CSP: Targeting Grid-Parity in Spain

Spain explores technologies that can achieve cheaper generation.

Geoff Nairn, Contributor
May 24, 2011 | 5 Comments

Spain-- A generous tariff regime as well as high insolation has driven spectacular growth in concentrated solar power (CSP) deployments in southern Spain. The challenge is now to drive down costs through economies of scale and new technologies so that CSP can one day stand subsidy-free.

Concentrated solar power (CSP) uses mirrors to concentrate sunlight and generate heat and is typically used to generate electricity via a conventional steam cycle.

Unlike photovoltaic farms or wind energy — which has grown to become Spain's third largest power source — CSP plants can cost-effectively store energy that cannot immediately be used. In Spain, which has a second demand peak in the evening, this is important. Most new CSP projects incorporate storage so they can keep generating electricity several hours after the sun has gone down, or even right through the night.

But, while CSP is more dispatchable than other renewable energy sources, it also currently costs more. So Spain is the focus for efforts to drive down costs, both through economies of scale and improvements in technologies.

'All the CSP technologies are expensive so a lot of research seeks to reduce component costs and optimise production and installation,' says Eduardo Zarza, head of R&D for solar concentrating systems at the Plataforma Solar de Almería (PSA), Spain's leading solar energy research centre, which researches all four types of CSP technologies. The most mature CSP technology is the parabolic trough design, which accounts for 93% of the 2500 MW of new CSP capacity that Spain has authorised up to 2013. While the other three technologies — solar tower, Fresnel collector and Stirling dish — all have commercial potential, the financial backers of Spain's CSP projects have opted to reduce their risks through parabolic trough's longer track record. In the US, parabolic-trough plants date back to the 1980s.

IMAGE GALLERY

'With a tower system, for example, it is difficult to get project finance because no one knows how long the receiver will last,' says Frank Dinter, head of solar at RWE, the German utility, which is investing in several Spanish renewable projects.

To benefit from Spain's generous feed-in CSP tariff — currently 28 euro cents/kWh for 25 years — CSP plants cannot exceed 50 MW. This size limit is seen as less than optimal, given the current maturity of parabolic-trough technology, and limits potential benefits from economies of scale. Several costs in a CSP project are not proportional to its size. For example, a 200 MW turbine costs less than four times as much as a 50 MW turbine. Dinter estimates that a 200 MW plant would be about 25% cheaper per megawatt than a 50 MW plant.

RWE has a 25 percent stake in Andasol 3, a 50 MW parabolic-trough CSP plant near the Andalucian town of Guadix. The solar field at Andasol 3 consists of 7296 solar collectors arranged in eight banks of 304 parallel rows aligned north to south. Each solar collector comprises a parabolic mirror with a Dewar receiver tube running horizontally along its focal line. A hydraulic drive moves the collector rows in an arc to track the sun from east to west during the day.

Synthetic oil is pumped through the receiver tubes to absorb the sun's heat, reaching a maximum of 393°C when it exits to the heat exchanger. There, the heat makes steam which drives a turbine and generates electricity using a conventional steam cycle.

Unlike earlier generations of parabolic-trough plant, Andasol 3 also incorporates molten-salt heat storage. When the plant is generating more heat than is needed to produce electricity, some of the hot oil is shunted off to a storage circuit, in which a second exchanger is used to heat up a nitrate salt mixture as it is pumped from a cold tank to a hot tank. To produce electricity once the sun goes down, the flows are reversed and energy is transferred back from the hot salt to the oil.

The heat stored in the 28,500 tonnes of salt can provide an additional seven hours of power at full load in summer evenings and an extra three hours in winter. 'If we reduced the capacity we can run at 24 hours but we would only be producing 30 MW during the night,' explains Dinter.

The price of storage has traditionally been high and it complicates the plant design, but Dinter says adding storage to Andasol 3 allows it to operate 4000 hours a year instead of just 1000 operational hours available without storage.

A drawback for parabolic-trough plants that use synthetic fluid as a transfer liquid is the relatively low working temperature of 393°C, as the fluid degrades above 400°C. However, this low temperature limits the overall steam cycle efficiency to about 38%. 'You can boost the power block efficiency by four percentage points simply by working at higher temperatures,' says Peter Mürau, Siemens project manager for molten salt technology.

