AndaSol
- 50MW Solar Plants with 9 Hour Storage for Southern Spain

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Abstract - The proposed AndaSol projects will utilise solar energy to produce electricity in a highly efficient steam power cycle. An AndaSol 50 project can provide a fully dispatchable capacity of 50 MWe by combining solar concentrating parabolic trough collectors as the power source with a 9 full-load hours storage system . This solar technology is well proven in 354 MWe of operating plants in California. Solar energy is specifically used to generate steam for a conventional Rankine cycle power plant, similar to a standard fossil power plant, but using clean solar energy instead of fossil fuels such as coal or gas. The AndaSol projects are being developed by the Solar Milenio S.A., a Spanish private shareholding company, solely devoted to solar thermal parabolic trough plants project development and financing , and its Spanish partners.

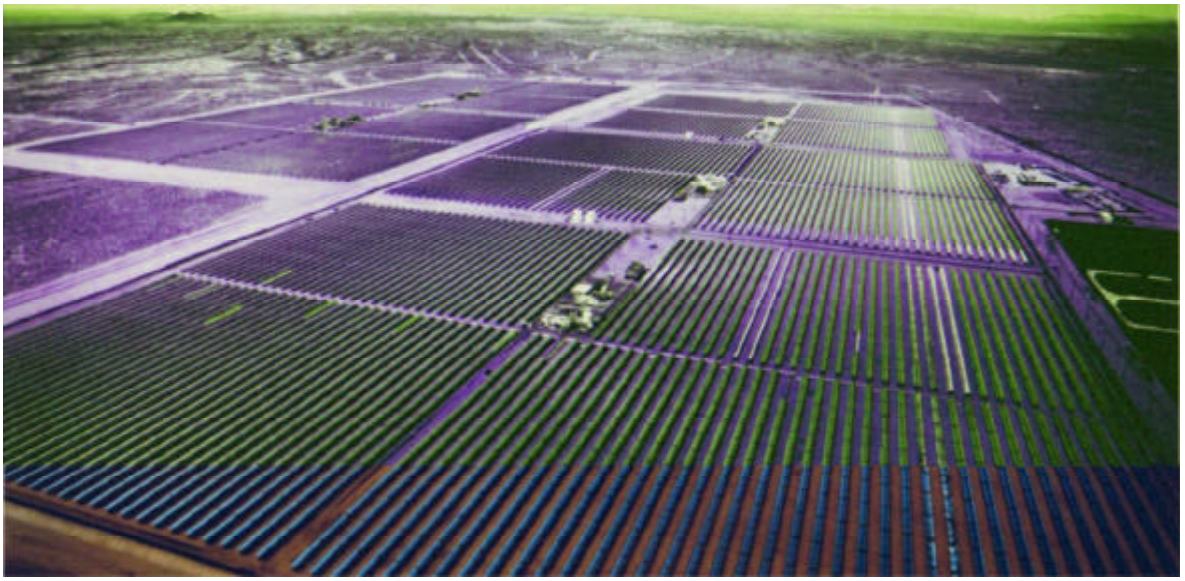

Fig. 2: Aereal View of the SEGS Plants in Kramer Junction (California, USA)

1 Project Background and Overview

Under Spanish Royal Decree 2818, the development and operation of solar electricity renewable energy plants is encouraged and conditions outlined to meet Spanish objectives in the reduction of global greenhouse gas emissions and the increased implementation of renewable energy resources. Evaluation of potential project sites in Spain has identified promising locations for the implementation of AndaSol solar thermal power plants with parabolic trough technology in the Andalusian Provinces of Almeria, Granada and Cordoba as well as in the Region of Murcia. Implementation of the initial two 50 MWe AndaSol projects will not only further the use of solar resources for the generation of clean, emission free solar electricity, but will also develop local jobs, open local and national manufacturing opportunities for this technology, and develop special expertise in a developing power source.
The proposed AndaSol projects will utilise solar energy to produce electricity in a highly efficient steam power cycle. An AndaSol 50 project can provide a fully dispatchable capacity of 50 MWe by combining solar concentrating parabolic trough collectors as the power source with a 9 full-load hours storage system . This solar technology is well proven in 354 MWe of operating plants in California. Solar energy is specifically used to generate steam for a conventional Rankine cycle power plant, similar to a standard fossil power plant, but using clean solar energy instead of fossil fuels such as coal or gas. The AndaSol projects are being developed by the Solar Milenio S.A., a Spanish private shareholding company t , solely devoted to project development and financing of parabolic trough solar thermal power plants, and its Spanish partners.

