Solar tower power plant in southern Spain

IT'S GETTING EVEN HOTTER…

Gas turbine power plants with a solar hybrid design

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Solar thermal power plants are coming into the focus as electricity generation based on solar energy booms. The need to reduce carbon-dioxide emissions has persuaded several countries to dedicate large-scale funding to the development of commercial solar power plants. In Spain, for example, the feed-in tariff for solar-generated electricity has been legally fixed at Euro 0.26 per kWh. All across the world, solar power plants are being planned and constructed for a capacity of about 10 GW. Several plants are already operational. The research activities at DLR aim to help the new technologies become more commercially viable. DLR's latest research project is being funded by the European Union – a solar hybrid microturbine.

Compared to conventional power plants, solar thermal plants still have a long way to go in terms of economic viability. The biggest development goal for solar technology, therefore, is to minimise the generating costs of solar power plants. In principle, a solar power plant has a very similar structure to a conventional power plant. While the process medium is traditionally heated using fossil or nuclear fuels, a solar thermal plant uses concentrated solar energy – the fuel resource is effectively replaced by sunlight. Solar thermal power plants only work with direct sunlight, making them particularly suitable in geographical areas with a lot of sunshine.

In order to exploit solar energy for power generation, it needs to be captured on a very large scale. Therefore, the collector panels are the most expensive part of a solar power plant. One way to reduce the power generation costs is to employ generation methods that exploit the collected solar energy more efficiently. This way, the same collector surface area can be used to produce more energy.

Most of the solar power plants built today are based on parabolic troughs, producing steam temperatures of up to 400 degrees Celsius. Power plants with solar towers, in contrast, can produce temperatures in excess of 600 °C, because they achieve a higher optical concentration of the captured sunlight. Higher temperatures are vital if the efficiency of the coupled power generation cycles is to be increased in an economically meaningful way. Solar combined-cycle gas and steam turbine power (CC) plants are currently considered as the most efficient solar power technology.

Natural gas replaced by sunlight

To convert the solar energy at maximum efficiency, it needs to be fed directly into the gas turbine. In solar hybrid CC plants, the air – which is used as the gas turbine's process

The solar hybrid gas turbine test plant

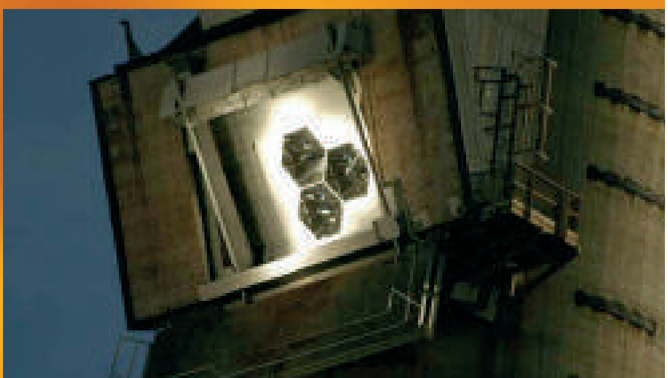
Main components of the solar hybrid Combined Cycle power plant (CC):

Heliostat field
Numerous slightly curved mirrors (heliostats), each tracking the sun in two axes to direct the sunlight to the solar energy receiver