The German engineering giant is promoting molten salt as a working fluid because its use enables plants to work at higher temperatures. Siemens is involved in a research project at the University of Evora in Portugal that will build a test facility using molten salt as the transfer medium. A 300 metre loop will be able to operate at temperatures above 500°C and will test different types of salt as the transfer liquid. A similar 5 MW demonstration plant is already operating in Sicily.

'Molten salt has significant potential to bring down the levelised cost of electricity

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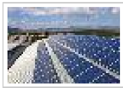
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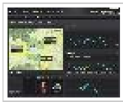
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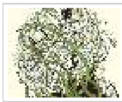
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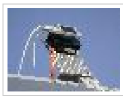
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MOST COMMENTED

(LCOE),' says Mürau. Another advantage of using molten salt both as a working fluid and for storage is that plant design is simplified as the oil-to-salt heat exchanger is not needed. Eliminating the exchanger allows the salts in the hot storage tank to reach higher temperatures than in an oil-based plant. The size of the tank can thus be reduced as less salt is needed to store a given amount of energy, leading to a cost saving of about 30% on the tank component.

But the big drawback with molten salt is that it changes phase and solidifies at about 220°C. Care has to be taken to ensure the viscosity of salt does not exceed the limits of the solar field piping during the night. 'That is quite a challenge over a big solar field,' admits Mürau.

Researchers are looking to develop new salts with lower freezing points but the attraction of the current mixture — 60% sodium nitrate and 40% potassium nitrate — is that the ingredients are cheap. 'There is a lot of research into new storage materials but molten salt is currently the favourite,' says Mürau. The existing salt mixture is also environmentally benign and — unlike synthetic oil — does not catch fire. Andasol has already suffered a fire in the solar field due to escaping oil.

Researchers at the PSA are also investigating other types of working fluids for parabolic-trough plants. Direct steam generation is one of the options that would allow parabolic plants to operate at still higher temperatures.

Parabolic trough reflectors (Andrew Duke)

Using steam would also greatly simplify plant design through eliminating the main heat exchanger. More expensive receiver tubes are needed to withstand high-pressure steam but the switch to steam could reduce total plant costs by 5% and increase efficiency by up to 7%, according to a recent report on CSP from consultancy firm AT Kearney. However, the big disadvantage posed by using steam is that an efficient and high-capacity storage solution still needs to be developed.

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Researchers at the PSA are also investigating using a compressed gas such as carbon dioxide or nitrogen as the working fluid, says Zarza. But plant designs would have to be radically redesigned to work with a gas instead of a liquid.

Mirrors and receiver tubes are critical components in a parabolic-trough plant and so are the subject of much innovation. The current thick-glass parabolic mirrors offer 93.5% reflectivity. By 2015, AT Kearney expects that new mirror technology could boost that figure to 95%, which translates into an increase in overall plant efficiency of 3.5%. According to the study from AT Kearney, more precise bending of the mirrors could also deliver a further 2% gain in plant efficiency for a new generation of CSP installations.

But only a few manufacturers produce mirrors and receiver tubes — just three in the latter case — and so competition in the supply of key components is currently limited. This is where linear Fresnel CSP technology offers a key advantage. Linear Fresnel plants have a much simpler and therefore cheaper solar field design than parabolic-trough installations.

Long strips of flat mirrors focus the reflected sunlight onto the solar receiver tube, through which saturated steam circulates at up to 285°C and 70 bar. As the sun moves, the mirrors rotate but the receiver tube remains fixed.

The drawback of a Fresnel plant is that it only captures 65% of the sunlight that a parabolic-trough plant can harvest. The business case for Fresnel technology therefore hinges on lower costs. 'If a Fresnel plant costs 20% less but produces 35% less electricity than a parabolic-trough plant, it is still not competitive,' says Zarza.

Novatec Solar, a German company, has been operating a small-scale 1.4 MW Fresnel plant — Puerto Errado 1 (PE1) — in the Murcia region of Spain since 2009. A larger 30 MW plant, called Puerto Errado 2 and majority-owned by two Swiss utilities, is being built and is due to go live in March 2012.

Martin Selig, founder of Novatec Solar, argues that while Fresnel technology is less mature, it has significant potential for cost reductions once its components are mass manufactured. Because it operates at lower temperatures, the receiver tube is much simpler than the Dewar tube technology used in parabolic-trough receivers. Similarly, the manufacture and installation of flat mirrors can more easily be automated.