The 50 MWe AndaSol power plant will be an important contributor to these goals. Using solar beam radiation as it's primary energy, it will avoid approximately 172,000 tons of CO2 annually in Spain. With positive experience in construction and operation of this demonstration plant, other projects are expected to follow in EU countries with similar conditions, such as Greece, Portugal and Italy. Until 2015, the market potential for parabolic trough plants is estimated at 7 GW in Southern Europe, representing a CO2 reduction potential of up to 12 million tons per year.
The state-of-the-art of large solar thermal power plants using parabolic trough technology will be significantly advanced and innovated by the AndaSol project. The prime technological objective of AndaSol is to demonstrate and qualify a 549'360m² parabolic trough field with the innovative EuroTrough design. As a further milestone in solar thermal power innovation, AndaSol features a 1,350 MWht thermal storage system based on molten salt technology for providing 9 hours of full load operation after sunset or during cloud periods. The developers feel confident to cut related solar thermal generation costs for this design down to 0.15 €/kWhe for clean and dispatchable solar electricity.

2 Principles of Concept

The basic principle of the AndaSol solar thermal plant is to convert primary solar energy into electricity for homes, business and industry by means of a collector field, steam turbine and electric generator. The solar field consists of parallel loops of parabolic trough collectors. These solar collectors have concentrators made of glass mirrors, as shown here.

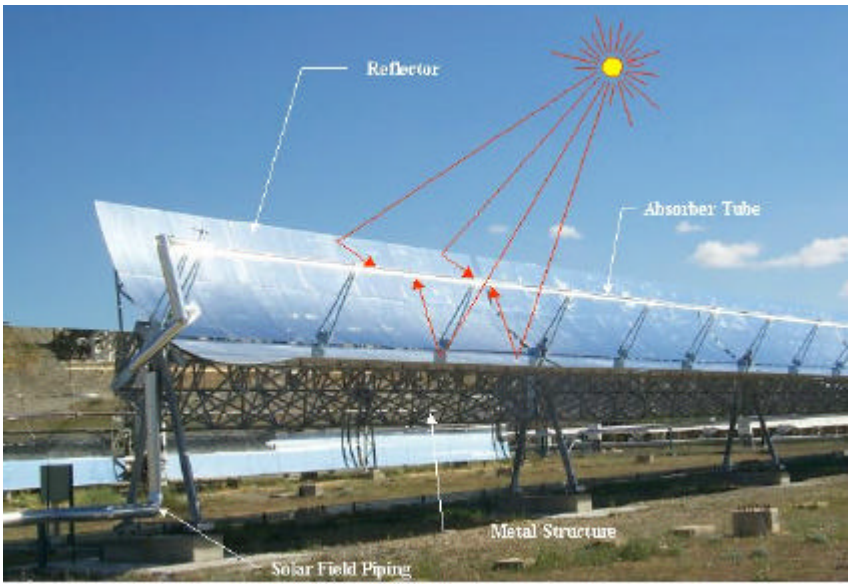

Fig. 2: Principle of Parabolic Trough Operation shown for the EuroTrough Collector

By tracking the sun from east to west, a parabolic trough collector concentrates the sun's radiation on an absorber tube. Through the absorber tube circulates a heat transfer fluid, normally a synthetic oil, which is heated to a temperature of 400°C. The energy contained in the heated oil flow can be directed in the AndaSol plant to the thermal storage system for being stored for later power generation and/or to the non-fired steam generators, which generate the superheated turbine steam.

