Solar Energy R&D
in the European Community

Series B Volume 1

Thermo-Mechanical Solar Power Plants

EURELIOS, The 1 MWel Experimental Solar Thermal Electric Power Plant in the European Community

Final report of the Construction of EURELIOS, assembled by the Industrial Consortium for the Implementation of the European Solar Power Plant

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for the Commission of the European Communities

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edited by

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Preface

This book reports on the construction phase of the European solar power plant EURELIOS.

EURELIOS was the first of half a dozen solar power plants in the MW range around the world to enter operation.

It is of the central receiver type employing steam as the heat transfer fluid and has a nominal electric power of 1 MW. The Project was built in Sicily as part of the Solar Energy R + D Programme of the Commission of the European Communities.

Funding was provided by the European Communities, the Governments of France Germany and Italy and the contractors themselves, i.e. ENEL, ANSALDO, CETEL and MBB.

The active involvement of the national utility of Italy, ENEL, the Commission's host partner for EURELIOS, was of paramount importance for the successful completion of the project and should be stressed here.

Many individuals made contributions. The original concept was developed by Prof. FRANCIA who was a leading expert in the field. Dr. STRUB, Director for Non-Nuclear Energy R + D at the Commission of the European Communities (D.G. XII) had the general responsibility for the project, Prof. CHABBAL from France and Dr. KLEIN from Germany very much contributed to its initiation, Dr. CORVI from Italy was actively following the project all the way through its implementation phase.

Implantation was carried out with Dr. GRETZ as the Commission's project leader assisted by General Technology Systems, Ltd from United Kingdom and under the guidance of a very efficient management committee. In this committee the industrial consortium was represented by the following members : Messrs BORGESE, DINELLI (ENEL), TUARDICH, AMADEI (ANSALDO), TREIBER, HOFMANN, SCHOBER (MBB), TOTH, FAURE, DEPAUW, BLANCHARDIE (CETHEL).

It is important to note that EURELIOS is a purely experimental plant. The prime objective of its construction was the technical evaluation of this new and highly innovative conversion process. Its implementation at a relatively large scale - still being much below the full scale for commercial power plants of this type - was necessary because of the complexity of the involved technology.

At this time it has become clear that the construction of EURELIOS was worthwhile. Its value as well as its technical and economical limits could be assessed and much detailed experience has been gained. It is also interesting to note that EURELIOS has become an outstanding example of transnational cooperation among Administrations and among industry in Europe.

W. PALZ,
Head of the EC Solar energy R + D Programme.

Contents

1. Introduction

A "power tower" solar-thermo-electric plant comprises a field of many mirrors controlled as heliostats which focus sunlight onto a receiver mounted on a tower. The resulting thermal energy is transferred by means of a working fluid, or fluids, to an electricity generator - in this project water and a steam turbine driven alternator, respectively. Optionally some means of short term energy storage may be included - in this project high pressure hot water and an additional superheating fluid, molten salt - to allow the plant to continue operation during, for example, the passage of clouds.

The Commission of the European Communities (CEC), DG XII - Research Science and Development, placed a contract for an initial feasibility study (Phase A) between May and October 1976. This contract resulted in the specification of a plant which would provide valuable design and operating experience on a number of novel problems inherent in achieving viable solar thermo-electric plants.

Phases B and C, which ran for three years from November 1977, comprised respectively detailed design and construction of the plant near Adrano in Sicily. Named EURELIOS, it was completed before Christmas 1980, commissioning operations having already started.

In January 1981, during the formal acceptance process of the Commission and ENEL (Ente Nazionale per l'Energia Elettrica, the operator of the plant) the project moved into its fourth phase, D, during which the output power is to be increased to the design figure and an experimental programme started.

The work was sponsored jointly by the CEC and the governments of Italy, France and F.R.Germany. The Commission's contract for design and construction provided for the payment by the Commission of half the expenditures incurred.

The organisation of the project is shown in Fig. 1.1. The plant has been built by an industrial consortium consisting of ENEL and ANSALDO-AMN (now Ansaldo Impianti) - Italy, CETHEL - France, and MBB (Messerschmitt Bölkow-Blohm GmbH) - F.R.Germany. ENEL also acts as host-partner, providing free of charge the site and supporting site services such as security and having been responsible for ensuring the safety and legality of the complete plant. Within the Consortium, ENEL was responsible for civil works interfacing with the Sicilian electrical grid, the design of the control system and the definition of the operation procedures

of the plant. ANSALDO supplied the tower and receiver, the steam cycle, hot water/steam storage and associated electrical and pneumatic controls. CETHEL's responsibility was to provide approximately half of the heliostat field and associated monitoring and controls, the molten salt thermal storage system and the internal electrical power system (alternator, main transformer and auxiliary power distribution). The other half of the heliostat field (rather more than half in terms of numbers of heliostats but, since its heliostats are smaller than those of CETHEL, less than half the total reflecting area) was supplied by MBB. Each company provides special electrical conversion and, where necessary, backup equipment, drawing power from Eurelios itself or from the grid. General Technology Systems Ltd., has been retained separately by the Commission, through its Belgian subsidiary, GTS SA, for assisting the Commission's project leader in the monitoring of the work and to act as the Commission's agent during acceptance testing at the end of Phase C.

