World's biggest solar power plant under construction in Spain

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Connecting the collector elements on the Andasol-1 field in Spain

Construction of the first European large-scale solar thermal plant began early this year in southern Spain. The first of three solar power plants with a capacity of 50 MW_{el} each is being erected in the high valley between Almeria and Guadix, near the small village of Aldeire, next to the new motorway leading to Granada.

History

Parabolic trough power plants count among the so-called large-scale solar power plants with capacities of 50 to over 100 MW. Work on their development was begun over 100 years ago.

Around 1880, Swedish-born American John Ericsson powered his hot-air engine using a parabolic trough collector. In 1907, Dr. Wilhelm Meier from Aalen and Adolf Remshardt from Stuttgart registered a patent for an appliance employing solar heat for direct steam generation in parabolic trough collectors. It was then 5 years before the first parabolic trough was employed in power generation, when Briton Frank Shumann and American C.V. Boys constructed a 45 kW steam engine pump in Meadi, Egypt, in 1912. They used parabolic trough collectors with a length of 62m, an aperture width of 4m and a total aperture area of 1200 m^2. *"20,000 square miles of collectors in the Sahara"*, wrote Shuman at the time, *"is capable of supplying the world with 270 million horsepower on a continuing basis"*, which was the amount required at that time. In 1916 the German Parliament granted 200,000 German marks for a parabolic trough demonstration in German South-West Africa. However, this plan was brought to an abrupt end with the onset of the First World War and the discovery of crude oil in the Near East.

Interest in parabolic trough technology was not reawakened

150 MW Solar Trough Power plant at Kramer Junction, California USA

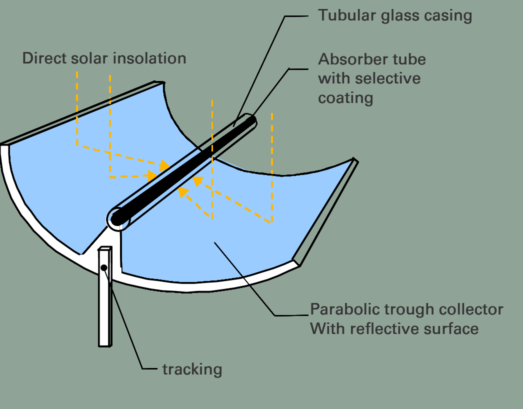
until the period between 1979 and 1980, as a reaction to the oil crisis. Several process heat plants and water pump systems using parabolic trough collectors were developed, constructed and tested, sponsored by the German Federal Ministry for Research and Technology and by the US Department of Energy (DOE). At the end of the seventies, nine Member States belonging to the International Energy Agency consented to the construction of the first demonstration plant with an electric capacity of 500 kW. The plant was put into operation on the Plataforma Solar de Almería, Spain in 1981.

Finally, between 1984 and 1991, LUZ International Limited developed a total of nine parabolic trough power plants with an electric capacity of 15 - 80 MWe per plant, and connected them to the grid. Over 2 million square meters of parabolic trough collectors were installed in these new power plants, with a total power generation capacity of $354MW_{el}$. The plants have now been in operation for over 15

The principle

Parabolic trough collectors are concentrating solar collectors employing single-axis sun-tracking technology. The uniaxial parabolic mirrored surface reflects sunlight onto a vacuum-isolated absorber tube fitted along the focal line of the parabola (Figure 1). Typical concentration factors are around 80 to 100. The heat transfer medium pumped through the absorber tube - usually a synthetic thermo-oil (Heat Transportation Fluid, HTF) - is heated, by means of the concentrated solar radiation, to a temperature of about 400°C. The mirror and the absorber tube track the sun uniaxially, usually by means of hydraulics.

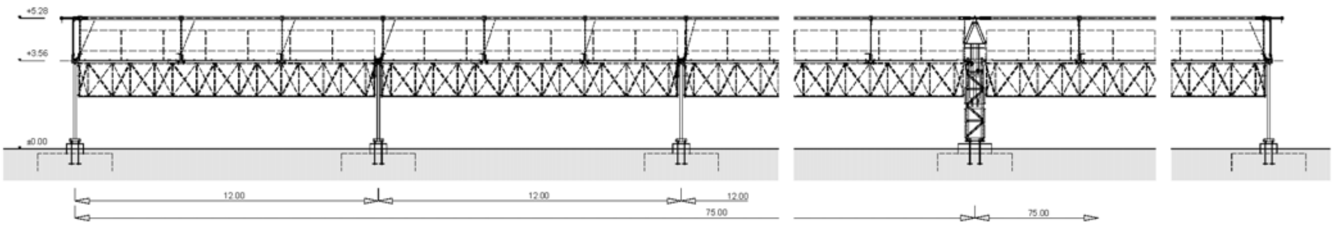
The collector field is formed of several hundred meter long rows (loops) of consecutively connected individual collector elements. The thermal heat transfer medium from a large quantity of these loops is collected and conveyed to a central steam generator connected to a conventional steam turbine (steam inlet is approx. 370°C at 100 bar) with generator. If the thermal energy generated by the collector field is not immediately required, it is possible to charge a thermal storage.



years in the Mojave Desert in Southern California and, by the end of 2001, had generated almost 10 billion kilowatt hours of pure solar power, equalling almost 1.5 billion US dollars worth of compensation for supply to the Californian grid.