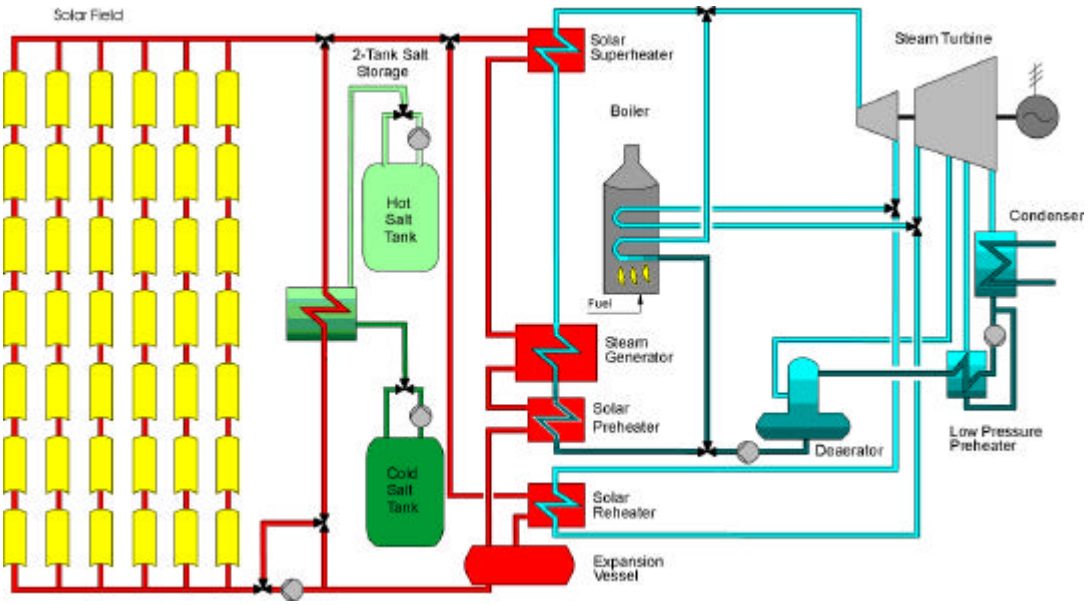

Fig. 3: Functional diagram of the AndaSol solar plant with Parabolic Trough Solar Field and Thermal Storage

The schematic drawing of Fig.3 illustrates the AndaSol power plant configuration, showing the solar field, where solar radiation is concentrated and collected, the storage system and the power conversion system. Depending on the specific local situation, the AndaSol projects can be principally configured with solar fields ranging from 330'000 (no storage) to 620'000m² and with economically sized thermal storage capacities ranging from 6 to 12 hours. The generator set for all configurations has a capacity of 50MWe and is run with a highly efficient steam turbine. Milenio Solar and its partners intend to use in the AndaSol projects for the first time the EUROTrough collectors.

With the solar radiation available at good sites in Andalucia , an AndaSol 50 plant can operate approximately 1,900 - 4,400 hours per year, depending on the chosen solar field size and storage capacity and supply 94 –210 GWhe of fully dispatchable, clean solar electricity per year to the grid.

The AndaSol 50 projects will protect the environment by avoiding emissions and produce clean and self sufficient electricity. With the realization of an AndaSol 50, the chosen region will be able to lay claim to significant local capacity of renewable electricity generation demonstrating technological leadership, safe operation, economic benefit and a high level of environmental protection. Significant regional and national benefits can accrue by the supply of services for component manufacture, plant construction and plant operation.

3 Site Requirements and Selection

For economic reasons, Milenio Solar and its partner plan to implement the AndaSol projects in twin pairs: The phased implementation of two AndaSol 50 projects at one site allows significant cost savings by reducing project transaction costs, smoothing the manufacturing and construction process and sharing infrastructure costs. For such implementation the following site requirements need to be fulfilled:

- The site must have an annual direct normal insolation of at least 2000kWh/m²a; site locations with higher insolation will receive bonus points in the evaluation.
- A minimum land area of 400hectars of flat land must be available for industrial land use.
- Sufficient cooling water per year must be available at reasonable cost
- A 220kV substation that can accommodate 100MVA must be available in the vicinity of the site
- Access and service roads are required for equipment and spare part delivery and for supply of auxiliary backup fuel; train and/or port access will receive bonus points for evaluation

In an extensive site selection effort, Milenio Solar has screened over 100 sites in Southern Spain, analysed in detail the meteo data of over 25 localities in this area and identified as most promising site Aldeire in the Marquesado valley, Province of Granada in Spain. Together with the technical experts of the Aldeire municipality, a 1,300m x 1,500m site has been identified. With the full support of the municipality, long-term land leasing agreements have already been signed. A second and third site for further project replication has already been reserved.

Fig. 4: AndaSol site location and grid connection in the Marquesado Valley in Andalucia (Spain)

After a survey of existing data sources and satellite images, the AndaSol consortium started measuring in the Marquesado valley with an own meteo station in March 2000 and has now over two years of reliable and gapless measured insolation data, on which all performance calculations and economic optimizations have been based. 2201kWh/m²a have been measured in annual average in the first two years from March 2000 until February 2002. Measurements are continuing. Ths value is about 10% higher than at other envisaged sites for solar thermal plants in Andalucia due to the altitude of 1000m of the Marquesado valley and due to the dry and clear climate. ·The site has excellent transport infrastructure, since the new freeway with an existing exit and the railway with an existing train station from Granada to Almeria are within less than 3km distance from the site. Heavy machinery and equipment will be shipped to the port of Almeria and brought to site by trains and trucks.·The site features excellent cooling water reserves, since a shut-down coal mine had already built-up wells and pumps that can be used for the site; furthermore, no water scarcities have been claimed by the environmental agency.·Due to its clean energy nature and the creation of 55 permanent jobs in the economically depressed region of the Marquesado valley, the municipality of Aldeire has declared the project to be of public interest in order to accelerate the construction permitting at the local administration level. Negotiations with Red Electrica de Espana (REE), the national Spanish grid operator, have started. Due to its storage based dispatchability and firm capacity the AndaSol plant has been explicitly welcomed by REE, who already has included the Hueneja substation, in 5 km distance from the project site, in its grid plan. Electricity will be evacuated at the 400 kV level, which has the capacity to evacuate also subsequent projects. Substation costs can be shared with 150 MW of wind projects, which will come on-line in the valley together with AndaSol.

