynamic analysis of basic energy generation processes in alternative energy

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Introduction

Concentrated solar facilities are used to achieve power of several dozen MWe. The solar power plants under construction now, in Spain for example, implement technological solutions but little innovative (reduction of industrial risk). Therefore, a major effort of R & D is required to propose alternatives that increase yields and lower production costs per kW·h.

Description

The proposed thermodynamic cycle is a Brayton cycle. The project requires the restoration of 100 heliostats (5400 m^2). Under a normal direct sunlight of 950 W/m^2, the power supplied to the thermal cycle by the solar receiver is 3620 kW_{th}, which represents a contribution of solar electricity of 61 % for a nominal production of 1.4 MWe (turbine GPB15 Kawasaki).

The objectives of this pilot experiment (Fig. 1) are science and technology. They are:

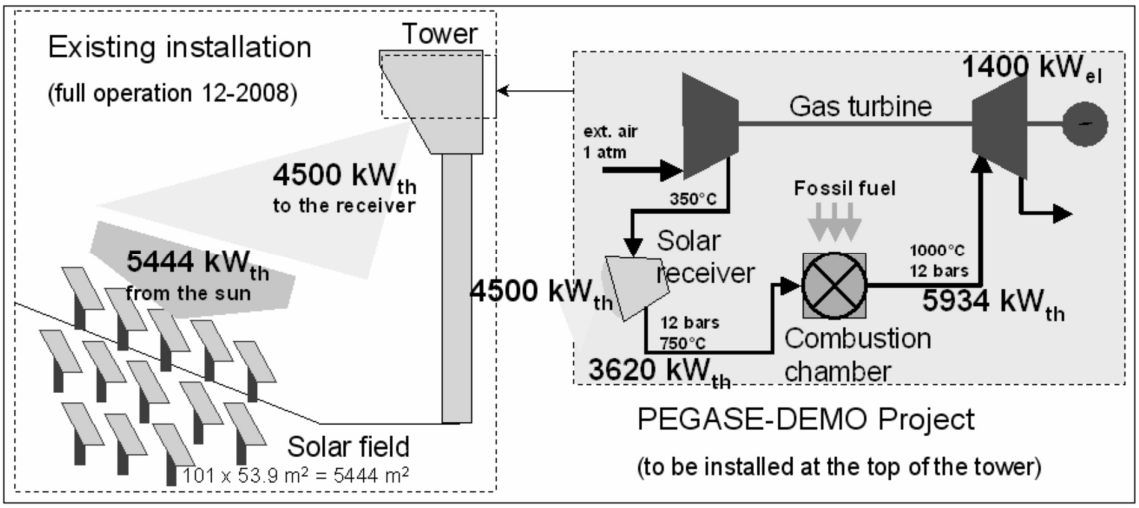

Fig. 1. *Scheme showing the principle of the thermodynamic cycle PEGASE installed at the top of the Themis tower*

• To validate a methodology for scaling up (from 0.23 to 1.4 MWe, namely a factor 6 in comparison with SOLGATE, single similar project (European) of R & D performed in Almeria-Spain between 2001 and 2003). From this point of view, the PEGASE experimentation has clearly a European dimension.
• To achieve the transformation of solar energy into electricity with high solar fractions: 60-80 % in instantaneous value and 50-60 % in average annual value.
• To develop solar receivers (research and technology) that can reach outlet air temperatures of 1000 °C and above. The involved research concern, in particular, the mechanics of turbulent flows (parietal transfers under strong gradients), and high-temperature materials.
• To establish a database allowing the conception and the reliable performance forecast of this technical solution for various conditions of sunlight and various powers.
• To establish collaborations (research organizations and industries) to ensure a future development of the sector.

Necessary scale

The unit power of the commercial power plants planned with hybrid technology solar-fossil gas turbine is typically 10 to 25 MWe with combined cycles. Today, only one experience at 230 kWe (scale 1/50) was carried out within the framework of a European research project (FP6 project Solgate, Almeria, 2001-2003), with a volumetric solar receiver. The PEGASE project aims at achieving an intermediate step at a power of 1.4 MWe, corresponding to the scale 1/10. This is a necessary step, particularly for a reliable receiver solar technology industrial design (outer wall receiver). The coupling with a combustion turbine will also be validated on a large scale. Based on the results observed on this demonstrator PEGASE, extrapolation to a commercial power plant with better economic performance will be possible without major technological barrier.