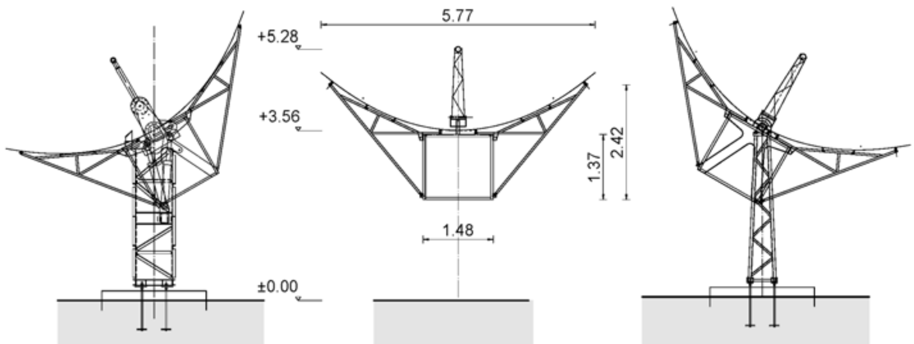
On the way to the first large-scale solar thermal power plant in Europe

Another 10 years passed before further work was carried out in this field of technology. Intensive development work was not taken up again until the end of the 90s. In the hope that concrete opportunities would present themselves for this type of technology in the light of the world's increasing energy needs, climbing oil prices and the obligations imposed on individual countries by the Kyoto Agreement, a European group began preparations for the construction of large-scale trough power plants. In cooperation with European partners and with EU support, Schlaich Bergermann and Partner developed a new collector structure, the so-called EuroTrough Collector and constructed the first prototypes in 2000 on the Plataforma Solar de Almería, Spain.



This development work produced a 12 m long, torsionally rigid collector element. The high torsional rigidity enables a total of 12 of these elements to be operated with just one drive mechanism. This meant that 150m long collectors per drive could be constructed which meet the high optical requirements, at all stages of operation when sunlight falling onto the 5.7 m wide aperture and has to be concentrated onto an absorber tube measuring just 7 cm in diameter.

Not only the horizontal wind loads but also the wind-induced torsional load and the low degree of permissible distortion are relevant to the design of a suitable steel-glass structure. A space truss measuring about 1.5 x 1.4 m with a length of 12 m was selected as a torsionally rigid support structure. The box is made up of four ladder beams, each of which is tension-locked to the girts. The cross-section is reinforced using diagonal struts and end frames.



14 cantilevered framework arms are located at hollow sections on each side of the box side ladder beams, providing the support points for the approx. 1.30 x 1.20 m glass reflector having a thickness of 4 mm. Consequently, a 12 m long collector element consists in a reinforced continuous torsion box with the 28 cantilevers supporting a total of 28 parabolic reflectors.

Every 12 m, a support for the pivotal mounting of the collector elements is located, which bears the dead weight of the collectors and the horizontal wind load. Six of these 12 m elements to the left and six to the right are consecutively connected to a rocker bar, and fixed to a drive pylon. The latter also withstands the total wind-induced torsion load of both rocker bars as well as the dead loads and wind loads of the mounted collectors. The drive pylons are fitted with hydraulic drives which enable the total 150 m long collectors to track the current position of the dirunal path of the sun, satisfying the high degree of precision (0.04 degrees) required.

Encouraged by the successful optical and economic results of the developed collector, preliminary planning of a commercial 50 MW power plant in Spain was embarked upon in 2002, together with partners FAGSOL GmbH in Cologne and Solar Millennium AG in Erlangen. In order to minimise the risks associated with the transfer from a small-scale prototype to a power plant with 510,000m² of collector aperture, a large-scale demonstration plant (4360 m² collector aperture area) was designed and implemented with financial support from the German "Federal Ministry for the Environment".

As part of this project, an existing 800 m long loop was removed in April 2003 and replaced with the newly developed collector at the existing 30 MW SEGS V parabolic trough power plant at Kramer Junction (California, USA). These measures not only allowed a qualification and a trial to be carried out at the power plant, but also detailed planning and testing of the entire acquisition and assembly procedure. In addition, the location has a natural advantage, in that the optical and thermal performance can be directly compared with the existing collectors.