Tower
Structure that houses the receiver

Receiver
Solar energy receiver mounted on top of the tower

Power block
Gas turbine with a bottoming steam cycle

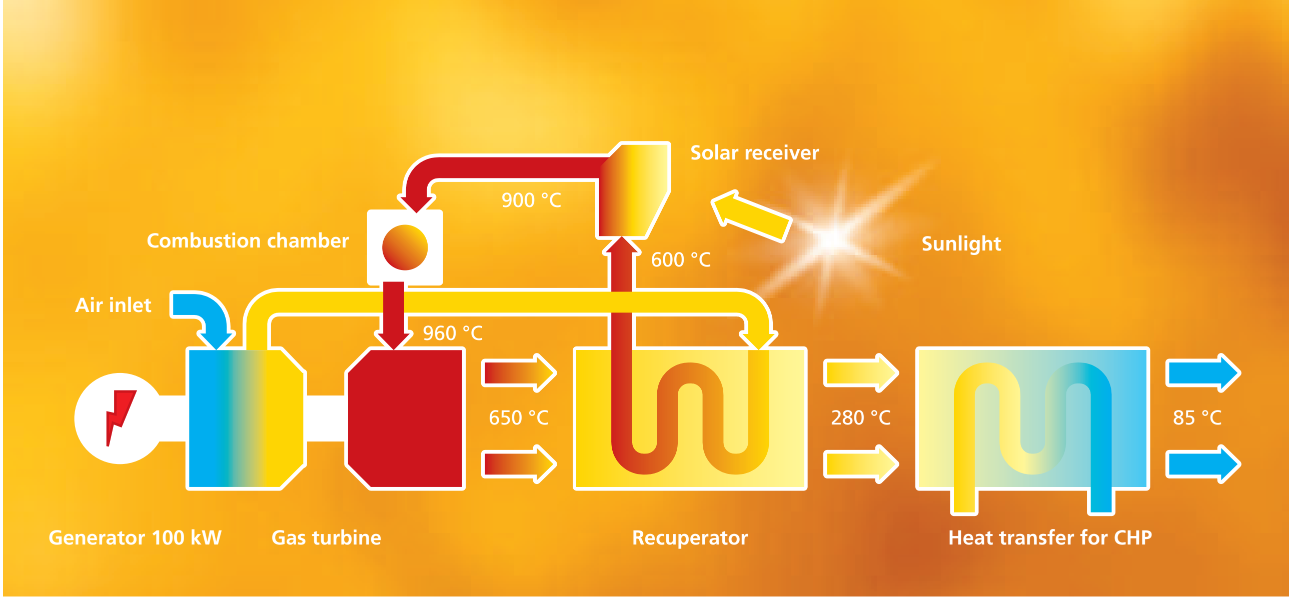


Detailed view of an operational receiver cluster (solar hybrid test plant).

medium – is heated by the solar radiation as well as by natural gas. A typical hybrid plant consists of heliostats, a solar tower, an solar receiver, and the power cycle itself.

Once the solar energy has been concentrated by the heliostats – by a factor of up to 1000 – it is absorbed in the receiver. This energy heats up the air that flows through the receiver. The higher the air temperature, the less external fuel is required to bring the air temperature up to the required turbine inlet temperature. A significant advantage of such a hybrid system is that the required power plant output can be produced reliably and at any time, regardless of weather or time of day. If biogenic fuels are used instead of natural gas, the plant can also be operated without net carbon dioxide emissions. This makes the concept even more environmentally attractive.

The solar hybrid concept has already been proving itself in the real world – albeit on a small scale. A receiver cluster consisting of three receiver modules was installed and tested on the PSA solar tower test plant in the Spanish province of Almería. The solar-heated air was fed into a gas turbine with an output of 230 kilowatts electrical (kW_e). In testing, up to 60 percent of the fuel was replaced with solar energy. Air temperatures of up to 1,030 °C were recorded in the receiver. The integration of the receiver into the gas turbine proved to work well. Recently, biodiesel was successfully used as an alternative fuel source – resulting in fully carbon-neutral electricity generation.



Flow chart of the solar hybrid microturbine system

As a first step towards market feasibility, a solar hybrid microturbine system with an output of 100 kW_e is being developed as part of an EU-funded development project. Because the power rating is too low for coupling with a steam turbine, the waste heat is used for CHP (combined heat and power). This way, the solar hybrid microturbine system achieves a very high overall efficiency. In this case, the waste heat is utilised for cold water production for air conditioning, which is realised through an absorption chiller. In sunny regions where these kinds of plants will typically be built, there is usually a high demand for air conditioning too. Very conveniently, the demand for cooling over the course of a day matches the hours of sunlight capture quite well. The first demonstration system is currently being developed in Spain and is to commence operation in 2009.

New tubing material

As part of the solar hybrid microturbine project, DLR is also leading the development of a multi-layer tube system. Simple metal tubes have several disadvantages: When an absorber tube is directly exposed to concentrated sunlight, most of the heat is impinging on one side of the tube's surface. As the tube has a low heat conductivity, this causes significant temperature differences on the two sides of the tube, which in turn causes high stresses within the material it is made of. By adding an intermediate layer with very high heat conductivity – such as copper – these temperature differences can be greatly reduced, and the material is subjected to lower stresses. This results in a longer lifespan of the tubes and higher temperatures can be achieved in the receiver.

In 2009, construction of a pre-commercial solar hybrid gas turbine power plant will commence in Seville. With project management provided by an industrial partner, DLR will contribute significantly to the overall system design. The plant is planned to produce an output of around 5 MW. One of DLR's main responsibilities is to design a high temperature receiver, which will need to produce air temperatures of up to 800 °C. The plant is to be erected next to the PS10 plant and commence operation in 2010, once it has been integrated with a tower and a heliostat field. During the two-year operating period, the new components deployed will need to prove their economic viability. Power generation will be based on a Mercury 50 gas turbine made by Solar Turbines.

The projects described in this article all work towards the commercial launch of solar hybrid power generation technology, and as such they are at the cutting edge of the energy market. In order to further improve the hybrid technology and utilise its full potential for cost reductions, the medium-term development goals are to increase power plant output and receiver temperature. A higher power output will reduce the specific component costs and thus reduce the total generating cost. A higher temperature in the receiver will result in a higher share of solar energy in the hybrid generation mix; the power output remains the same, but the CO_2 emissions are reduced. In light of the urgent need to deploy low-emission, cost-efficient power generation technologies, solar hybrid power plants are set to play a significant role – especially when the current push towards transnational power transmission lines will allow long distance solar power importing, e.g. from the Sahara to Germany.

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