Technological barriers over passed by the technology demonstrator

1. Development of a pressurized gas solar receiver at very high temperature. Works on two levels are necessary:
− Basic research on materials and on heat transfers between flow and wall at very high temperature.
− Development of receiver prototypes on the basis of based on the most advanced technologies of compact exchangers and evaluation of their performance on PROMES solar installations in Odeillo (solar furnaces). It should be noted that the modeling of turbulent flows in the vicinity of walls with high temperature gradients is a new field of knowledge.
2. Combustion of fossil fuels or biogas at high pressure and high temperature. The hybrid nature of the concept imposes to adjust the combustion chamber of the gas turbine to varying conditions of the receiver output power. Special attention will be paid to the regulation of the regime of the turbine.
3. Integration of components and system analysis. A solar power plant is a complex set of subsystems whose operation is characterized by variable regimes and frequent transient during startup and shutdown. The performance analysis of the PEGASE cycle and the prediction of production of the chain as a function of the climate require the development of adapted software tools. Similarly the command and control system must meet the requirements of sometimes contradictory optimal production and guaranteed security of components.

The timing of the project

The project will last 5 years: 2009-2013.
The renovation of the field of heliostats Themis for PEGASE, started in 2007 (Fig.2), will be completed by the end of 2008. This initial phase is already funded (1050 k€), in the frame of a public-private partnership including CNRS, ADEME, the Languedoc-Roussillon Region, the Department of Pyrenees-Orientales, the groups Total and EDF.

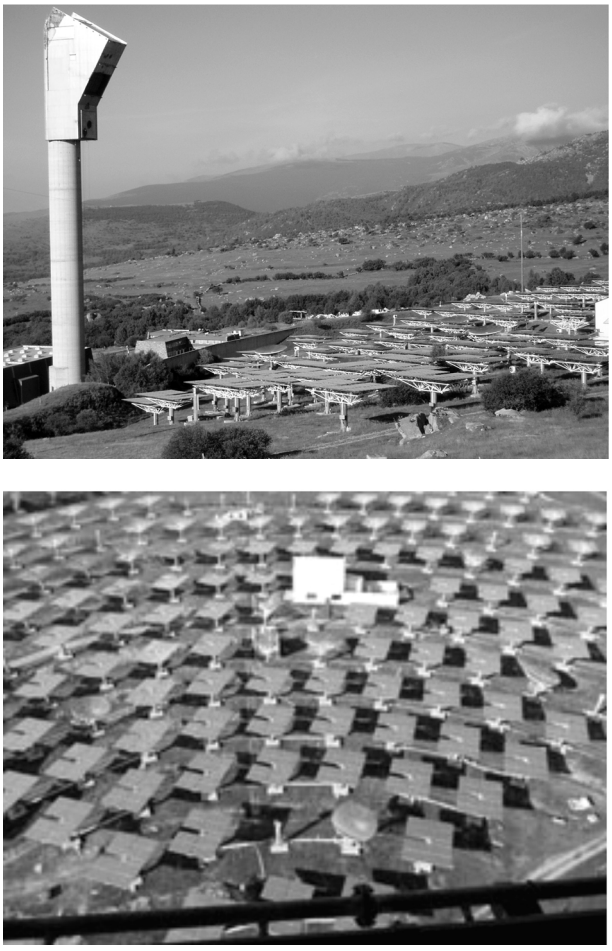

Fig. 2. *Pictures of the tower and of heliostats*

The demonstrator will be installed during the period 2009-2010. The installation covers the purchase of equipment and engineering work needed for installation.
The experiment is scheduled for 4 years (2010-2013). The program will focus on:

– The heliostat field: optical efficiency, concentration, availability.

– The solar receiver: air and walls temperatures, thermal efficiency, material behaviour.

– Turbine: performance, management mode of solar and fuel input power, and transients.

The complete cycle: overall performance of solar energy/electricity conversion (instantaneous and average efficiency), solar fraction, transient behavior, performance evaluation of more powerful commercial power plants (10 MWe).