As experts see linear Fresnel's relatively low thermal efficiency — of about 26% — as a potential stumbling block to its emergence as a low-cost, low-temperature technology, Novatec is therefore planning an evolution of its technology that uses superheated steam to boost turbine cycle efficiency. This will be done by adding an additional high-temperature loop to its PE1 demonstration plant, with redesigned piping and new collectors that can handle superheated steam at 450°C.

The third significant commercial CSP technology in Spain is the solar tower, which uses a circular arrangement of ground-based heliostats to focus sunlight onto a tower-mounted receiver.

The PSA research centre has had a small-scale tower in operation for more than 25 years, although Spain's first commercial tower plant, Abengoa's PS10 near Seville, only started operating in 2007. The 11 MW plant has very limited storage — sufficient to ride out 30 minutes of cloud cover — and uses saturated steam as the transfer medium.

The new generation of tower technology is represented by Gemasolar, a 17 MW tower built by Torresol Energy, a joint venture between Spanish engineering firm Sener (60%) and Abu Dhabi's Masdar (40%). Gemasolar was due to go live this spring.

Gemasolar uses molten salts both as the heat transfer medium and for storage of up to 15 hours. Although Gemasolar's rated power is only 17 MW, it can still produce as much energy as a 50 MW parabolic-type design due to its longer hours of operation.

By using molten salts, Gemasolar works at higher temperatures than previous generations of tower plant such as the PS10. At 560°C, the efficiency of a molten-salt tower plant is about 24% higher than that of its steam-powered predecessors.

Juan Ignacio Burgaleta, head of technology at Torresol Energy, argues that one of the big advantages that a central tower design can offer over the alternatives is simpler operation and maintenance. In a parabolic-trough or Fresnel plant the transfer fluid must travel through perhaps 80 km of collector pipes before reaching the power block. In a tower plant, the transfer fluid is confined to a much smaller circuit comprising the central tower and the nearby storage system.

Researchers are already looking beyond today's tower plants to new designs that can work at up to 800°C using ambient air as a transfer fluid. That would boost the efficiency of the plant by as much as 13%. Temperatures could be pushed even higher using new materials, but the more innovative the receiver, the more difficult it is to obtain project finance.

CSP's fourth competing technology is Stirling dish technology, which has yet to be deployed commercially in Spain. This uses a parabolic dish to focus sunlight onto a Stirling engine and, theoretically, could offer the highest efficiencies of the four alternative approaches.

Stirling dish technology is inherently small-scale and commercial systems typically generate around 2.5 kW. That makes it more suitable for off-grid applications, although PSA's Zarza says many dishes could be located together to create a larger grid-connected system.

A solar tower at the PSA centre (Andrew Duke)

Stirling technology also offers perhaps the most potential for cost reduction, by shifting manufacturing to low-cost countries and using more off-the-shelf components, for example. But Zarza says the big commercial stumbling block is the poor long-term reliability of Stirling engines, which have to withstand temperatures of up to 700°C and pressures of 150 bar.

'At the moment the engine components suffer a lot so we are going to need new materials,' he says.

Another big advantage of the Stirling dish is that it requires less water than other competing solar technologies. Water use can generate considerable controversy in southern Spain.

The best places to locate CSP plants tend to be arid regions with little cloud, but such environments are often subject to water restrictions. A plant such as Andasol 3 consumes 500,000 m² of water a year, mostly to condense steam, but also to clean mirrors.Investors in Novatec Solar's PE2 plant insisted on air cooling to avoid such controversy, even though reduces the economic return.

'Air cooling costs much more and it reduces the output by 5%-6%,' says Selig. Opinions are nevertheless divided on this issue. RWE's Dinter says water cooling is essential to boost the thermodynamic efficiency of the steam cycle of parabolic-trough plants like Andasol 3 with a relatively low inlet temperature. 'With dry cooling, you cannot reduce the outlet temperature as much as with water,' he says.

Burgaleta of Torresol Energy says that even though the Gemasolar central tower plant works at higher temperatures, water access was not a problem, and so the designers opted for water cooling. But one of Torresol's central tower projects planned for the future will have air cooling instead, he adds.