A Helioelectric Plant Consultative Committee (HPCC), which consists of members proposed by the Commission (3) and the participating member states (3) and which has observers from the Consortium and from ENEL (as host), advises the Commission on overall policy and strategy of the project, on matters relating to the project needing a decision by the Council of the European Communities and on the passage from Phase B to Phase C and commented on the contractual reports of the Consortium.

This report first outlines the original requirements of the plant, and briefly describes it (Chapter 2) and then describes the plant in detail, subsystem by subsystem (Chapter 3).
Chapter 4 outlines the operating procedures and the report ends with a look forward into Phase D.

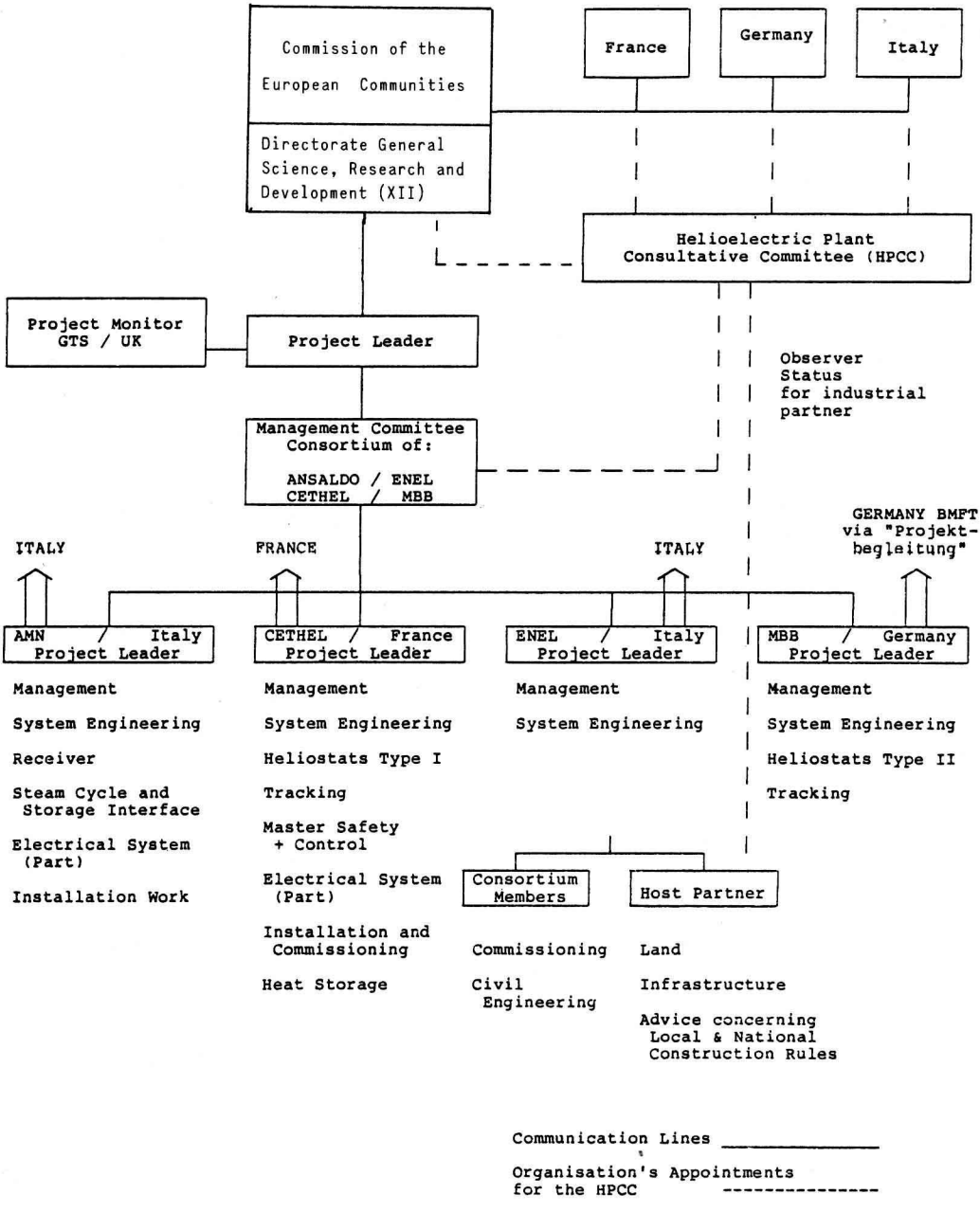

Figure 1-1 - EURELIOS Project Organisation (Phase B and C)