The entire steel structure (about 100 t) for the loop was manufactured in Turkey, shipped to the USA in containers and assembled at the power plant site in the USA. This involved dividing up the steel structure into individual transportable components, which were then bolted together on site in special jigs. As the collectors are optical devices, and a high degree of geometric precision is required – which, as a welded construction, is only achieved at great effort and cost – the individual components were manufactured using the degree of precision typical to the steel construction industry and the final collector geometry was then achieved when accurately assembling in special jigs on site. This enabled geometric precision to be achieved, almost to the nearest millimetre, necessary for optical performance.

Construction site at the power plant compound in the USA

Assembly of the reflector pannels

Assembly of the field framework and reflectors

Assembly of the absorber tube

Course of the pivot connecting tubes between two collectors

Collector in operation

Assembly of the demonstration loop with 4.360 m² collector aperture area in California, USA

The 50 MW AndaSol-1 power plant in Spain

During the first half of 2004, the Spanish government enacted a special feed-in tariff for solar thermal power. This law guarantees power plants a fixed rate of compensation per solar thermal kilowatt hour supplied to the national grid. This legal framework paved the way for the construction of the first solar thermal power plants in Europe.
Together with the Spanish construction company ACS/Cobra and the German project developer, the erection of a total of three 50 MW plants, almost identical in construction, was begun last year. The high valley between Almería and Granada near the small town of Aldeire was chosen for the location. Due to its elevation above sea level of 1100 m and sheltered position, the location is characterised by high levels of solar radiation. Furthermore, there is a high-voltage power line in the vicinity which holds sufficient capacity for the three planned power plants.

A total of approx. 7.488 individual collector elements, each with a length of 12 m and width of approx. 5.8 m are installed on a surface area covering 1.3 by 1.5 km. Each 12 collector elements are joined together to an approximately 150m long collector unit, tracking the sun by using hydraulic drives .

One loop is made up of four of these collectors which are arranged in the field in a north-south direction. Therefore, a collector field is made up of a total of 156 loops and a total reflective surface area of approximately 510.000m². The thermal heat transfer medium – a synthetic oil – is pumped through the individual loops and is heated by about 100°K as it flows through a loop, by means of the concentrated solar radiation. The heat transfer medium thus heated to a temperature of about 400°C is then pumped to the heat storage or directly to the steam generator.

The power plant is equipped with a heat storage (molten salt), which temporarily stores the heat generated by the solar field. The collector field is designed not only to provide sufficient thermal energy for operating the turbines during the day, but also to load the storage to a level which will ensure operation of the turbines at full load, for up to 6 hours after the sun has gone down.

Due to the high degree of solar radiation at the location (2.100 to 2.200 kWh/m²/a), annual solar power generation per power plant of roughly 179 GWh is anticipated.

Transport of the first assembled solar collector elements on the field in Spain

First assembled loops on the field in Spain

Location	Near Guadix in Andalusia, Granada province (Spain), one of the sunniest regions in Spain
General information	First commercial parabolic trough power plant in Europe World's largest solar power plant with a total of 510.000 m² collector surface area
Project developer	Solar Millennium AG, Erlangen, in cooperation with their affiliated companies
Collector developer	Schlaich Bergermann und Partner in cooperation with Flagsol GmbH
Power plant operator	Andasol 1 S.A, owned by the Spanish ACS/Cobra group (largest construction company and plant constructors in Spain) and the Solar Millennium Gruppe AG in Erlangen
EPC contractor	ACS/Cobra – SENER
Commissioning	Middle of 2008
Performance	50 MW_{el}
Financial volume	300 million euros
Collector type	EuroTrough: six 12 m elements per drive unit
Heat accumulator	Liquid salt heat storage for bridging passage of clouds and power generation for up to 6 hours after sun has gone down
Turbine	Siemens 50 megawatt steam turbo set, type SST-700RH
Annual power generation	approx. 179 gigawatt hors; covers energy needs of approx. 50,000 homes or 200,000 people
CO_2 savings	approx. 86 000 t per year per plant
Net metering	25 euro cents per kilowatt hour (kWh) for 25 years
Project engineer	Parabolic trough collector: Schlaich Bergermann und Partner, Stuttgart Solar field design and HTF system: Flagsol GmbH, Cologne Salt storage: SENER, Bilbao Power block: SENER, Bilbao
Other	Two further power plant are to be erected at the same location (AndaSol-2 und AndaSol-3). Excavation work was begun for AndaSol-2 in April 2007.

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