As Spain is now discovering, concentrating solar power is far from being a single technology, but rather embraces a wide range of designs and key technologies, each with different operating characteristics, risk profiles and trade-offs. 'There is no clear winner,' clarifies Siemens' Mürau.

Even without any radical technological breakthroughs, improvements in technologies and greater economies of scale are expected to drive a 30% reduction in the cost of CSP-generated electricity in Spain by 2015. And by 2025, costs may fall as much as 50%, at which point CSP plants will finally be in a position to substitute conventional sources in Spain's energy mix.

CSP — A Win-Win Situation for MENA

While strong growth in the capacities of concentrating solar thermal power plants can be observed all around the world, these plants have so far been constructed mainly in southern Europe and the US, even though North Africa and the Middle East actually have some of the world's best conditions, the biggest global application potential, and therefore the largest opportunities for this technology. So concludes a new Fraunhofer and Ernst & Young study: 'Middle East and North Africa Region Assessment of the Local Manufacturing Potential for Concentrated Solar Power (CSP) Projects' which explores the potential of this technology for industry in the MENA region.The region also stands to profit greatly from the expansion of CSP capacity, found the study, which was conducted on behalf of the World Bank. In addition, European plant manufacturers and technology providers are ready to get involved, according to the analysis.

But high initial capital costs remain a significant obstacle to adopting CSP technology. In the short- to medium-term, cost-effective CSP projects in MENA require a combination of factors, including local incentives, concessional finance and the export of green electricity to Europe.

In the longer-term, to make concessional finance less critical, generation costs will need to be dramatically lower. This implies that investment costs, and therefore the manufacturing costs of the main components and systems, need to decrease. This could be made possible by a combination of technical innovation, economies of scale and the experience curve effect, the study concludes. The potential for cutting costs is considerable, as CSP is a young industry, with few large or experienced players. MENA, like other emerging regions, has technical and industrial capabilities that are likely to form a good basis on which to build CSP-related activities, as shown for example by the strong auto parts industry in several countries of the region. It could become home to a new, high potential industry, serving local markets, as well as existing markets in areas such as southern Europe and the US. The region could also gain through significant job and wealth creation, while the global energy sector would benefit from increased competition and lower costs in CSP equipment manufacturing, the study concludes.

The transformational opportunity from local manufacturing of CSP in MENA countries could benefit from interrelated factors such as the massive scale-up of concessional climate financing envisaged under the United Nations Framework Convention on Climate Change (UNFCCC). In addition, MENA CSP is central to a high-level political agreement between MENA and the European Union to make solar energy trade a fundamental pillar of MENA-EU economic integration. MENA CSP could be key to realising the EU's GHG emissions reduction and energy security objectives. Furthermore, MENA's oil-producing countries are embarking on CSP investment programmes to liberate oil and gas from the power sector for higher value-added uses and exports, and in the longer term for CSP energy export, according to the study.

The combination of these factors could uniquely advantage MENA as a global location of choice for CSP production and, while creating demand for installed capacity, could strongly drive local manufacturing. The opportunity for local manufacturing of different components in the value chain depends on scenarios that represent critical levels of market development.

The market volume of five countries is outlined in the study. The success and acceptance of solar power plant construction in these nations — Egypt, Algeria, Jordan, Morocco and Tunisia — depends heavily on the integration and participation of local industry. The study results indicate that the local value added for CSP plants in the MENA region can average up to 60%. Christoph Kost, head of the study at Fraunhofer ISE, estimates the effect due to local value added in the region to be US$14.3 billion if sustainable, long-term demand is created. In addition, 60,000 to 80,000 new jobs, some of them highly qualified permanent positions, can be created in the MENA region by 2025.

European plant manufacturers and component suppliers also see large growth opportunities in this market in the medium term. Europe and MENA both stand to benefit from the enormous solar power potential of the region via new markets for the companies of the two continents.

5 COMMENTS

REGISTER TO COMMENT

GOPAL LAL SOMANI

June 10, 2011

The first CSP development took place in Mojave Desert in 1982-89. The parabolic trough technology now stands time tested, matured and fully commercialized. The generous tariff regime in southern Spain in recent past largely helped suppliers to adjust and retain explosive capital cost till recently

Withdrawal / Revision in FIT in EU countries and competitive bidding process followed by Indian government and now in Rajasthan has forced the CSP technology supplier to work hard on cost cutting measures and fight with cost competitive PV market. The winning bidders in India under National Solar Mission will bring in 480 MW of CSP plant on cost economic viability with reduced tariff to Indian government.