2. System Design Considerations

2.1 BASIC REQUIREMENTS

Ideally, all parameters of the plant could be considered to be adjustable to maximise cost-effectiveness according to system level requirements: e.g. the increase of temperature of the receiver could lead to a higher efficiency of the power conversion cycle and to a reduction of number of heliostats but requires an increase in pointing accuracy. In practice, however, the opportunities for parameter variation are limited by available or preferred technology.

For the EURELIOS plant, once the site had been selected, the following features were specified (although many were slightly altered during the design phase as a result of optimisation).

- Nominal power output: 1 MWel at an insolation of 1 kW/m^2 at equinox noon at the site of Adrano/Sicily with the following geographical co-ordinates:
  37.6466° north
  14.8034° east.
  The site slopes down about 4° from north to south and 2.5° from east to west. The elevation above sea level of the foot of the tower is 214 m. The heliostat field to be north of the receiver.
- Tolerable wind forces:
  - nominal output power to be available up to 18 km/h, the maximum tower deflection being ± 10 cm;
  - operation (reduced power) to be possible up to 50 km/h;
  - survival (no permanent deformation) up to 120 km/h (130 km/h for the tower, a figure which was, in the event, adopted for most of the plant).
- Utilisation of a steam cycle and cavity type boiler with anti-radiating structure (made of Pyrex glass, design of Prof. Francia) using water/steam directly as heat transfer and working medium with a flow rate of up to 5300 kg/h allowing growth over the then nominal conditions of 4860 kg/h. Nominal steam conditions are 510°C, 64 atm. Receiver aperture about 4.5 m diameter (amended as a result of early optimisation work from an initial 4.2 m x 4.2 m square aperture in a 5 m cube). Incoming radiation flux into the aperture is 4800 kW at the nominal design point.
- A steel tower to support the receiver, about 50 m high (centre of aperture) but this increased to 55 m, again resulting from optimisation during design.
- CETHEL heliostats each with 52 m^2 reflective surface and MBB heliostats with 23 m^2, each giving a reflected beam accurate to ± 4 mrad

(1 sigma). The CETHEL field section to give at least 57% of the total requirements; the MBB section at least 43%.
- Thermal storage to allow the plant to continue operating for 30 minutes without insolation.
- A conventional electrical system with a 1.1 MW alternator (minimum), connected to the national grid's Contrasto hydroelectric power station via a 1.0 MW output transformer (minimum). To have automatic emergency shut-down and appropriate emergency devices to ensure the safety of the plant despite equipment failures or loss of power.
- Centralised control.
- The whole plant to conform to the relevant Italian law and regulations.

Priority has been given to the experimental character of the plant. Hence although automatic start-up and shut-down are ultimate and important objectives, operation will involve considerable manual intervention. Similar comments apply to recovery from abnormal, including emergency, conditions subject, of course, to the need for automatic initiation of activities needed to ensure the safety of personnel and plant.

2.2 SYSTEM DESCRIPTION OF THE PLANT

Figure 2.1 is a simple schematic of the EURELIOS plant, the principal characteristics of which are summarised in Table 2.1.

The individual subsystems are described in detail in Chapter 3 of this volume. This section explains the overall configuration so that the individual sections of Chapter 3 can be read in isolation by those interested in only limited parts of the plant.

2.2.1 Heliostats

Sunlight is intercepted by the heliostat "field" and reflected into the receiver (boiler) just to its south. The field is split into two roughly equal "subfields", East and West, supplied by MBB and CETHEL, respectively. The subfields are each divided, for control purposes, into four independent "groups". Each heliostat has its own microprocessor-based local electronics unit which is controlled by, and reports its status to a "Central Unit" (one each for CETHEL and MBB). The Central Units can be used manually to control individual heliostats, groups or the corresponding subfield. The Central Units are also controllable by, and report to, the plant's Generator Control System (GCS) for routine and emergency control at group level and above only.

The CETHEL heliostats also contain emergency batteries with several times the amount of energy needed to move the heliostats to a safe position in the event of loss of the electrical supply.