4 Technical and Economical Performance

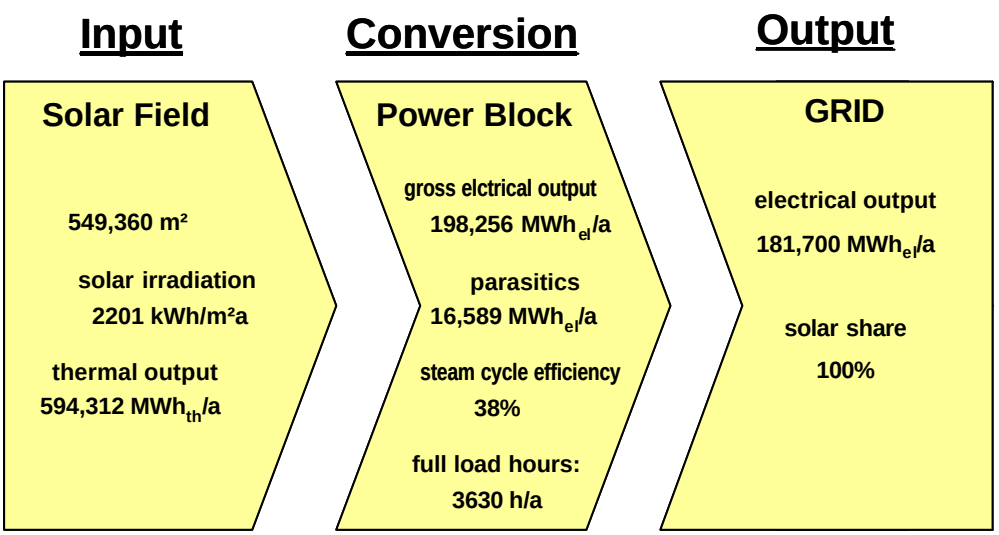

Fig. 5: Key Annual Performance Characteristics of the AndaSol project in Aldeire

A detailed design has been developed and optimized for the chosen site in the Marquesado valley; the economic calculation is based on the following design parameters:

?? full load turbine cycle efficiency: 38% gross
?? equivalent full load hours per year: 3'630 h/a
?? normal direct irradiation: 2,201 kWh/m^{2}a
?? aperture area of solar field: 549'360 m^2
?? annual thermal output of the solar field: 594,312 MWh$_{th}$/a
?? net annual electrical production by solar energy: 181'700 MWh$_e$/a

Total AndaSol project cost amount to ap.. 200 million Euro. With an expected Lifetime of 25years, an annual depreciation of 6.7%, an annual discount rate of 9.0%, an annual insurance rate of 1.0% and an annual income tax rate of 35.0%, the Levelized Electricity Costs according to the IEA method are 0.15€/kWh.

5 Creation of Jobs

More than half of the equipment and services supply of the AndaSol projects will be contracted from local and national Spanish suppliers, giving a significant boost to the creation of jobs in this innovative technological sector. During the 15 months of construction a peak labour demand of up to 1'000 workers is expected when two AndaSol 50 projects are built at one site; through phased implementation (with slight time shifting of construction and erection for the second plant) this period will expand to about 24 months.

Operation and maintenance of two AndaSol 50 projects will create approximately 116 permanent qualified jobs. The necessary qualification level includes skilled maintenance and power plant operating workers and technicians. Subsequent solar projects of comparable size in Spain and the Mediterranean region will secure some 300 permanent jobs for component manufacture and engineering for skilled technicians and engineers in both, the project host country as well as in Spain.

6 Environmental Benefits

In the context of the Kyoto Protocol in 1997, the EU member states committed themselves to reduce CO_2 emissions on the community level by 8% until 2008-2012. To achieve this goal, the Commission has set the objective that 12% of the European Union's primary energy consumption should come from renewable enrgy sources by 2010. The acknowledgement of this objective is reflected in the 1997 Resolution 97 /C 210/10, Law 54/1997, the Spanish Real Decreto 2818 and several other legal acts. The exploitation of solar energy for clean electricity generation will avoid the use of fossil fuels, such as coal, which would otherwise be necessary to produce an equivalent amount of power. Compared against modern coal plants like the one at Carboneras, each of the two AndaSol 50 projects will avoid burning of up to 65'400 tons of coal per year, or up to 1.6 million tons of coal over the 25 year life of the plant. This will save emissions of up to 172'000 tons of CO_2 per year or up to 4.3 million tons CO_2 over the plant lifetime.