The Fresnel and Tower Technology with molten salt storage will overtake Parabolic Trough technology as HTF circuits, HCE and Solar Steam Generator are avoided. Continued innovations will enhance efficiency and declining cost trends in PV systems will force CSP technology also to approach grid parity by 2015.

Affordable CSP capital cost in competitive market will facilitate solar energy systems for building large capacity integrated plants with fossil fuel, atomic energy and other renewable source. The concept of integration and opportunity will prove these solar systems comparable with conventional power plants .

The challenge is now to drive down costs through innovations, development on economies of scale and new technologies so that CSP can one day stand subsidy-free.

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ROBERT EMERY

May 27, 2011

A 17-33% increase in the volume of steam flow depending on temperature and pressure can be achieved by simply reducing superheated temperature by water spray and then reheating to superheat using solar direct steam superheater receivers. Engineering is required.

GARY TULIE
May 27, 2011

It is good to see the CSP technologies beginning to mature and more closely approaching grid parity.

There is in the above post one area not covered, and that is the possibility of adding CSP capacity to existing fossil fuelled power plants. In this application, achieving the highest possible steam temperature is far less critical and the costs can theoretically be substantially lower.

Why and How?

When you add CSP to an existing steam driven fossil fuel power station, the steam you generate effectively acts as a preheat stage with fossil fuels taking the high pressure steam up to perhaps 500 centigrade. In this way, the CSP rides on the back of the Carnot efficiency of the existing plant (less any losses in the plumbing), and can give an effective CSP efficiency in excess of that achieved by stand alone CSP.

The arrangement also saves costs as the existing boiler, turbine, grid connection, transformers etc. can be used in conjunction with the CSP, and in effect making a contribution to the fuel supply of the existing plant rather than needing all the components of a stand alone plant.

A further advantage of this combined system is that it can to an extent load track as the highest electricity requirements coincide with the highest level of sunshine.

One further suggestion, there may be scope for reducing the generator cost by using screw expanders or scroll expanders - in effect, screw and scroll compressors built to operate in reverse. Such devices are significantly less expensive than turbines, particularly at smaller scales.

ROBERT EMERY
May 25, 2011

Solar has a "Capacity Factor of only 26-31% and that’s it without the ability to make the sun stand still. At other hours costly thermal storage or a fossil fuel natural gas boiler at Half of the efficiency of a modern combined cycle gas turbine it used to increase Capacity. It makes more economic sense to add solar components to an existing highly efficient fossil fuel power station than adding fossil fuel components to a so-called solar power station. A fossil fuel plant incorporating Solar Direct Steam COMPONENTS into key areas is an efficient means to utilize solar energy.

ANUMAKONDA JAGADEESH

May 25, 2011

Very good post on CSP in Spain. CSP is the future Solar energy option.
Concentrated solar power (CSP) systems, also known as concentrated solar thermal (CST) systems, are systems that use mirrors or lenses to concentrate a large area of sunlight, or solar thermal energy, onto a small area. Electrical power is produced when the concentrated light is converted to heat which drives a heat engine (usually a steam turbine) connected to an electrical power generator.
CSP should not be confused with photovoltaics, where solar power is directly converted to electricity using semiconductor materials and without the use of steam turbines. The concentration of sunlight onto photovoltaic surfaces, similar to CSP, is known as concentrated photovoltaics (CPV).
CSP is used to produce electricity (sometimes called solar thermoelectricity, usually generated through steam). Concentrated solar technology systems use mirrors or lenses with tracking systems to focus a large area of sunlight onto a small area. The concentrated light is then used as heat or as a heat source for a conventional power plant (solar thermoelectricity). The solar concentrators used in CSP systems can often also be used to provide industrial process heating or cooling, such as in solar air-conditioning.
Concentrating technologies exist in four common forms, namely parabolic trough, dish stirlings, concentrating linear fresnel reflector, and solar power tower.[1] Although simple, these solar concentrators are quite far from the theoretical maximum concentration. For example, the parabolic trough concentration is about 1/3 of the theoretical maximum for the same acceptance angle, that is, for the same overall tolerances for the system. Approaching the theoretical maximum may be achieved by using more elaborate concentrators based on nonimaging optics.
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